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EFFICIENT ENERGY FOR EU CULTURAL HERITAGE

Engineering School Bejar

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EFFICIENT ENERGY FOR EU CULTURAL HERITAGE

Case Study 7
Engineering School of Béjar
Salamanca - Spain

Centro tecnológico CARTIF

Grupo Unisolar

VNiVERSiDAD D SALAMANCA

Béjar (Salamanca), 30/10/2012

Local Case Study Team

CARTIF Technology Centre

Cartif is a horizontal center which covers a wide range of scientific disciplines. This characteristic, which makes us stand out from other technology centres of a more vertical or specialised nature, enables us to provide companies with integral solutions. Today, Cartif has a staff of 200 researchers, revenue exceeding €10 million and a client portfolio comprising 120 enterprises and institutions. The centre has facilities of 16,500 m2 (distributed in three buildings).

G1S – Soliker

SOLIKER design and manufacturers Solar Thermal Collectors, Thin Film photovoltaic modules and laminated photovoltaic glass for architectural envelopes under the ISO 9001 quality standards at it production plant located in Béjar (Salamanca- Spain), which has more than 18000 m2 of net industrial surface.

University of Salamanca

The University of Salamanca, founded in 1218, is a medium sized university with over thirty thousand students. It is the second most popular university in the country for students wanting to study outside their home districts.

The historical features and architectural aspects

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Built in 1968

Architect: Manuel Blanc Díaz

- Engineering School founded in 1852
- Current building built in 1968
- Built in concrete and large glazed areas
- Number of floors: 7
- Orientation: West-East

1- Influenced by the Constructivist Architecture
2- Breaks with traditional architecture in the zone
3- Takes into account climatic conditions (i.e. lattice)
4- First building of the University of Salamanca in the village
5- Influence of textile industry

Centro tecnológico CARTIF
Grupo Uniaolar
UNIVERSIDAD DE SALAMANCA

The historical features and architectural aspects

...the esthetical solution of the building is based in its own function and the environmental and climatic conditions...

...we may say that the dignity the School requires has been achieved considering its simplicity in the composition and treatment...

Manuel Blanc Díaz

School of Engineers in Béjar project report

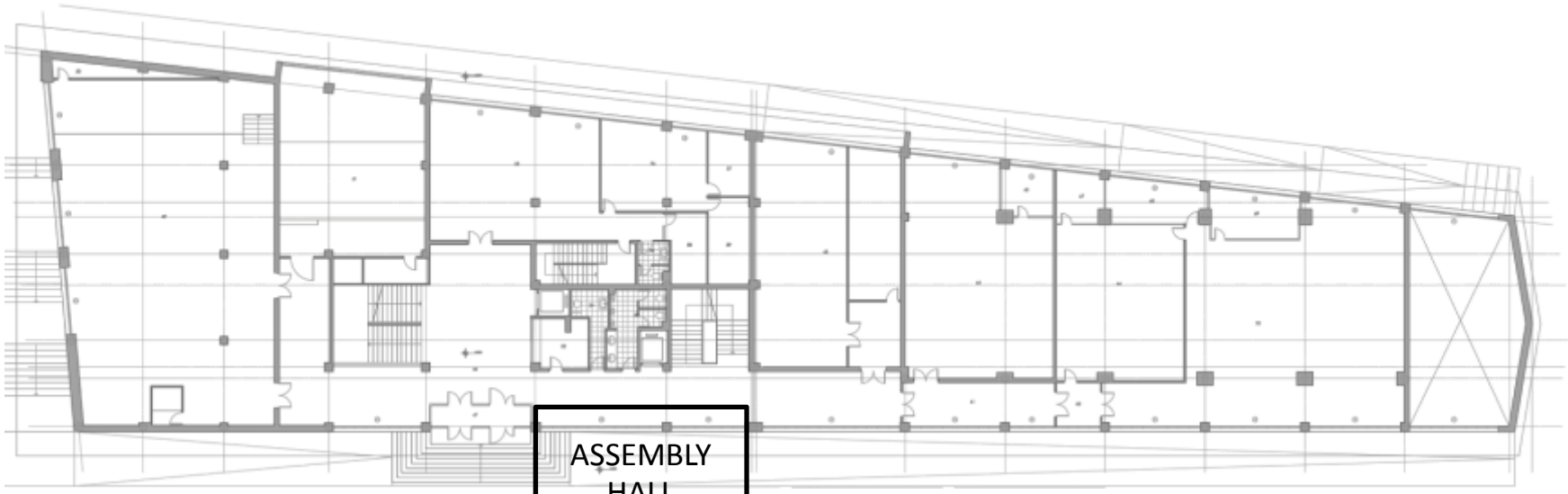
The historical features and architectural aspects

Location	Béjar (Salamanca)	**Altitude**	959 m.a.s.l.
Project year	1962	**Construction year**	1968-1972
Use	Industrial Engineering High Technical School in Béjar		
Stylistic 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 a 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 and 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.		
Conservation state	Its conservation state is well, although it has some pathologies in the jutting outs due to the humidity. There were made two interventions. In both the roof was changed, replacing all the external windows in the second refurbishment, using ones with thermal bridge rupture and isolating glass.		

The historical features and architectural aspects

Structure	Reinforced concrete pillars and grid slabs. Foundations were made with piles of 60 cm diameter and between 6 and 12 meters in deep with pile cap and perimeter walls made in reinforced concrete.		
Envelopment	Concrete bricks with air chamber and interior layer in double-hollow brick in most of façade elements. Roof is made in zinc plate above brick light partitions. Metallic windows with thermal bridge rupture and double glass 4/20/4 which were integrated in the last refurbishment.		
Floors	5 floors in access level (west façade) and 2 semi-basement floors (exterior in east façade)		
Built area	13.624,85 m^2	**Heating system**	Gas boilers and radiators
Net usable area	9.467,10 m^2	**Heating days / HDD**	240 days / 1804,45 HDD
Heated area	9.467,10 m^2	**Cooling systems**	Fan-coils in library
Heated volume	33.150 m^3	**Average power consumption**	230.000 kWh/year
Cooled area	150 m^2	**Average heating consumption**	60.000 liters/year

The historical features and architectural aspects



The historical features and architectural aspects

4ª P	DIBUJO	O. TECNICA	LABORATORIOS
3ª P	AULAS	DELEGACIONA.	LABORATORIOS
2ª P	AULAS	BIBLIOTECA	LABORATORIOS
1ª P	AULAS	DIRECCION	LABORATORIOS
P BAJA	AULA MAGNA	ADMINISTRACION	LABORATORIOS
SEMIS. 1º	COMEDOR	CLINICA	TALLERES
SEMIS. 2º	SERVICIOS		

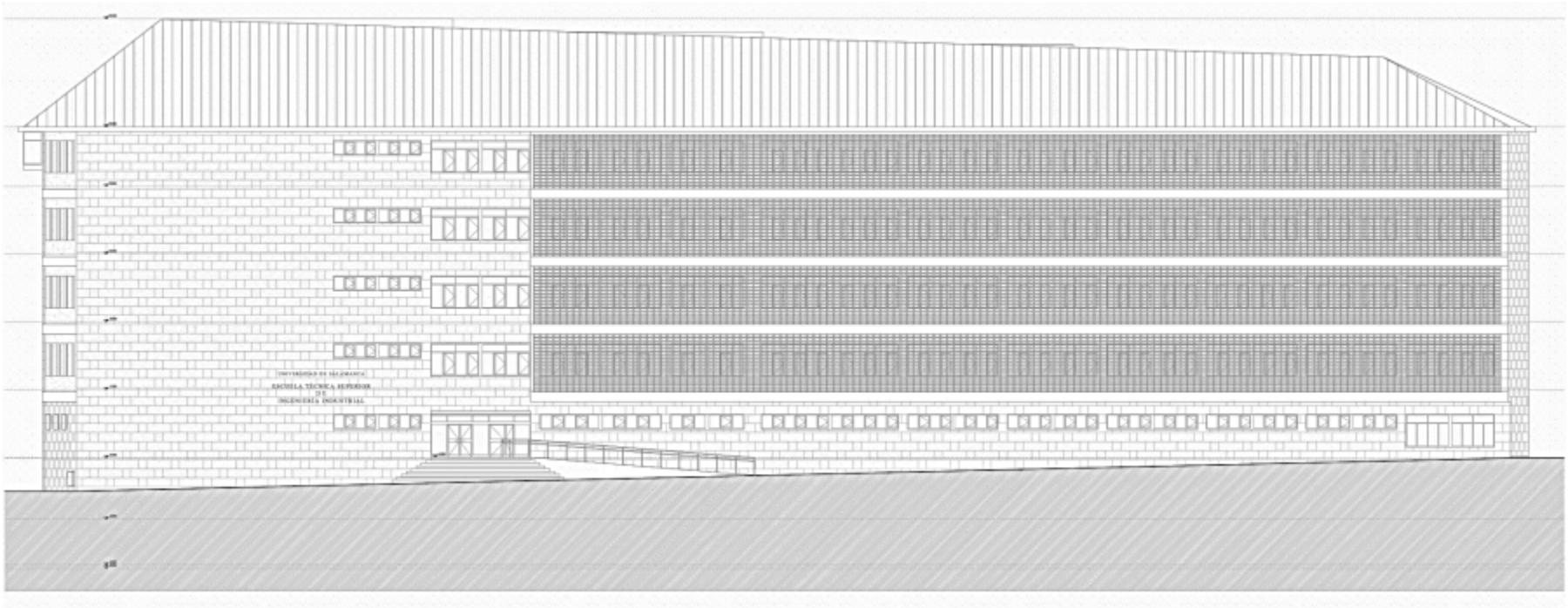
The historical features and architectural aspects

Traditional architecture elements reinterpretation.

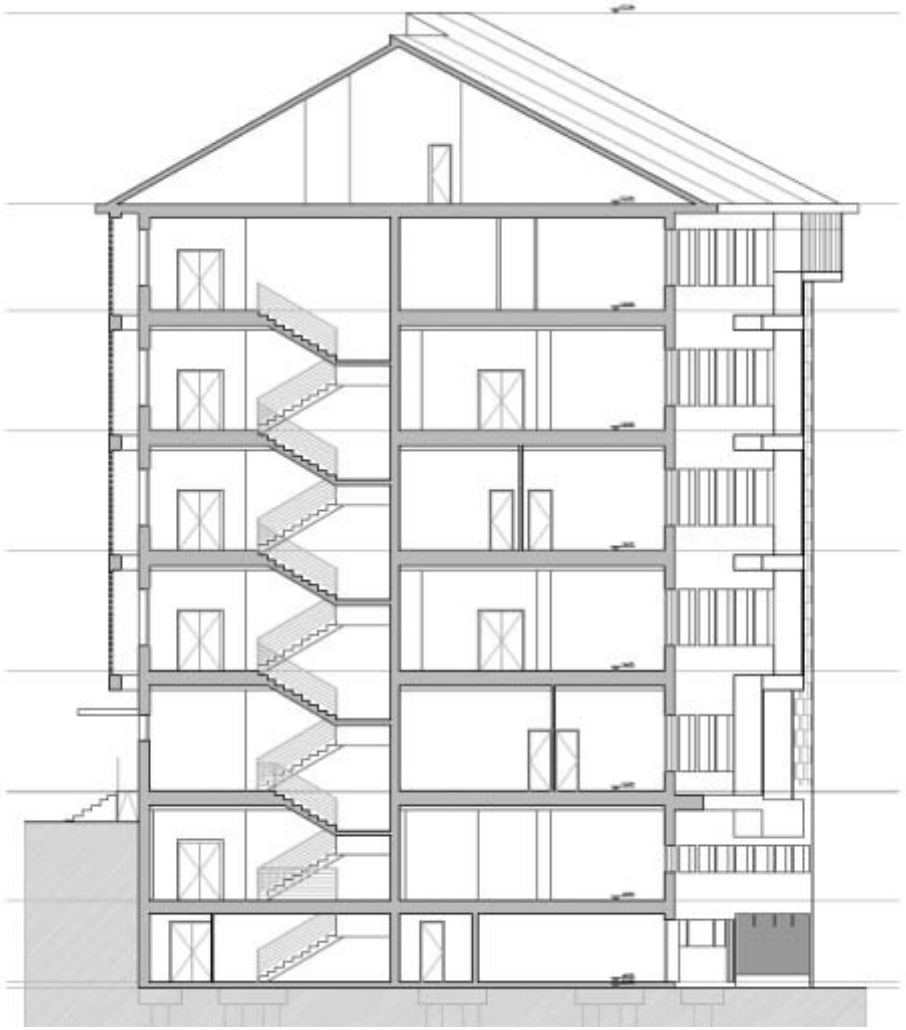
The historical features and architectural aspects

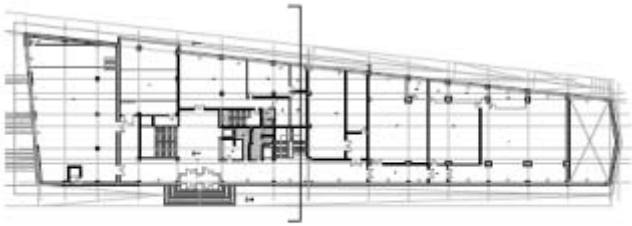
Traditional architecture elements reinterpretation:

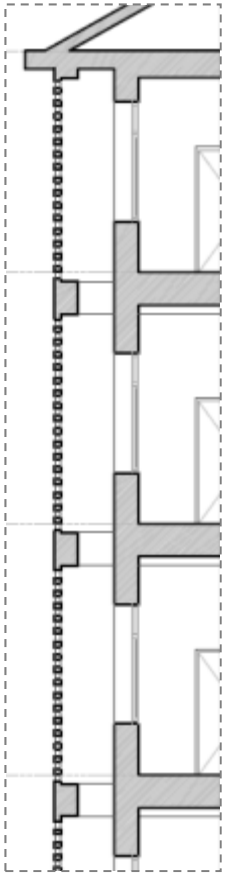
- Climate conditions protection (wind and rain)



The historical features and architectural aspects







The historical features and architectural aspects

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The historical features and architectural aspects

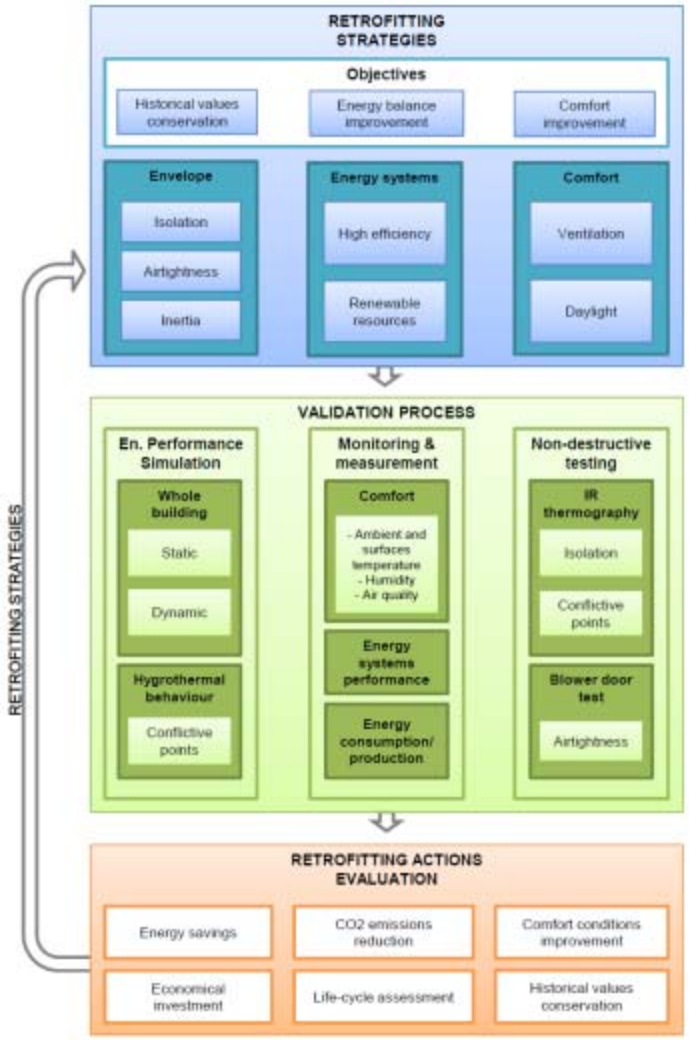
Problems, diagnosis and interventions

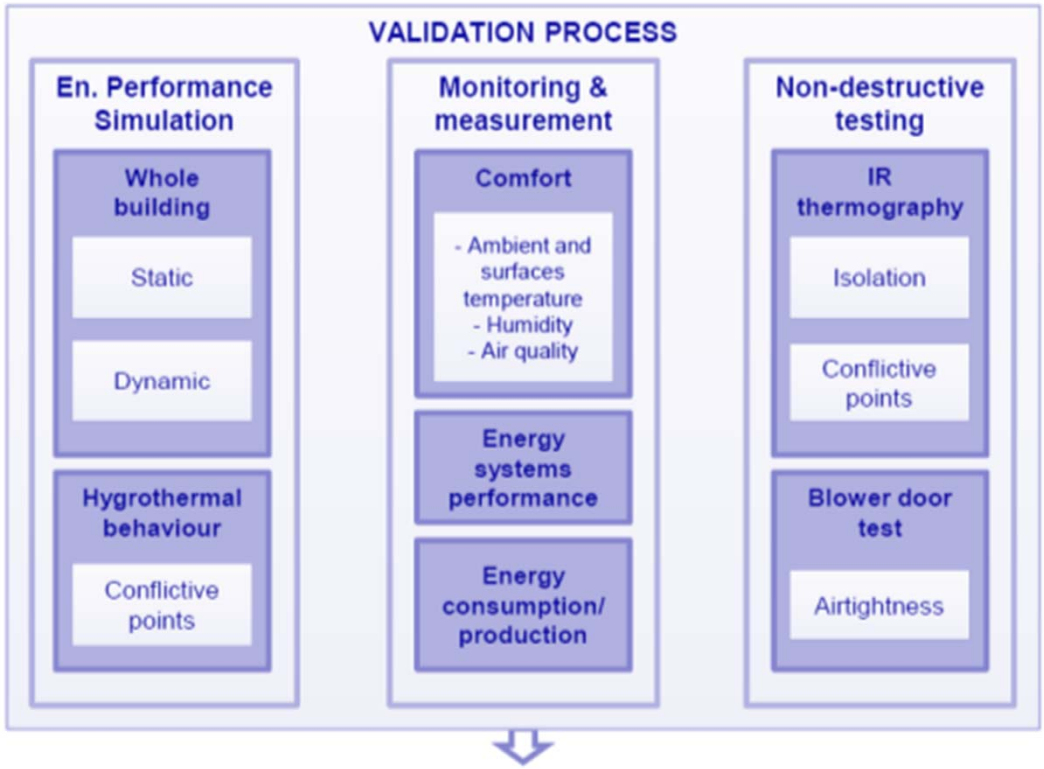
Main problems identifyed	Overheating in summer, mainly in east façade.
	Heating system: only two distribution systems for the whole building, so there are very different temperatures and discomfort problems derived.
	Cooling system: manual control strategy of library's cooling system, so appears discomfort problems.
	Oversized lighting system on corridors and hall.
	Lighting circuits incorrectly distributed on clashrooms.
	Daylight and solar radiation underutilized.
	High airthightness level on external windows and doors.

Problems, diagnosis and interventions

Diagnosis	Energy performance simulation by using the PHPP tool to compare with other tools and real data (both historical and real-time monitored).
	RES integration viability study.
	Analysis of thermal bridges by using infrared thermography system.
	Blower door test in order to analyse the air thightness on external windows.
	Local studies regarding energy efficient solutions as in lighting system, etc.

Diagnosis: Methodology

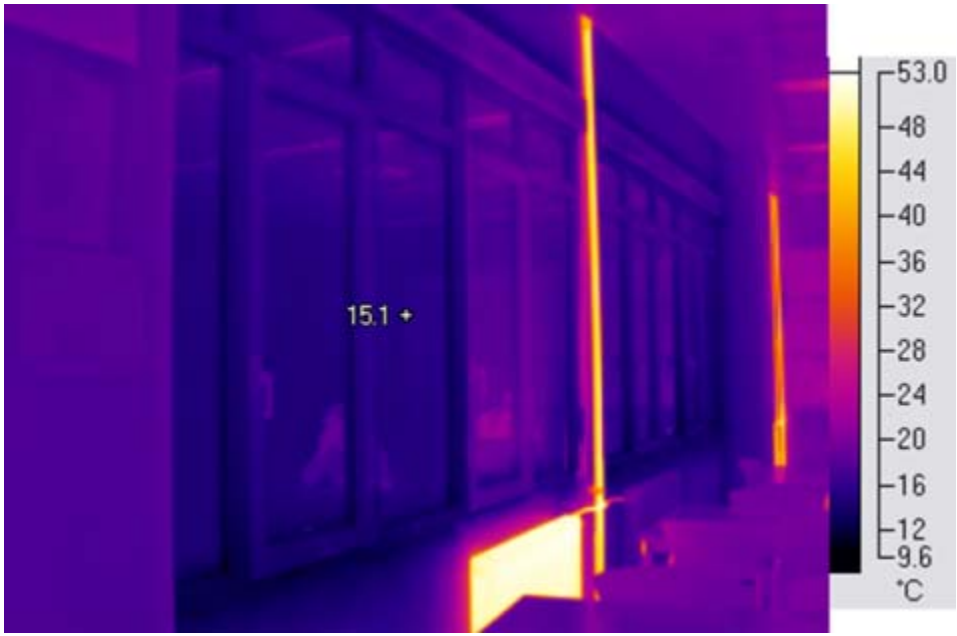




Diagnosis

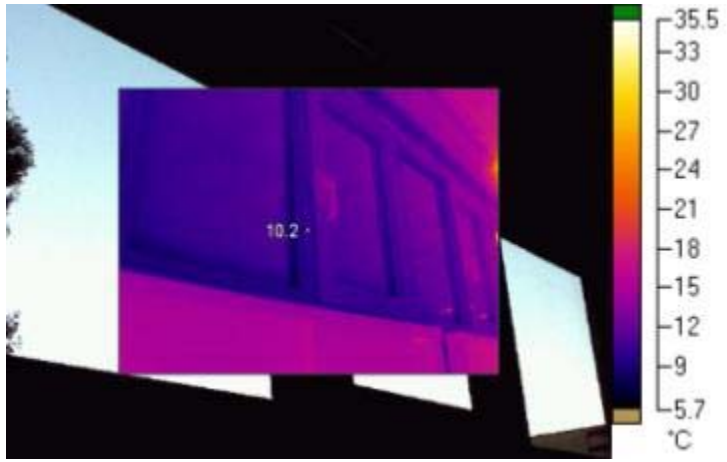
1. Infrared thermography

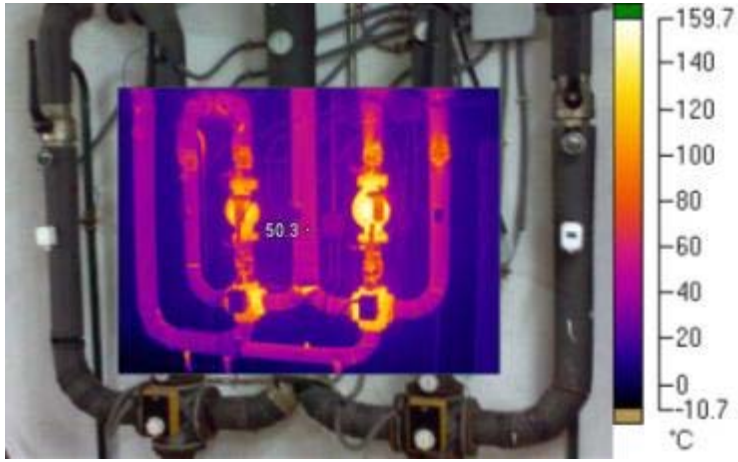
First IR report approach
Planned to develop a second IR thermography report

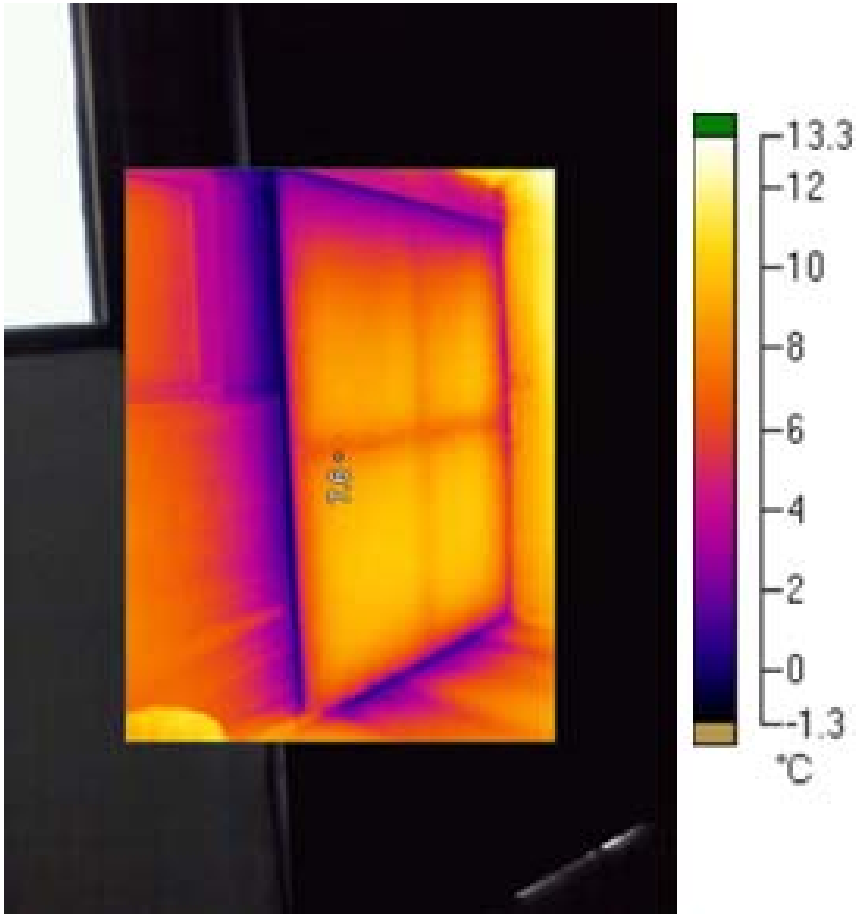


Diagnosis

1. Infrared thermography

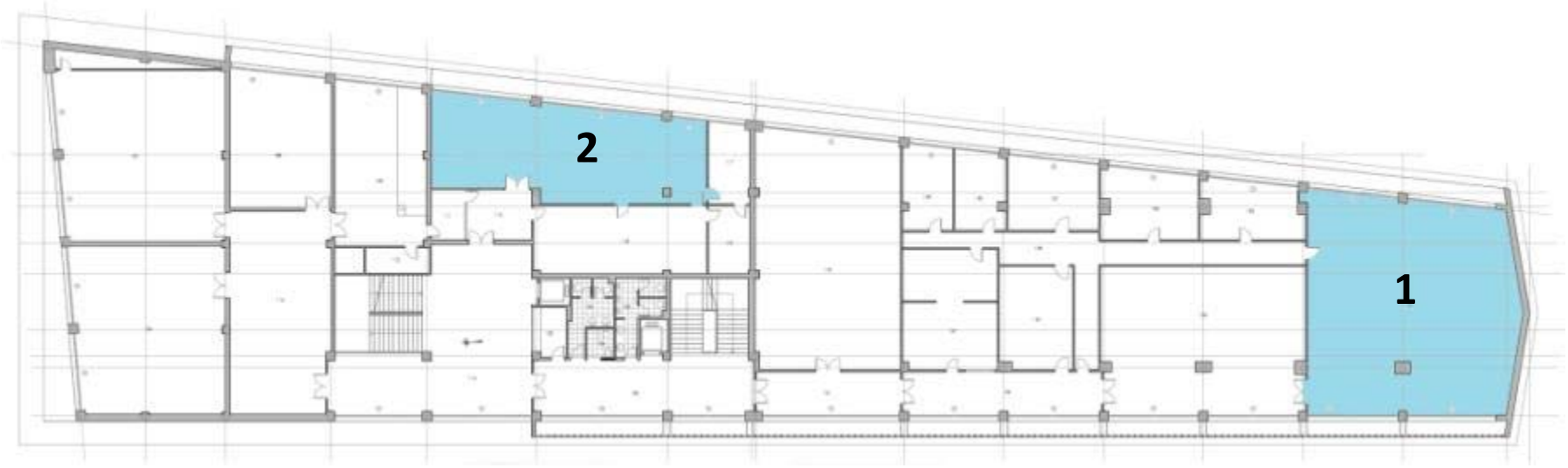






Diagnosis

2. Blower door test



1. Physics laboratory
2. Library

Diagnosis

2. Blower door test

Room	Floor area (m^2)	Height (m)	Furnitures (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 diplays a light flag

Initial conditions

- Physics Laboratory
  - Outdoor temperature = 3ºC
  - Indoor temperature = 19,1ºC
  - Indoor RH = 34,2%
- Library
  - Outdoor temperature = 5ºC
  - Indoor temperature = 20,3ºC
  - Indoor RH = 38,4%

Diagnosis

2. Blower door test

TEST 1 - LABORATORY

Test BlowerDoor

EN 13829

Minneapolis BlowerDoor Modell 4 - Tectite Express 3.6.7.0

Edificio objeto:	ETSI Béjar Béjar	Técnico: Fecha:	A. Meiss 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:	93465 Pa	Exposición al viento del edificio:	C
		Incertidumbre a causa del viento (Tabla de Delfiko)	11 %

Elementos de medida

Diafragma	Edificio Presión	Ventilador Presión	Flujo del ventilador Vr	Tolerancia
GA60D	[Pa]	[Pa]	[m³/h]	[%]
Δp_{01}	-3,2			
0	-74	85	6439	0,37
0	-68	76	6098	-0,50
0	-64	71	5890	-0,80
0	-59	66	5690	0,15
0	-54	60	5416	0,37
0	-48	53	5093	0,12
0	-44	48	4846	0,60
0	-38	40	4465	0,01
0	-33	35	4181	0,35
0	-29	28	3781	-0,66
Δp_{02}	-1,7			

Coeficiente de correlación r:		1,000	Intervalo de confianza
C_{vm}	[m³/h·Pa^n]	705	max. 738 / min. 674
C_L	[m³/h·Pa^n]	687	max. 710 / min. 667
n	[-]	0,52	max. 0,53 / min. 0,50

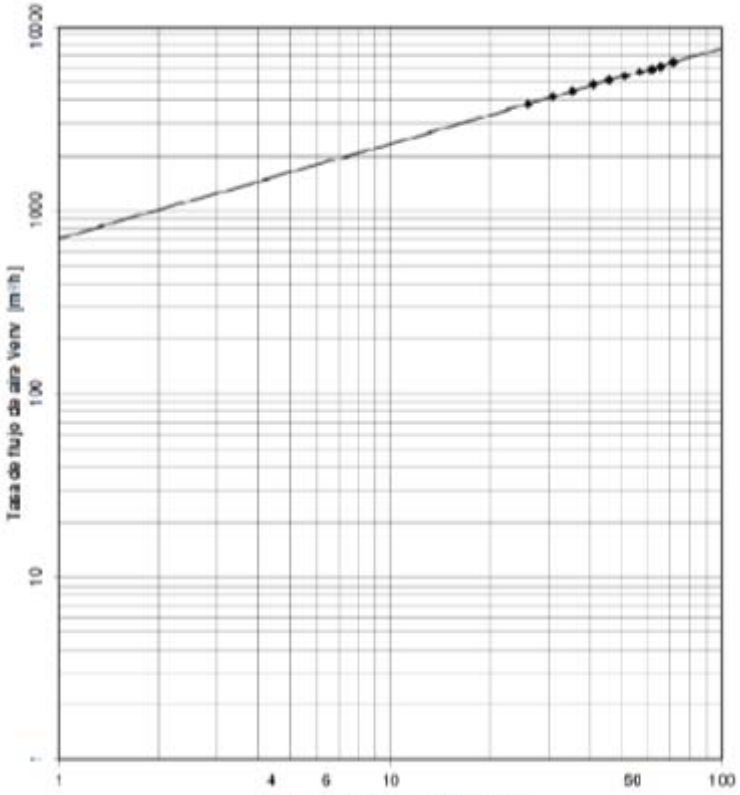
Resultados

V = 567 m³ | A_E = 172 m² | A_L = 521 m²

	V_{50}	Incertidumbre	n_{50}	Incertidumbre	w_{50}	Incertidumbre	q_{50}	Incertidumbre
	m³/h	%	1/h	%	m³/h·m²	%	m³/h·m²	%
Despresurización	5191	+/- 12 %	9,2	+/- 13 %	30,2	+/- 13 %	10,0	+/- 13 %

RESULTS

Air flow rate (m3/h) resulting from the Blower Door Test



Diagnosis

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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:	93465 Pa	Exposición al viento del edificio:	C
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DA0000	[Pa]	[Pa]	[m³/h]	[%]
Δp_{01}	-3,2	—	—	—
0	-74	85	6439	0,37
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0	-33	35	4181	0,35
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Δp_{02}	-1,7	—	—	—

Coeficiente de correlación r:		1,000	Intervalo de confianza	
C_{DA}	[m³/(h·Pa^n)]	705	máx. 738	mín. 674
C_L	[m³/(h·Pa^n)]	687	máx. 719	mín. 657
n	[-]	0,52	máx. 0,53	mín. 0,50

Resultados

	V =	567 m³	A_E =	172 m²	A_L =	521 m²
	V_{50}	n_{50}	w_{50}		q_{50}	
	m³/h	1/h	m³/m²h		m³/m²h	
	%	%	%		%	
Despresurización	5191	+/- 12 %	9,2	+/- 13 %	30,2	+/- 13 %	10,0	+/- 13 %

RESULTS

Laboratory test 1 (with opened ventilation chimneys)

- V_{50} Average flow at 50 Pa (m^3/h) = 5191 m^3/h
- n_{50} Airchange 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 airchange rate = 9,2/20 = 0,46 h^{-1}

Laboratory test 2 (with closed ventilation chimneys)

- V_{50} Average flow at 50 Pa (m^3/h) = 4778 m^3/h
- n_{50} Airchange 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 airchange rate = 8,4/20 = 0,42 h^{-1}

Diagnosis

3. Monitoring system

Monitored areas:

- Library and offices
- Boilers room
- Physics laboratory and corridor
- Roof (climatic conditions)








Diagnosis

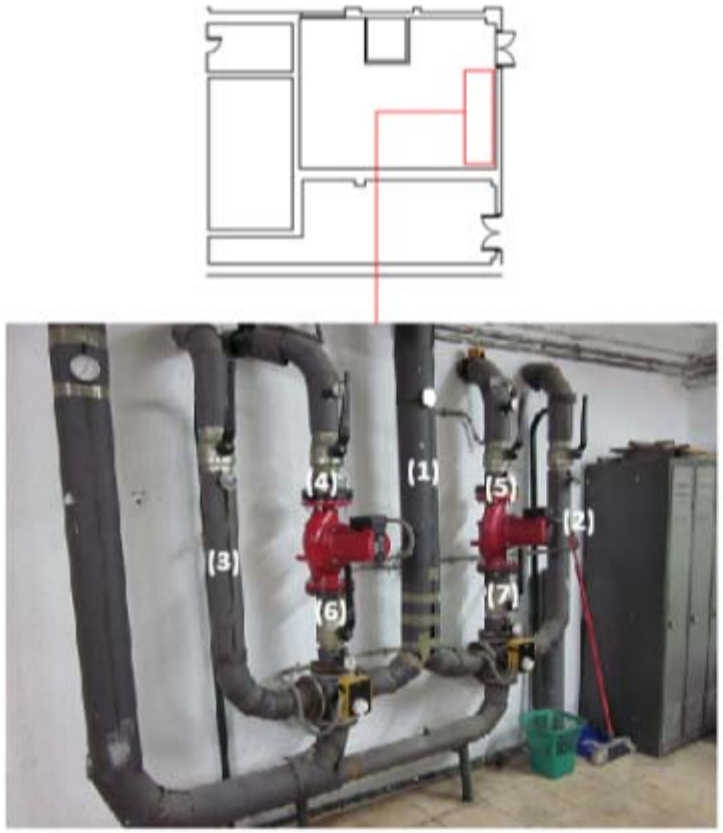
3. Monitoring system

Thermal energy consumption	Thermal demand (kWh)	**Comfort conditions**	Indoor relative humidity (%)
	Water inlet and outlet temperature (ºC)		Indoor temperature (ºC)
	Pressure (bar)		Occupancy (binary)
Lighting system	Indoor iluminance (lux)		Available temperature (ºC)
	Lighting actuators state (binary)		Windows opening (binary)
	Occupancy (binary)		Heating system state (binary & %)
Electric energy consumption	Voltage (V)	**Climatic conditions**	Outdoor temperature (ºC)
	Intensity (A)		Outdoor irradiance (lux)
	Real power (W)		Sunset (lux)
	Reactive power (VAr)		Rain sensor (binary)
	Power factor (value)		Wind direction (degrees)
	Armonics distorsion (value)		Wind speed (m/s)
	Real energy (Wh)		Direct solar radiance (W/m^2)
	Reactive energy (VAhr)		Outdoor relative humidity (%)
			Pluviometer (l/h)

Diagnosis

3. Monitoring system

Monitoring System before refurbishment - List of Sensors & Meters installed in the Boilers' Room



(1) - Inlet Water Temperature Sensor

(2) - Outlet Water Temperature Sensor Circuit 1

(3) - Outlet Water Temperature Sensor Circuit 2

(4) - Pressure Sensor - After Water Pump Circuit 2

(5) - Pressure Sensor - After Water Pump Circuit 1

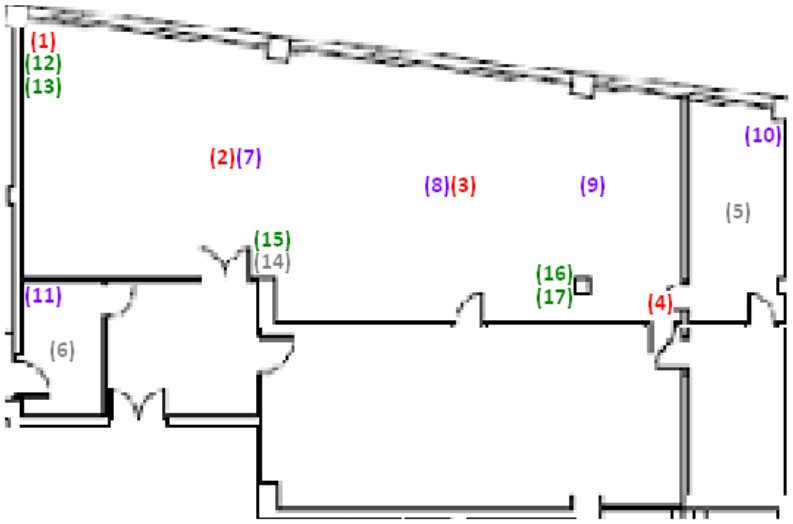
(6) - Pressure Sensor - Before Water Pump Circuit 2

(7) - Pressure Sensor - Before Water Pump Circuit 1

Diagnosis

3. Monitoring system

Monitoring System before refurbishment - List of Sensors & Meters installed in the Library and Offices.



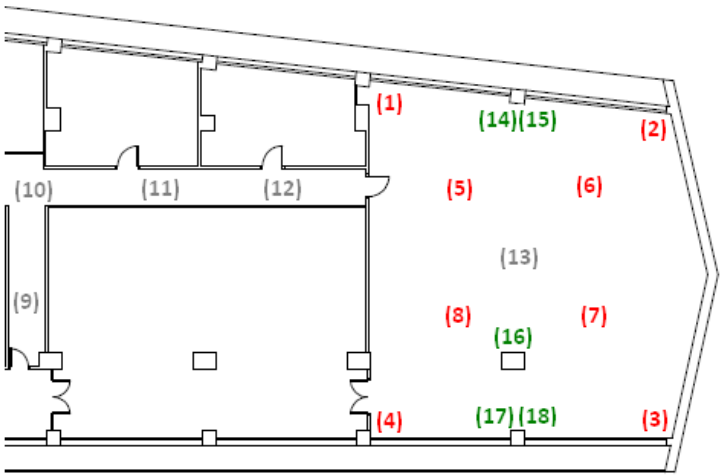
Plan of the Library & Offices

(1) Occupancy Sensor 120º
(2) Occupancy Sensor 360º
(3) Occupancy Sensor 360º
(4) Occupancy Sensor 120º
(5) Comfort & Occupancy Multisensor
  a) Occupancy Sensor 360º
  b) Indoor Temperature (ºC)
  c) Indoor Brightness (lux)
(6) Comfort & Occupancy Multisensor
  a) Occupancy Sensor 360º
  b) Indoor Temperature (ºC)
  c) Indoor Brightness (lux)
(7) Electrical Consumption - Fancoil North Library
(8) Electrical Consumption - Fancoil Center Library
(9) Electrical Consumption - Fancoil South Library
(10) Electrical Consumption - Fancoil Office II
(11) Electrical Consumption - Fancoil Office I
(12) Comfort - Temperature Sensor (ºC)
(13) Comfort - Indoor Brightness (lux)
(14) Comfort Multisensor
  a) Indoor Temperature (ºC)
  b) Indoor Relative Humidity (%)
(15) Comfort - CO2 Level
(16) Comfort - Indoor Brightness (lux)
(17) Comfort - Indoor Temperature (ºC)

Diagnosis

3. Monitoring system

Monitoring System before refurbishment - List of Sensors & Meteris installed in the Physics Laboratory



Plan of the Physics' Laboratory

(1) Occupancy Sensor 120º

(2) Occupancy Sensor 120º

(3) Occupancy Sensor 120º

(4) Occupancy Sensor 120º

(5) Occupancy Sensor 360º

(6) Occupancy Sensor 360º

(7) Occupancy Sensor 360º

(8) Occupancy Sensor 360º

(9) Comfort & Occupancy Multisensor
- a) Occupancy Sensor 360º
- b) Indoor Temperature (ºC)
- c) Indoor Brightness (lux)

(10) Comfort & Occupancy Multisensor
- a) Occupancy Sensor 360º
- b) Indoor Temperature (ºC)
- c) Indoor Brightness (lux)

(11) Comfort & Occupancy Multisensor
- a) Occupancy Sensor 360º
- b) Indoor Temperature (ºC)
- c) Indoor Brightness (lux)

(12) Comfort & Occupancy Multisensor
- a) Occupancy Sensor 360º
- b) Indoor Temperature (ºC)
- c) Indoor Brightness (lux)

(13) Comfort Multisensor
- a) Indoor Temperature (ºC)
- b) Indoor Relative Humidity (%)

(14) Comfort - Temperature Sensor (ºC)

(15) Comfort - Indoor Brightness (lux)

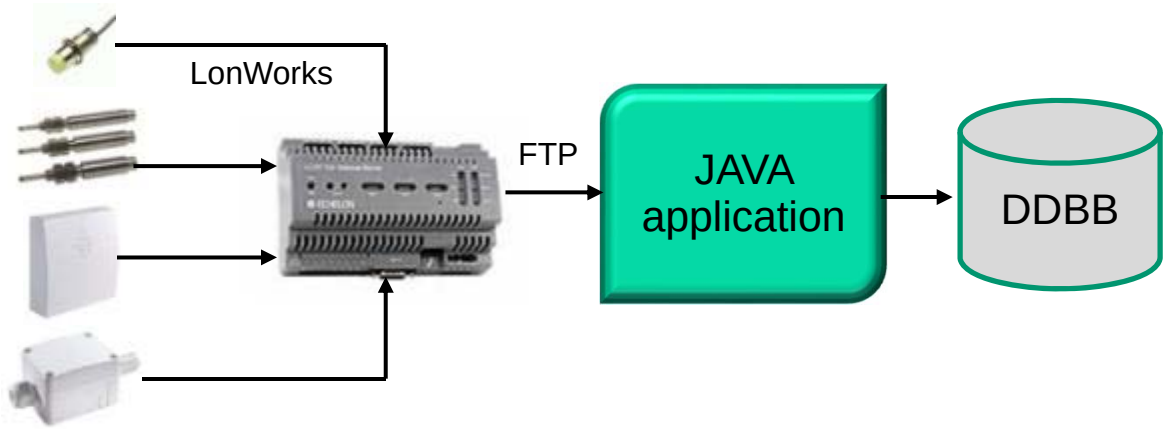
(16) Comfort - CO2 Level

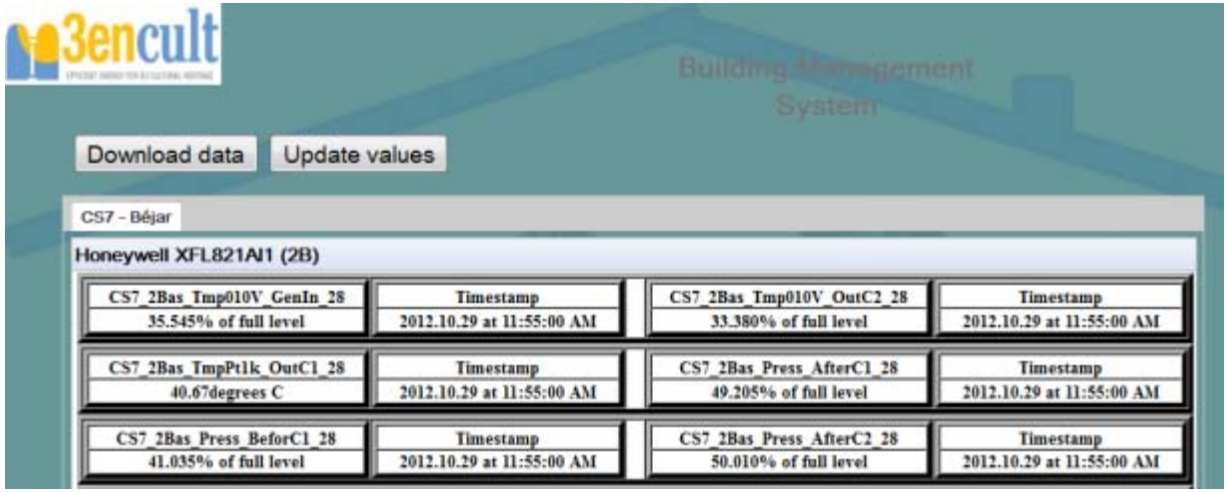
(17) Comfort - Indoor Temperature (ºC)

(18) Comfort - Indoor Brightness (lux)

Diagnosis

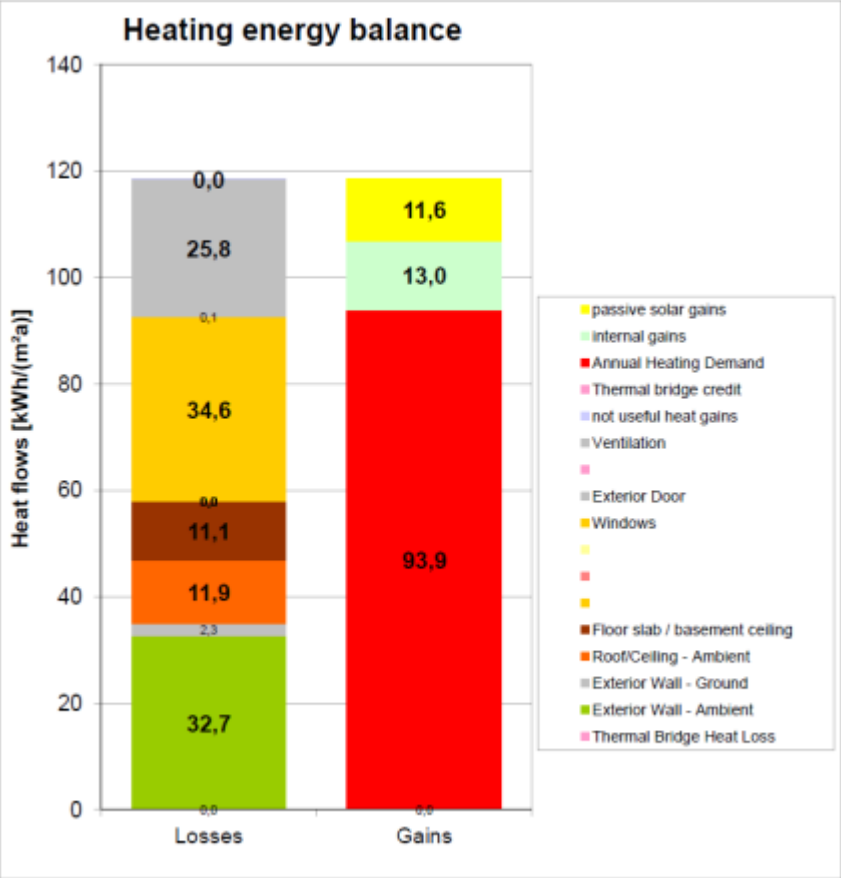
3. Monitoring system

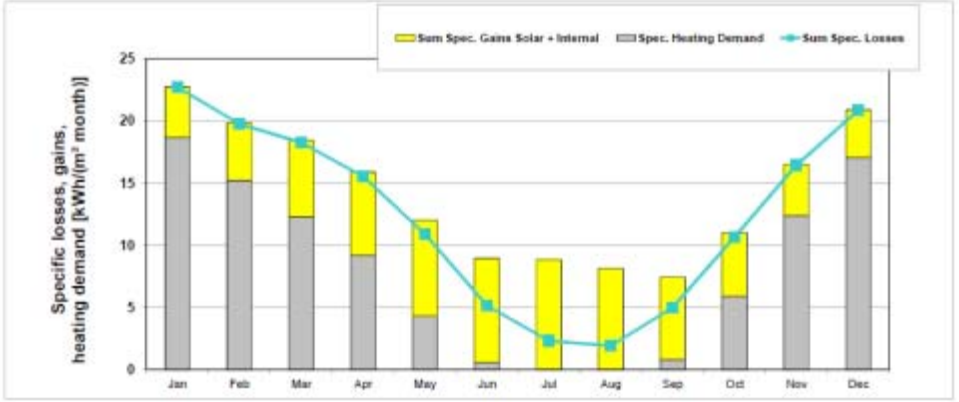




Diagnosis

4. Building energy performance simulation (PHPP)





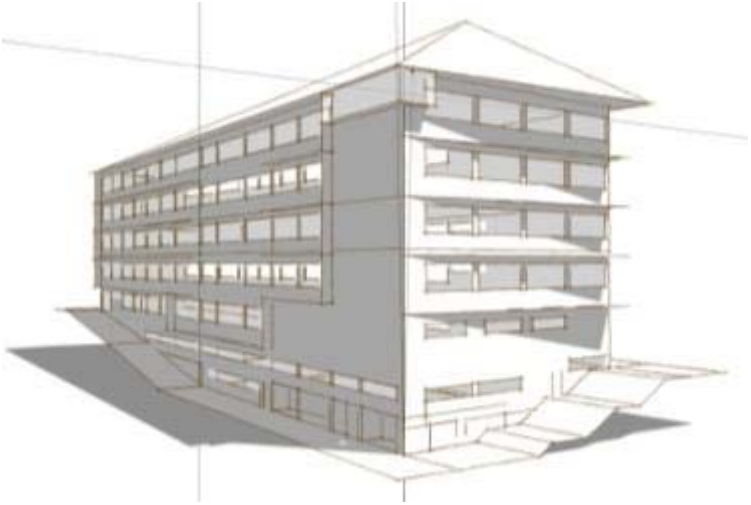
Specific building demands with reference to the treated floor area — use: Monthly method

				Requirements	Fulfilled?*
	Treated floor area	10525,5	m²		
Space heating	Annual heating demand	97	kWh/(m²a)	15 kWh/(m²a)	no
	Heating load	39	W/m²	10 W/m²	no
Space cooling	Overall specific space cooling demand		kWh/(m²a)	-	-
	Cooling load		W/m²	-	-
	Frequency of overheating (> 25 °C)	12,0	%	-	-
Primary Energy	dehumidification, cooling, household electricity		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

Diagnosis

4. Building energy performance simulation (TRNSYS)



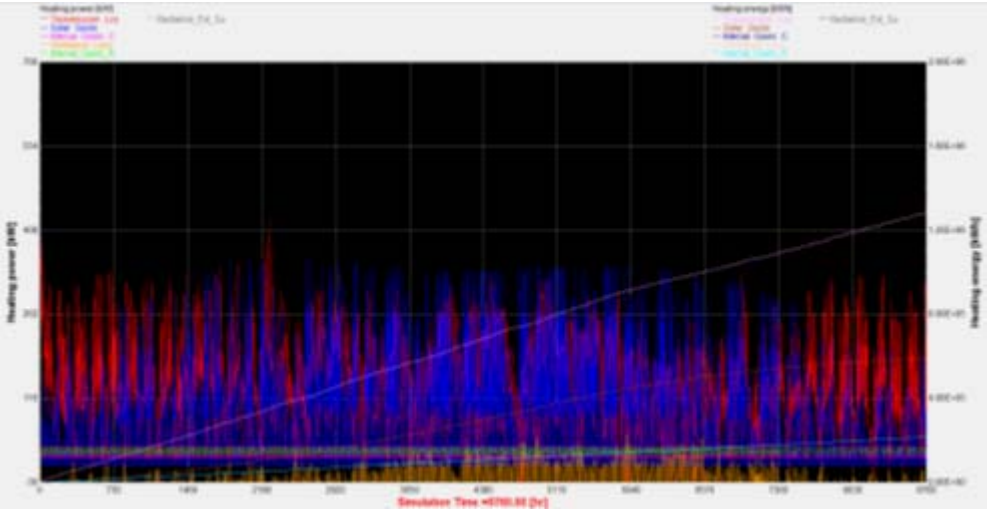


Table 2. Simulation results for comparing simulation tools

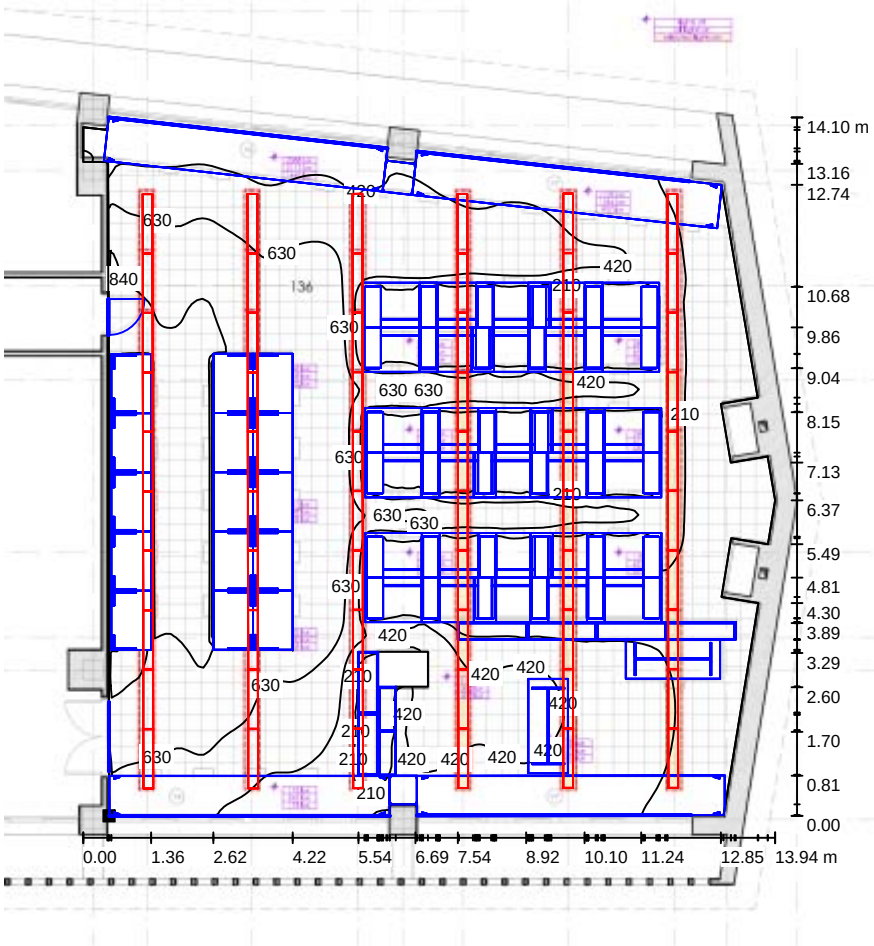
Heating energy balance	PHPP (kWh/m²a)	TRNSYS (kWh/m²a)
Ventilation	17.90	25.70
Transmittance losses	94.70	154.89
Windows	*34.60*	
Floor/slab basement	*13.20*	
Roof	*11.90*	
Ext. wall (ground)	*2.30*	
Ext. wall (ambient)	*32.70*	
Solar gains	11.60	62.72
Internal heat gains	13.00	22.23
Convection		*12.26*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

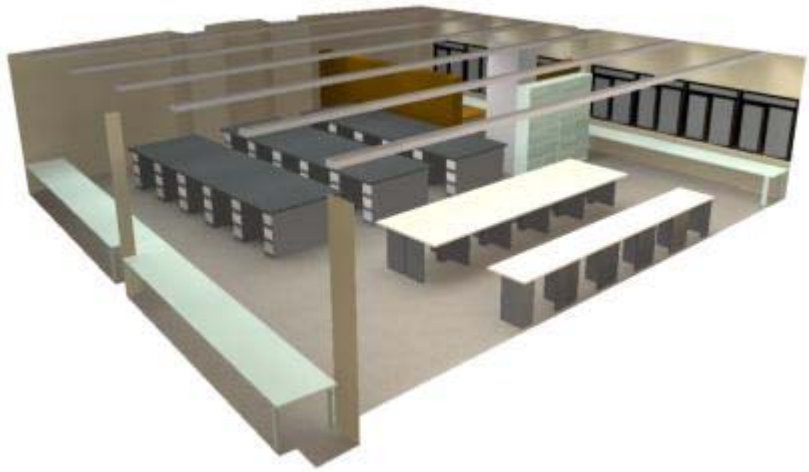
Table 3. Simulation results for base lining

Heating energy balance	kWh/m²a
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

Diagnosis

5. Lighting simulation (Dialux)



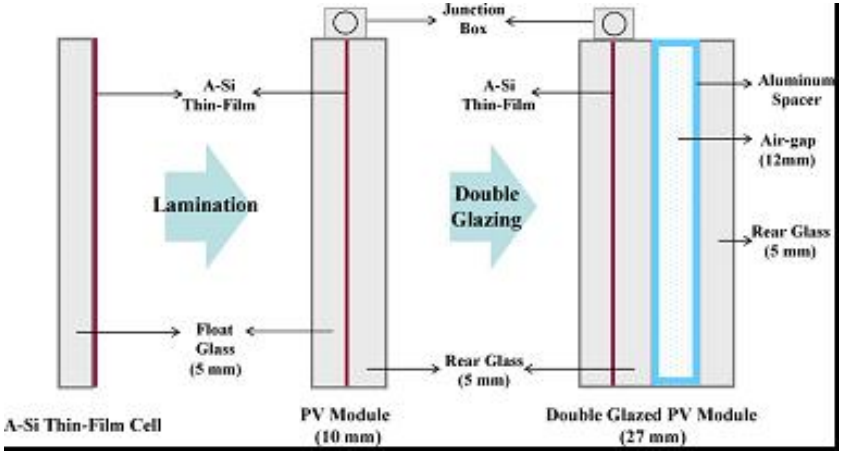


Problems, diagnosis and interventions

	Passive solutions	Active solutions	Control
Energy efficiency	Insulation Airtightness decrease	-	Lighting system
Comfort	-	-	Lighting system HVAC system
RES Integration	-	Biomass boilers	-

Interventions

1. RES integration: solar photovoltaic

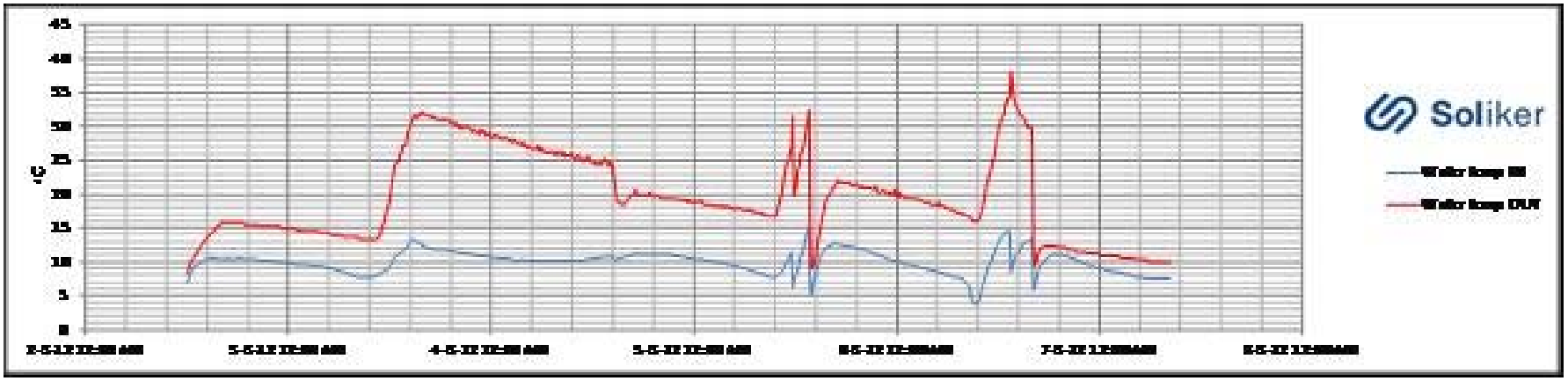


Interventions

1. RES integration: solar thermal and biomass

Interventions

1. RES integration: solar thermal and biomass



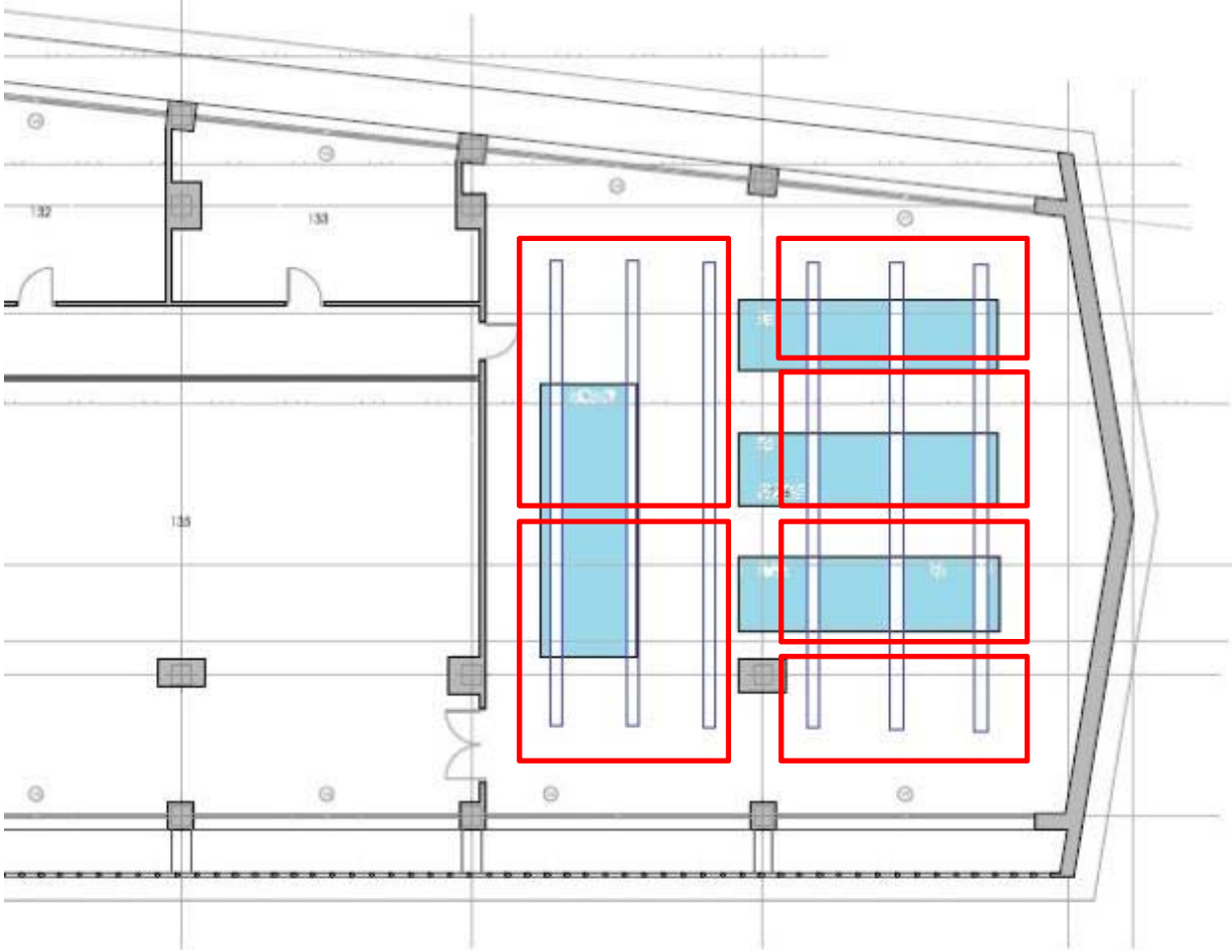
Interventions

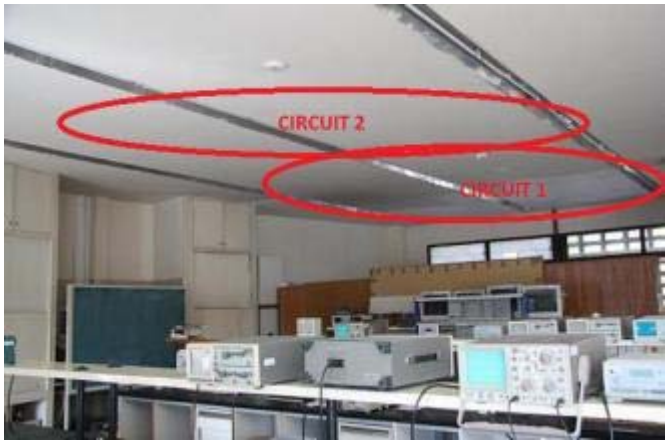
2. Energy efficient solutions

- Lighting circuits redistribution
- FCU and ventilation system management

Interventions

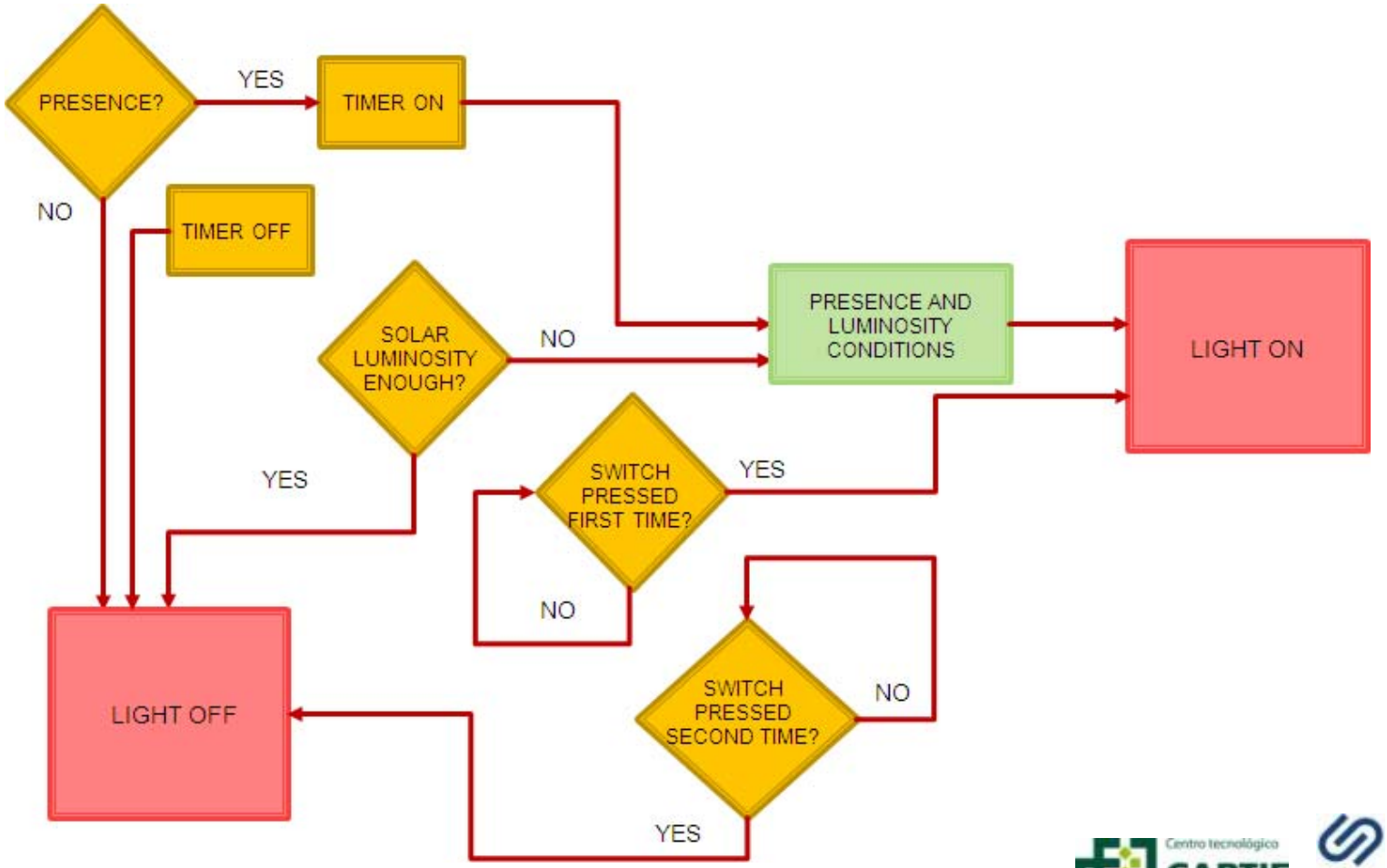
2. Energy efficient solutions: Physics laboratory – Redistribution of luminaires





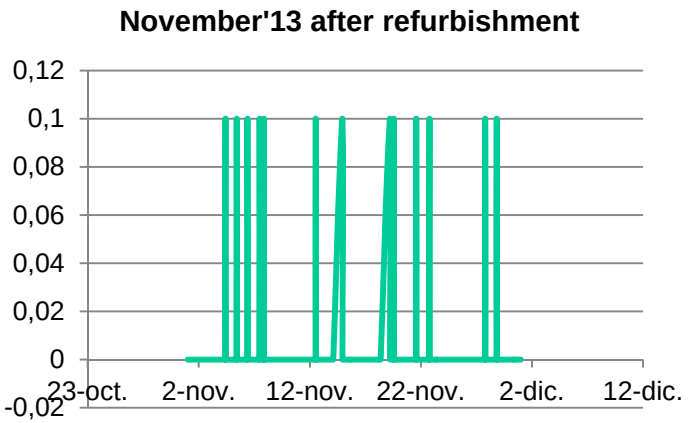
Interventions

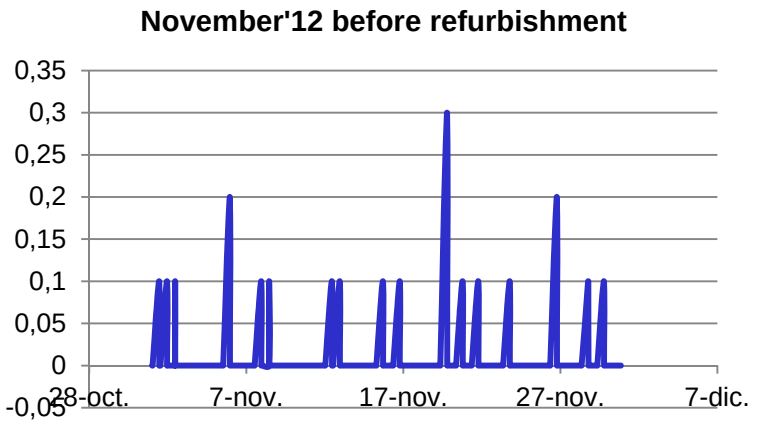
2. Energy efficient solutions: Physics laboratory – Control algorithm



Interventions

2. Energy efficient solutions: Physics laboratory – Results

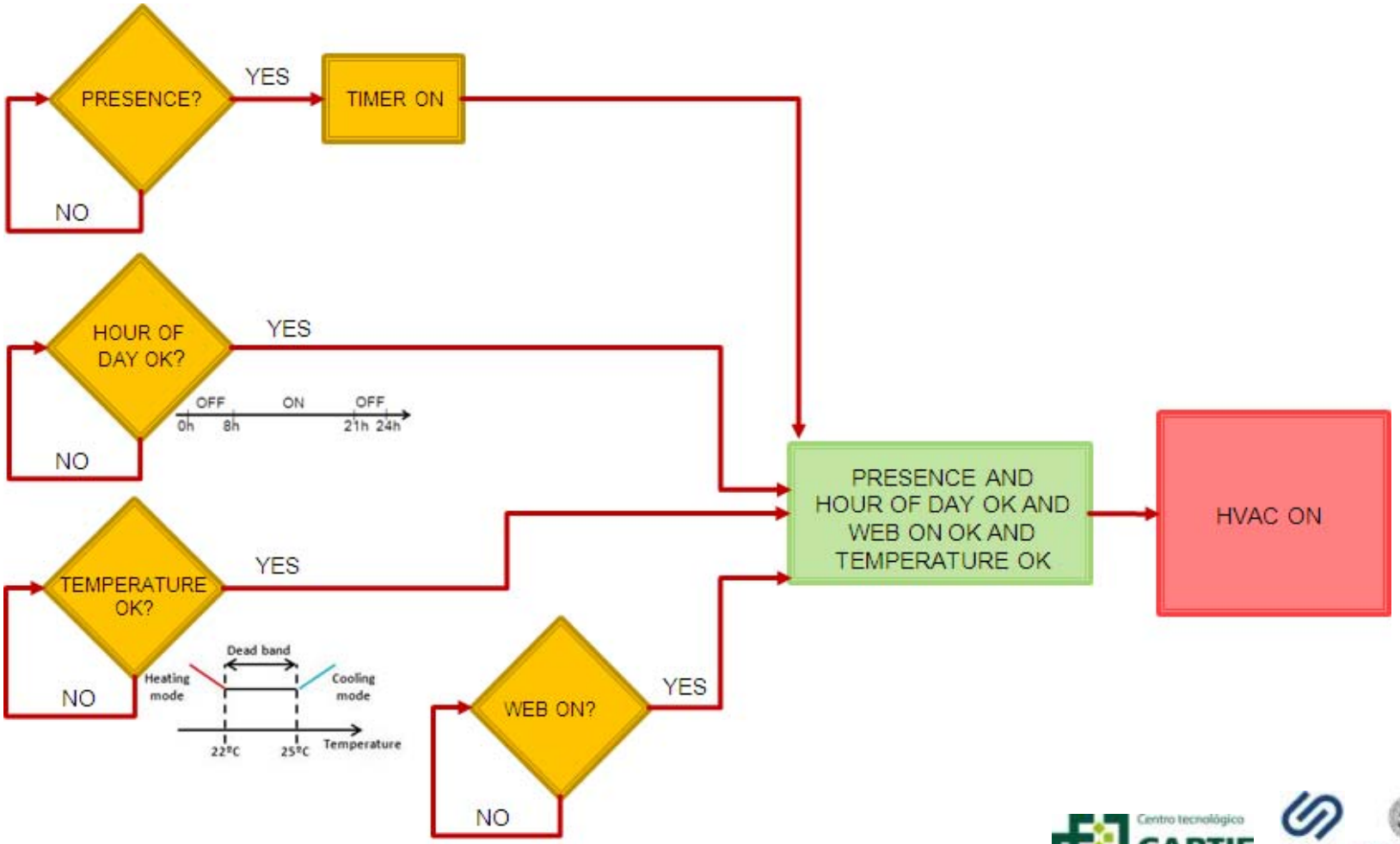




- **Total consumption reduced**
  - **2.2 kW in November 2012**
  - **1.3 kW in November 2013**
  - **Lighting comfort level**
- **Results could be extrapolated to other rooms**

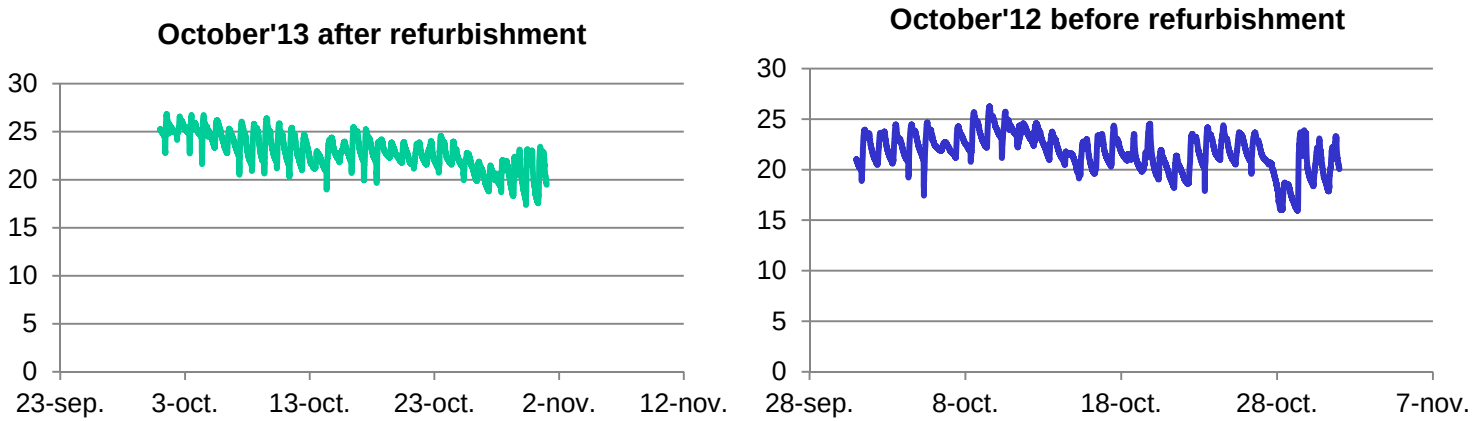
Interventions

2. Energy efficient solutions: Library – Control algorithm



Interventions

2. Energy efficient solutions: Library – Results

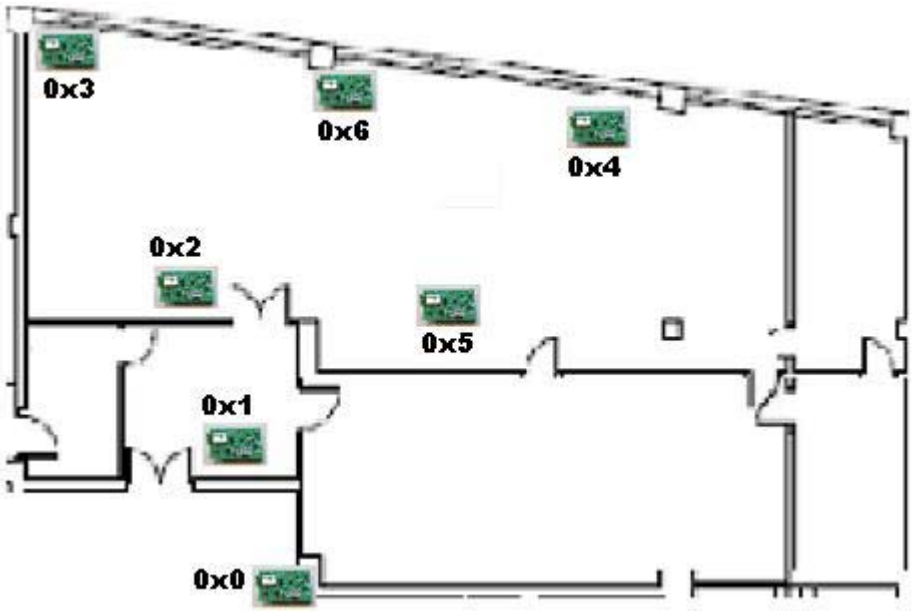


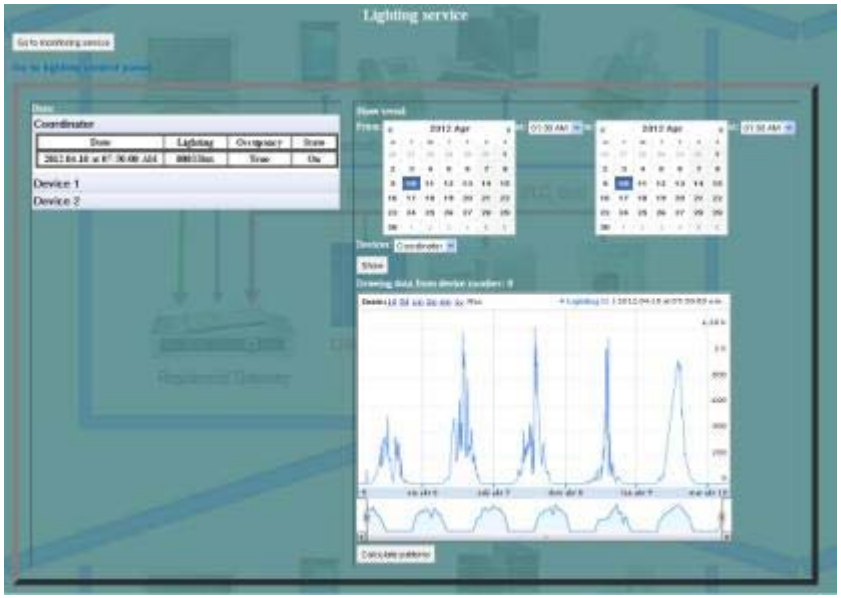
- **Average temperature**
  - **21.91°C in October 2012 with a standard deviation 1.86**
  - **22.89°C in October 2013 with a standard deviation 1.79**
  - **Dependency of min and max set-points**
- **Comfort level achieved – Reduction of claims**
- **Not signification increment of consumption**
  - **In fact, it is sometimes reduced because of automatic control**

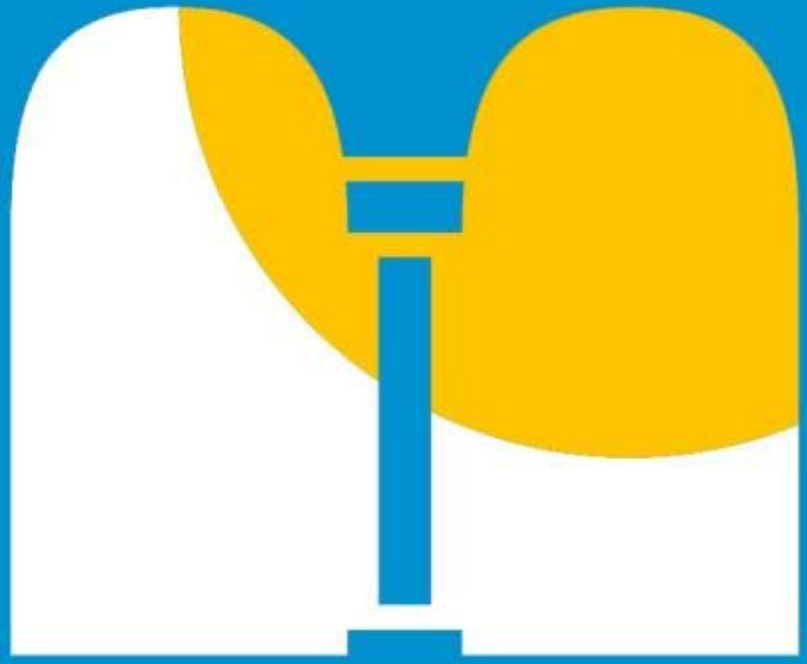
Interventions

3. Monitoring and control strategies (BMCS)

Zigbee devices installation in combination with the WP4 developed BMS







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