D 6.2 Documentation of each study case: CS7 Engineering School of Béjar, Salamanca (Spain)

Delivered at M42

EUROPEAN COMMISSION

DG Research and Innovation

Seventh Framework Programme

Theme [EeB.ENV.2010.3.2.4-1]

[Compatible solutions for improving the energy efficiency of historic buildings in urban areas]

Collaborative Project – GRANT AGREEMENT No. 260162

Technical References

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Project Coordinator	Alexandra Troi EURAC research, Viale Druso 1, 39100 Bolzano/Italy Alexandra.troi@eurac.edu
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0. Template for Case study presentation

0.1 General Information

Location

Name and location of building	Industrial Engineering School Avda. Fernando Ballesteros 37700 Béjar (Salamanca, Spain) Cadastral number: 5744401TK6754S0001AO Altitude: 962 m Heating days: 240 days Heating degree days: 1804 HDD
Previous locality names	Unknown
Legal investigation	The University of Salamanca makes all the decisions with regard to the legal investigation. Any actuation, equipment deployment and so on must be approved by the University staff before. The University of Salamanca is also the owner of the building which is not subject to any special legislation apart from the internal laws applied by the University and local laws.
Heritage administration	Pastora Vega, vice-head of infrastructures of the University of Salamanca
Responsible Planner/ Architect	Manual Blanc Diaz
Local case study team	CARTIF, GrupoUnisolar, University of Salamanca
Name and company of surveyor	Miguel Á. García-Fuentes, José L. Hernández, CARTIF; Javier Izard, Óscar Montero, G1S; Esteban Sánchez, Raúl García, USAL

Comments	The main material in the structure is the reinforced concrete for the pillars and slabs. The pillars and slab fronts, without thermal insulation, embedded on the walls, and independents of the brick surfaces, cause the most important pathologies (thermal bridges, lines of infiltrations, etc.). The walls do not have insulation material but between the two faces there is a non-ventilated air gap, of 5 cm, so that the thermal transmittance of these elements is U = 1.50 W/m^2 ·K. On the other hand, the roof is made in zinc plate with a transmittance of 1.75 W/m^2 ·K. Finally, the window frames are metallic in large horizontal stripes with thermal-bridge-optimization f and double glazing 4/20/4 with a transmittance of 3.45 W/m^2 ·K and a g-value of 0.76. The total transmittance of the building is 2.10 W/m^2 ·K. The building orientation is North-South in the longitudinal axis, meanwhile the biggest façades are East-West oriented which contain big glazed surfaces. The aforementioned lattice is in the West façade, whereas the East one includes some cantilevers protecting the wall from solar radiation

General description incl. building problems

Date of construction	1968
Architect/Artist/other persons	Manuel Blanc Díaz
Architectural style	Functionalism and constructivism
Typology of building	Educational establishment

Original objective	Public school
present use	Public school
expected use in the future	Public school
Construction materials	Concrete, brick and zinc plate
Construction method	Concrete construction
Short description of building	The current building of the Industrial Engineering School was built between 1968 and 1972, following the design project of the architect Manual Blanc Díaz. The formal definition of the building, characteristic of the Modern Movement, supposed a rupture with traditional architecture of the region in that period. However, it takes some minor formal aspects from the regional architecture, as the big lattice which reinterprets the façades of the traditional houses of Béjar, that were made with roof tiling for protecting the most exposed façades to strong winds and rain. The building is north-south oriented in the longitudinal axis, with bigger façades east-west oriented, where glazed surfaces are remarkable. The big lattice protects the west façade, while in the east façade there are some cantilevers protecting the wall from the solar radiation.
Number of Axes	not specified
Shape of roof	not specified Central access
Internal access	Central access
Status quo	The building is in general in good condition and nowadays is still used as University school.
Overall conservation status	The state of conservation of the building is considerably good, although it has certain pathologies due to the humidity in cantilevers. The main detected problems, however, are due to low comfort conditions in the indoor spaces (both thermal and lighting) and high energy consumption because of a design little concerned about passive conditioning strategies, as it is usual on all buildings designed before than the energy crisis of 1973.
Actual European energy standard	Not applicable
building problems with regards humidity	Not applicable
building problems with regards salts	Not applicable

Planned activities within the project	
Diagnosis	In a first approach to the diagnosis of the problems of the building, the following aspects were detected: - overheating during the warmer months, especially in the east façade; - deficient heating distribution system, with only two circuits, which derives in high temperature differences and comfort problems; - manual control strategy for cooling system elements, what generates low comfort conditions on the cooled area; - oversized lighting system in corridors and halls; - inefficient lighting system due to the incorrect distribution of the lighting circuits in the classrooms and laboratories; - underutilization of daylight and solar radiation; and, - problems due to the low level of insulation and infiltrations
Planned solutions	As first proposal of interventions the following list remarks the main ones selected in the building: - increase the insulation level of the building envelope and optimization of the airtightness in order to reduce the energy consumption. - deployment of the photovoltaic cells in the east façade in order to take advantage of the solar radiation. - redistribution of lighting systems in the rooms so as to favour the daylight, improving the comfort. - combination of the redistribution of the lighting systems with a control strategy for switching off those luminaires where pupils are not working, decreasing the energy consumption. - development of a control strategy based on room temperature and occupancy pattern for the improvement of the comfort of the cooling systems. Finally, the three latest ones are the basis of the control systems deployed in the building for the evaluation of the comfort improvements and the energy savings which will be evaluated with the second reporting period.
Monitoring system	The monitoring system is a LonWorks based where a backbone has been deployed from top floor to the second basement. From this backbone, several branches set up the sensor network of the system. There are four main branches: library, physics laboratory, weather station and boilers room. The test rooms have been selected in function of the facilities. In the case of the boilers room, the generation systems are quite important in order to get the thermal consumption and the behaviour of the boilers of the whole building. Regarding the weather station, the weather conditions, mainly solar radiation, is needed for the study of the implementation of photovoltaic cells. Finally, library is the only room with cooling systems and the physics laboratory has windows in the east and west

<table>
<tr><td></td><td>façades which improves the natural light. In the library and physics laboratory, the sensor network measures mainly comfort parameters (temperature, humidity, presence and CO2), although, there are also some wattmeter in the electrical boxes for the electrical consumption. In the boilers room, the thermal consumption has been measured without flow meters, but pressure and temperature sensors. Thus, with the help of the characteristic curving, it is possible to work out the flow of the pumps. Also, the status of these pumps is collected. For collecting all the information a server actuating as a data logger has been installed which centralizes the collection of information from sensors. Afterwards, a remote application reads this information which is being stored in a persistent database and shown in a Web application for monitoring and downloading.</td></tr>
<tr><td>Simulation</td><td>Two simulations have been performed in the building. First of all, PHPP calculation before refurbishment has been completed. Secondly, a comparison with a TRNSYS simulation has been undertaken.

Simulation results for comparing simulation tools:

<table>
<tr><th>Heating energy balance</th><th>PHPP (kWh/m²a)</th><th>TRNSYS (kWh/m²a)</th></tr>
<tr><td>Ventilation</td><td>17.90</td><td>25.70</td></tr>
<tr><td>Transmittance losses</td><td>94.70</td><td>154.89</td></tr>
<tr><td>Windows</td><td>34.60</td><td></td></tr>
<tr><td>Floor/slab basement</td><td>13.20</td><td></td></tr>
<tr><td>Roof</td><td>11.90</td><td></td></tr>
<tr><td>Ext. wall (ground)</td><td>2.30</td><td></td></tr>
<tr><td>Ext. wall (ambient)</td><td>32.70</td><td></td></tr>
<tr><td>Solar gains</td><td>11.60</td><td>62.72</td></tr>
<tr><td>Internal heat gains</td><td>13.00</td><td>22.23</td></tr>
<tr><td>Convection</td><td></td><td>12.26</td></tr>
<tr><td>Radiation</td><td></td><td>9.97</td></tr>
<tr><td>Annual heating demand</td><td>88.00</td><td>95.64</td></tr>
</table>

Having a look at the disaggregated losses and gains there are substantial differences: transmittance losses (a 30 % less in PHPP) and ventilation losses (a 30 % less in PHPP), meanwhile solar and internal heat gains are increased in an 81 % and 40 %, respectively, in TRNSYS compared to PHPP. That is because TRNSYS sums up the losses over the whole year whereas PHPP only sums up the results for the heating period.</td></tr>
<tr><td>Transfer to urban scale concept</td><td>Not applicable</td></tr>
<tr><td>Others</td><td>Not applicable</td></tr>
</table>

0.2 Building Assessment

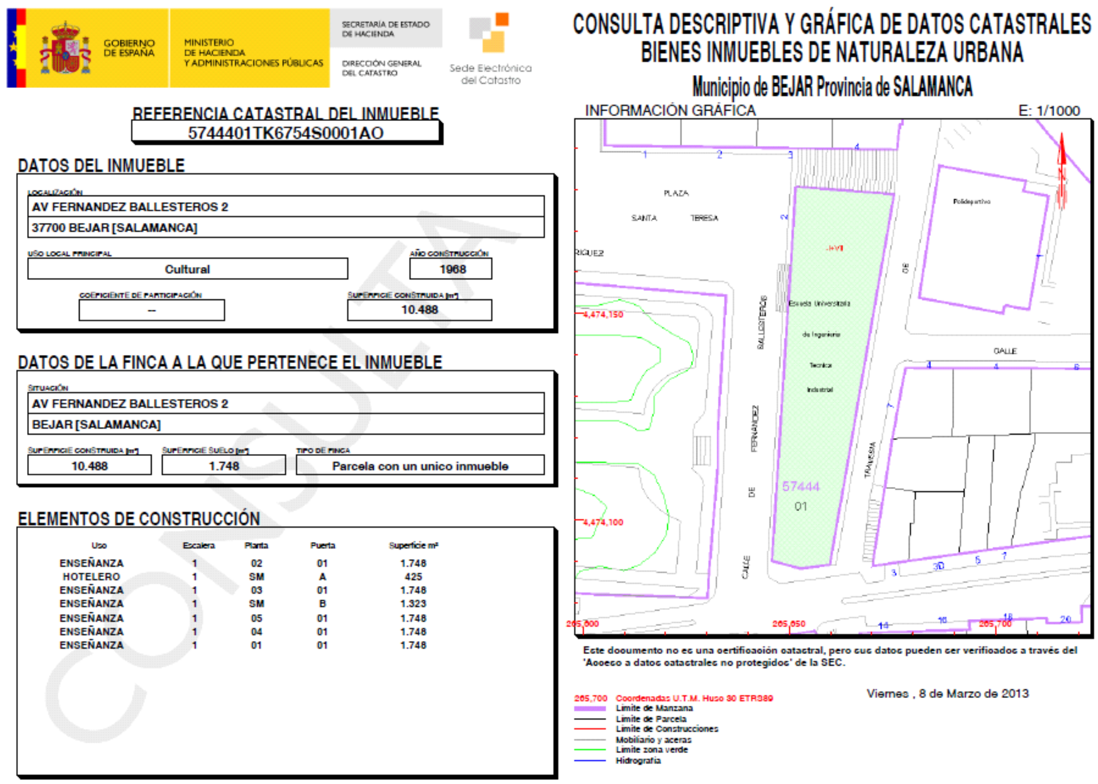
Cultural Value (Specific valuable aspects)	
Architectural historical value	This building influenced by the Constructivist Architecture, which flourished in the Soviet Union, achieves a rupture with the traditional architecture of the site, carried out under industrial design criteria, without adornment, and with huge geometrical and functional principles, reinterpreting some characteristics of the local construction, influenced by climate conditions, as big lattices for protecting from winds and rain.
Cultural historic value	It is the first building that the University of Salamanca builds in this village. Its construction meant a big academic activity growth in the area, and a big support to the textile industry, which had a long tradition in the region.
Context value	Not applicable
Social value	Not applicable
Constraints conditions	As far as this building is not listed as cultural heritages, it is not subject to any Authority for Cultural Heritage. The constraints are imposed by the owner of the building, in this case the University of Salamanca. The decisions of the conditions are made by the University government.
Limits and prescriptions arising from Area Regulations	The local area regulations establish the concerns with regard to external actuations in the building (façades, roof, building envelope) keeping the aesthetical issues of the city regulations.
Limits and prescription determined by the owner	The owner of the building is the University of Salamanca which makes the decisions for retrofitting activities, actuations, interventions or any installation concern. There are no limits imposed, apart from the University government decisions. That means the procedure for any intervention in the building is asking the direction of the School which requests the permissions to the University of Salamanca's government.
Preservation concept	There are no preservation concepts apart from the internal rules established by the owner (the University of Salamanca) which must be followed. But, at the end, the steps, in the CS7, are asking for permissions to the owner, the University studies the possibilities, advantages/disadvantages, weakness/strengths and make the decision.
Others	Not applicable

Documentation	
diagrams/drawings	AnnexCS7_OriginalDrawings.pdf, AnnexCS7_SurfaceUseDrawings.pdf, AnnexCS7_Drawings.pdf
expertise/reports	Not applicable
files/correspondence	Not applicable
guidelines/specifications	Not applicable
photographs/images	AnnexCS7_Photographs.pdf
publications/press	Appearance in a local newspaper

0.3 Detailed description

0.3.1 Urban Context and Local climate data

Urban Context


GOBIERNO DE ESPAÑA
MINISTERIO DE HACIENDA Y ADMINISTRACIONES PÚBLICAS
SECRETARÍA DE ESTADO DE HACIENDA
DIRECCIÓN GENERAL DEL CATASTRO
Sede Electrónica del Catastro

CONSULTA DESCRIPTIVA Y GRÁFICA DE DATOS CATASTRALES
BIENES INMUEBLES DE NATURALEZA URBANA
Municipio de BEJAR Provincia de SALAMANCA

REFERENCIA CATASTRAL DEL INMUEBLE
5744401TK6754S0001AO

DATOS DEL INMUEBLE

LOCALIZACIÓN
AV FERNANDEZ BALLESTEROS 2
37700 BEJAR [SALAMANCA]

USO LOCAL PRINCIPAL: Cultural
AÑO CONSTRUCCIÓN: 1968
COEFICIENTE DE PARTICIPACIÓN: --
SUPERFICIE CONSTRUIDA [m²]: 10.488

DATOS DE LA FINCA A LA QUE PERTENECE EL INMUEBLE

SITUACIÓN
AV FERNANDEZ BALLESTEROS 2
BEJAR [SALAMANCA]

SUPERFICIE CONSTRUIDA [m²]: 10.488
SUPERFICIE SUELO [m²]: 1.748
TIPO DE FINCA: Parcela con un unico inmueble

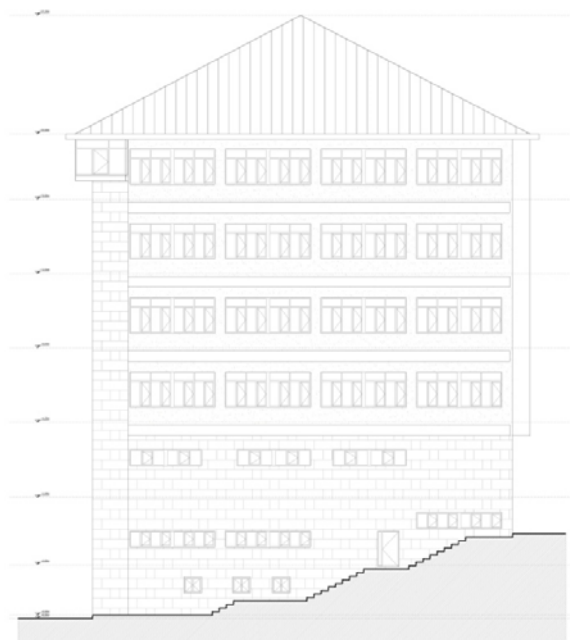
ELEMENTOS DE CONSTRUCCIÓN

Uso	Escalera	Planta	Puerta	Superficie m²
ENSEÑANZA	1	02	01	1.748
HOTELERO	1	SM	A	425
ENSEÑANZA	1	03	01	1.748
ENSEÑANZA	1	SM	B	1.323
ENSEÑANZA	1	05	01	1.748
ENSEÑANZA	1	04	01	1.748
ENSEÑANZA	1	01	01	1.748

Relation with neighbouring buildings	Part of historical residential complex
Quarter/town/surrounding	The surroundings of the building contain some interesting information from a historical point of view with the fact of the river is quite close of the building. This river was used in the village as natural source and the building is sited in the riverbank. Moreover, in the main façade a park is the attraction and the main reason for implementing the lattice in this façade. There are no barriers to the strong winds and rain, being the lattice the element to avoid damages. Finally, the rest of the building is surrounded by building without major interest than the provided by the fact they were built in the same epoch.
location/orientation/ accessibility	The building is north-south oriented in the longitudinal axis, with bigger façades east-west oriented, where glazed surfaces are remarkable. The big lattice protects the west façade, while in the east façade there are some cantilevers protecting the wall from the solar radiation.
Development plans	Not applicable

Certificates/reports/regulations on energy efficiency	Not applicable
Historical context	• Conservation aspects: It is not a catalogued building as cultural heritage, but its historical and architectural values lie on its formal character and the social and economic impact that its construction had in the region since it is the first building of the University of Salamanca in the city. • Energy-related aspects: The historical value of the building lies more on cultural features than in aesthetical or formal ones, so strategies as add internal insulation or reduce the level of infiltrations have a low impact to its historical value. Nevertheless, other strategies, as the integration of energy generation systems from renewable sources (as photovoltaic) have a higher impact.
Key figures as e.g. % of historic buildings, renovation rate	Not applicable
Necessary data for PHPP calculation available: Monthly mean averages of temperatures and solar radiation?	Monthly mean averages of temperatures and solar radiation used from local weather stations both Béjar village and University weather station.
Particular architectural solutions according to the local climate	The local climate presents strong winds and rain during winter season, being the lattice an architectural solution for avoiding the damage of the façade.
Overshadowing	Also, the lattice provides overshadowing because of the high radiation during the afternoons.

Local climate date	
Climate zone	Continental Mediterranean
Climate area	Continental Mediterranean
Degree days	1804
Coordinates:	40.3853393 / -5.76057830000002
Altitude	962 m
Average wind speed	10 km/h
Prevailing wind direction	West



Winter climate data		Summer climate data	
Winter design temperature	-5ºC – 15ºC	Temperature: dry/wet bulb	---
HR max (Nov.-Dec.)	90%	HR	---
Heating day per year	240	Daily temperature range	5ºC– 36ºC

Available data for the project	In the Industrial Engineering School of Bejar,a weather station has been added. In the following links, is possible to consult the data: http://212.128.198.13:8080/FTP/ http://212.128.198.13:2505/FTP/
Reference statistic data from “common database” (e.g. Meteonorm)	Aemet web page for Spanish cities weather: http://www.aemet.es
Reference climate data	Béjar local weather station
Data measured from local weather station	Béjar local weather station: http://www.electrosan.es/estaciones-meteo/estacion-meteorologica-bejar/

Necessary data for PHPP calculation available: Monthly mean averages of temperatures and solar radiation	See above
Measured climate data	Data available in the aforementioned links
Comments	Not applicable

0.3.2 Report on history of the building

The current building was built between 1968 and 1972 and the architect who designed the project was Manuel Blanc Díaz. However, the first building of the school was already built in 1852 ordered by Queen Isabel II. Thus, this first building started teaching three months after that, being the location the Mansillastreet just behind the “San Juan” church and the first principal Nicomedes Martín. Afterwards the School was translated to the San Gil church between 1880 and 1903 and it was called Industries Superior School. This building is currently refurbished, it contains two more floors and it is conserved in the village. Moreover, in 1901, the Spanish Industries Superior Schools are created and one of the head offices began in the village of Bejar during the season 1902-1903 in the same building San Gil church (at present, it is a museum). Years later, between 1903 and 1948, the School was moved to the San Francisco monastery, also sited on Béjar, owing to the small size of the church. After the Second World War, a new building was needed which was the headquarter of the university until the current building. At the beginning, the subjects were textile, mechanics and electricity, meanwhile, currently, there are several specialities.

The aesthetic solution of the building is based on its own needs due to the functionality and the climatic conditions. One important change is the use if the exposed reinforced concrete instead of granite.

The conditions of conservation are considerably good, although it presents some pathologies in projecting concrete slabs due to moisture. However, the main problems are related to the low comfort conditions (both thermal and lighting), as well as high electricity consumption.

Two interventions were made by the University from the original building before this project. In both the roof was changed and, in the second actuation all the external windows were replaced by conventional double glazing and thermal-bridge-optimized frames.

History of the building	
Use of building over time	The building has always been used as educational building.
Construction phases	
Name/Time	Description
Basements	With screeds or wrought, and lateral and posterior walls of reinforced concrete, waterproofed and plastered internally.
Enclosures	Brick + Air chamber + Partition wall. In certain areas is used reinforced concrete with double hollow brick.
Exterior carpentry	Metallic
Floorings	Terrazzo
Foundation	Pilotage with depths of 10 m
Interior carpentry	Wood

Interior partitions	Almost exclusively partition wall.
Roof	Traditional inclined boards system, with a layer of concrete and slate.
Structure	Reinforced concrete.
Comments	

0.3.3 Building consistency

Building consistency	
Description state of the building	The status of conservation of the building is good without structural damages.
Description construction method	The aesthetical solution of the building is based on its own function and the environmental and climatic conditions. The structure is made of reinforced concrete pillars and slabs, which are the cantilevers in the east façade. The pillars and slab fronts, without thermal insulation, embedded on the walls, and independents of the brick surfaces, cause important pathologies (thermal bridges, lines of infiltrations, etc.). The building envelope is made of two faces, where the outdoor face is made of concrete blocks and the indoor face is a double hollow bricked wall with interior plaster. The walls have not insulation material but between the two faces there is a non-ventilated air camera, of 5 cm. The windows appear as large horizontal stripes alternating fixed glazes and windows.
Description shape	Elongated building
Description of facades and roof	It takes some minor formal aspects from the regional architecture, as the big lattice which reinterprets the façades of the traditional houses of Béjar, that were made with roof tiling for protecting the most exposed façades to strong winds and rain. The roof was modified several times during the building's life, being the current solution made of zinc plate above ceramic board and light brick partition walls.


Number of floors above ground	5
Number of basement floors	2
Covered area	1748 m2
Numbers of rooms	Unknown
Gross area	13624.85 m2
Net area	9467.10 m2
Heated surface	9467.10 m2
Surface cooled	150 m2
Heated volume	33150 m3
Other comments	Not applicable

Occupancy rate (number of inhabitants/users)	From Monday to Thursday the average number of users/students is about 250-300 people, whereas on Friday, owing not to teaching day, the number of users is around 30-40.
Occupancy time (h/week, d/month)	The University works from 8:00am to 21:30pm from Monday to Friday, all the hours open, although during lunch time (14:00-16:00) the occupancy is too low, as well as at the beginning of the morning and end of the day. During the rest of the day, the distribution of the students in the building is pretty much stable depending on the timetables for the classes (which change every year but no so much).
Target energy demand heating/cooling	The heating demand is 70 kWh/m2a in the whole building. However, the following strategies for energy saving could be carried out: Interior insulation -- It has been detected a high amount of airtightness in the whole building and heating losses which could be improved by means of interior insulation. Thus, by adding internal insulation to the external walls (50mm of an insulation

	material with lambda=0.04W/mK), the global energy demand could be reduced in a 25%, while if also the roof and the floor would be insulated (under the same conditions) the demand would decrease in a 46% related to the baseline demand (from 106.5kWh/m2a to 57.5kWh/m2a). Also, the airtightness could be improved by solving the problems of infiltrations detected through the non-destructive testing done. Supposing the reduction of the q50 to the 50% of the current level (10.0m3/m2·h), the energy demand would be reduced in a 10%. By combining previous interventions, the global energy demand of the building would be 52.2kWh/m2a, which means approximately the 50% of the baseline demand. PV cell -- Depending on the size of the PV panels installed in the building, the heating demand could be reduced by balancing the load from the boilers and the PV cells. As well, the orientation and radiation levels affect to the performance of these solar panels, but the complete study is not fully available. Biomass -- By putting off the current boilers with biomass ones, the consumption of gas will be reduced. This consumption is not collected because the bills belong to the University and there are not accessible
Other comments	With regard to the lighting system, it is oversized and distributed in a bad manner because the luminaires are distributed perpendicular to the windows. Nevertheless, a re-distribution of the luminaires by means of occupancy patter favouring the daylight with an automatic control strategy could improve the performance of the lighting system and then the electricity consumption. In the physics laboratory test room is estimated the required usage of luminaires is the half of the current use, therefore, the estimation electricity consumption of such room is decrease to the 50%. In the real implementation we have determined almost this decrease in the consumption.

Building Services (as- is-state)	
Heating system	The heating system is based on two boilers. The main boiler has a power of 581kW whereas the second has 418.6kW. The performance of both boilers is 88.5% and 88.1% respectively. These boilers provide the heating system to the remaining parts of the building through two distribution circuits. In the room level, there is radiation so as to heat the individual rooms. The total demand is 70kWh/m2a.
Plant room	Not applicable
Electrical System	The electrical system is composed by a single meter at building (ground) level and individual electrical boxes with electrical distribution systems for each floor, but also for some specific rooms such as the laboratories whose power is high owing to the requirements in such rooms (engines, machines,

	workbenches…). The electricity demand of the whole building is 45.1 kWh/m2a
Ventilation System	The ventilation systems of the building are the extractors installed only in the library. The rest of the building does not cover the ventilation systems at all.
Cooling System	The only cooling system in the whole building is placed on the library where three fan-coil units set up this cooling system. The trademark of the fan-coils is PANASONIC. Also, the adjacent offices to the library where the library staff works contain one fan-coil unit in each office (two offices).
Wastewater disposal	Common wastewater.
Renewable Energy	No renewable energies are being used in the building either electrical generation or thermal generation.
Artificial Lighting	All the building facilities and rooms are equipped with luminaires. The electricity demand is 23 kWh/m^2 a before refurbishment and 18 kWh/m^2a after refurbishment.
Use of Daylight	No control strategies or systems take advantage of the daylight in the building.
DHW production	There is not DHW in the building except for the showers in the gym with an electrical water-heater for that purpose.
Chimney/ducts	Not applicable

Building Potential	
Potential for energetic use	The orientation of the building presents a high potential for the deployment of photovoltaic cells as renewable energy. The north façade is opaque easing the installation without disturbing windows for daylighting. Also, this façade receives the sunlight during almost all the day because of the height of the building in comparison with the surroundings.
Subterranean floors and basements and the possibility of air exchange with upper floors/roof	Not applicable
Possible heat exchange with the surrounding ground	Not applicable
Possible use of energy sources on the building or from nearby, possible application of “smart grids”	• Conservation aspects: As the building is not listed and no restrictions from local governments are detected, the inclusion of a "smart grid" does not break with the rules. The only permission in this case is with regard to the owner (University of Salamanca) and its interest in retrofitting the building from a energy point of view.

	• Energy-related aspects: In the surroundings of the building there are the possibility of possible "smart grids" as far as several natural energy sources are nearby: • Photovoltaic: As the sun light is very important in the building during almost all the day, and the energy could be taken for the heating system of the building, a PV installation could provide some energy savings in a "smart grid". • Water: Due to the near river, a hygrothermal system could be thought for integrating in a "smart grid". It is important to note, this solution has not been analysed so far. • Wind: The surroundings present an open view because the buildings and park around has lower high than the building; therefore, wind turbine could be used in the building.
Short description/overview on space available for building services/combustible/installations	The adjacent room is empty and available for the storage of combustible. For that reason, one of the proposed solutions remains in the biomass boilers, due to the storage space.
Possibility of installation of geothermal collectors (dimension)	Not applicable
Possibility of de-/central ventilation system (available space/wiring etc.)	Not applicable
Transferability of (energetic) refurbishment solutions to other buildings	• Conservation aspects: The refurbishment control strategy carried out in the Engineering School of Béjar is completely replicable in other historic buildings as far as the great novelty of the control algorithm can be summarised in the usage of Freely Programmable Modules (FPM) for the development which is an incoming technology that allows the integration of more advanced algorithms and improvements in the time response. As we are in historical buildings, there are some restrictions when more hardware installations are needed, therefore, this development should be integrated into the current hardware. For such reason, the FPM framework provides a piece of software such as a "virtual hardware" which could be deployed into the current Building Management Systems. • Energy-related aspects: Moreover, it allows the calculation of more efficient and advanced occupancy patters with the combination of several sensors in order to detect in a better way the presence status of big rooms. Furthermore, the control algorithms improve the indoor comfort conditions (in this case lighting and temperature, but also humidity and air quality could be included) by keeping and even reducing the energy consumption. These conditions are especially important in museums and buildings with drawings and frescos which should be conserved.

Others	Not applicable

0.3.4 Building Energy consumption

Energy bills	The energy bills are divided into several parts: Gas-oil, gas and electricity. This information is collected in the document enclosed where the information of the consumption is compiled with the bills provided by the University of Salamanca. Data is represented in kWh, litres (when applicable), m3 (when applicable) and € for the years 2010 and 2011.
Documents/files	AnnexCS7_CS7Consumption.xlsx AnnexCS7_CS7ConsumptionGraphs.xlsx
Documentation of former energy audits	Not applicable
Measured energy consumption as-is-state	The energy consumption measured and analysed is related to the electricity and fuel consumption. The enclosed Excel sheet compiles the information and the trend of the information during the years before the project. Thus, the electricity consumption measured in kWh and € is represented where the trend is the reduction of the consumption whereas the costs depend on the €/kWh. On the other hand, for the fuel, there is not any specific trend, but a dependency with the needs of the year (heater or cooler years) and the cost is directly related to this distribution.

Building Energy consumption			
Electricity	**Years**	**Consumption (kWh)**	**Cost (€) (average cost €/kWh)**
	2008	204,968	30,003.58 (0.15)
	2009	191,469	35,266.86 (0.18)
	2010	180,659	28,806.35 (0.16)
Diesel	**Year**	**Consumption (l)**	**Cost (€) (average cost €/l)**
	2008	62,965	45,563.00 (0.72)
	2009	44,604	24,398.75 (0.55)
	2010	59,990	39,876.67 (0.66)
Gas	**Years**	**Consumption (mc)**	**Cost (€) (average cost €/mc)**
	2008	2,477	2,042.89 (0.83)
	2009	---	---

	2010	1,653	1,386.35 (0.84)
Water	**Years**	**Consumption (mc)**	**Cost (€) (average cost €/mc)**
	2010	5,093	9,485.16 (1.86)

0.4 Constraint condition and protection

The Engineering School of Béjar is not a catalogued building as cultural heritage, but its historical and architectural values lie on its formal character and the social and economic impact that its construction had in the region since it is the first building of the University of Salamanca in the city, adding value to an institution previously established (19th century). This fact reinforced the textile industry developed in the area of Béjar.

Regarding the legislation or constraints, within the Case study CS7 the Industrial Engineering School-Béjar/Salamanca all building and conservation action is directly related to the organisation of the University. First of all, anyone must contact with the "Infrastructure and economic assistant principal" of the School. Once the permission from this person is achieved, the next step is the contact with the "principal" of the School. In case the principal allows the intervention, the owner must be informed for the approval, in this case the University of Salamanca. For that purpose, the "Infrastructure and innovation vice-rector" is the responsible for that. Usually, this person keeps in contact with his/her people (the technical office of the University) and makes the decision. However, other times the vice-rector redirects directly to the technical office. That means there are internal laws which govern the actuations and installations in the University, but the final decision is always made by the University people when the refurbishment is an interior one. If the exterior walls require any intervention, then the Spanish laws with regard to the aesthetic aspects in the surroundings and neighbourhoods are applied. These regulations affect to the harmonisation of the aesthetic aspect of all the buildings in a same neighbourhood.

There is no superior monument office involved in the decision making.

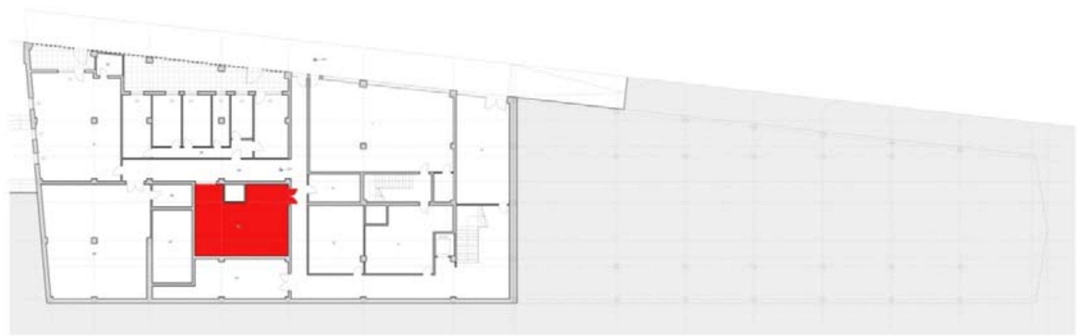
Constraint condition and protection	
Description of building safety with regards statics/structural problems - compliance with local regulations	No structural problems detected in the building
Certificates/reports/regulations on statics	Not applicable
Description of building safety with regards dangerous materials (to remove)-Compliance with local regulations	Not applicable
Certificates/reports/regulations on dangerous materials	Not applicable
Description of building safety with regards fire protection - compliance with local regulations	Not applicable

Certificates/reports/regulations on fire protection	Not applicable
Description of building safety with regards seismic safety - compliance with local regulations	Not applicable
Certificates/reports/regulations on seismic safety	Not applicable
Description of building safety with regards noise protection - compliance with local regulations	Not applicable
Certificates/reports/regulations on noise protection	Not applicable

0.5 Selected area of intervention

0.5.1 Functional area: Area 1 (Technical rooms)

Functional area consistency	
Description	This floor is used for the facilities regarding the generation systems, storage and workshops. This floor is important because contains the boilers and distribution systems for the whole building. From this room, the heating of the building is generated and distributed. The technical room contains the generation and distribution systems for the whole building. There are two gas-oil boilers from ROCA trademark where one of them is working in support mode. The main boiler has a power of 581kW whereas the second has 418.6kW. The performance of both boilers is 88.5% and 88.1% respectively. The area of the room is of 51.40m^2.
Number of rooms	10
Heritage aspects	Not applicable
Balance boundary	Not applicable
Treated floor area according to balance boundary	Not applicable



Height interpolated average net (m):	726.75 m^2
Surface area (Gross/Net) heated (mq):	No heating system in the second basement
Volume (gross/net) heated (mc):	Not applicable for the second basement
Opening to the public (from/to; hours /day; temperature set-up):	The University working day is from 8:00 to 21:30 and Monday-Friday. The number of average students from Monday to Thursday is about 250-300 students, whereas Friday, the estimated people in the building is around 30-40.
Hours of working (from/to, hours/ day; temperature set-up):	The heating system is working from 7:00 to 19:00 and it is totally controlled from the central side of the University placed on Salamanca, Spain.
Hours of air conditioning (from/to; hours/day; temperature set-up)	Not applicable
Comments	---

0.5.2 Functional area: Area 2 (The library)

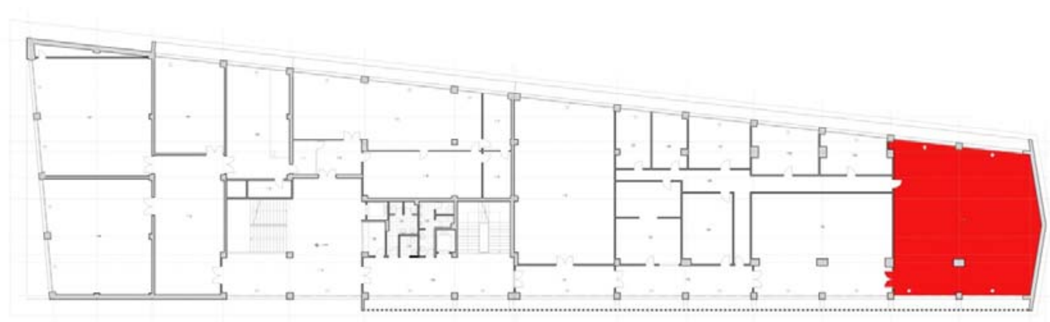
Functional area consistency	
Description	This floor in one of the main rooms of the building for the project purposes because it contains the two test rooms where the interventions are deployed. This floor is divided in classrooms, the laboratories part and the main hall where the library is placed. The library is the room used by the pupils of the University for studying and doing work with their laptops. Therefore, the comfort conditions are the most important issue in this test room, above of all during warmed seasons. A lot of claims from students are recollected by the staff of the school, being one of the main purposes the improvement of the comfort conditions.
Number of rooms	31

Heritage aspects	Not applicable
Balance boundary	Not applicable
Treated floor area according to balance boundary	97.60 m^2
	
Height interpolated average net (m):	1470.30 m^2
Surface area (Gross/Net) heated (mq):	1470.30 m^2
Volume (gross/net) heated (mc):	All the volume of the building is heated through the radiators.
Opening to the public (from/to; hours /day; temperature set-up):	The University working day is from 8:00 to 21:30 and Monday-Friday. The number of average students from Monday to Thursday is about 250-300 students, whereas Friday, the estimated people in the building is around 30-40.
Hours of working (from/to, hours/ day; temperature set-up):	The heating system is working from 7:00 to 19:00 and it is totally controlled from the central side of the University placed on Salamanca, Spain.
Hours of air conditioning (from/to; hours/day; temperature set-up)	Manually controlled the cooling systems in the library room, being difficult the estimation before intervention.
Comments	There are no air conditioning systems installed in the building, with the exception of the extractors and fan-coils in the library room. However, these systems are manually controller, being very difficult to estimate the working hours before the intervention.

0.5.3 Functional area: Area 3 (The Physics and Electronics Laboratory)

Functional area consistency	
Description	This floor in one of the main rooms of the building for the project purposes because it contains the two test rooms where the interventions are deployed. This floor is divided in classrooms, the laboratories part and the main hall where the library is placed. That is one of the laboratories for practical

	activities in the building whose occupancy pattern is irregular due to the timetable of the activities in this laboratory. However, the main feature of the room is the east and west windows which favour the daylight. On the other hand, the distribution of the circuits is not the most appropriate one because the luminaries are perpendicular to the windows. Also, the lighting system is oversized in the room. These are the reasons why the laboratory is one of the test rooms with energy savings and comfort improvements potential.
Number of rooms	31
Heritage aspects	Not applicable
Balance boundary	Not applicable
Treated floor area according to balance boundary	172.50 m^2



Height interpolated average net (m):	1470.30 m^2
Surface area (Gross/Net) heated (mq):	1470.30 m^2
Volume (gross/net) heated (mc):	All the volume of the building is heated through the radiators.
Opening to the public (from/to; hours /day; temperature set-up):	The University working day is from 8:00 to 21:30 and Monday-Friday. The number of average students from Monday to Thursday is about 250-300 students, whereas Friday, the estimated people in the building is around 30-40.
Hours of working (from/to, hours/ day; temperature set-up):	The heating system is working from 7:00 to 19:00 and it is totally controlled from the central side of the University placed on Salamanca, Spain.
Hours of air conditioning (from/to; hours/day; temperature set-up)	No air-conditioning use is in this area.
Comments	---

1 Report on status pre-intervention

During the pre-intervention analysis or diagnosis, the main goal is the detection of potential interventions for energy savings and comfort improvements. Thus, several tests have been carried out in the building in order to detect the air-tightness, moisture and discomfort, among others. Thus, the different architectural elements, facilities and current systems have been identified.

Moreover, the interventions proposed for this type of building are focused on three objectives: conservation of the historical value, energy balance improvement and comfort conditions improvement, acting on the building envelope (thermal isolation, airtightness, thermal inertia), the energy systems (increasing efficiency, optimized control systems, renewable energies integration) and indoor comfort conditions (IAQ and lighting).

The validation process of these proposals combines the use of three diagnosis resources (Figure 1 left side): the energy performance simulation, monitoring and measurement processes and non-destructive testing in the building. Finally, it is proposed a benchmarking system based on energy savings, CO_2 emissions reduction, comfort conditions improvement, economical investment, life-cycle assessment and, one of the most important, due to the character of the project: the conservation of the historical value of the building. The main objective of this methodology is to establish a quantifiable basis, based on scientific foundations in order to assess the impact that some energy efficient interventions may have in this type of building.

In the presented case study, the methodology is now developing the validation process (Figure 1 right side), in order to select the most appropriate interventions to be deployed in the building.

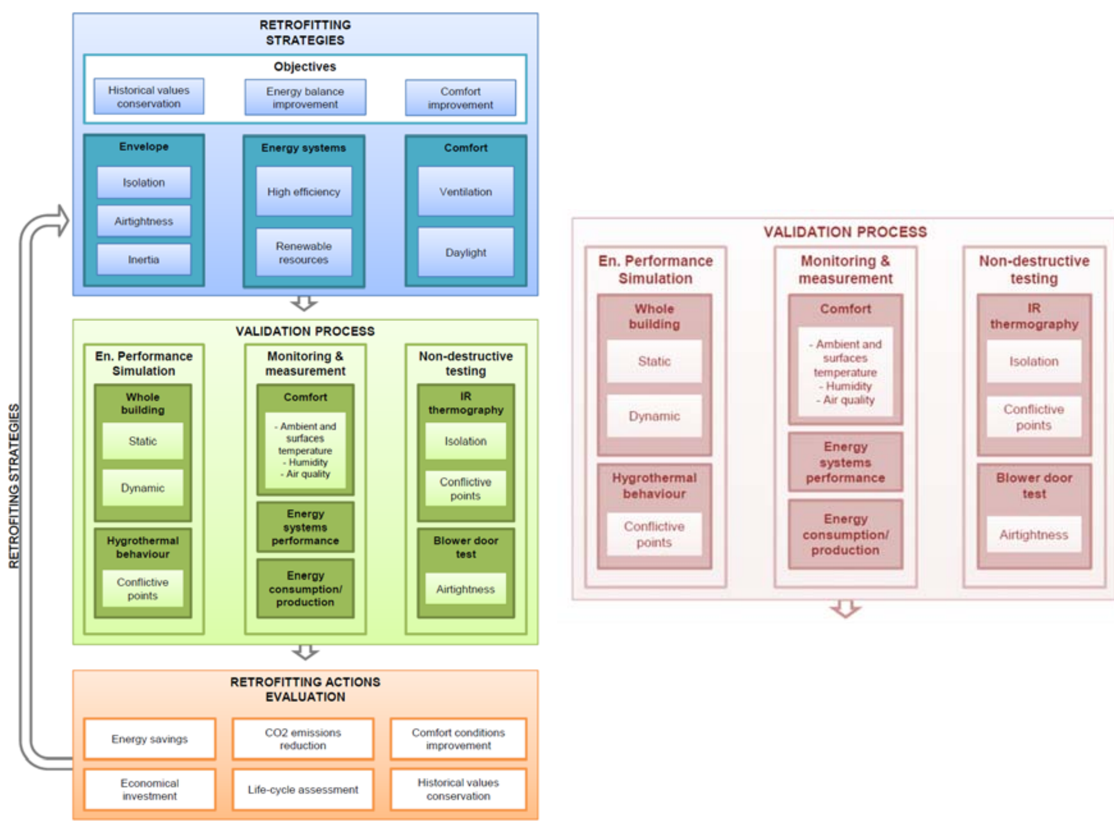


Figure 1: Diagnosis methodology

1.1 Analysis of architectural elements

The building has a net built area of 13,624.85 m^2 and a net usable area of 9,467.10 m^2 distributed on ground floor, two basements and four floors above ground.

1.1.1 Thermal envelope

General description
The structure is made of reinforced concrete pillars and slabs, which are the cantilevers in the east façade. The pillars and slab fronts, without thermal insulation, embedded on the walls, and independents of the brick surfaces, cause important pathologies (thermal bridges, lines of infiltrations, etc.). The building envelope is made of two faces, where the outdoor face is made of concrete blocks and the indoor face is a double hollow bricked wall with interior plaster. The walls have not insulation material but between the two faces there is a non-ventilated air camera, of 5 cm, so that the transmittance of these elements is U=1.50 W/m^2·K. The windows appear as large horizontal stripes alternating fixed glazes and windows. In a recent refurbishment, all windows were replaced with aluminium windows with thermal bridge rupture and double glazing (4+6+4), so that the transmittance of the windows is U=3.45 W/m^2·K, and the g-Value is 0.76. The roof was modified several times during the building's life, being the current solution made of zinc plate above ceramic board and light brick partition walls, so that the transmittance is U=1.75 W/m^2·K. Then, the global transmittance of the building is U=2.10 W/m^2·K.
Heritage aspects
Not applicable

Façade 1: North façade

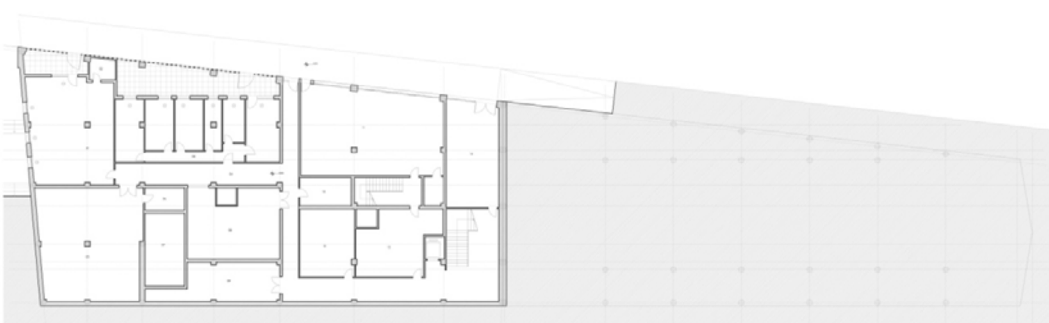
Façade 2: South façade

Façade 3: West façade

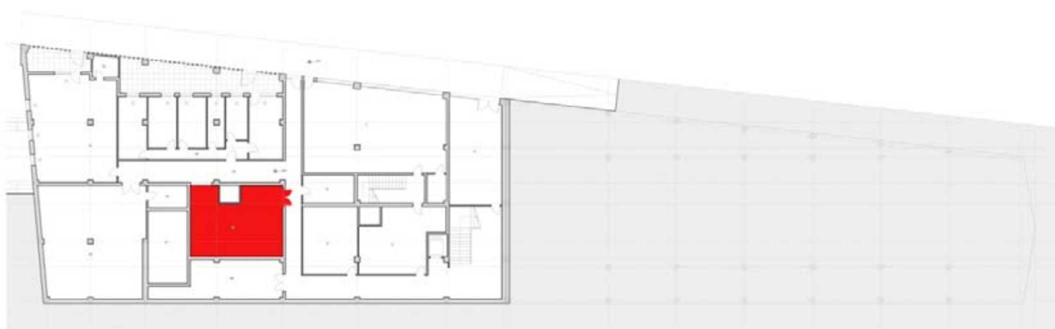
Façade 4: East façade

1.1.2 Rooms and room units

2nd basement

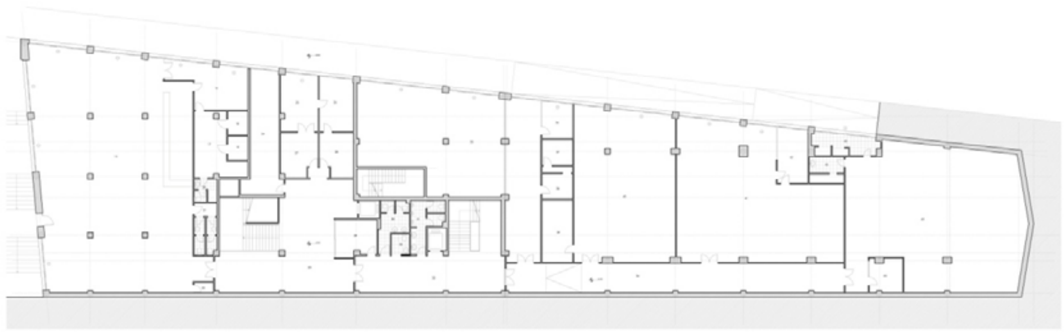


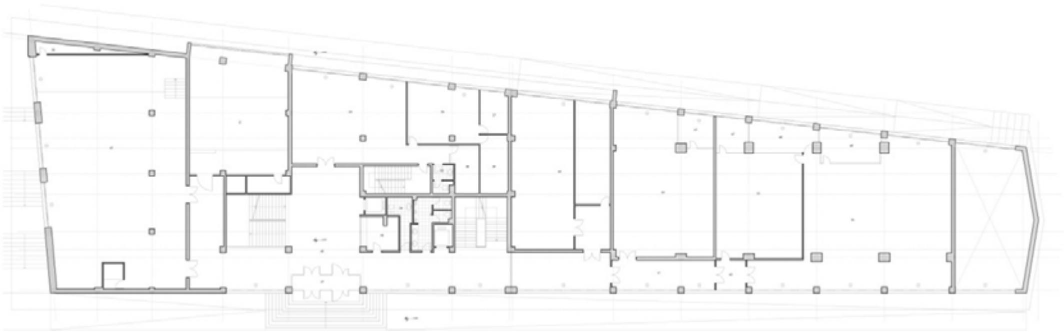
Description	The surface of this floor is the half of other normal floors. It is used to whole services of heating, transformation center, stores and whole files, as well as it is placed two housing of

	subordinate members of the team. The transformation center and housings have independent outside access.
Height interpolated average net (m)	----
Surface area	726.75 m^2
Volume (gross/net) heated (m^3)	This floor is not heated at all
Number of rooms	14
Comments	----
Heritage aspects regarding the floor	Not applicable
Description of room	
Name/ room number	Boilers room
Construction phase	See building construction phase
	
Description	This room contains the generation and distribution systems for the whole building.
Dimension	The area of the room is of 51.40m^2.
Design Phase	During the design phase, the thermal consumption has been measured in order to find out solutions for the energy generation improvement.
Description of design phase	In a first step, the visual inspection was carried out. Afterwards, the monitoring system for measuring the thermal consumption was completed with temperature and pressure sensors and knowing the performance of the pump, the energy can be calculated. Once evaluated the values, the proposal could be finished.
Description conditions	No additional comments.
Actual/planned use	Generation and distribution systems

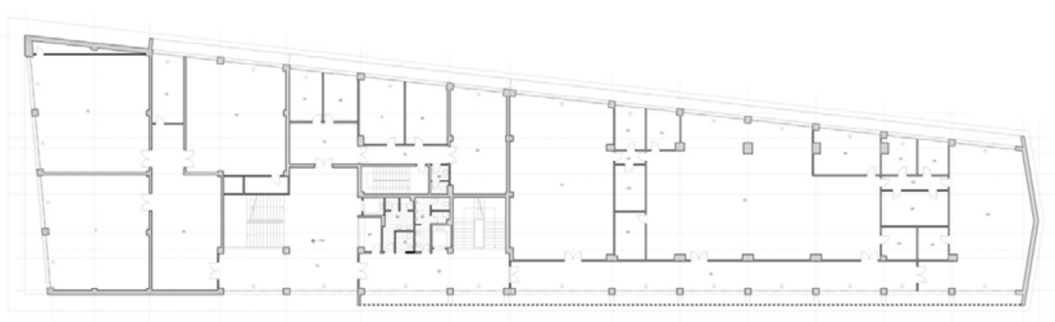
Mobile equipment	Not applicable
Present room conditions: temperature, air humidity (measured room climate as-is-state)	Not applicable
Daylight potential	No daylight available
Comments	----
Technical equipment	
Heating	
Description	There are two gas-oil boilers from ROCA trademark where one of them is working in support mode. The main boiler has a power of 581kW whereas the second has 418.6kW. The performance of both boiler are 88.5% and 88.1% respectevely.To supply of boilers, they have a tank/cistern of 25000 litres. The normal consumption during winter season is 60000 litres. This year they think that will be decreased the consumption to 45000 litres due to the timetable is reduced one hour. Years ago the boiler performs from 7:00 to 20:00. Currently, it performs from 7:00, but to 19:00. Weekends, the university college is closed and the boilers are switched off. It is estimated the consumption of boilers are about 600 litres each 13 hours. Although, it was before managed from the building, actually it is remote managed from Salamanca.
Lightning	No picture available
Description	Luminaries number: 6 - Philips TL-D 36W/840 1SL (Low-pressure mercury discharge lamps with a diameter of 26 mm)

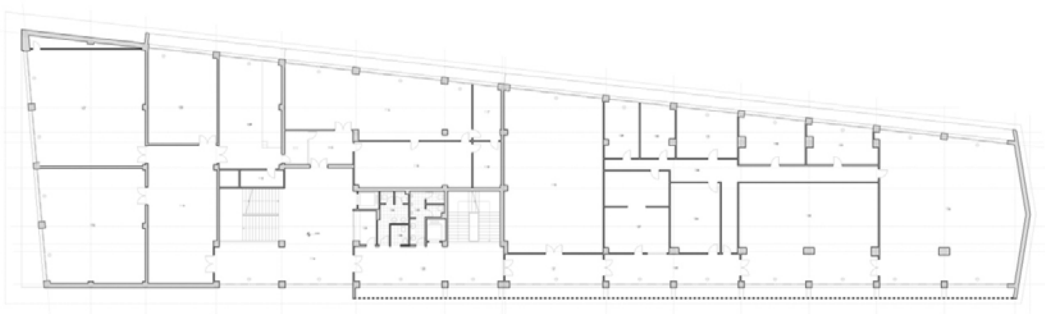
Potential and Limitations regarding the room	
Heritage value of room and its equipment in general	Not applicable
Possibility of additional window openings in exterior walls (max. size/limitations)	Not applicable
Possibility of additional layer inside ---> see also facade level	Not applicable
Possibility of installation of additional shading system (typology, integration in glazing/box type window) c.f. facade	Not applicable
Conservation/changing of installations (like heaters and lighting)	The possibility for replacing the current boilers by biomass ones is possible both from the conservation point of view and from the space one.
Conservation/changing of wall surfaces (outside), historic plaster, historic wall paintings by e. g. installation of insulation etc. c.f. facade.	Not applicable
Conservation/changing of window recesses, cornices and plastic elements ---> see also facade level	Not applicable
Constraints regarding wall thickness, c.f. facade	Not applicable
Possible breaches/openings, running of cables/tubes	Not applicable
Changing of window shape, materials and colours (with regard to window sashes and frame) ---> see also facade level	Not applicable
Conservation/changing of window glazing/glass visual appearance ---> see also facade level	Not applicable
Elimination, changing, moving of internal partitions	Not applicable
Comments	----

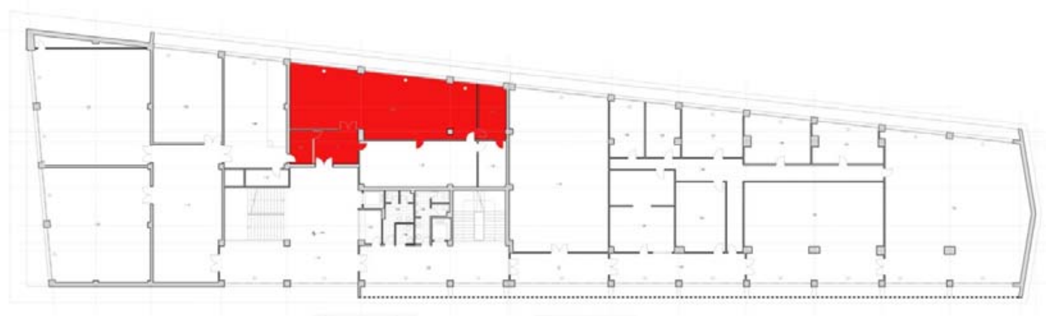
First basement	
	
Description	This floor is assigned to common services of clinic and bar-canteen, in one part. In another part, it is assigned to machinery specialty workshop. Its installation will need special foundation lying.
Height interpolated average net (m)	----
Surface area	1470.75 m^2
Volume (gross/net) heated (m^3)	All the volume in this floor is heated
Number of rooms	32
Comments	----
Heritage aspects regarding the floor	Not applicable

Ground floor	
	
Description	It is to park street level. This floor is the main access to building, students' activities hall, chapel, regime and secretary offices, etc. On lab zone of this floor, it is the Adjustment workshop and a theoretical-practice classroom.

Height interpolated average net (m)	----
Surface area	1361.60 m2
Volume (gross/net) heated (m^3)	All the volume is heated in this floor
Number of rooms	24
Comments	---
Heritage aspects regarding the floor	Not applicable

First floor	
	
Description	On its teaching part, it is assigned to three theoretical classroom and electricity labs: measures, electronics and electric machinery. Central zone of the floor is to direction offices: director, deputy director, secretary and academic secretary's offices.
Height interpolated average net (m)	----
Surface area	1442.45 m^2
Volume (gross/net) heated (m^3)	All the volume is heated
Number of rooms	35
Comments	----
Heritage aspects regarding the floor	Not applicable

2nd floor	
	
Description	The floor is made up for three classes as northeast facade classes of lower floor. It is projected the physics and heat engineering labs, with a theoretical-practice classroom. At the same floor, it is placed the library, with files and reading rooms, books warehouse, librarian office and a little classification and book binding room. The library has direct access from lobby
Height interpolated average net (m)	----
Surface area	1470.30 m^2
Volume (gross/net) heated (m^3)	All the volume is heated
Number of rooms	31
Comments	----
See also room group:	Below
Heritage aspects regarding the floor	Not applicable
Description of room	
Name/ room number	Library
Construction phase	See the construction phases of the whole building



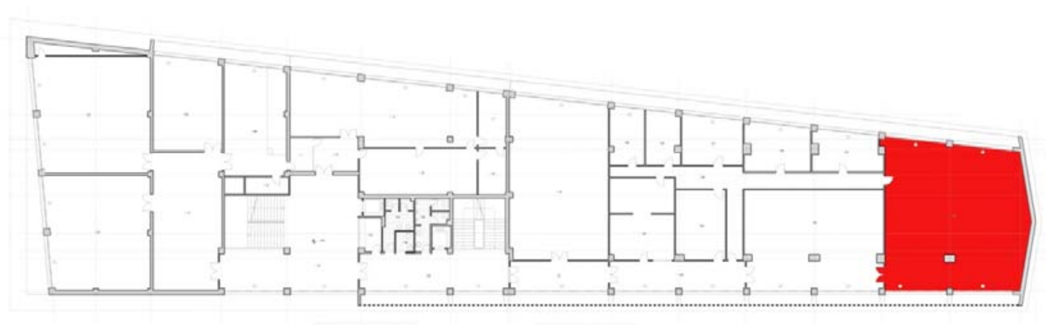
Description	The library is the room used by the pupils of the University for studying and doing work with their laptops. Therefore, the comfort conditions are the most important issue in this test room, above of all during warmed seasons. A lot of claims from students are recollected by the staff of the school, being one of the main purposes the improvement of the comfort conditions. The room is equipped with three fan-coil units which set up the only cooling system of the building. This is the reason of choosing the library as one of the test rooms.
Dimension	The total area of the library including the adjacent offices is 122.9m2. However, the study room is 97.60m^2.
Design Phase	• During the design phase, several steps have been covered: • Diagnosis: Blower door test and monitoring • Proposal of interventions: Design of the control strategy • Actuations: • Deployment of a combined HW/SW solution with the automatic control strategy.
Description of design phase	The design phase was covered by several steps where the visual inspection and several surveys for knowing the first approach of the problems. Afterwards, it was deployed the monitoring installation so as to measure the performance of the room.
Description conditions	The status of the library is a discomfort with regard to the thermal levels because during summer the temperature is too high and in winter the fan-coils are not used to support heating system, therefore a discomfort is achieve. This fact is due to manual control, which is not able to detect discomfort levels and actuate in consequence.
Actual/planned use	The use is the room for studying.
Mobile Equipment	Not applicable
Present room conditions: temperature, air humidity	The room conditions both before and after refurbishment can be accessed through:

(measured room climate as-is-state)	http://212.128.198.13:8080/FTP/ http://212.128.198.13:2505/FTP/
Daylight potential	This room presents a low daylight factor because it has windows only in the east facade, therefore the natural light is going into the room only during the early morning of every day.
Comments	----
Technical equipment	
Lightning	
Description	Luminaires number: 48- Philips TL-D 36W/840 1SL (Low-pressure mercury discharge lamps with a diameter of 26 mm)
Other	
Description	Fan-coils units – There are 3 cassettes on library and 1 split in each office. All systems are inverter. Although the equipment is only used on summer, it was detected that in one of the offices, it is connected to heating generation

Other	
Description	Radiators number: 3
Ventilation	
Description	Extractors number: 8
Potential and Limitations regarding the room	
Heritage value of room and its equipment in general	Not applicable
Possibility of additional window openings in exterior walls (max. size/limitations)	Not applicable
Possibility of additional layer inside ---> see also facade level	Not applicable
Possibility of installation of additional shading system (typology, integration in	There is a possibility for including shadow system in the windows on the East façade.

glazing/box type window) c.f. facade	
Conservation/changing of installations (like heaters and lighting)	Not applicable
Conservation/changing of wall surfaces (outside), historic plaster, historic wall paintings by e. g. installation of insulation etc. c.f. facade.	Not applicable
Conservation/changing of window recesses, cornices and plastic elements ---> see also facade level	Not applicable
Constraints regarding wall thickness, c.f. facade	Not applicable
Possible breaches/openings, running of cables/tubes	Not applicable
Changing of window shape, materials and colours (with regard to window sashes and frame) ---> see also facade level	Not applicable
Conservation/changing of window glazing/glass visual appearance ---> see also facade level	Not applicable
Elimination, changing, moving of internal partitions	Not applicable
Comments	----

Description of room	
Name/ room number	Physics laboratory
Construction phase	See construction phases above

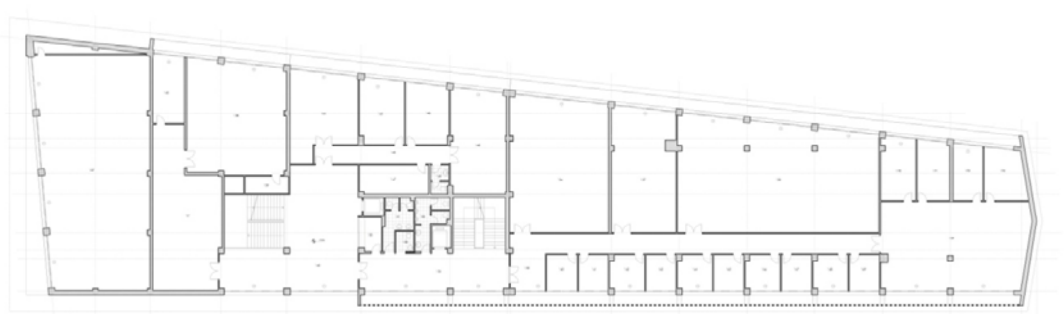


Description	That is one of the laboratories for practical activities in the building whose occupancy pattern is irregular due to the timetable of the activities in this laboratory. However, the main feature of the room is the east and west windows which favor the daylight. On the other hand, the distribution of the circuits is not the most appropiate one because the luminaries are perpendicular to the windows. Also, the lighting system is oversized in the room. These are the reasons why the laboratory is one of the test rooms with energy savings and comfort improvements potential.
Dimension	The total size of the physics laboratory is of 172.50m^2.
Design Phase	• During the design phase, some tests have been carried out: • Blower door test • Monitoring system • Dialux simulation • Design of the control strategy • Moreover, in the implementation of the solutions: • Re-distribution of lighting circuits • Deployemnt of control strategy
Description of design phase	Similar than before
Description conditions	This room presents a high level of daylight inside, which is underused. Besides that, the lighting system is oversized and overused owing to the bad distribution of the luminarires (perpendicular to windows instead of parellel). Thus, high energy consumption related to lighting system is being achieved, therefore, the strategy reduces this electricity consumption meanwhile the comfort level is maintained.
Actual/planned use	The laboratory has currently two purposes: practical classes and teacher office. However, in the next future, the laboratory will only be used as practical classes.
Present room conditions: temperature, air humidity	The room conditions both before and after refurbishment can be accessed through:

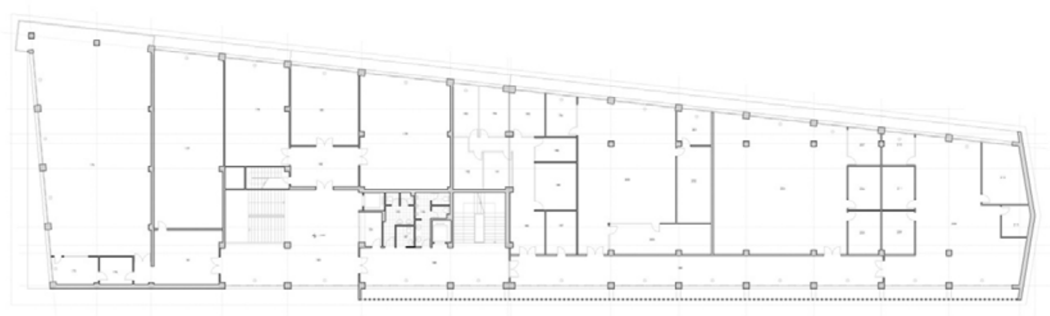
(measured room climate as-is-state)	http://212.128.198.13:8080/FTP/ http://212.128.198.13:2505/FTP/
Daylight potential	This room is the most suitable room of the building for the daylight factor because it presents windows in the east and west façades. That means the sunlight is going into during the early morning, but also the early afternoon, being the lighting levels enough for achieving the comfort conditions during all the day.
Comments	---
Technical equipment	
Lightning	
Description	Luminaires number: 60- Philips TL-D 36W/840 1SL (Low-pressure mercury discharge lamps with a diameter of 26 mm)
Other	See above
Description	Radiators number: 8

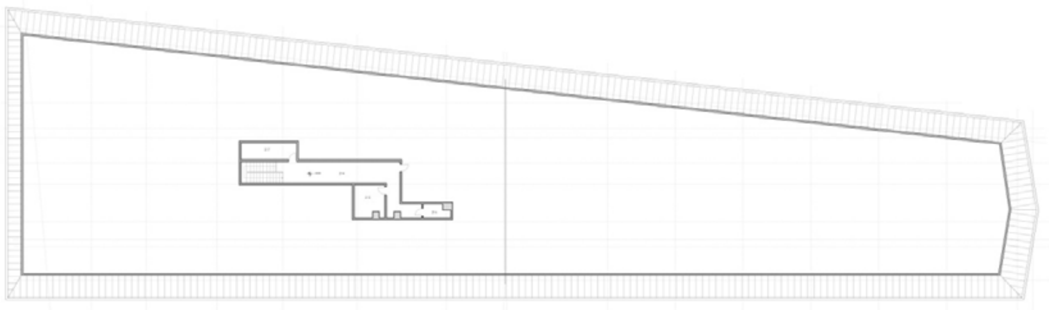
Other	
Description	The windows on the building are relatively news. They are frames with glasses “Isolarglas”. (They are looking for the invoices to obtain the features). “Isolarglas” is a thermic and acoustic isolated glazing formed by two or more glass panes separated by an aluminium profile filled in of molecular tapestry which absorbs residual humidity that avoids condensation inside the air chamber. An “Isolarglas” glazing with 12 mm chamber offers an energetic transmission coefficient U of 2.8W/m^{2}K, while one simple glass pane reaches a coefficient of 5.8W/m^{2}K. It is able of reduce the transmission loss of energy through the glass on 50% with this kind of glass.
Potential and Limitations regarding the room	
Heritage value of room and its equipment in general	Not applicable
Possibility of additional window openings in exterior walls (max. size/limitations)	Not applicable
Possibility of additional layer inside ---> see also facade level	Not applicable
Possibility of installation of additional shading system (typology, integration in glazing/box type window) c.f. facade	Currently, there is the lattice as shadow element, although in the East façade could be added an additional shadow system.
Conservation/changing of installations (like heaters and lighting)	Not applicable
Conservation/changing of wall surfaces (outside), historic plaster, historic wall paintings by	Not applicable

e. g. installation of insulation etc. c.f. facade.	
Conservation/changing of window recesses, cornices and plastic elements ---> see also facade level	Not applicable
Constraints regarding wall thickness, c.f. facade	Not applicable
Possible breaches/openings, running of cables/tubes	Not applicable
Changing of window shape, materials and colors (with regard to window sashes and frame) ---> see also facade level	Not applicable
Conservation/changing of window glazing/glass visual appearance ---> see also facade level	Not applicable
Elimination, changing, moving of internal partitions	Not applicable
Comments	----

3rd floor	
	
Description	At this floor it is repeated the three theoretical-practice classrooms like lower floors. In similar arrangement of physics lab, it is projected chemistry lab which has complementary services. These are practice training room, balance, store and teacher's offices. In central zone of the floor is placed Delegation of Students.
Height interpolated average net (m)	----
Surface area	1467.35 m^2

Volume (gross/net) heated (m^3)	All the volume is heated
Number of rooms	37
Comments	----
Heritage aspects regarding the floor	Not applicable

Fourth floor	
	
Description	Due the needs of sunlight and less frequency of use, at this floor it is laid out drawing class and technical office next to textiles labs. Between these labs, it has been done without spinning and weaves workshops. It is cause of the existence of the current College and similar workshops on Béjar industry. Also, it is added the high cost of accurate machines and the high surface needed.
Height interpolated average net (m)	----
Surface area	1481.25 m^2
Volume (gross/net) heated (m^3)	All the volume is heated
Number of rooms	40
Comments	----
Heritage aspects regarding the floor	Not applicable

Top floor	
	
Description	This top floor is the corresponding to the roof of the building where the weather station is installed, as well as the lift rooms.
Height interpolated average net (m)	----
Surface area	46.65 m^2
Volume (gross/net) heated (m^3)	No volume is heated in this floor.
Number of rooms	4
Comments	----
Heritage aspects regarding the floor	Not applicable

1.2 Structural analysis and assessment of moisture

Building safety	
Description of building safety with regards statics/structural problems - compliance with local regulations:	At the moment of the intervention, the status of conservation of the building is good without structural damages. Besides that, the refurbishment actions only require the re-installation of the system in the ceiling of the rooms, with no structural issues/problems to be faced.
Certificates/reports/regulations on statics:	Not applicable
Description of building safety with regards dangerous materials (to remove) - compliance with local regulations:	Not applicable
Certificates/reports/regulations on dangerous materials:	Not applicable

Description of building safety with regards fire protection - compliance with local regulations:	Not applicable
Certificates/reports/regulations on fire protection:	Not applicable
Description of building safety with regards seismic safety - compliance with local regulations:	Not applicable
Certificates/reports/regulations on seismic safety:	Not applicable
Description of building safety with regards noise protection - compliance with local regulations:	Not applicable
Certificates/reports/regulations on noise protection:	Not applicable
Description of building problems with regards humidity:	Not applicable
Description of building problems with regards salts:	Not applicable

1.3 Hygrothermal and environmental monitoring

See the monitoring system specification section which details all the monitoring variables.

1.4 Results derived from the application of PHPP

Specific building demands with reference to the treated floor area

		Value	Unit	Requirements	Fulfilled?*
	Treated floor area	10525.5	m²		
Space heating	Heating demand	70	kWh/(m²a)	15 kWh/(m²a)	no
	Heating load	36	W/m²	10 W/m²	no
Space cooling	Overall specif. space cooling demand		kWh/(m²a)	-	-
	Cooling load		W/m²	-	-
	Frequency of overheating (> 25 °C)	25.5	%	-	-
Primary energy	Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances		kWh/(m²a)	120 kWh/(m²a)	
	DHW, space heating and auxiliary electricity		kWh/(m²a)	-	-
	Specific primary energy reduction through solar electricity		kWh/(m²a)	-	-
Airtightness	Pressurization test result n_{50}	3.0	1/h	0.6 1/h	no

* empty field: data missing; '-': no requirement

Table 1. PHPP simulation results

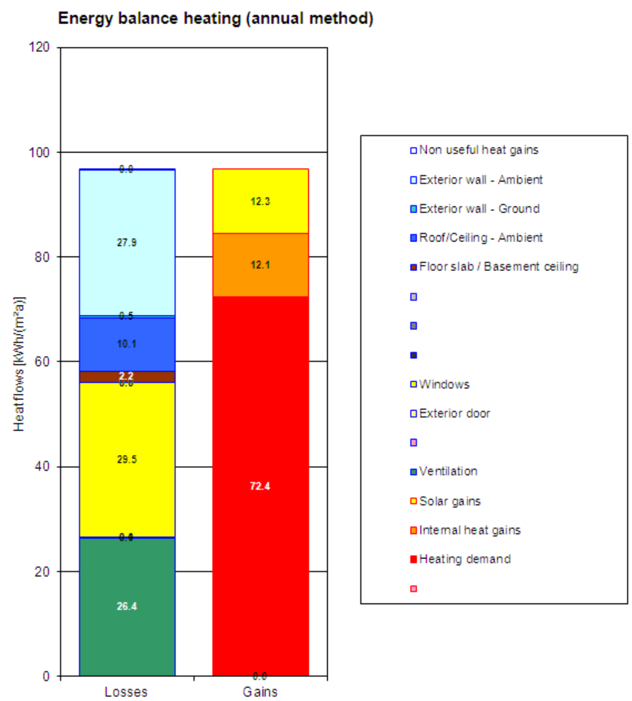


Table 2. Balance of the heating energy demand (initial evaluation)

In this case, the cooling system is minimal, being the cooled area of 150m², which supposes only the 2% of the heated area. Also, in summer periods the occupancy level of the building is very low. Therefore, the simulations are focused on the heating system energy demand.

After an initial evaluation, thermal bridges and airtightness level (which has an important influence in the global energy behaviour) were included in the simulation.

Comparing real consumption data (≈70 kWh/m²a) and simulated energy demand, it is verified that the covered range is not sufficient in order to keep the indoor parameters in comfort conditions during the heating period. By simulating the existing heating systems, the energy consumption is similar than the simulated demand, and under this premise, temperature conditions are out of comfort parameters in approximately the 30% of the heating period.

Heating energy balance	kWh/m²a
Controlled ventilation losses (rate 0.3h^{-1})	24.70
Transmittance losses (incl. thermal bridges)	141.15
Infiltrations losses (ACH rate 0.14h^{-1})	25.85
Solar gains	62.72
Internal heat gains (conv.)	12.26
Internal heat gains (rad.)	9.97
Annual heating demand	106.75

Table 3. Balance of the heating energy demand

1.5 Overall rating

In a first approach to the diagnosis of the problems of the building, the following aspects were detected:

- overheating during the warmer months, especially in the east façade, in spite of the air-based cooling systems installed in the rooms with this trouble;
- deficient heating distribution system, with only two circuits, which derives in high temperature differences and comfort problems;
- manual control strategy for cooling system elements, what generates low comfort conditions on the cooled area;
- oversized lighting system in corridors and halls;
- inefficient lighting system due to the incorrect distribution of the lighting circuits in the classrooms and laboratories;
- underutilization of daylight and solar radiation. Despite of the many hours of sunlight, the natural solar light is not being put to good use and much electrical energy is being wasted in artificial lighting;
- problems due to the low level of insulation and infiltrations

2 Design

2.1 Intervention needs

As said in the previous chapter, several inefficiencies have been detected and potential energy saving could be achieved by the intervention. Furthermore, discomfort has been also confirmed in the pre-intervention status. In fact, there are a lot of claims due to thermal discomfort is come room, but, above of all, in the library.

All these problems detected establish the wide range of the required interventions in order to improve the behaviour of the building both at energy level and at comfort.

When analysed the energy behaviour of the building and its systems, the main interventions planned in order to reduce the energy consumption and improve the comfort conditions are focused on the improvement of the passive systems, in particular acting on the building envelope.

Thus, through increasing the insulation level of the building envelope and the optimization of the airtightness, the energy consumption could be considerably reduced. If these interventions are combined with others acting over active systems (e.g. by improving the efficiency of the heating system and the zoning of the distribution system) the comfort rate of the building could be increased, reaching comfort levels during the whole building operation. An optimized zoning should consider the use of thermostatic valves that could reduce the set-point where the comfort requirements are not as demanding (e.g. in corridors or halls) as in the classrooms or laboratories. Also, a control system with occupancy profiles (in function of the classes schedules), could be used in order to reduce the set-point on classrooms and laboratories when they are not occupied, allowing a more efficient use of the existing resources.

The high electricity consumption level (25kWh/m^{2}a) could be reduced by using an optimized lighting system, more efficient (e.g. using LED devices) and integrating an optimized control. Also, renewable energy sources could be integrated in order to reduce the final energy consumption from the grid. According to the characteristics of the building, a biomass boiler could be integrated, replacing the existing boiler, while the integration of other sources such as photovoltaic would mean a higher impact in the building, and it needs to be evaluated with the other key aspects (historical value, etc.)

This methodology covers the evaluation of the proposed interventions in terms of energy savings, CO_2 emissions reduction, comfort conditions improvement, economical investment, life-cycle assessment and conservation of the historical value. This paper only presents the evaluation related to energy savings, comfort and historical value.

2.2 Simulation

The way to evaluate the energy savings due to the interventions can be based on the simulation baseline or developed through the comparison of the baseline monitored data with the reported data after the intervention. In this first stage, only a simulated evaluation can be done, since the second monitoring phase is now beginning. Following are presented the results obtained through the use of the simulation. For the simulation results, it can be viewed the section 1.4 and the energy savings by simulation is included in 4.1.2 and 4.1.3.

The benchmarking system for evaluating the reduction of the energy demand has been established considering the percentage of the demand reduction compared to the baseline demand. Thus, the different strategies can be compared. This benchmarking system is combined with the evaluation of the other key aspects considered in the methodology.

2.3 Planned solution

Taking into consideration the problems aforementioned and the results from the diagnosis, as first proposal of interventions the following list remarks the main ones selected in the building:

- increase the insulation level of the building envelope and optimization of the airtightness in order to reduce the energy consumption.
- deployment of the photovoltaic cells in the east façade in order to take advantage of the solar radiation.
- redistribution of lighting systems in the rooms so as to favour the daylight, improving the comfort.
- combination of the redistribution of the lighting systems with a control strategy for switching off those luminaires where pupils are not working, decreasing the energy consumption.
- development of a control strategy based on room temperature and occupancy pattern for the improvement of the comfort of the cooling systems.

The three latest ones are the basis of the control systems deployed in the building for the evaluation of the comfort improvements and the energy savings which will be evaluated with the second reporting period.

As summary of the proposal of intervention, Table 4 classifies the different alternatives into passive, active and control solutions and which parameter affects. Thus, for example, the energy efficiency could be improved with passive solutions through the internal/external insulation.

	Passive solutions	Active solutions	Control
Energy efficiency	Internal/external insulation Air tightness	Thermal distribution improvement Ventilation with heat recovery	Lighting system
Comfort	-	-	Lighting system HVAC system
RES Integration	-	Solar PV Biomass boilers	-

Table 4: Summary and classification of the planned interventions

2.4 Transfer to urban scale concept

Not applicable.

2.5 Information for on-site retrofit works

Description of nearby areas for organizing the on-site retrofit works	#feld2_2_2_#
How is the building/building part used during the retrofit works?	#feld5_2_2_#

2.6 Others

2.6.1 Blower door test

The Blower Door test was carried out in the physics laboratory and library as test rooms in order to evaluate the envelope through the air flow from inside to outside and vice versa. For the measurements it has been followed the UNE-EN 13829:2002 Spanish regulation. For the analysis, the following equipment has been used:

- Minneapolis Blower Door, model 4.1 of Blower Door GmbH (reference number 3638) with the fan, velocity variator.
- Pressure and air flow rate probe from The Energy Conservatory (TEC) model DG-700 able to measure pressure differences with 1% of accuracy in the span -1250 Pa / +1250 Pa.
- Tectite Express 3.6 software.
- Testo AG 880 infrared camera.
- Testo AG temperature and humidity probe with accuracy of ±0.5 °C / ±2 %HR.

Furthermore, the room conditions are summarised in Table 5.

Room	Floor area (m^2)	Height (m)	Furniture (m^2)	Volume (m^3)	Envelopment area (m^2)
Laboratory	171.78	3.30	-	566.87	520.97
Library	97.36	3.51	-	341.73	361.66
Beaufort number	**Name**	**Wind speed (m/s)**	**Description**		
3	soft breeze	3.6-5.4	Small leaves and twings in constant motion, the wind displays a light flag		

Table 5: Blower door test room conditions

With regard to the climate conditions, they can be summarised as following, applying with the restrictions of the temperature differences.

- Physics Laboratory
  - Outdoor temperature = 3ºC
  - Indoor temperature = 19.1ºC→ (19.1ºC – 3.0ºC)·3.30m = 53,13 m·K < 500 m·K
  - Indoor RH = 34.2%
- Library
  - Outdoor temperature = 5ºC
  - Indoor temperature = 20.3ºC→ (20.3ºC – 5.0ºC)·3.51m = 53,70 m·K < 500 m·K
  - Indoor RH = 38.4%

Some pictures of the test can be viewed in Figure 2 and Figure 3.

Figure 2: Blower door test in the physics laboratory

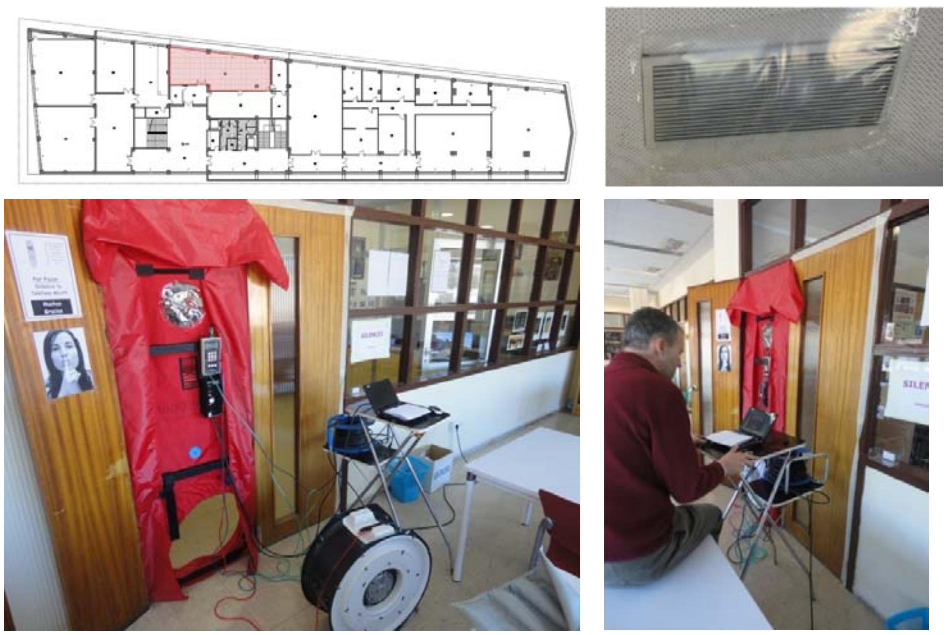


Figure 3: Blower door test in the library

With regard to the results, Table 6 and Table 7 summarise the measurements, meanwhile Figure 4 and Figure 5 draw the air flow rate in function of the differential pressure. Thus, the results are interpreted as follows:

- Laboratory test 1 (with opened ventilation chimneys)
    - V_{50} average flow at 50 Pa (m^3/h)= 5191 m^3/h
    - n_{50} air change rate at 50 Pa (1/h)= 9,2 h-1
    - w_{50} air flow at 50 Pa / usable floor area= 30,2 $m^3/m^2 \cdot h$
    - q_{50} air flow at 50 Pa / envelopment area= 10,0 $m^3/m^2 \cdot h$
    - Annual average air change rate= 9,2/20 = 0,46 h-1
- Laboratory test 2 (with closed ventilation chimneys)
    - V_{50} average flow at 50 Pa (m3/h) = 4778 m^3/h
    - n_{50} air change rate at 50 Pa (1/h) = 8,4 h-1
    - w_{50} air flow at 50 Pa / usable floor area = 27,8 $m^3/m^2 \cdot h$
    - q_{50} air flow at 50 Pa / envelopment area = 9,2 $m^3/m^2 \cdot h$
    - Annual average air change rate= 8,4/20 = 0,42 h^{-1}

Analysing the results, it is obvious the air-tightness level very low. However, these results are representative because it had not been validated with the pressurization test; therefore they could be taken on basis of the envelope characterization. Moreover, the results vary if the ventilation conducts are closed in the South façade (chimneys) and owing to the inexistence of elements for closing them; they are assumed as air inlet ways, being the first test valid. Finally, the constructive features of the space avoid neglecting the ait-tightness coming from outside with those coming from the indoor space.

Regarding the library, the existence of a false permeable ceiling conforms a common air chamber with the adjacent space, being not controllable. Thus, it is impossible to determine the area as a unique zone and complete the essay. The only chance is the inclusion of all the spaces near the library and disassembles the ceiling in order to avoid the air flow from other air chambers.

Test BlowerDoor

EN 13829

Minneapolis BlowerDoor Modell 4 - Tectite Express 3.6.7.0

Edificio objeto:	ETSII Béjar	Técnico:	A. Meiss
	Béjar	Fecha:	02/07/2013

Temperatura y Viento

Temperatura interior:	19 °C	Fuerza del viento:	3
Temperatura exterior:	3 °C	Puntos exteriores de referencia de medición:	1
Presión barométrica: Normativa:	90465 Pa	Exposición al viento del edificio:	C
		Incertidumbre a causa del viento (Tabla de Geißler)	11 %

Elementos de medida

Diafragma	Edificio Presión	Ventilador Presión	Flujo del ventilador Vr	Tolerancia
O ABCDE	[Pa]	[Pa]	[m³/h]	[%]
Δp_{01}	-1,5	—	—	—
0	-71	70	5857	-0,46
0	-67	68	5744	1,08
0	-62	60	5441	0,08
0	-56	54	5145	0,39
0	-52	48	4892	-0,71
0	-46	42	4538	-1,15
0	-42	38	4352	0,51
0	-36	31	3957	0,44
A	-31	186	3630	-0,73
A	-26	155	3318	0,58
Δp_{02}	-2,0	—	—	—

Coeficiente de correlación r:		*0,999*	Intervalo de confianza	
C_{env}	[m³/(h Pa^n)]	547	max. 583	min. 512
C_L	[m³/(h Pa^n)]	534	max. 570	min. 501
n	[-]	0,56	max. 0,58	min. 0,54

Resultados

V =	567 m³	A_F =	172 m²	A_E =	521 m²

	V_{50}	Incertidumbre	n_{50}	Incertidumbre	w_{50}	Incertidumbre	q_{50}	Incertidumbre
	m³/h	%	1/h	%	m³/m²h	%	m³/m²h	%
Despresurización	4778	+/- 12 %	8,4	+/- 13 %	27,8	+/- 13 %	9,2	+/- 13 %

Table 6: Blower door laboratory results

Test BlowerDoor

EN 13829

Minneapolis BlowerDoor Modell 4 - Tectite Express 3.6.7.0

Edificio objeto:	ETSII Béjar Béjar	Técnico:	A. Meiss
		Fecha:	02/07/2013

Temperatura y Viento

Temperatura interior:	19 °C	Fuerza del viento:	3
Temperatura exterior:	3 °C	Puntos exteriores de referencia de medición:	1
Presión barométrica: Normativa:	90465 Pa	Exposición al viento del edificio:	C
		Incertidumbre a causa del viento (Tabla de Geißler)	11 %

Elementos de medida

Diafragma	Edificio Presión	Ventilador Presión	Flujo del ventilador Vr	Tolerancia
O ABCDE	[Pa]	[Pa]	[m³/h]	[%]
Δp_{01}	0,9	—	—	—
0	-55	106	7155	-1,04
0	-54	104	7090	-0,75
0	-51	100	6948	0,23
0	-50	98	6871	0,59
0	-44	85	6435	0,13
0	-44	85	6423	0,25
0	-38	75	6038	1,72
0	-35	65	5630	-0,22
0	-29	51	5033	-0,47
0	-24	42	4556	-0,43
Δp_{02}	1,0	—	—	—

Coeficiente de correlación r:		*0,999*	Intervalo de confianza	
C_{env}	[m³/(h Pa^n)]	761	max. 830	min. 697
C_L	[m³/(h Pa^n)]	739	max. 807	min. 678
n	[-]	0,56	max. 0,58	min. 0,54

Resultados

			V =	342 m³	A_F =	97 m²	A_E =	362 m²
	V_{50}	Incertidumbre	n_{50}	Incertidumbre	w_{50}	Incertidumbre	q_{50}	Incertidumbre
	m³/h	%	1/h	%	m³/m²h	%	m³/m²h	%
Despresurización	6646	+/- 12 %	19,4	+/- 13 %	68,3	+/- 13 %	18,4	+/- 13 %

Table 7: Blower door results in the library

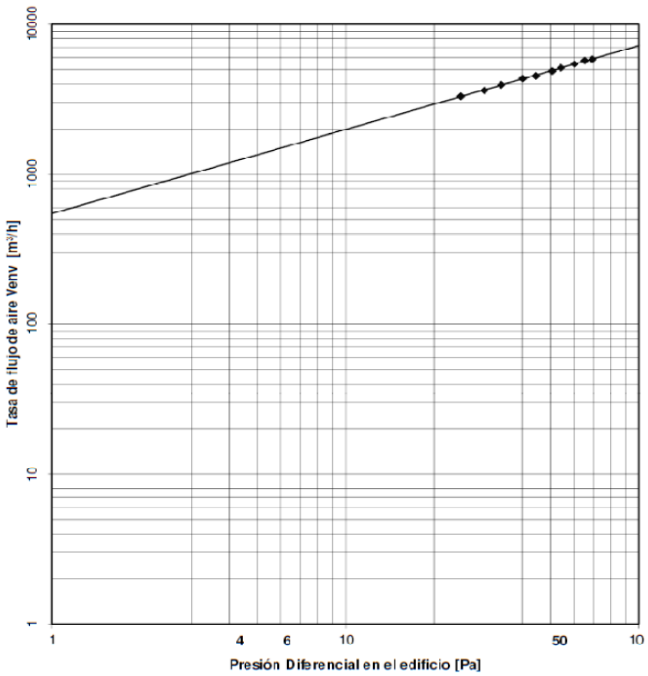


Figure 4: Differential pressure and air flow rate in the laboratory

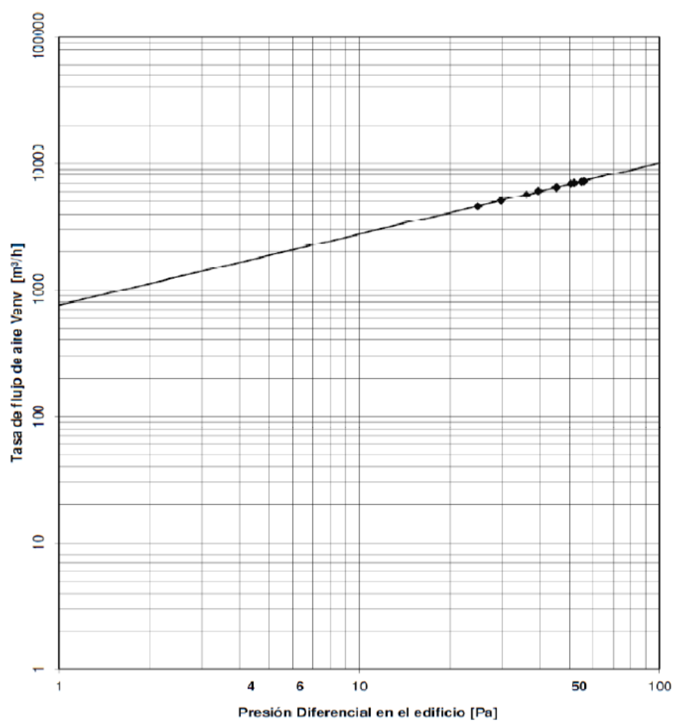


Figure 5: Differential pressure and air flow rate in the library

In combination with the blower door test, an analysis of the infrared thermography has been carried out so as to detect the air tightness and the heat losses in the test rooms. The following pictures illustrate the main losses detected in both rooms (some pictures have been neglected in order to reduce the size of the document).

Figure 6: Blind thermal losses in the laboratory

Figure 7: Junction thermal losses in the laboratory

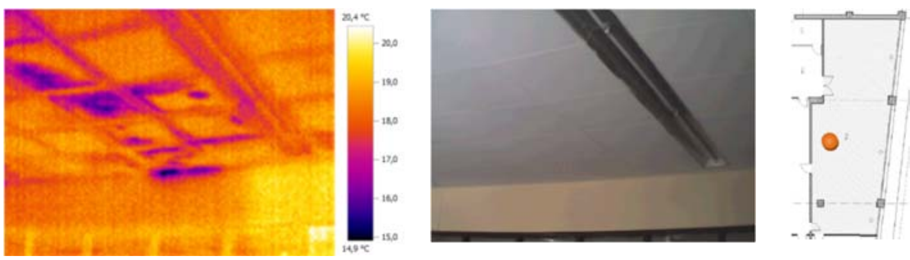
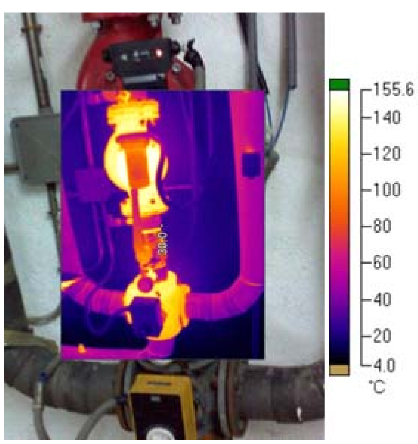


Figure 8: Thermal losses in the ceiling of the library

2.6.2 Infrared thermography

Moreover, another phase of the infrared thermography was done to detect thermal losses in other zones of the building. For this additional thermography a FLIR A300 camera was used. Some examples are represented in the next pictures.

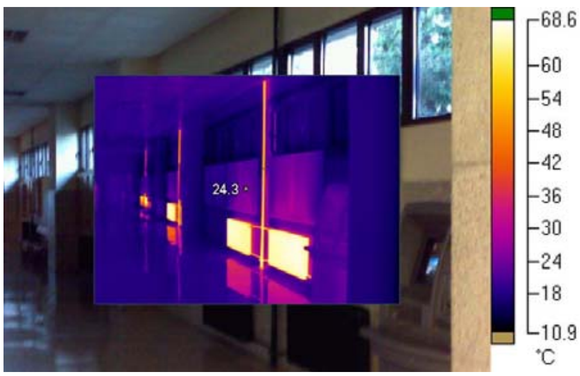


- Problem: Pipes insulation
- Emissivity: 0.25
- Reflected temperature: 25.9ºC

Figure 9: Boilers room infrared thermography

- Problem: Windows frame insulation (Thermal Bridge)
- Emissivity: 0.85
- Reflected temperature: 25.9ºC

Figure 10: Windows infrared thermography



- Problem: Radiator emission
- Emissivity: 0.85
- Reflected temperature: 25.9ºC

Figure 11: Radiators infrared thermography

2.6.3 Dialux simulation

In order to determine the possibilities of the lighting solution planned in the physics laboratory, a study of the lighting levels via dialux simulation has been carried out in the case study. Thus, several tests have been completed. First of all, the luminaires of the building are Philips TL-D 36W/840 1SL (Low-pressure mercury discharge lamps with a diameter of 26 mm).

As starting point, Figure 12 displays the 3D model for the physics laboratory as input of the simulation tool.

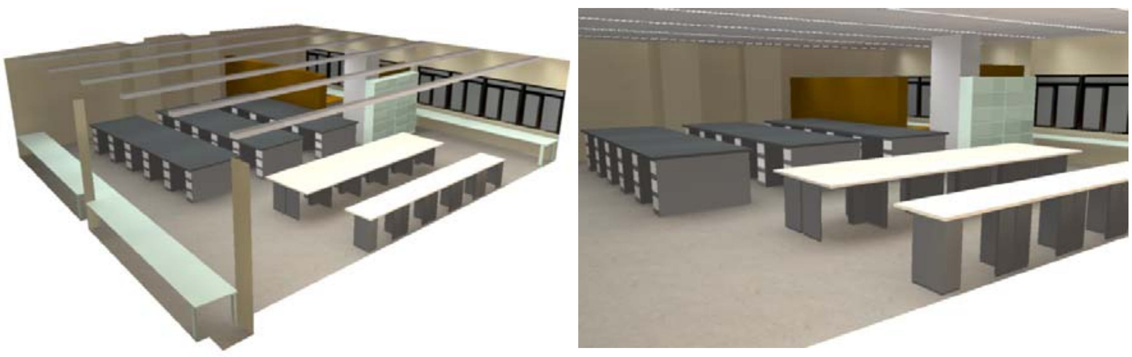


Figure 12: 3D model for the dialux simulation

As said, different simulations has been done. First of all, the lighting level with all the luminaires switched on. Figure 13 shows the results in contour line and grey scale. It can be clearly observed on the North area (left side of the picture), the lux condition is higher than the South zone and, in fact, these workbenches are not used in classes. Also, the distribution of the comfort condition is not homogeneous, as well as, the North region levels are higher than the necessary. Nevertheless, in the South façade and central workbenches, this comfort level is not achieved, being under the minimum.

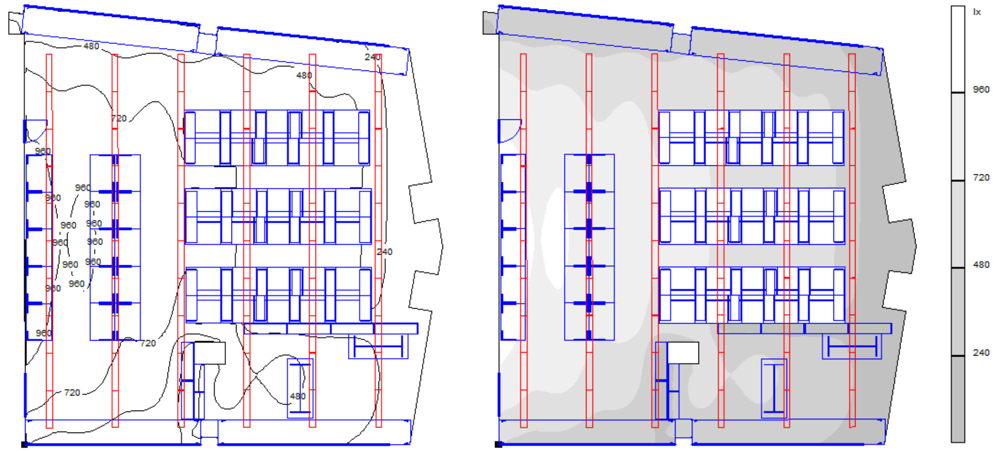


Figure 13: Lighting level with all lights on

The second test is done by switching off the half of the luminaires, those nearest the East façade (top of the picture). Then, the results are in Figure 14. The values in all the regions of the room are similar but lower than the minimum established by the UNE Spanish regulations.

Finally, the last simulation carried out is having the room rezoned and the half of the lighting system turned on. Only the luminaires of the main workbenches have been switched on (zones 4, 5 and 6 in the implementation of the solution). Thus, looking at the results (Figure 15), the central part of the room, where usually the people are, reaches the comfort level with approximately 600 lux, being the Spanish regulation 500 lux for these spaces. Then, the solution of the re-distribution of the system could improve the lighting levels and reduce the electricity consumption as far as it is required only the half of the lighting system.

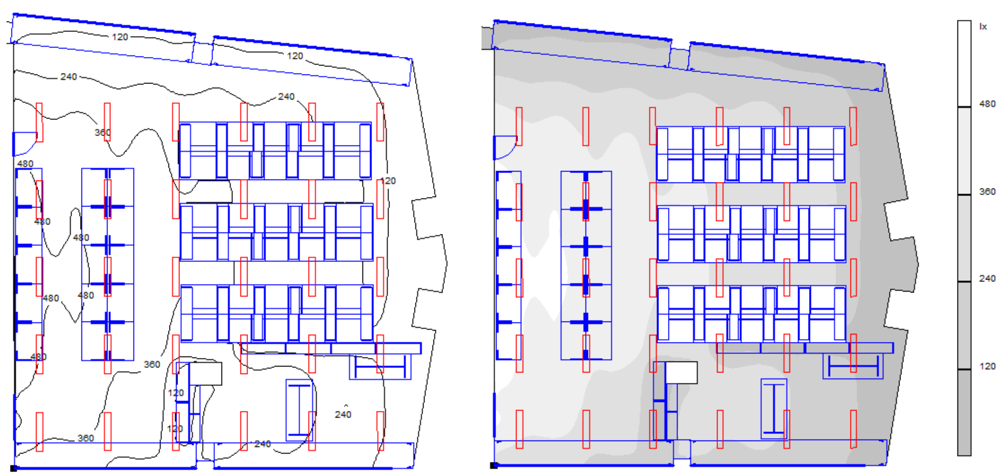


Figure 14: Lighting level with the half of the lights on

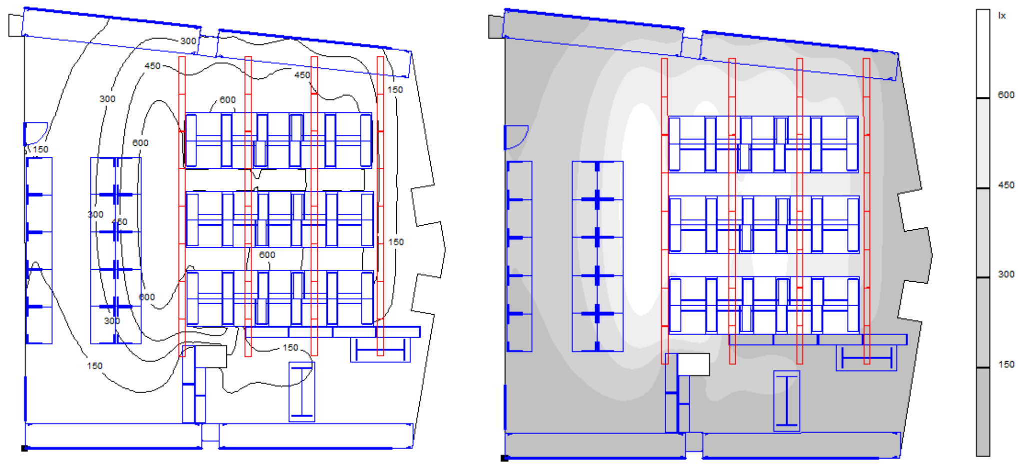


Figure 15: Lighting level after rezoning

2.7 Intervention Hypothesis

After evaluating the possibilities of the interventions, the decision was made in function of costs, involvement of the owner and capability of the local case study team. Thus, the intervention selected is the deployment of the automatic control system in the library and the physics laboratory.

Firstly, the library is one of the most problematic rooms with the problem of overheating and the only one with cooling facilities, being the study area of the building, therefore, the comfort is required in this case. At the current status, the cooling system is only used in summer and manually. However, these systems could be also used in heating mode as support of the radiators if needed to reach the comfort level. Besides that, the manual control is unable to detect the discomfort and lacks of the continuous evaluation of the room such as the occupancy patters and the parameters quality. Thus, the automatic system detecting presence and temperature levels could increase the level of comfort inside the room, as well as improving the performance of the cooling system by means of switching on only when required. The idea is the integration of a hardware gateway to translate the proprietary protocol of this equipment into an open and standard one. Afterwards, the integration of a software solution in the controller would be able to control the system being replicable in any system with the unique restriction of using the same controller. The solution is viable bearing in mind there are hardware solution for shifting the signals and possibility of deploying software solutions without interfering in the historical values of the buildings. Even more, the replication of a solution like this could be useful in museums where the quality of the environment is really important to maintain the frescos and drawings. Regarding costs, it is a very cheap solution, being needed to buy the hardware solution and to develop the control algorithm.

About the other solution is the re-distribution and automatic control of the lighting system in the physics laboratory. For this hypothesis, it could have been selected other rooms, but this is especially interesting because of the windows in the east and west façades. Thus, there is a great amount of daylight which could take advantage of. At the moment, the lighting system is oversized and the dialux simulation represents a non-uniform distribution of the lighting levels. The idea is to harmonise the lighting in the whole room via re-distribution of the luminaries circuits in order to establish the working areas in the room and actuates in consequence. The actual distribution is perpendicular to the windows, being the new circuits based on the workbenches. Then, it is estimated the usage of the half of the luminaires so as to keep the lux levels according to the regulations, being also a cost-effective solution and replicable by controlling circuits with an automatic control algorithm in function of the lighting system circuits.

3 Implementation

Starting up, the library is designed through the hardware and software gateways. In the case of hardware, a solution for the translation from the ECO-I Panasonic communication protocol to LonWorks one is required. Thus, Figure 16 represents the hardware installation from the fan-coils to the controller deployed in the building facilities.

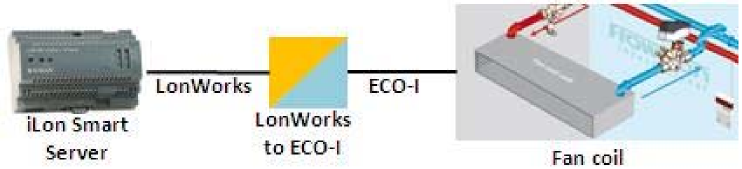


Figure 16: Signalling translation in the library

Regarding the two modes of performance defined in the hypothesis, Figure 17 displays those. In a first approach, it is defined the range of 22ºC-25ºC as comfort zone where there is no actuation in the fan-coils. However, the final implementation allows the maintenance staff to define this dead band where it is achieved the comfort conditions.

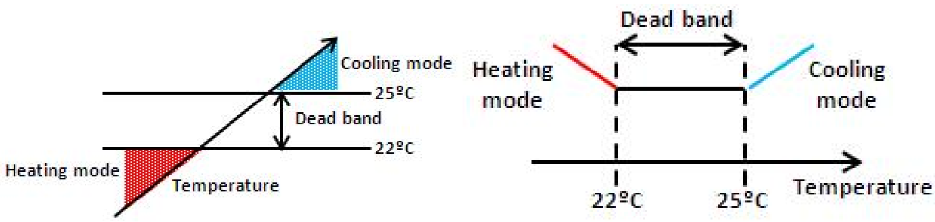


Figure 17: Definition of behaviour modes

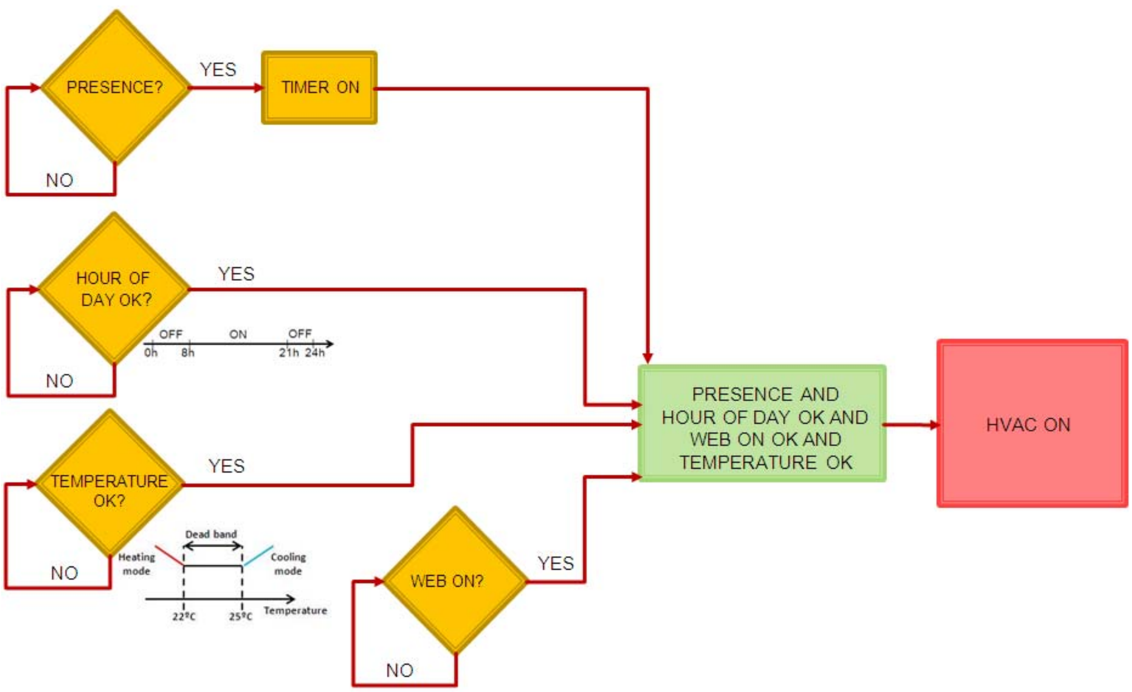


Figure 18: Work flow of the HVAC control algorithm

The implementation of the control algorithm is based on the work flow in Figure 18 where it is represented a high-level definition. Thus, the system detects the presence of the room, activating a timer for the new check before switching off the systems (bear in mind the presence sensor could send an unoccupied signal if people inside are motionless as happens in a library. Also, it takes as input the working hours of the library in order to avoid the running of the system out of the timetable. Moreover, it is checked the indoor temperature in comparison with the minimum and maximum temperature range inserted by the staff in the Web application (Figure 19) for such purpose. With all of these variables, it is determined whether the system must be on or off. In addition,

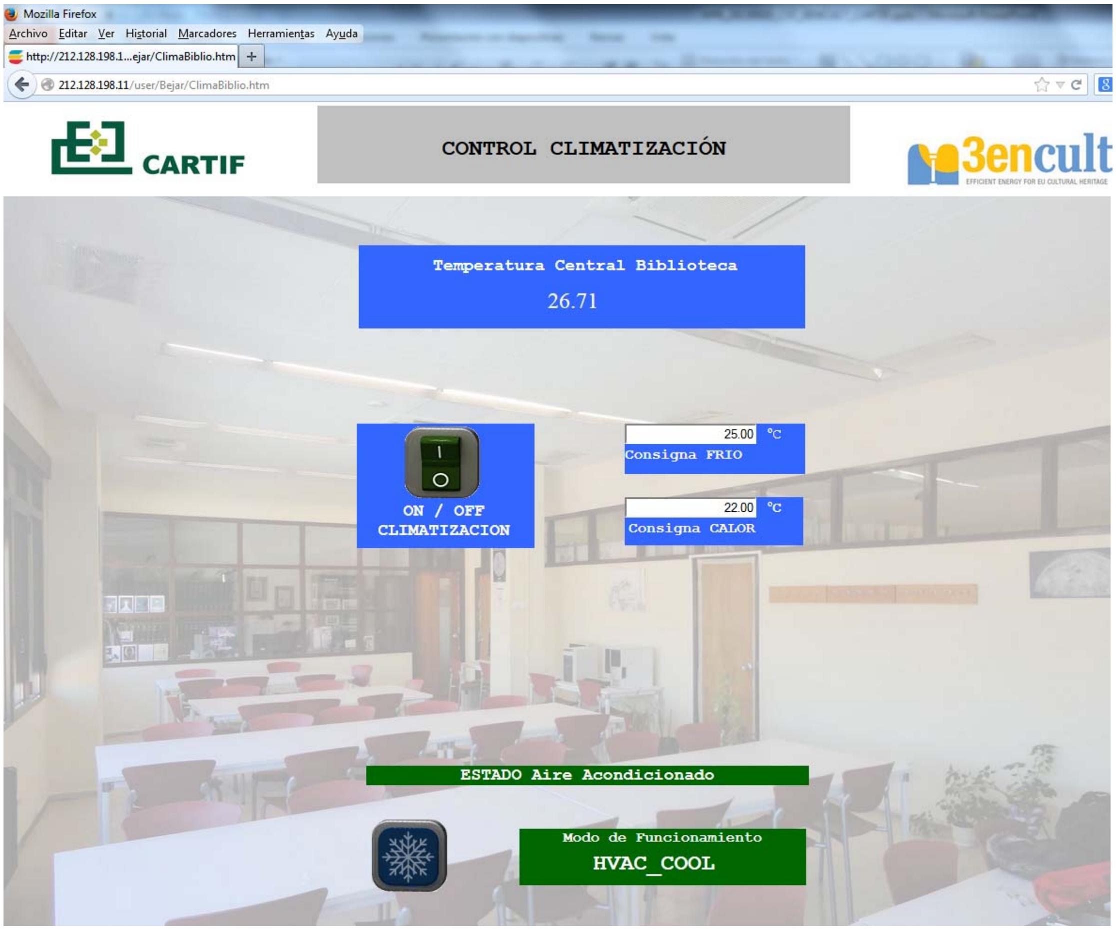


Figure 19: Web application for inserting the temperature range

The challenges faced in the implementation are the following:

- Adaptation of signals between LonWorks and HVAC protocol
    - For solving it, a combined hardware/software gateway has been developed. The hardware translates the signals and the software is able to adjust the communication due to translation mistakes detected.
- Innovation in the usage of Freely Programmable Modules (FPM) supported by iLon device
    - The controller presents the capability of implementing simple control algorithms in the device. However, complex systems are limited, but extension points are allowed. Thus, the implementation of these extension points requires the development of the code in a programming language and, after that, integrating the “virtual” controller in the current hardware.
- Combination of several sensor signals for working out the best approach
    - The room is big, being complicated the control over the system by using a single occupancy sensor because the position of a person could be detected in different ways.

For that purpose, a beam study of the presence detection has been integrated in order to ensure a better approach in the detection of occupancy.

Finally, the implementation of the control algorithm can be viewed in the Figure 22 where the block diagram is represented with the different developed functionalities. In the centre of the image an AND gate is shown. This gate checks whether all conditions about presence, schedule and timer are true and enables its output if applied. These conditions come from several switches and occupancy sensors setting up a presence sensor grid in the room. Also, there are two blocks for modifying the temperature values between a minimum and a maximum, which go towards HVAC_ block that has programmed the control algorithm for the HVAC system. This block enables the real HVAC machine depending on the previous incoming data-points.

In the case of the physics laboratory, the first step of the implementation is the re-distribution of the lighting circuits as shown in Figure 20. On the left side, it is the perpendicular original distribution, meanwhile on the right side it is the new zones of the circuits distributed in the room.

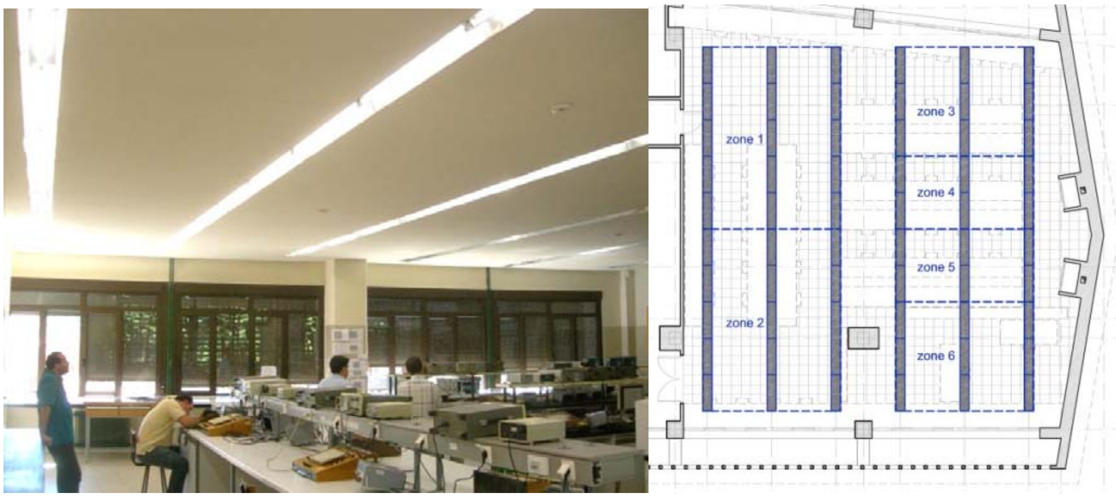


Figure 20: Old and new luminaires circuits in the physics laboratory

Thus, it is important to determine the circuit which must be switched on/off in function of the presence. However, with a single sensor it cannot be detected the circuit to be turned on. For this reason, it has been combined the different sensors installed in the room setting up a grid where the zone can be univocally determined by combining the sensor signals. Then, following Figure 21, if no presence is detected the luminaires are switched off, as well as the indoor lux level is enough or the timer is off. When occupancy, a timer is started up in order to check again the presence after a time, avoiding the usage of lighting if unoccupied. Moreover, the indoor lighting level is measured so as to decide whether the indoor conditions are enough (configurable value, at the moment 500 lux following the UNE Spanish regulation for this kind of buildings) or not. An additional feature which has been included is the priority given to the switches. Then, if the switch is pressed the first time, the light is on, meanwhile when the switch is pushed the second time, the luminaires are turned off.

The implementation of the “virtual” controller is illustrated in Figure 23 where the functional blocks are detailed. The picture shows many switches and occupancy sensors which are read by the FPM INVSENS and the FPM Acopla_Switch. The logic values of these switches and sensors are sent to different logic gates which enable its output depending on the combination of the before mentioned values. The logic gates enable a timer for occupancy controllers and the geographic zone into the room to be illuminated. The final value of the lamps depends on the constraints about occupancy sensors or hardware switches and the value of two luminance sensors. Lighting values are read by the block called Ilum_TRANS_ which enables one or two different outputs depending on the geographic zone of the room to be illuminated and it is configured the values for the minimum and maximum required lux level allowed in the room.

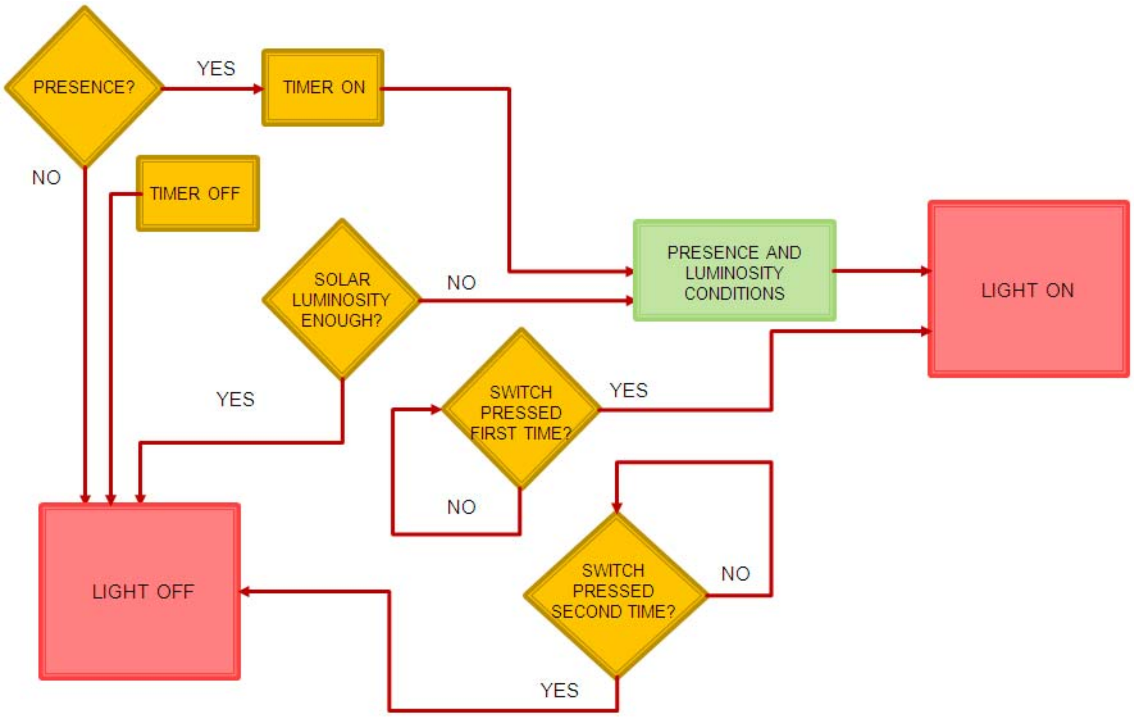


Figure 21: Flow diagram for the physics laboratory control strategy

In this second control strategy the challenges faced are the next:

- Combination of several presence detector in order to avoid switching on the wrong luminaires
  - Creation of a presence sensor grid so as to univocally detect the zone where people are working inside the room.
- Prioritize the switches and come back to the normal behaviour
  - Automatically switch off when a timer expires for avoiding lights on by error (adaptation of signals).
- Usage of timers in the hardware installed in the physics laboratory
  - It avoids the usage of the luminaires when they are really not necessary because people are out of the room or it is forgotten turning off the lights.
- Last but not least, the use of Freely Programmable Modules like before.

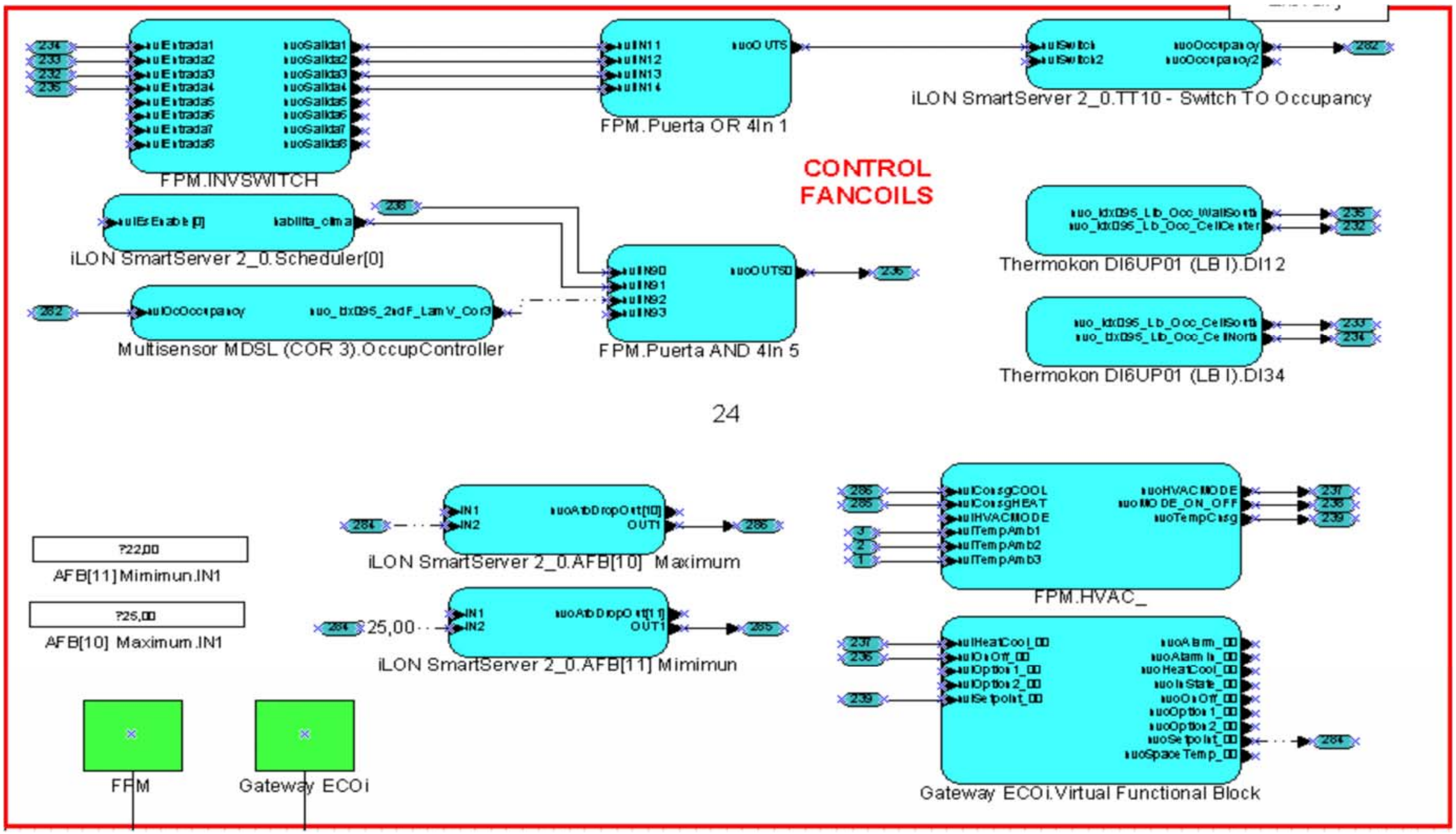


Figure 22: Implementation of the library control algorithms

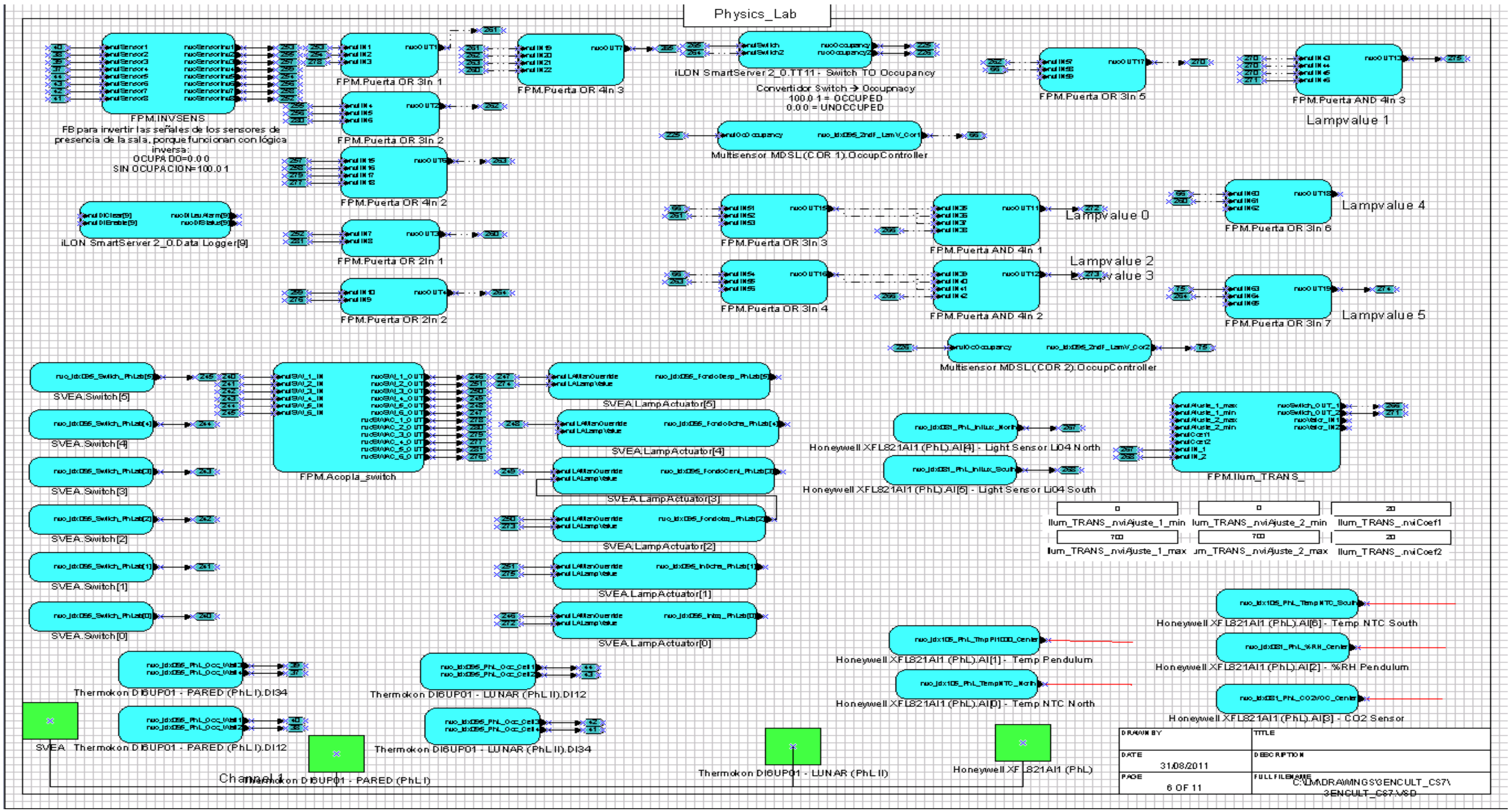


Figure 23: Implementation of the physics laboratory control algorithm

4 Post evaluation

4.1 Evaluation of the energy consumption

4.1.1 Measured energy consumption

With regard to the measured energy consumption after refurbishment, two parts must be taken into account, the electricity consumption and comfort levels both in the library and the physics laboratory. First of all, about the library, Table 8 illustrates the comparison of the electricity consumption before and after refurbishment of each one of the three fan-coils available in this test room. It is noted that the overall consumption is maintained and even reduced with the exception of the south fan-coil. This decrease can be explained because of the dead band, because in this range the fan-coils is turned off, whereas before retrofitting it was running until the staff decided to switch them off. However, seeing Figure 24, Figure 25 and Figure 26, it is observed as during August where the room is almost empty, before the refurbishment it was electricity consumption, meanwhile in the current control system is substantially decreased. That is important, taking into consideration that the goal of this approach in the library was the improvement of the comfort level by keeping the consumption and it has been decreased apart from the south fan-coil. Regarding this last result, the table shows an increment of the electricity consumption whose explanation could be some deterioration of the system because the three fan-coil units work together at the same time and the other two facilities do not experiment the same increase.

	Fan-coil centre before	Fan-coil centre after	Fan-coil north before	Fan-coil north after	Fan-coil south before	Fan-coil south after
April	2.10 kWh	2.00 kWh	4.30 kWh	4.60 kWh	4.40 kWh	8.90 kWh
May	2.30 kWh	2.10 kWh	6.60 kWh	4.60 kWh	6.90 kWh	8.90 kWh
June	2.30 kWh	2.10 kWh	7.10 kWh	6.40 kWh	7.40 kWh	10.70 kWh
July	2.40 kWh	2.10 kWh	5.60 kWh	6.90 kWh	5.90 kWh	11.20 kWh
August	2.30 kWh	0.90 kWh	5.50 kWh	0.00 kWh	5.80 kWh	0.00 kWh
September	2.20 kWh	1.90 kWh	4.80 kWh	4.80 kWh	5.10 kWh	8.70 kWh
October	2.20 kWh	2.10 kWh	4.80 kWh	4.90 kWh	5.10 kWh	9.60 kWh
November	2.20 kWh	2.00 kWh	4.60 kWh	5.60 kWh	5.00 kWh	10.10 kWh
December	1.70 kWh	2.10 kWh	3.70 kWh	5.60 kWh	3.90 kWh	10.30 kWh
January	1.70 kWh	2.10 kWh	3.90 kWh	5.40 kWh	7.40 kWh	9.90 kWh
Total	21.40 kWh	19.40 kWh	50.90 kWh	48.80 kWh	56.90 kWh	88.30 kWh

Table 8: Electricity consumption in the library before and after refurbishment

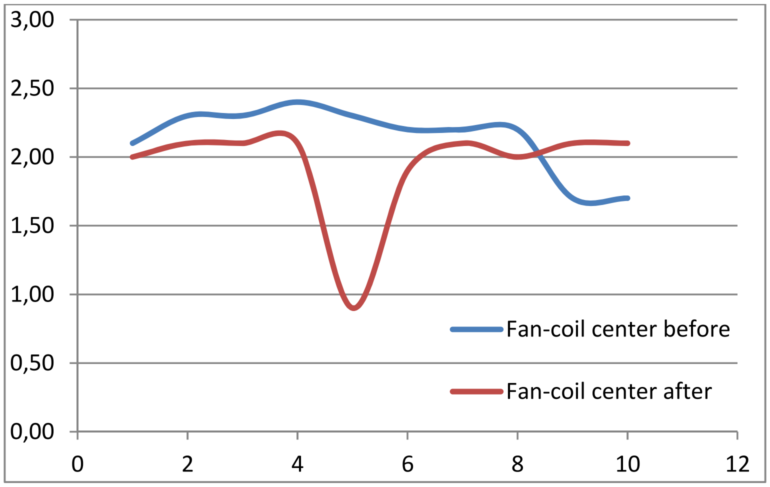


Figure 24: Fan-coil centre electricity consumption comparison

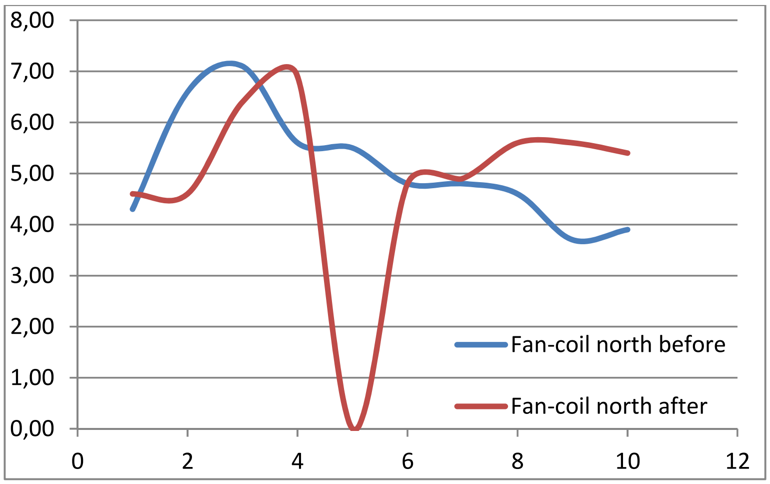


Figure 25: Fan-coil north electricity consumption comparison

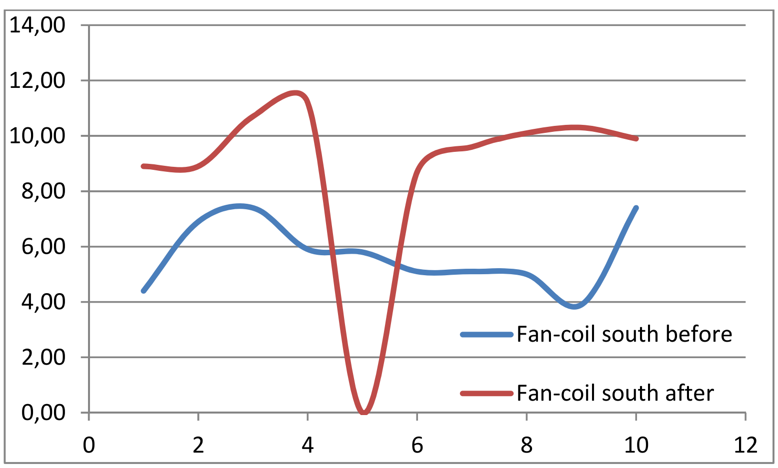


Figure 26: Fan-coil south electricity consumption comparison

Secondly, the other room where the deployment of the energy efficiency solutions has been carried out is the physics laboratory. In this case, the main objective is the reduction of the electricity consumption by means of the re-distribution of the lighting system and the combination with an automatic control algorithm. Thus, the results of the consumption are shown in Table 9. It can be observed the electricity consumption has been considerably reduced in a 43%. The reason behind is the use of the daylight in a better way in order to fulfil the requirements of comfort conditions making use of the only strictly necessary luminaires in the new circuits.

	Electricity consumption before	Electricity consumption after
April	2.60 kWh	0.90 kWh
May	3.30 kWh	1.70 kWh
June	0.60 kWh	0.70 kWh
July	1.60 kWh	0.40 kWh
August	0.00 kWh	0.10 kWh
September	0.50 kWh	0.40 kWh
October	1.40 kWh	1.00 kWh
November	2.20 kWh	1.30 kWh
December	1.50 kWh	1.00 kWh
January	1.30 kWh	1.10 kWh
Total	15.00 kWh	8.60 kWh

Table 9: Electricity consumption by the lighting system in the physics laboratory

4.1.2 PHPP Calculated energy consumption

First of all, the thermal energy demand is not modified because of the lack of interventions in such systems. Thus, the result of the after-intervention state shows the same values for the thermal system, while the reduction in the consumption of the lighting system is shown through the monitoring system.

4.1.3 Calculated energy consumption by Energy plus or other tools

In the case study has been assessed the possible energy savings by the integration of other planned solutions, making use of TRNSYS software. The possible energy savings are detailed as follows:

- Interior insulation -- It has been detected a high amount of airtightness in the whole building and heating losses which could be improved by means of interior insulation. Thus, by adding internal insulation to the external walls (50mm of an insulation material with lambda=0.04W/m·K), the global energy demand could be reduced in a 25%, while if also the roof and the floor would be insulated (under the same conditions) the demand would decrease in a 46% related to the baseline demand (from 106.5kWh/m2a to 57.5kWh/m2a).
- Also, the airtightness could be improved by solving the problems of infiltrations detected through the non-destructive testing done. Supposing the reduction of the q_{50} to the 50% of the current level (10.0m3/m2·h), the energy demand would be reduced in a 10%.
- By combining previous interventions, the global energy demand of the building would be 52.2kWh/m2a, which means approximately the 50% of the baseline demand.

4.1.4 Briefly Summarizing word

Within this post-intervention evaluation, it has been demonstrated that the building presents potential possibilities for energy savings, as well as comfort improvements. In fact, through the implementation of the control strategies has been reached a better comfort condition in the two tests rooms, besides the energy savings related to the electricity consumption.

Last but not least, those solutions which have been simulated and not integrated allow a great possibility of energy savings. These ideas have been transferred to the owner so that they could be integrated in the future.

4.2 Evaluation of the construction´s situation

4.2.1 Evaluation of Delphin hygrothermal simulation

Not applicable.

4.2.2 Evaluation of monitoring data into the construction

The two interventions by means of control strategies are related to the temperature and lighting levels in the two test rooms. Although more elements are measured for the pre-intervention analysis, in the post-evaluation these variables are the interesting ones. Thus, in the case of the library, Table 10 shows the average temperatures and standard deviations for every month before and after refurbishment. Moreover, Figure 27, Figure 28, Figure 29, Figure 30, Figure 31, Figure 32, Figure 33, Figure 34, Figure 35 and Figure 36 print the temperature charts for the comparison of before and after retrofitting. The improvement of the temperature is not clearly observed because it depends on the occupancy patterns in the room. Nevertheless, this temperature is kept in the range defined by the library staff when people are inside the room, otherwise there is no actuation. For example, that is well viewed in the December and January months during Christmas season. Also, because of the modification of the temperature limits by the staff, the months differ in the temperature level.

	Average Temperature before	Average Temperature after	Standard deviation before	Standard deviation after
April	19.17 ºC	20.43 ºC	2.11 ºC	3.21 ºC
May	23.95 ºC	22.22 ºC	2.22 ºC	1.92 ºC
June	25.69 ºC	24.72 ºC	1.27 ºC	1.84 ºC
July	27.20 ºC	26.99 ºC	1.50 ºC	1.73 ºC
August	28.33 ºC	27.82 ºC	1.10 ºC	1.02 ºC
September	25.66 ºC	25.89 ºC	1.66 ºC	1.12 ºC
October	21.91 ºC	22.89 ºC	1.86 ºC	1.79 ºC
November	20.44 ºC	19.81 ºC	1.74 ºC	2.44 ºC
December	19.30 ºC	16.64 ºC	2.40 ºC	3.25 ºC
January	19.18 ºC	18.22 ºC	3.07 ºC	3.67 ºC

Table 10: Temperatures in the library

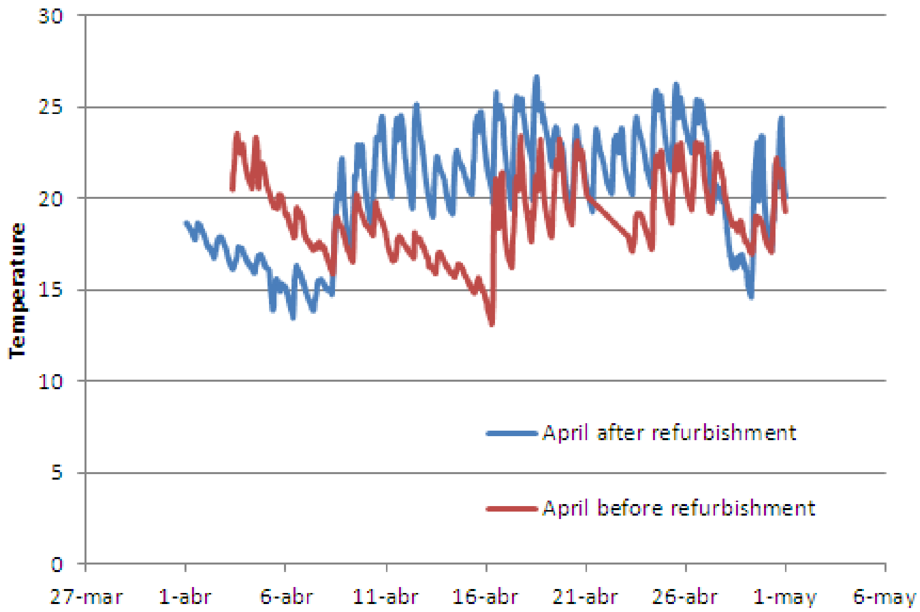


Figure 27: Temperatures trends for April in the library

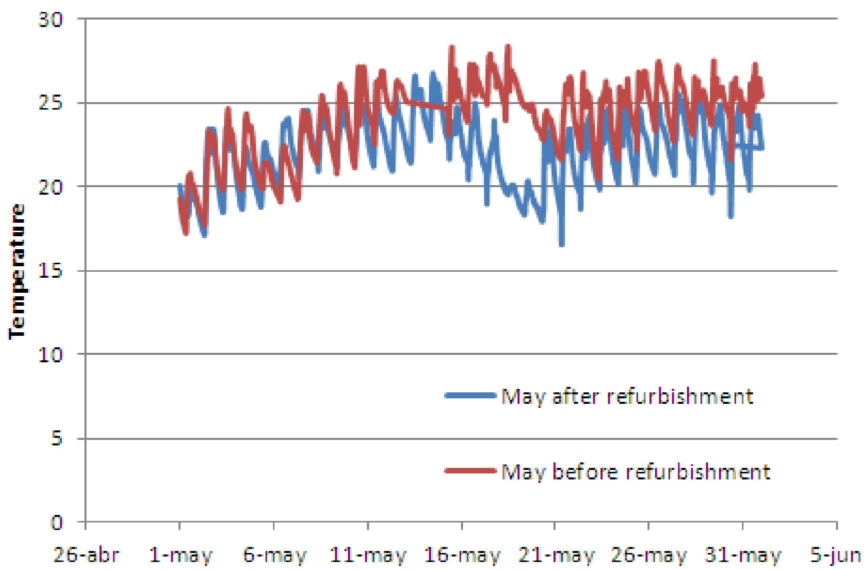


Figure 28: Temperatures trends for May in the library

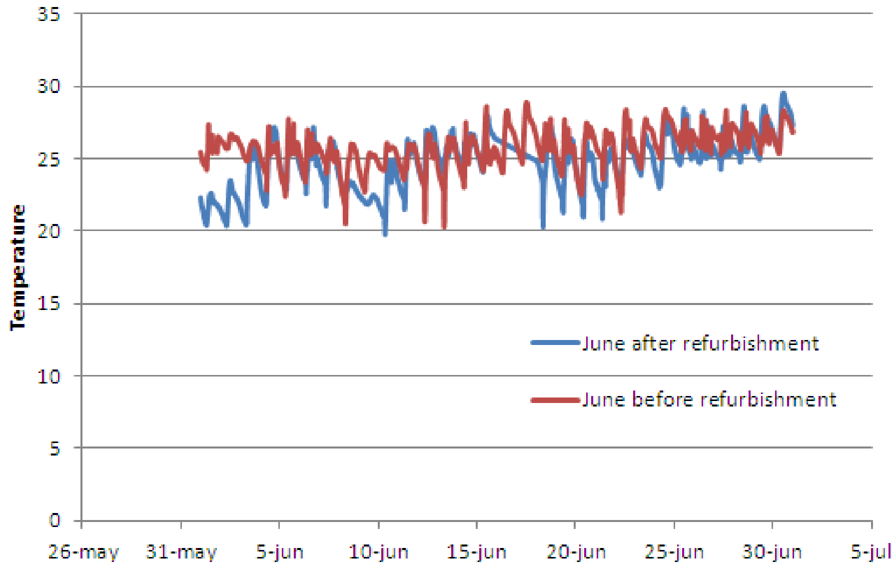


Figure 29: Temperatures trends for June in the library

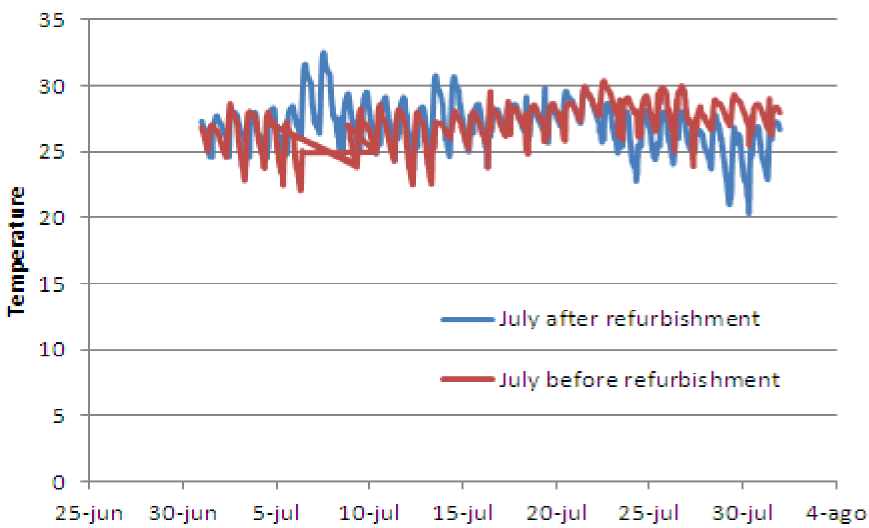


Figure 30: Temperatures trends for July in the library

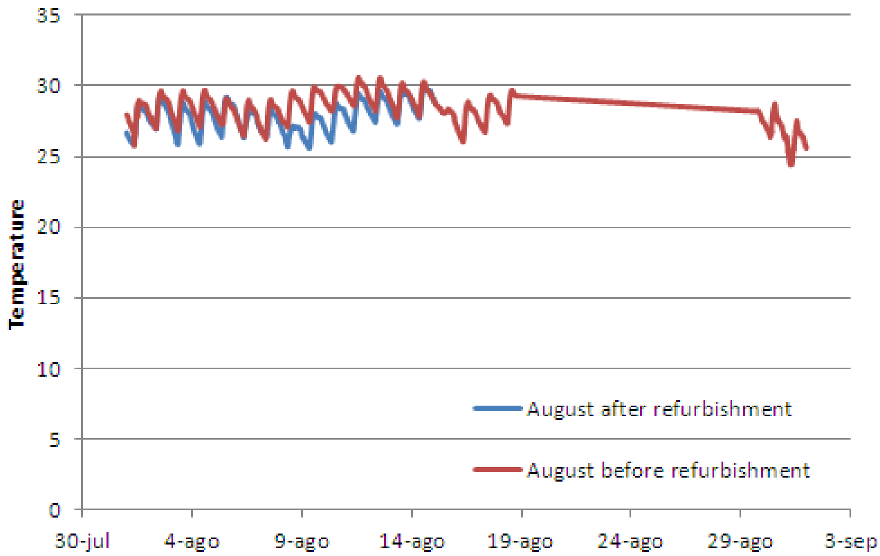


Figure 31: Temperatures trends for August in the library

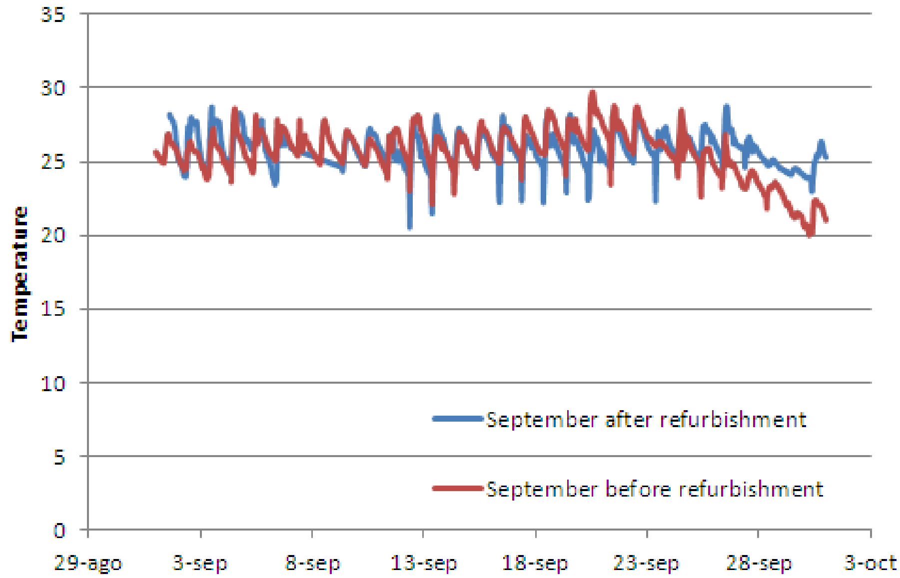


Figure 32: Temperatures trends for September in the library

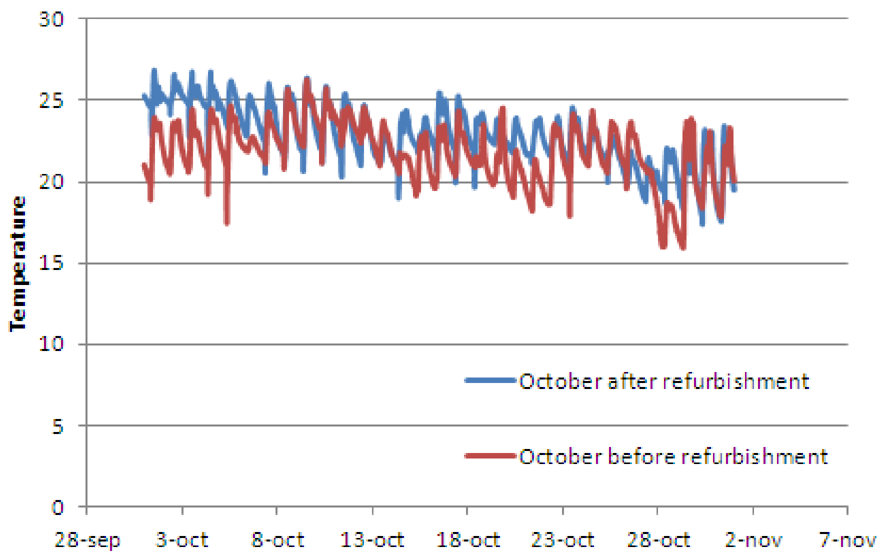


Figure 33: Temperatures trends for October in the library

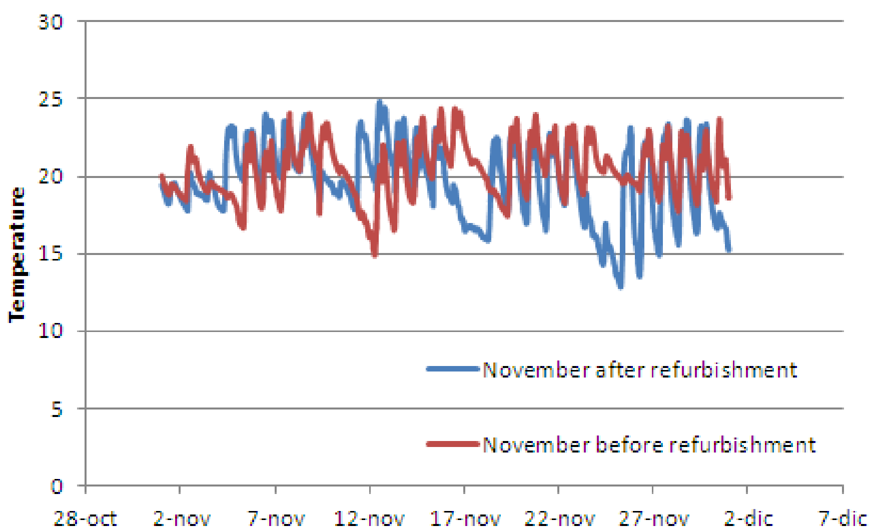


Figure 34: Temperatures trends for November in the library

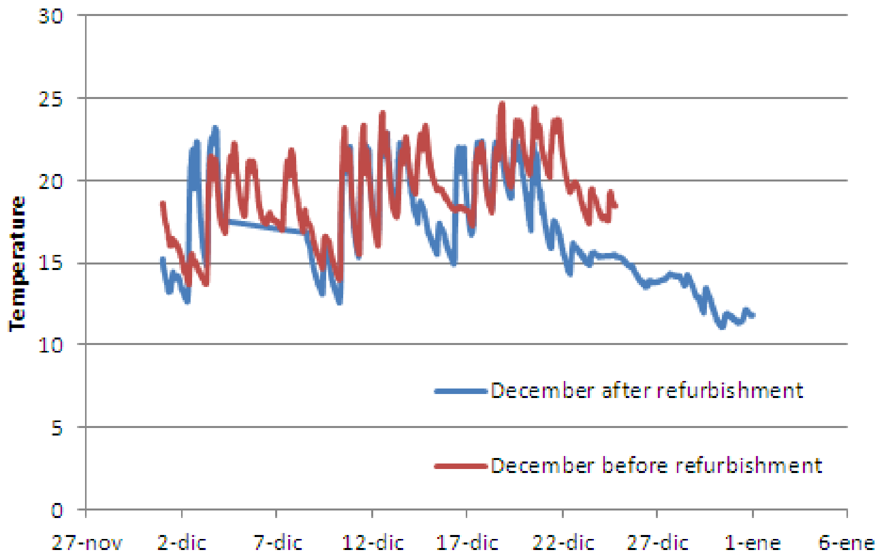


Figure 35: Temperatures trends for December in the library

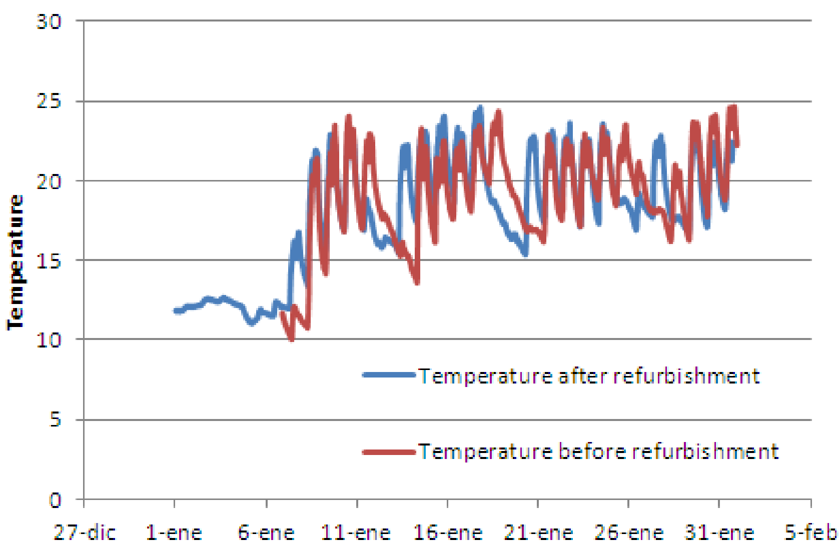


Figure 36: Temperatures trends for January in the library

Related to the physics laboratory, in this case, the lighting levels before and after retrofitting are detailed in Figure 37, Figure 38, Figure 39, Figure 40, Figure 41, Figure 42, Figure 43, Figure 44, Figure 45 and Figure 46. It can be observed the lighting level is also improved with the new distribution of the systems and favouring the natural lighting due to the wide windows in the room. Thus, in April, May, June and November, which are the main classes months, the lighting level is better and kept in the comfort range defined by the UNE Spanish regulations with 500 lux in this type of rooms when people are working inside. Furthermore, some months, like October, the level is reduced (the peak values) in order to avoid high values and be close to the regulation.

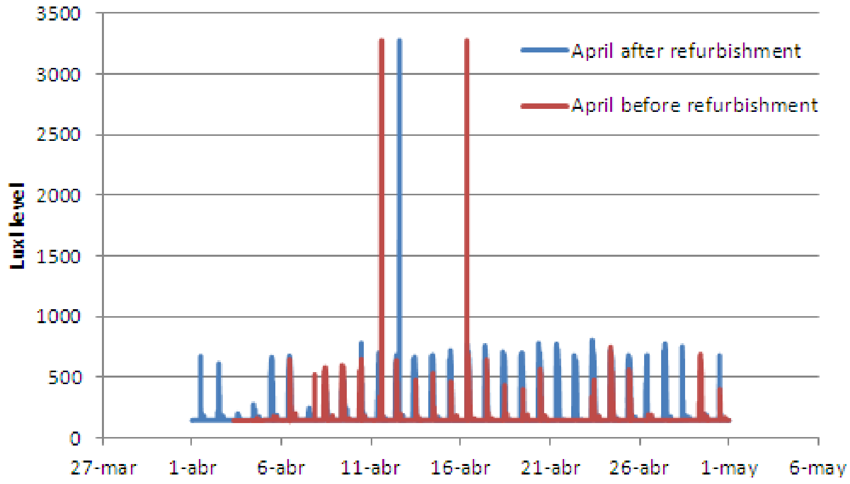


Figure 37: Lighting level before and after in April

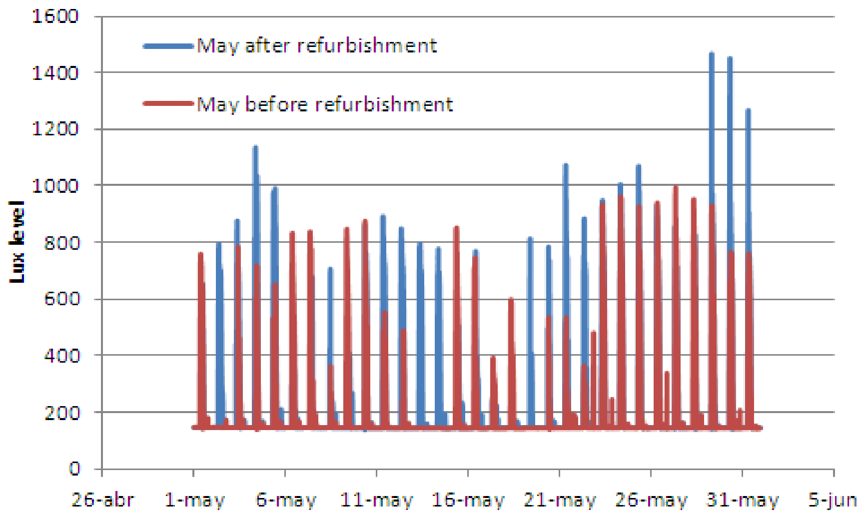


Figure 38: Lighting level before and after in May

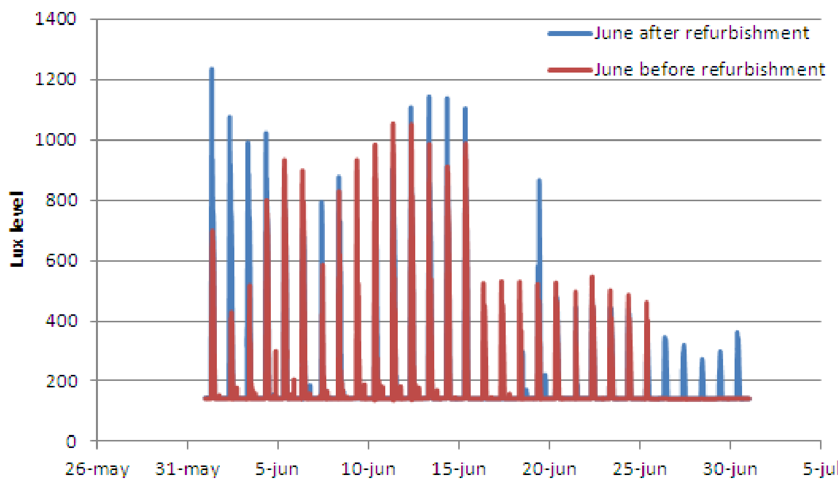


Figure 39: Lighting level before and after in June

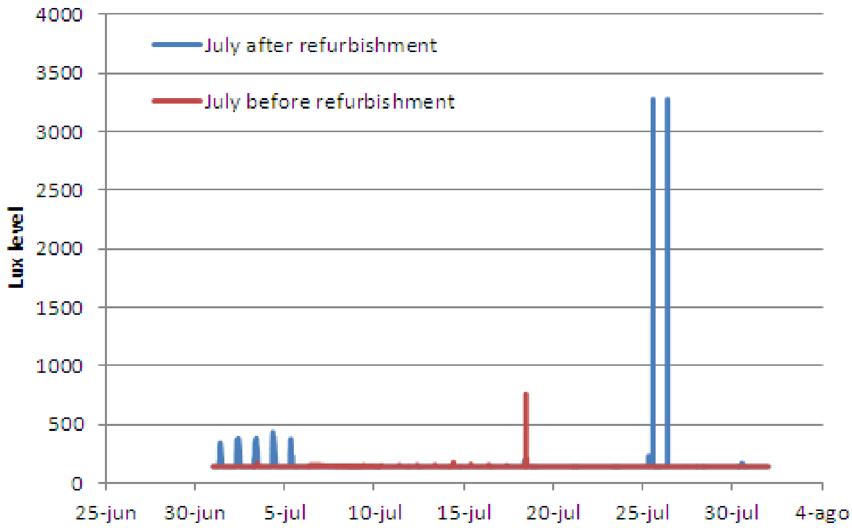


Figure 40: Lighting level before and after in July

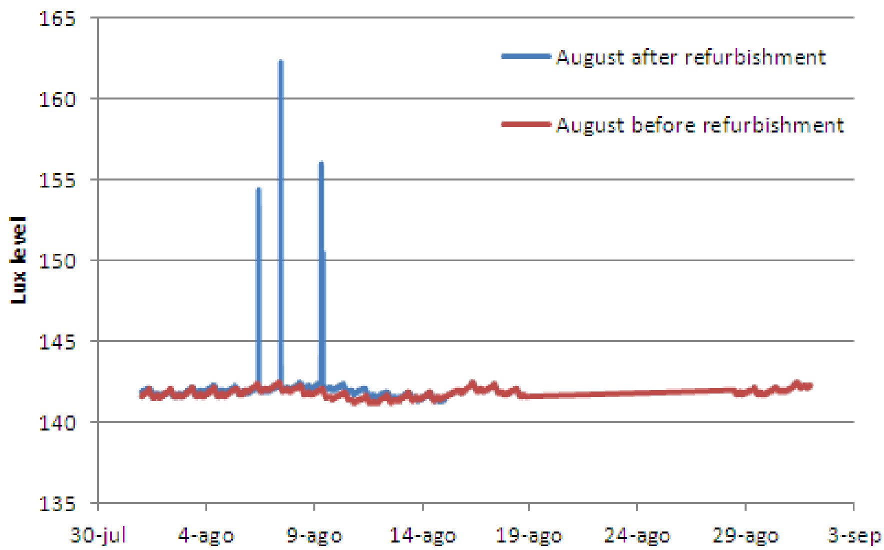


Figure 41: Lighting level before and after in August

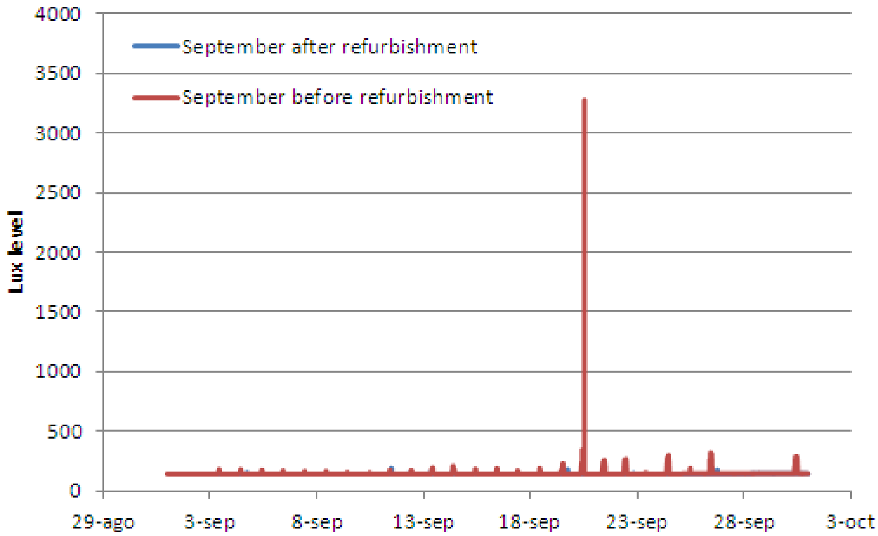


Figure 42: Lighting level before and after in September

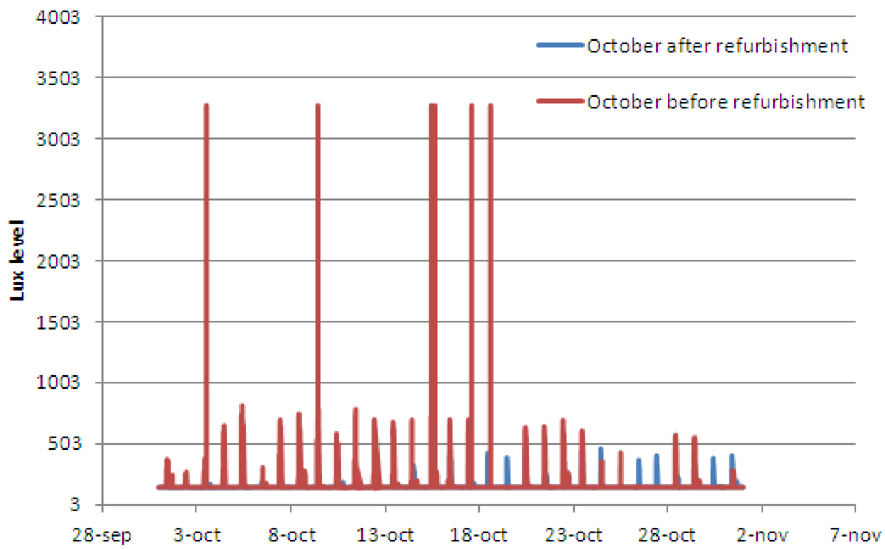


Figure 43: Lighting level before and after in October

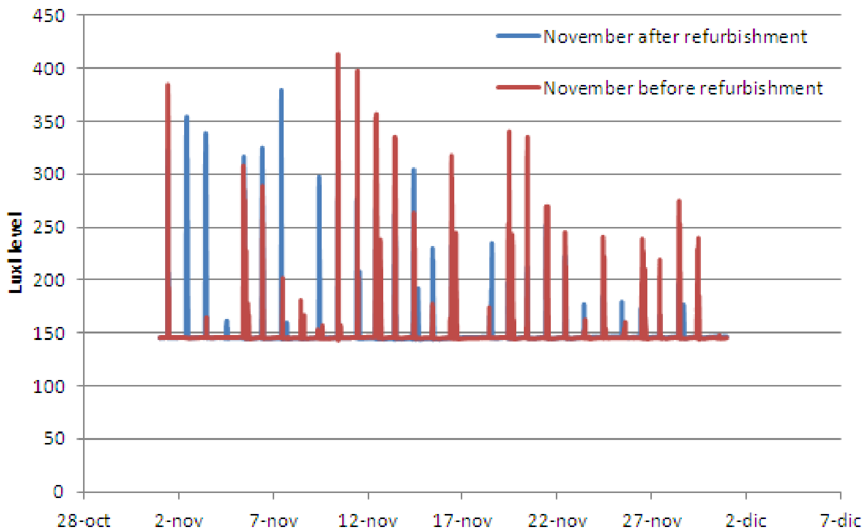


Figure 44: Lighting level before and after in November

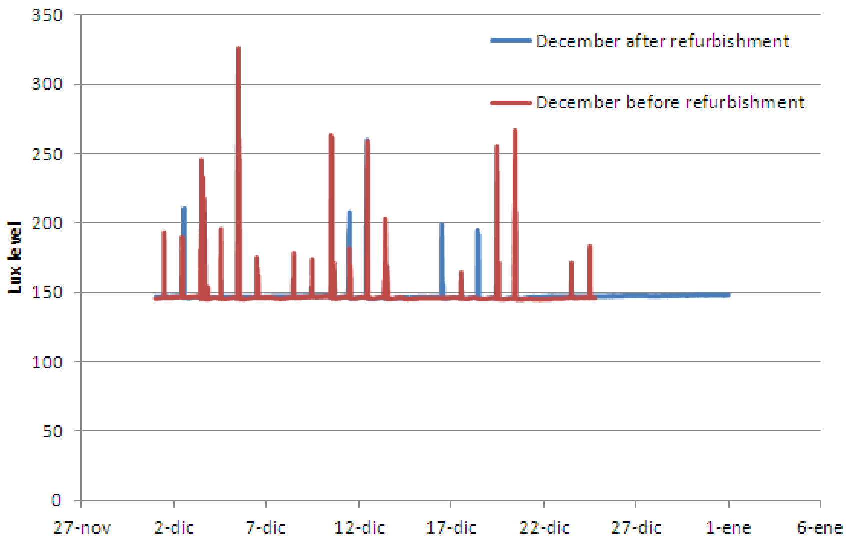


Figure 45: Lighting level before and after in December

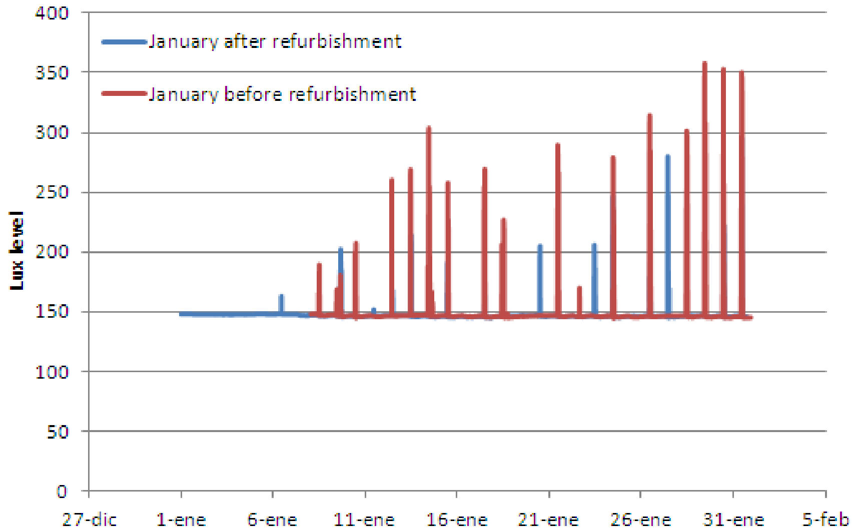


Figure 46: Lighting level before and after in January

4.2.3 Evaluation of other used hygrothermal simulation tools

Not applicable.

4.2.4 Evaluation of the wooden beam (in special case)

Not applicable.

4.2.5 Evaluation of the internal insulation system

No internal insulation system was deployed in the retrofitting strategy, so there is no content in this section.

4.2.6 Briefly Summarizing word

As viewed, the application of the solutions presented has substantially improved the comfort levels, reducing the number of claims from the students of the University. In fact, the temperature in the library is kept within the comfort range defined by the staff, as well as the luminosity has been established according to the UNE Spanish regulations.

4.3 Evaluation of Impact on cultural heritage value

4.3.1 Impact on building fabric

The refurbishment of this case study does not degrade any heritage element of the building. The only facility which has been detected in degradation is one of the fan-coils of the library but it does not belong to the cultural value of the building. Moreover, the re-distribution of the luminaires circuits required some modifications in the physics laboratory ceiling but it was not damaged and it neither belongs to the cultural value.

4.3.2 Impact on the appearance

As long as the solutions are mainly software and "virtual" gateways integrated in the current controllers installed in the building, there are neither appearance damages nor surrounding effect. Besides the software solution, the re-distribution of the lighting circuits do not affect to the appearance because the same space of the "old" circuits has been re-used.

4.3.3 Reversibility of measures

The retrofitting strategies are completely reversible as far as the software solution can be uninstalled in the current controllers and the previous manual control will take effect. Regarding the luminaires, the “old” circuits are possible to be recovered, although it will carry out an additional cost for the owner and it is not recommendable, being this approach better taking into account the zones of the workbenches.

4.3.4 Overall rating

Not applicable.

5 Summary and conclusion

During the lifecycle of the project a methodology has been followed in order to analyse the requirements of the buildings, the possible solutions, decision of the interventions and the post-evaluations. In the whole process the owner of the building has played a very important role because the decisions in this case study belong to the owner and no conservation technical office is involved. Regarding the diagnosis, as first step, it was deployed a complete monitoring system for the measurement of the current behaviour of the building which was combined with the energy performance simulations that give us the thermal inertia of the building, Moreover, the blower door test and the infrared thermography allow the detection of thermal losses and potential energy savings by the insulation systems. Last but not least, the problem of the oversized lighting system was studied by dialux simulations.

With all the information collected, the possible planned solutions and the opinion of the owner, two actuations were decided so as to deploy a control strategy both in the library and the physics laboratory with the aim of improving the comfort in both rooms, as well as the reduction of the electricity consumption. These two rooms were selected owing to the special characteristics where the viability of the interventions could be demonstrated.

Finally, in the post-evaluation was assessed the energy savings and the comfort improvement. In both rooms, the comfort parameters behave better after retrofitting and the owner is studying the possibility of widening the scope of the solutions in other rooms. At the same time, the electricity consumption due to the lighting system has been decreased almost a 50% which extrapolated to the remaining rooms in the building could notably reduce the monthly bills.

6 Annex 1 - PHPP calculation for status pre-intervention

This annex can be found in the document: AnnexCS7_PHPP_V8.4 _as_is_state.pdf

7 Annex 2 - Description of the monitoring system

The monitoring system to be installed and commissioned is aimed to analyse the behaviour of the building in terms of energy as well as the comfort and behaviour of the users of the building. In this respect, a thorough study of the building conditions and systems is needed, in order to set the parameters to be monitored.

7.1 Monitoring Concept

The monitoring concept is the shown in Figure 47 which is divided in several layers: On-field, communication, data storage and application level. The first layer refers to the physical sensors and actuators. Communication level contains both hardware and software available for the collection of data from the sensors. Next, it represents the persistent way to storage the information and keep record of the information. Finally, the application level is the visualization interface available for the project partners so as to access and download the information from the case study.

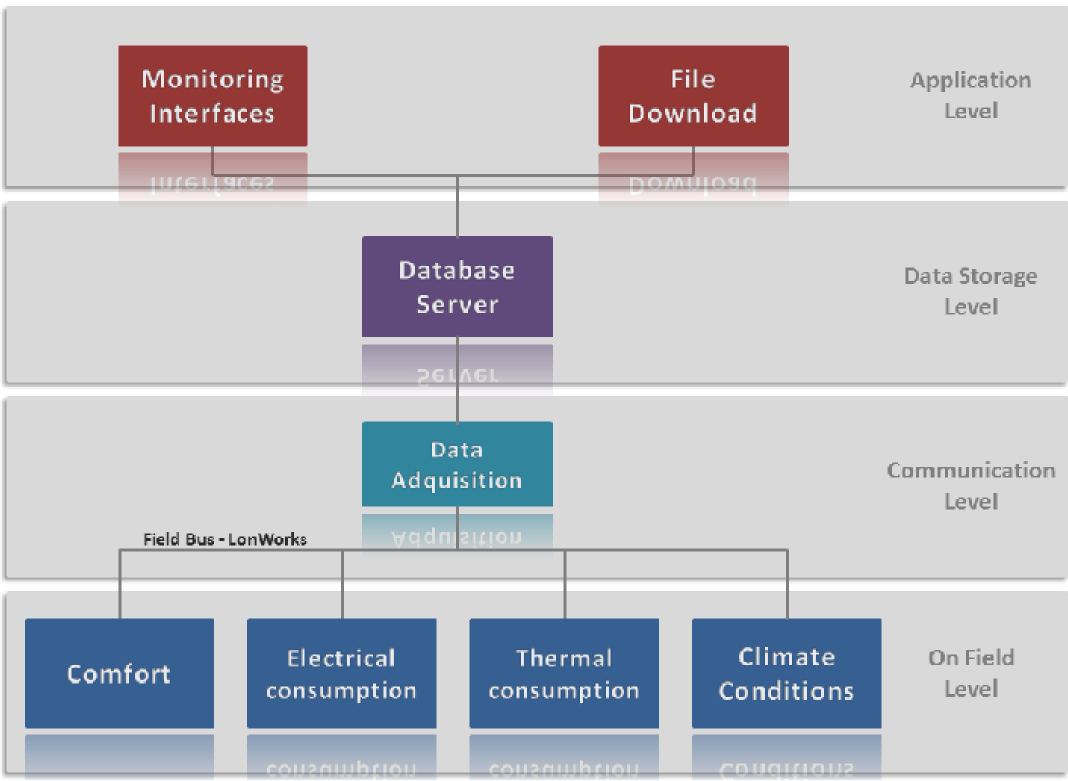


Figure 47: Monitoring concept

7.2 Monitoring system before intervention

7.2.1 General description

The monitoring system is a LonWorks based where a backbone has been deployed from top floor to the second basement. From this backbone, several branches set up the sensor network of the system. There are four main branches: library, physics laboratory, weather station and boilers room.

The test rooms have been selected in function of the facilities. In the case of the boilers room, the generation systems are quite important in order to get the thermal consumption and the behaviour of the boilers of the whole building. Regarding the weather station, the weather conditions, mainly solar radiation, is needed for the study of the implementation of photovoltaic cells. Finally, library is the only room with cooling systems and the physics laboratory has windows in the east and west façades which improves the natural light.

In the library and physics laboratory, the sensor network measures mainly comfort parameters (temperature, humidity, presence and CO2), although, there are also some wattmeter in the electrical boxes for the electrical consumption.

In the boilers room, the thermal consumption has been measured without flowmeters, but pressure and temperature sensors. Thus, with the help of the characteristic curving, it is possible to work out the flow of the pumps. Also, the status of these pumps is collected.

For collecting all the information a server actuating as a data logger has been installed which centralizes the collection of information from sensors. Afterwards, a remote application reads this information which is being stored in a persistent database and shown in a Web application for monitoring and downloading.

7.2.2 Monitoring scheme (data logger)

The scheme for the monitoring system is the presented in Figure 48 where the right side corresponds to the sensor network, central part is the data logger itself and the left side is the collection applications and web interfaces. Then, the electrical signals from the sensors (comfort, thermal/electrical consumption and climate conditions) are collected in the LonWorks bus which is designed as a backbone from the top floor to the second basement with branches for the different monitoring floors. Thus, the branches are the second basement, second floor and the weather station. The LonWorks bus is connected to the LonWorks Smart Server which works as data collector, but also as controller of the network. This device contains all the intelligence for the management of the network and collection of data, as well as allowing remote management. Through the Web interface (Figure 49) of the data logger, it is connected to the Intranet of the case study where a computer is installed in order to deploy the database and the software application to store the information from the data logger (with limited capacity) to the persistent way (database). Finally, this computer has Internet connectivity allowing the access to the data through a Web application in order to share this information with the 3EnCult partners.

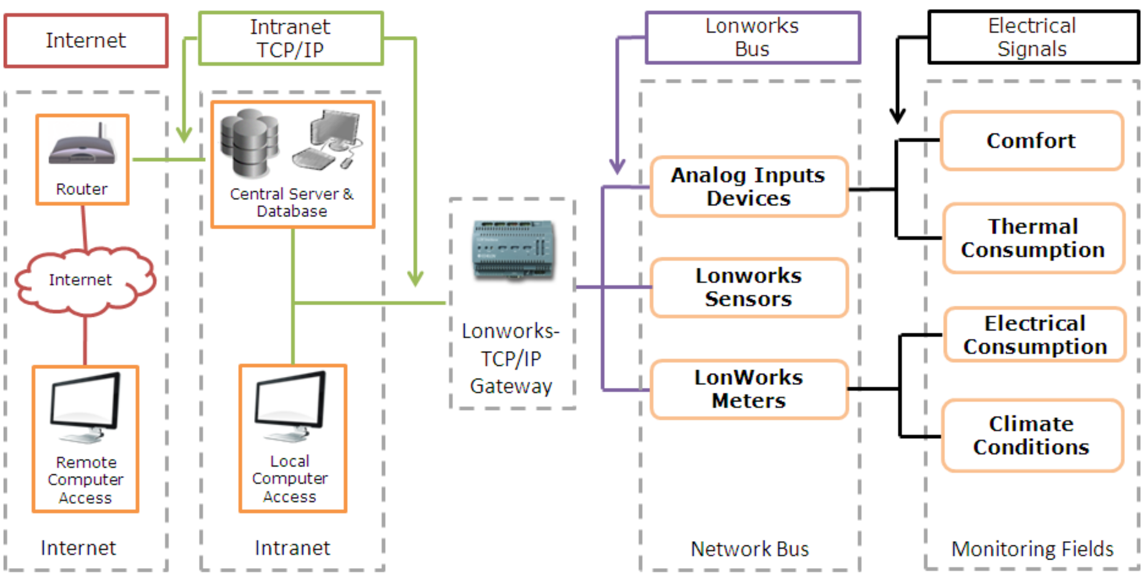


Figure 48: Monitoring scheme

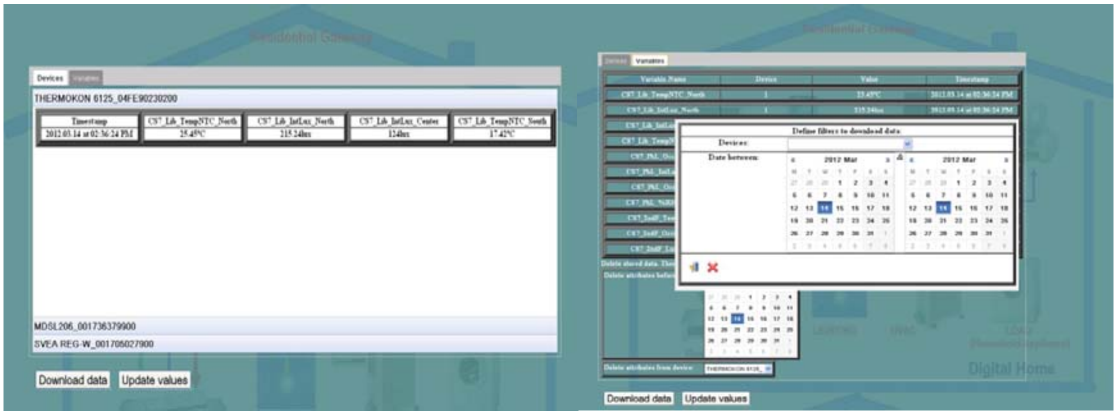


Figure 49: Web interface for monitoring and downloading data

7.2.3 Measuring system

Due to the large building to be monitored, the behaviour of the building must be assessed by choosing some singular rooms which represent that behaviour. The criteria followed in this case study to define the monitoring system are based in the following points:

- Size and use of the different rooms monitored
- Orientation of those places.
- Systems installed in each room. (particularly cooling systems)
- Possibility of monitor the different parameters.

Thus, the rooms selected are described in advance. The 2nd basement is the first one where the thermal generation systems are installed.Figure 50 displays the distribution and kind of sensors deployed in such room.

In order to assess perfectly the behaviour of the building, some singular rooms have been chosen, all of them located in the second floor (Figure 51):

- The library, which is the unique part of the building with cooling systems installed. In this room, besides the comfort of the users, their behaviour with regard to the control of the cooling systems will be analysed (Figure 52).
- The Physics Laboratory, with windows in the façades east and west which allows the monitoring of both orientations. In this room, the comfort of the users will be analysed, in terms of temperature, humidity, lighting, etc. as it is defined in Figure 53. In addition, the electrical consumption of different circuit will be monitored in this room (Figure 54).

Furthermore, other places will be monitored so that the analysis of the building behaviour will be more complete. These places are distributed through the different floors:

- Offices: 3 of them will be monitored, in order to have different data of 3 different scenario:
    1. office with windows in the east façade,
    2. central office with no windows.
    3. Corridors: The monitoring of these places let us analyse the potential savings of the control strategies in these kind of areas. (halls, corridors, toilets, etc.)

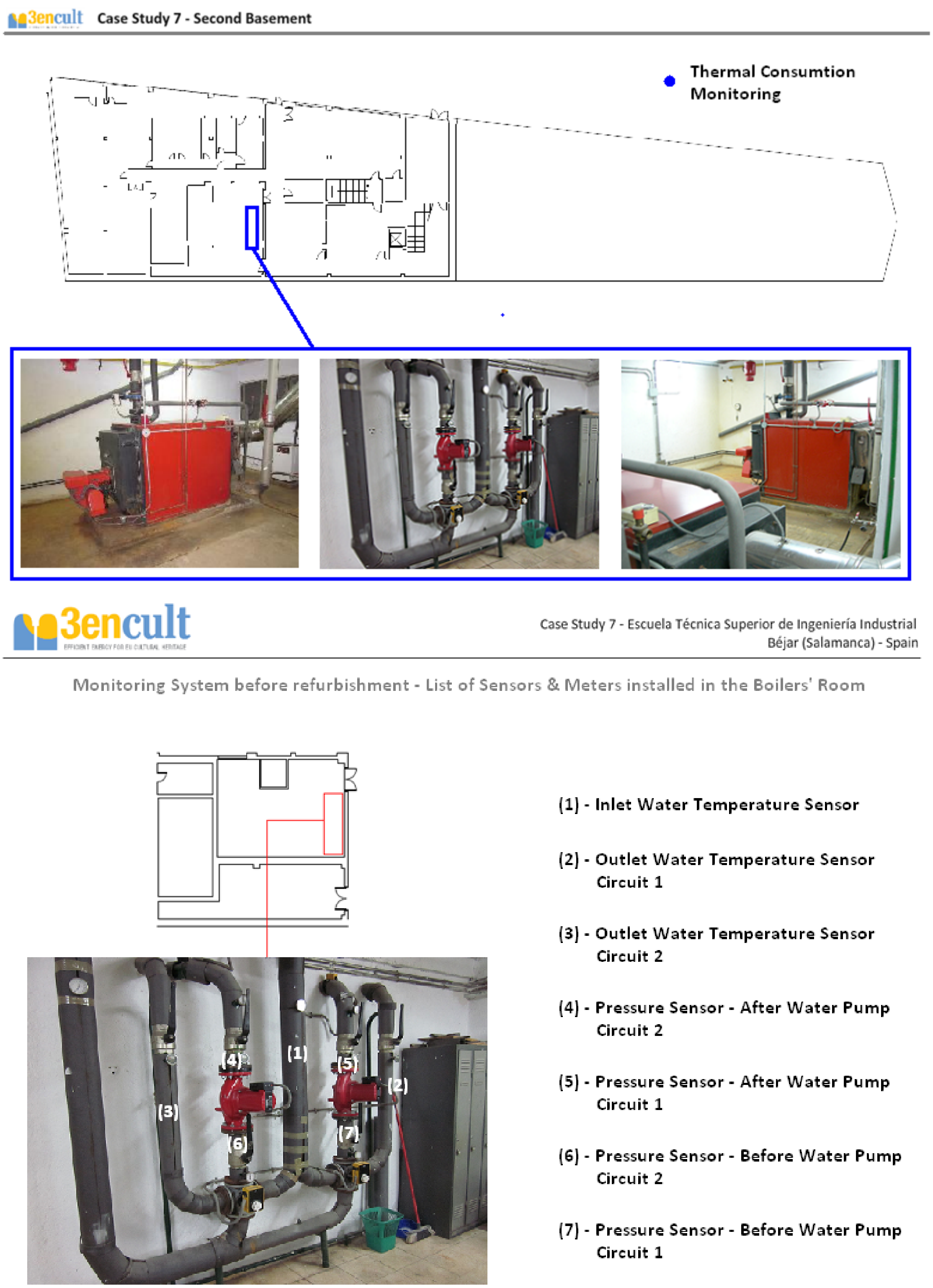


Figure 50: 2nd basement monitoring system

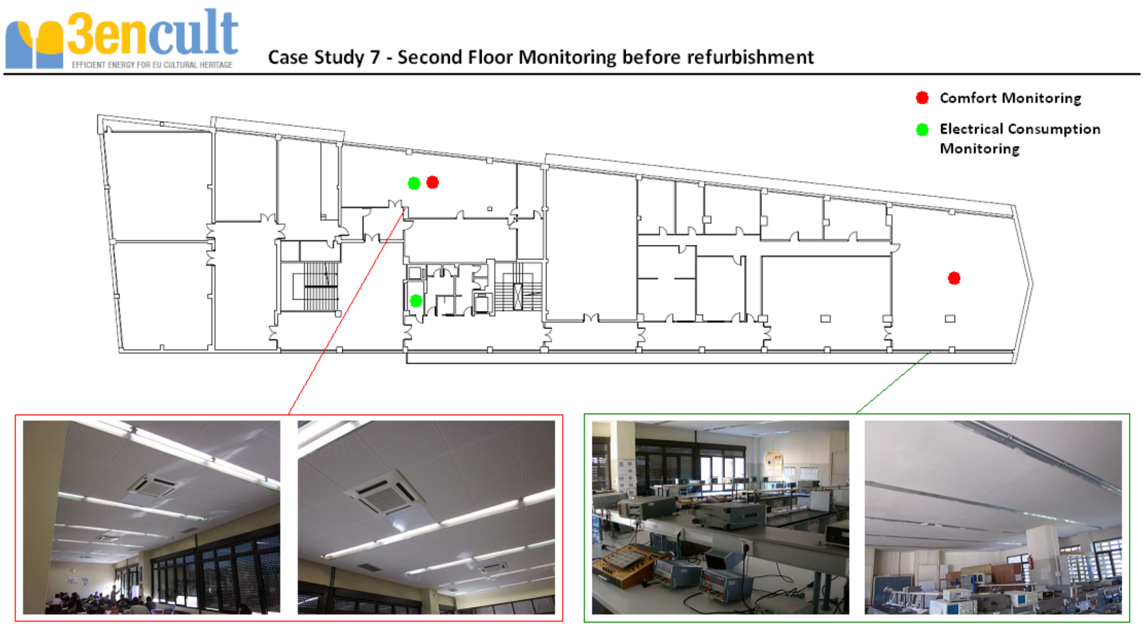


Figure 51: Overall picture of the 2nd floor monitoring system

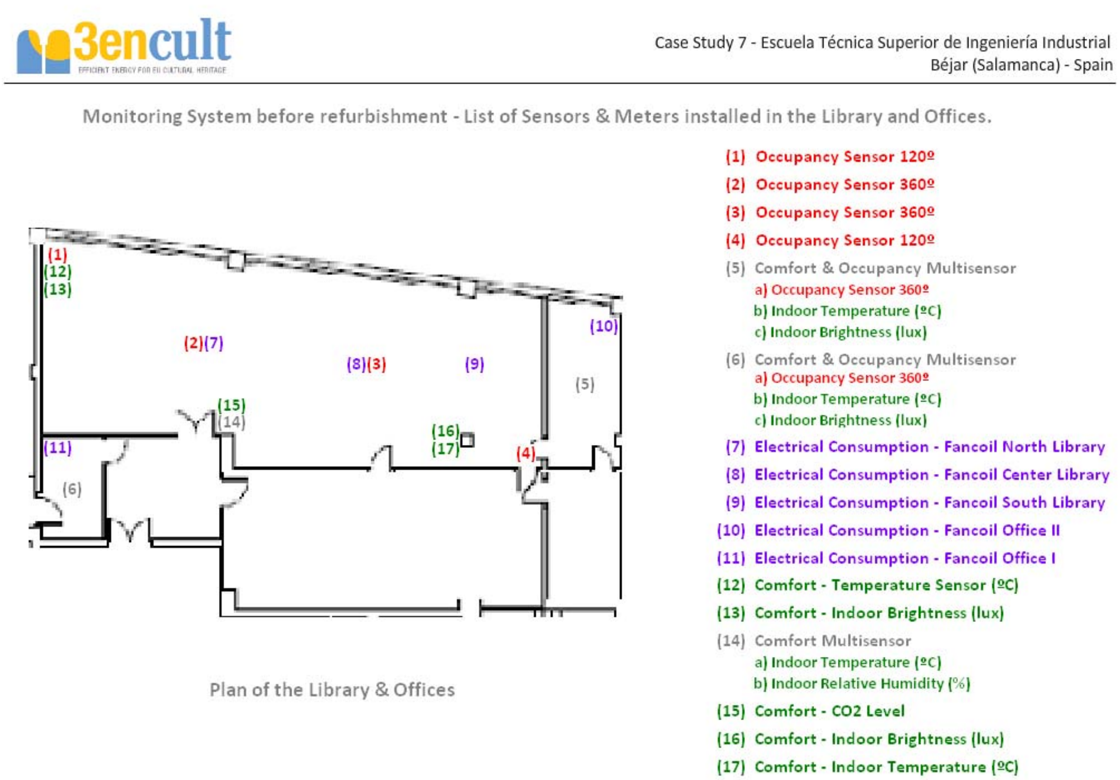


Figure 52: Library monitoring system

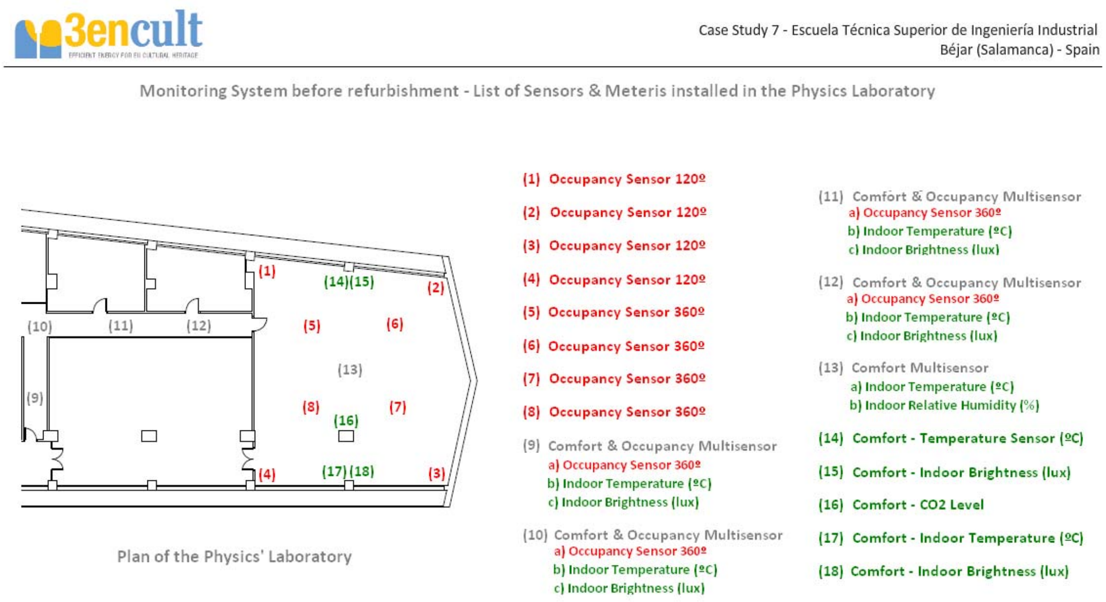


Figure 53: Physics laboratory monitoring system

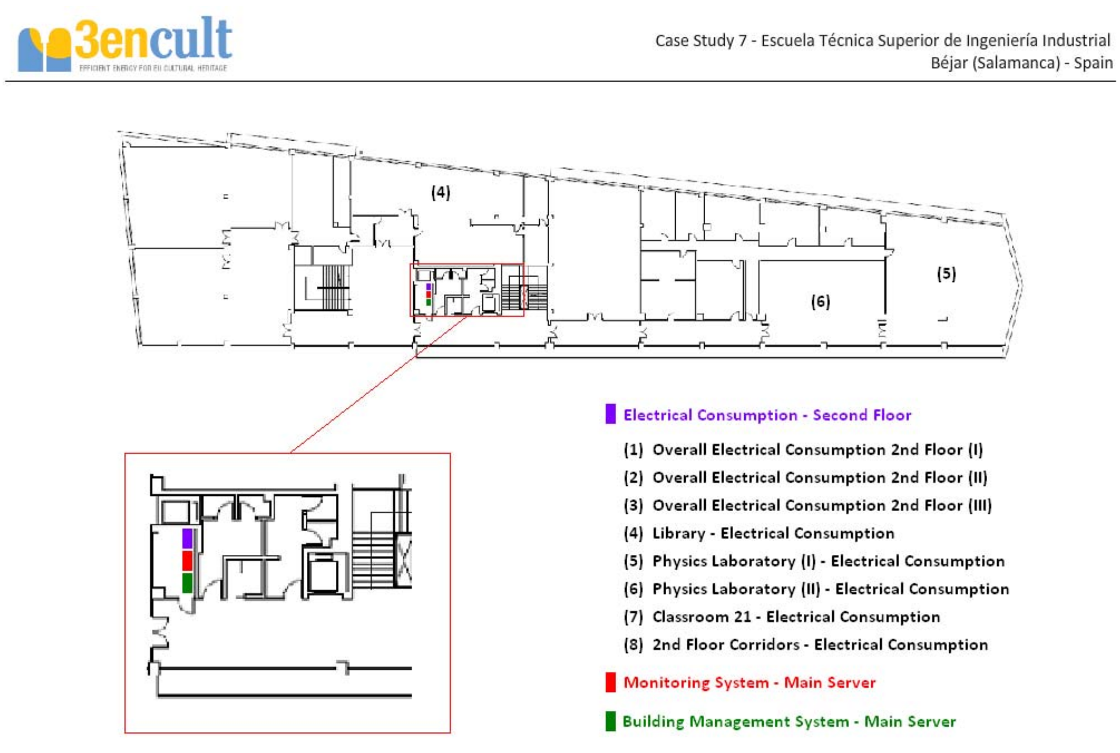


Figure 54: Electricity consumption in the 2nd floor

7.2.4 Measuring Sections

The measurements of the different areas of the building are divided into the purpose of the data-points. Thus, the following tables show the information of the measurements based on HVAC and lighting values, electrical/thermal consumption and outdoor/climate conditions.

The measurements of environmental variables (temperature, relative humidity ..) and energy consumption (hot water, heating, cooling, electricity) will be recorded and analysed, in a real situation of occupation and in real time, which will give us information about use conditions and behaviour of the building

The assessment of the electrical consumption of the building will be carried out following two different monitoring criteria:

- Zone Division: A wattmeter will be located in the main line of the building in order to meter the total consumption of the building. In addition, different measures will be taken in several problematic rooms.
- System discrimination: In order to assess the contribution of the different systems to the global consumption, in some of these problematic rooms the electrical consumption will be monitored directly in the individual lines (lighting, cooling, sockets, etc).

Parameter	Units	Description	Polling Period
Indoor Relative Humidity	%	Room humidity sensor for measuring relative humidity in room and office spaces etc. Located in different places of the selected rooms, out of air drafts and direct solar radiation.	300 seconds
Indoor Temperature	ºC	Thermistor (PTC or NTC) located in different places of the selected rooms, out of air drafts and direct solar radiation.	300 seconds
Occupancy Sensor	Binary	Shared with Lighting Monitoring System	On event
Heating System Status	Binary	Radiator, Radiant floor, Fancoil, heat pump, etc.	On event
Source Temperature	ºC	Temperature of the source of the HVAC Systems, water or air, in order to check if that temp. is suitable.	Each 0,5 ºC variation

Table 11: List of HVAC sensors

Parameter	Units	Description	Polling Period
Indoor Lux level	lux	Measurement of the lighting level of the selected rooms	300 seconds
Light Actuator Status	Binary	Status of the lighting system: On, Off, %	On Event
Occupancy Sensor	Binary	Shared with HVAC Monitoring System	On event

Table 12: List of lighting system

Parameter	Units	Description

Voltage (Urms)	V	Low voltage rms values. Measured for each of the phases, for total building and for each of the main circuits (lighting, air conditioning) or rooms (rooms , hallways ,...)
Current (Irms)	A	Low current rms values. Measured for each of the phases, for total building and for each of the main circuits (lighting, air conditioning) or rooms (rooms , hallways ,...)
Real Power (P)	W	Total real power and for each of the phases, for total building and for each of the main circuits (lighting, air conditioning) or rooms (rooms , hallways ,...).
Reactive Power (Q)	VAr	Total reactive power and for each of the phases, for total building and for each of the main circuits (lighting, air conditioning) or rooms (rooms , hallways ,...).
Real Energy (W)	Wh	Global energy balance of the building and in the main systems / equipment or rooms
Reactive Energy (Wq)	VArh	Global reactive energy balance of the building and in the main systems / equipment or rooms

Table 13: Electricity consumption

Parameter	Units	Description	Polling Period
Outdoor Temperature	ºC	Outdoor Thermistor. Important to measure the exact outdoor temperature	300 seconds
Outdoor Brightness (East, South, West)	lux	The current light intensity is measured in three different orientations.	300 seconds or 500 lux variations
Rain	Binary	The sensor shows if it is raining or not.	On event
Rain gauge/pluviometer	l/h	Meters the rainfall in each specific instant	On event
Wind direction	orientation	Using a weather vane.	On event
Wind Speed	m/s	The measurement of wind speed is accomplished electronically or with anemometer.	On event
Twilight	lux	Detects the exact moment of dawn.	On event
Direct Solar Radiation	W/m2	Solar radiation	300 seconds
Outdoor Relative Humidity	%	Outdoor humidity sensor for measuring relative humidity in exterior spaces.	300 seconds

Table 14: Climate conditions

7.3 Monitoring system after intervention

7.3.1 General description

The monitoring system after the intervention is the same of the pre-intervention one with the only exception that a Wireless Sensor Network has been included through seven ZigBee sensors developed in the Work Package 4 in combination with the Building Management System. Figure 55 prints an overall concept of this new monitoring system where the wireless nodes have been deployed in combination with the combination driver to collect the information, the business logic for the storage of the information in the database and, finally, the Web access to the data.

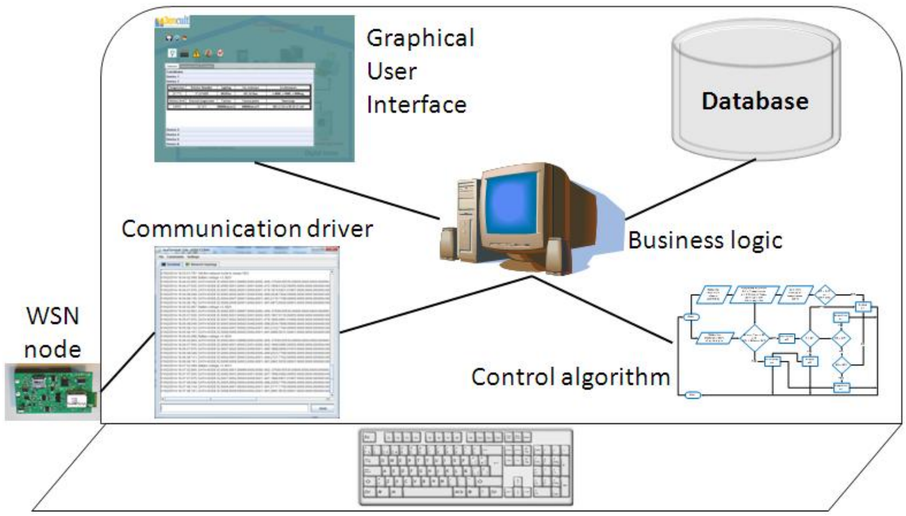


Figure 55: General concept of the wireless monitoring system

7.3.2 Measuring system (planning shows the position of the sensor)

This section contains only the information of the wireless network as long as the measuring system for the LonWorks system remains unchanged.

As said before, the installation of the wireless sensor network contains seven sensors and the test room select is the library because the computer with the data logger is nearer than the physics laboratory.Figure 56 shows the library and the collocation of the sensors in this area, as well as the parent-child relationship among the sensors setting up a tree scheme of the network. Moreover, it can be appreciated the identifiers for the sensor and the timeslots when they emit the information to the coordinator (ID=0) that is connected via USB to the computer.

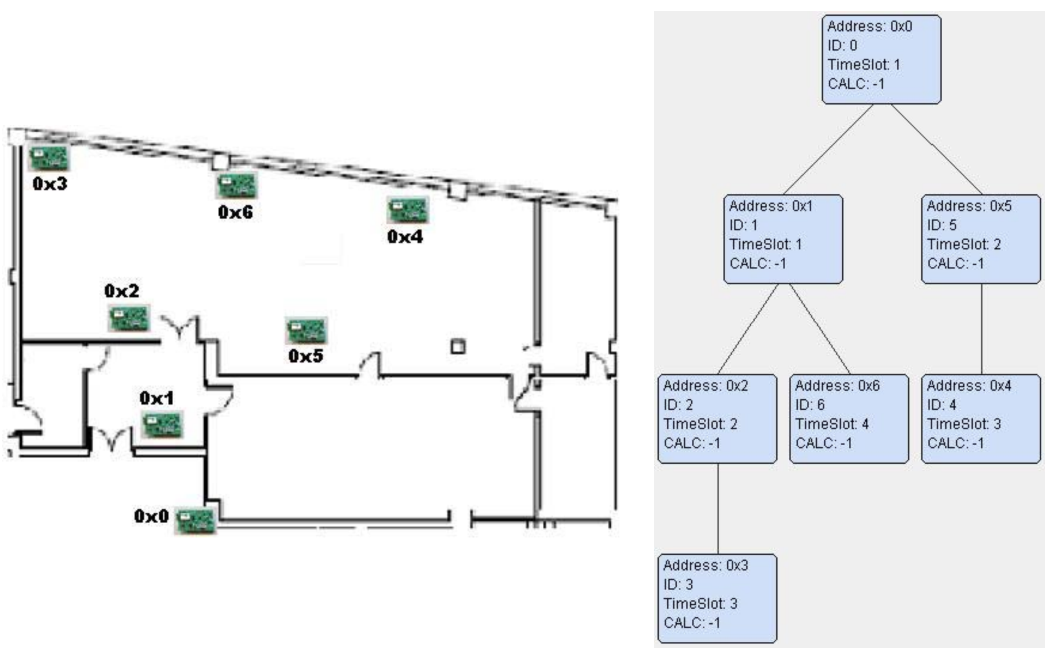


Figure 56: Deployment of the wireless sensor network

7.3.3 Monitoring scheme (data logger)

As aforementioned, the monitoring scheme remains unchanged in the second phase of monitoring, being the methodology for collecting the data exactly the same. With regard to the scheme of the wireless sensor network, the scheme is the explained in the general description (Figure 57).

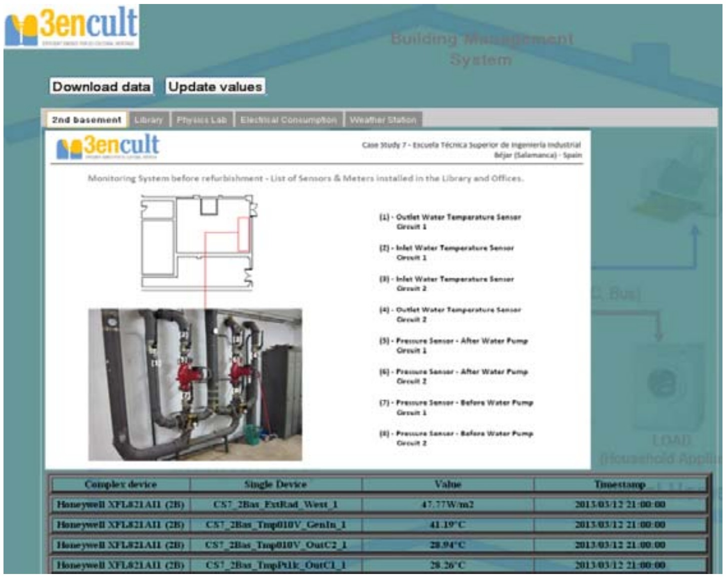


Figure 57: Web interface of the second monitoring system

7.3.4 Measuring Sections

See section 7.2.4.

7.3.5 Sensor details

First of all, as explained, the monitoring system after intervention is combined by two different sensor networks. Regarding the ZigBee based wireless sensor network, the details of the sensors can be looked up in the D4.3. In the case of the LonWorks network, Table 15 summarises the sensors, location and description of the measurements.

Device	Image	Location	Description
iWise Quad		**Library** **Physics Laboratory**	Wall Occupancy detector (120º) , to be installed in the corners of the different rooms monitored.

Lunar GreenLine DT		**Library** **Physics Laboratory**	Ceiling occupancy detector (360º), aimed to complement the wall detectors.
Honeywell XF821A		**Library** **Physics Laboratory** **Boilers' Technical Room**	Analog Inputs Device: To connect the temperature, humidity and luminosity sensors and link it to the network bus and; therefore, to the Building Management System.
Thermokon DI6UP		**Library** **Physics Laboratory**	Digital Inputs Devices: To connect the occupancy sensor and link it to the network bus and; therefore, to the Building Management System
Thermokon Li04		**Library** **Physics Laboratory**	Indoor light sensor, located close to the façade and in the center of the room. The aim of the sensors is collect the lighting information in the different parts of the day.
Thermokon Li65		**Library (East Façade)** **Roof (West Façade)**	External Lighting level sensor, and placed in the West façade of the building. The goal of this sensor is to compare the external lighting level in this façade and link it with the internal lux level in the different points of the room.
NICO – Power Monitor Meter 8108 – 8C		**Library & Offices** **2nd Floor Technical Room**	Device to meter the electrical consumption of both the lighting systems and the cooling devices.
Thermokon LC-WRF04 CO2		**Library** **Physics Laboratory**	CO2 sensor located in the centre of the room, aimed to measure the quality of the air. The sensor is connected to an Analog Inputs Device, which is connected to the network bus.

Thermokon – WRF04		**Library** **Physics Laboratory**	Sensor NTC10K, connected to the Analog Inputs Device, which is connected to the network bus.
ThermokonFTP100VS		**Physics Laboratory**	Temperature and relative humidity sensor, located in the centre of the laboratory, in the ceiling. The main goal of this sensor is measure those parameters out of the effect of solar radiation.
Thermokon MDS LON2 – Multisensor		**Offices** **Corridors**	Multisensor which measures Occupancy, Temperature and Luminosity. Located in the offices and the corridors.
Weather Station – Warema		**Roof**	Weather Station placed on the roof of the building, aimed at assessing the climate conditions. LonWorks Compatible.
i.Lon SmartServer 2.0		**2nd Floor Technical Room**	Web Server, ftp Server, Datalog, Event Scheduler. Heart of the monitoring system, aimed at managing all the information which circulate through the monitoring & control network.
TRITEC Specktron 310		**Library (East Façade)** **Roof (West Façade)**	Radiation sensor, located in the east and west façades and aimed at measuring the solar radiation in W/cm2
Thermokon - AKF10 10.62.07 PT1000 **LCD**		**Boilers' Technical Room**	Temperature Sensor to be installed inside the thermal installation pipes with the aim at measuring the inlet and outlet water temperature.
SITRANS P Serie Z		**Boilers' Technical Room**	Pressure Sensor to be installed inside the thermal installation pipes with the aim at measuring the water pressure before and after the water pumps. With this value and the pump performance

			graphics, the water flow can be estimated.

Table 15: List of sensors installed in the building

7.3.6 Significant measured records (evaluated)

The measured records are available in a PostgreSQL database installed in the case study, so any data-point can be evaluated at any time. However, the most relevant values are being specified in the previous section where the electricity consumptions and trends of temperatures and lighting levels have been detailed. Furthermore, it is available a Web interface through the intranet where the instantaneous electricity consumption of the different circuits monitored can be checked (Figure 58).

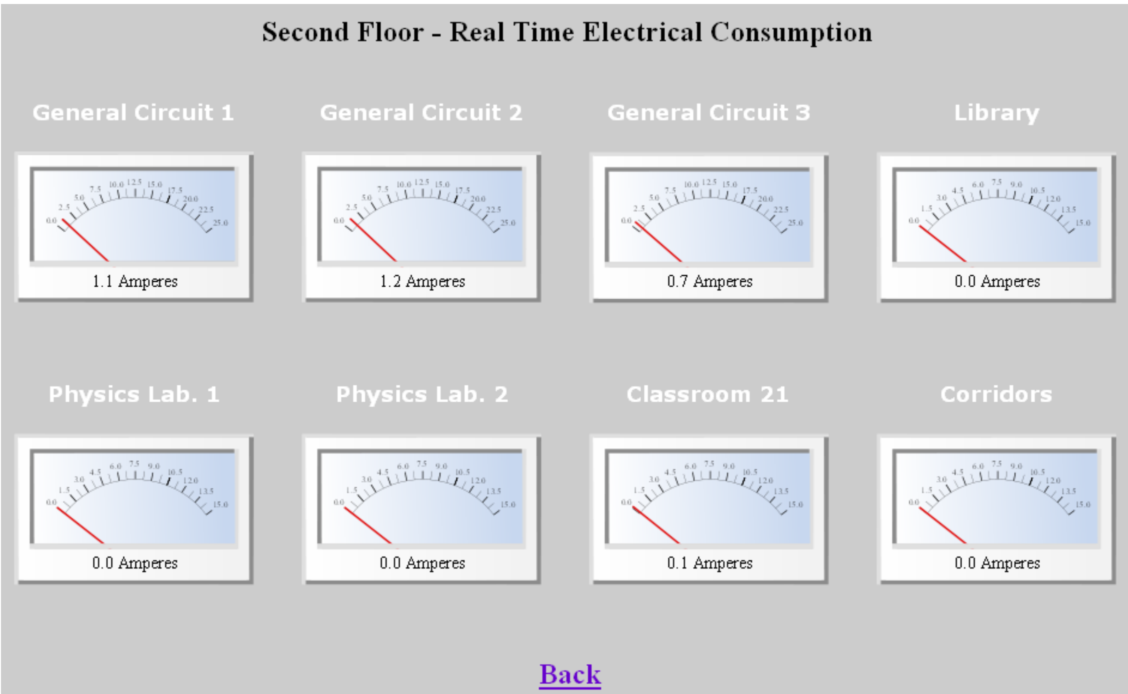


Figure 58: Instantaneous electricity consumption

In the case of the ZigBee network, the BMS services allow the visualization of trends of the information collected in the database; therefore, all these data can be evaluated. For more information, please check the D4.4.

Last but not least, the thermal consumption before and after retrofitting has been evaluated in order to compare the monitoring results with the PHPP calculation as input of D7.5. In this case, no graphical chart is done, but data files with the sensor measurements and the calculations.

8 Annex 3 - Case Study organisation

8.1 Local Case Study Teams (LCS teams)

The LCS-Team of Case Study 7: Engineering School of Bájear is composed by:

the following partners:

- CARTIF as technical expert
- GrupoUnisolar as industrial solutions partner

the following stakeholders:

- University of Salamanca as owner of the building

8.2 LCST formalisation

For the local case study formalisation, it has been used the cooperation agreement and the non-disclosure agreement following the two templates provided by EURAC and available in the team-sitehttp://teamsites.eurac.edu/renene/3encult

As main points reached in commitment in both documents, the following bullets had agreed:

- Installation of a monitoring system (energy consumption, climate attack and users comfort) before the refurbishment tasks), in order to assess the energy behaviour of the building.
- Assessment of the possibility of the installation of different prototypes aimed to improve the energy behaviour of the building: PV solutions, daylighting systems, etc., developed in the scope of the project.
- Installation of Efficient Energy Solutions, including:
    - Renewable Energy Systems integrated in the building structure.
    - Daylighting and other solutions: After a previous analysis of viability.
- Installation of a Building Management System, including the infrastructure needed to make it work.
- University of Salamanca offers free access the 3EnCult members to the building.
- All the information in whatever form or mode of transmission, which is disclosed by a party or the partners in the 3Encult Project to another Party in connection with the 3Encult Project and which has been marked as confidential.
- Each Partner of the 3Encult Project is liable solely and exclusively with regard to its own activities and supplied material.
- University of Salamanca is providing in time the necessary technical information needed for the implementation of the activities, particularly all the information about the systems to be monitored and refurbished (electricity and thermal systems plans, LAN structure, building plan, etc.)
- All the parties agreed in obeying to the time-schedule established by the Consortium plan.

8.3 LCST meetings

During the lifecycle of the project, the following local case study meetings have been carried out:

- 20/01/2011
    - o Agenda:
        - Agreement signature and local case study team formalisation

    - Responsibility determination from the parties involved in the case study.
    - Visiting the facilities of the building as first view.
    - Take pictures of the installations,
  - Parties involved
    - University of Salamanca
    - GrupoUnisolar
    - Cartif
  - Minutes:
    - The commitment among the parties involved in the case study has been reached and documented in the non-disclosure agreement and the cooperation agreement.
    - The facilities and installation of the building has been visited, taking pictures of the most important areas for the pre-intervention analysis.
    - Agreement in sending the energy consumptions of the University via mail in the following days.
- 19/11/2011
  - Agenda:
    - Presentation of the monitoring system installation
  - Parties involved
    - University of Salamanca
    - GrupoUnisolar
    - Cartif
  - Minutes:
    - Cartif presented the monitoring system to be deployed in the building with the needs and requirements, as well as the timeline.
    - The university will contact the maintenance staff in order to install the sensors in the pumps and distribution circuits for the thermal consumption measurements.
    - Agreement from the technical office and the people of the university with the installation of the monitoring system.
- 17/04/2012
  - Agenda:
    - Status of the project
    - Need of a person involved by the University to provide information
    - Next steps
  - Parties involved
    - University of Salamanca
    - Cartif
  - Minutes:
    - Change in the contact person both in the University and in Cartif, therefore the local case study team is slightly modified.

        - The deployment of the monitoring system is almost finished and the visualization interfaces are available for the University people soon.
        - Several suggestions of people were made and the final decision should be taken in function of the technical requirements and the efforts.
        - As next steps, it will be installed the automatic control strategy in the library, re-distribution of the lighting circuits in the physics laboratory and GrupoUnisolar will integrate the photovoltaic panels.
- 21/05/2012
    - Agenda:
        - New responsibilities in the LCST
        - Contact person in the conservation issues
        - Technical information of the building
        - AR&PA fair
        - General assembly
    - Parties involved
        - University of Salamanca
        - GrupoUnisolar
        - Cartif
    - Minutes:
        - From Cartif the responsible for the project is changed from Daniel Garcia to Jose Hernandez. In the case of the University, the new contact person needs to be decided because the elections are coming.
        - The person about conservation issues will be the architect in of the technical office of the University of Salamanca.
        - The digitalisation of the plans, sections and elevations of the building are abot to finish. When ready, they will be shared with the people involved in the Case Study.
        - The AR&PA fair is going to be celebrated in Valladolid and the 3EnCult project will be present. Thus, Alexandra will come to Valladolid and it is organised a visit to the case study where Alejandro Reveriego y Francisco Labajos will be as participants of the University of Salamanca.
- 18/07/2012
    - Agenda:
        - New responsibilities in the LCST
        - Next interventions in the case study
        - Organisation of the next meeting
    - Parties involved
        - University of Salamanca
        - GrupoUnisolar
        - Cartif
    - Minutes:

        - Due to the elections of the Management Board, the new contacts in the University are Esteban Sánchez y RaúlGarcía.
        - Agreement for actuating in the library during August (testing period) and 17-23 of September in order to deploy the final control strategy, as well as the hardware gateway.
        - A study with the technicians of the Engineering School for the re-distribution of the lighting circuits. Thus, a proposal of intervention will be sent to the University for the viability analysis.
        - Photovoltaic integration – Soliker will carry out a viability study in contact with the University of Salamanca with several proposals: roof, south façade or even integration in the blinds of the computers room.
        - Next 3EnCult meeting will be in October and it is considered the possibility of being celebrated in Salamanca. Therefore, Cartif requires the help of the people of the University so as to rent meeting rooms and organise the trip and visit to the University of Béjar.
- 06/02/2014
    - Agenda:
        - Results of the interventions carried out
        - Final meeting of the project
    - Parties involved
        - University of Salamanca
        - Cartif
    - Minutes:
        - Cartif presented the results after retrofitting to the University people in a Word document format where the energy savings and the comfort parameters have been evaluated.
        - The University accepts the results of the project and take into consideration these results as possible future interventions in the building.
        - Cartif also presented the final results of the 3EnCult, the outcomes and the improvements achieved during the lifecycle of the project in order to update the information of the University as owner of the case study, widening the possibility of actuations for the future in the Engineering School with some other interesting results of the project.

8.4 Case Study meetings

The Case Study meetings have been more technical meetings where it has been tried to reach a solution in some technical aspects. These meetings have not been treated as the aforementioned because it has been taken advantage of the visit to the University for installing sensors or actuators, deploying control strategy system or doing some tests to discuss technical aspects with the people of the University. No minutes have been collected apart from the technical aspects gathered in the before minutes of the LCST meetings where some technical issues have been discussed as well.

9 Annex 4 – Associated documents

The original memory of the project is associated to this deliverable. This report is in Spanish and the name of the file is AnnexCS7_MemoriaProyectoOriginal.pdf.