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ENERGIA para a SUSTENTABILIDADE

ENERGY for SUSTAINABILITY • EfS | UC

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Modernised Portuguese Schools: From IAQ and Thermal Comfort, towards Energy Efficiency Plans

PhD Thesis in Sustainable Energy Systems

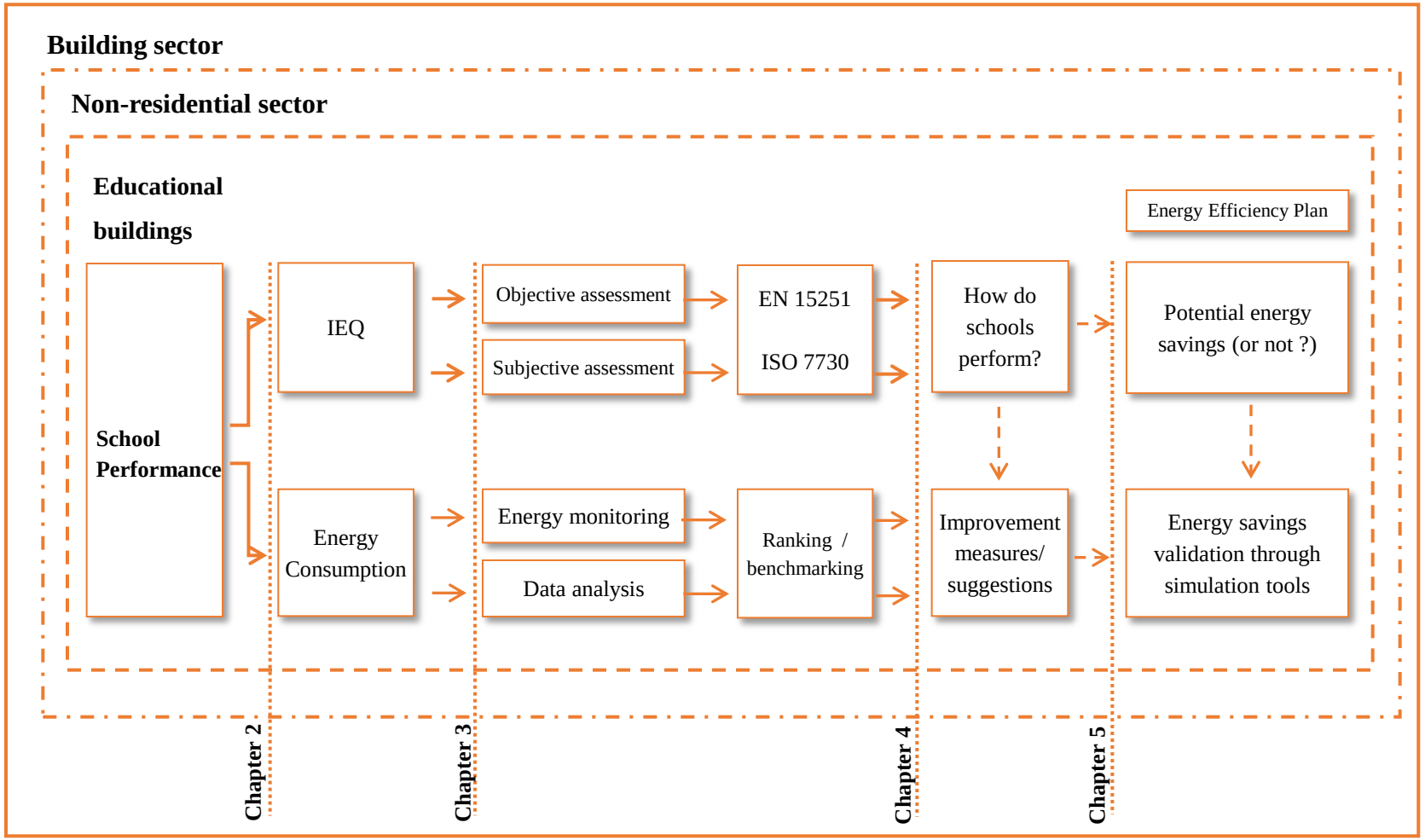
supervised by Professor Manuel Carlos Gameiro da Silva

EPBD

Certificação Energética e Ar Interior EDIFÍCIOS

PARQUESCOLAR

- Do MV buildings guarantee better IEQ than NV?
- How are the modernised schools in PT responding in terms of IEQ legislation?
- Does energy consumption increase reflect students' comfort & satisfaction?
- How can monitoring help improving IEQ in retrofitted schools?
- Is it possible to reduce on energy costs? Or is it possible to improve IEQ?

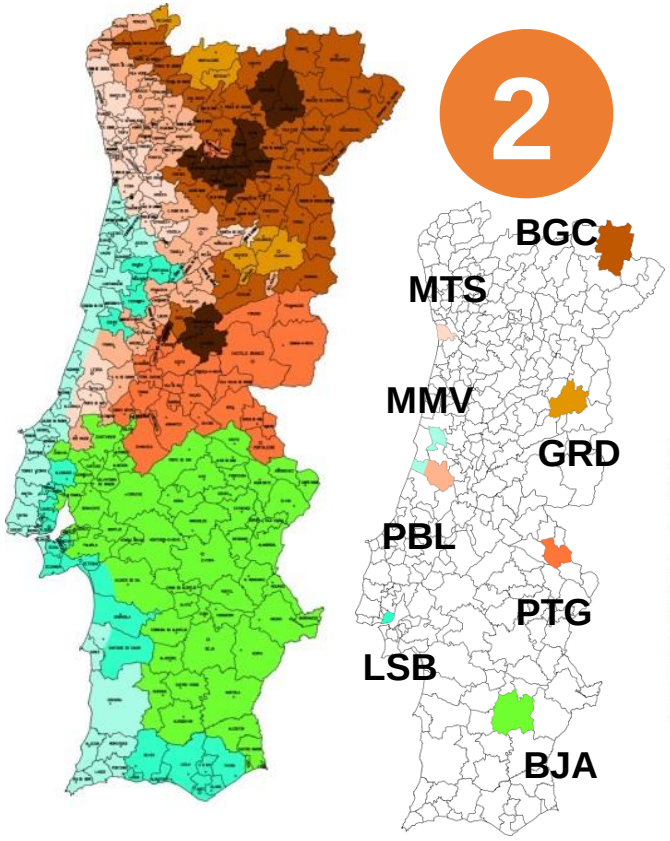

Building sector
Non-residential sector
Educational buildings
School Performance
IEQ
Energy Consumption
Objective assessment
Subjective assessment
Energy monitoring
Data analysis
EN 15251
ISO 7730
Ranking / benchmarking
How do schools perform?
Improvement measures/ suggestions
Energy Efficiency Plan
Potential energy savings (or not ?)
Energy savings validation through simulation tools
Chapter 2
Chapter 3
Chapter 4
Chapter 5

case studies presentation

***An assessment of the Modernisation of Public Secondary Schools Programme** (focused on energy consumption) **performed in the framework of an R&D project (3Es)** involving UC's R&D units (ADAI, INESC-C & GEMF) & TDGI*

A 3-step process was determined:

1 A single Climatic Map of Portugal (combining winter and summer climatic zones), propped on RCCTE (2006) was established
Schools w/ refurbishment works completed until **2011** were considered

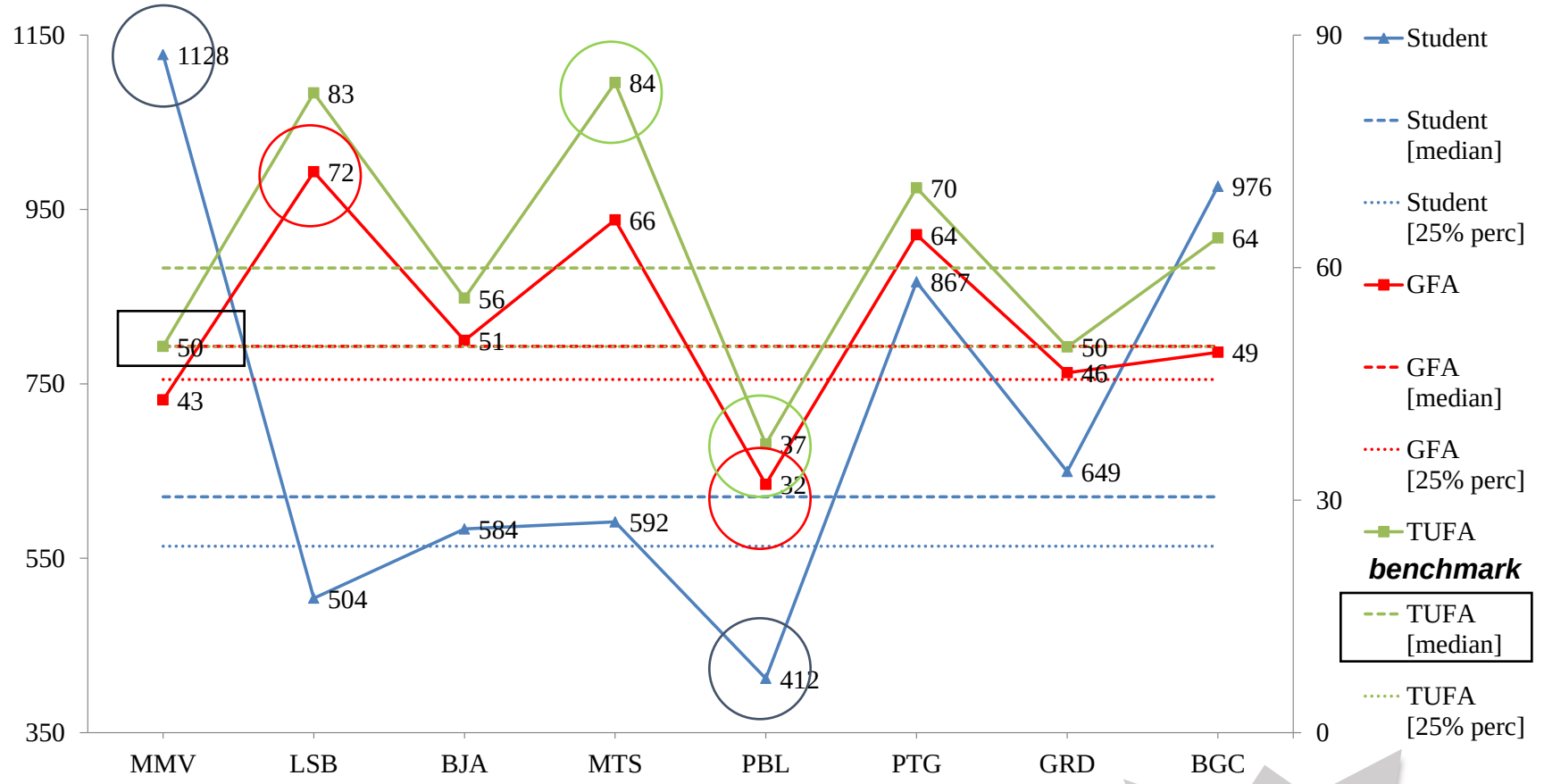


2 Having verified the absence of refurbished schools in some municipalities (& corresponding climatic zones), some other schools were selected (although only completed in 2012)

Geographical diversity & representativeness of the sample was achieved

3 Final selection of **8** schools based on calculated energy use indicators

Figure 1 –Map of Portugal with climatic zones for the heating and cooling seasons; Map highlighting the 8 schools' selection



1. ***Student*** = *Energy Consumption / No. of students (kWh/student)*
2. ***GFA*** = *Energy Consumption / Gross Floor area (kWh/m²)*
3. ***TUFA*** = *Energy Consumption / Total useful Floor area (kWh/m²)*

Weather SBI was tested & showed to be misleading

indoor environmental quality

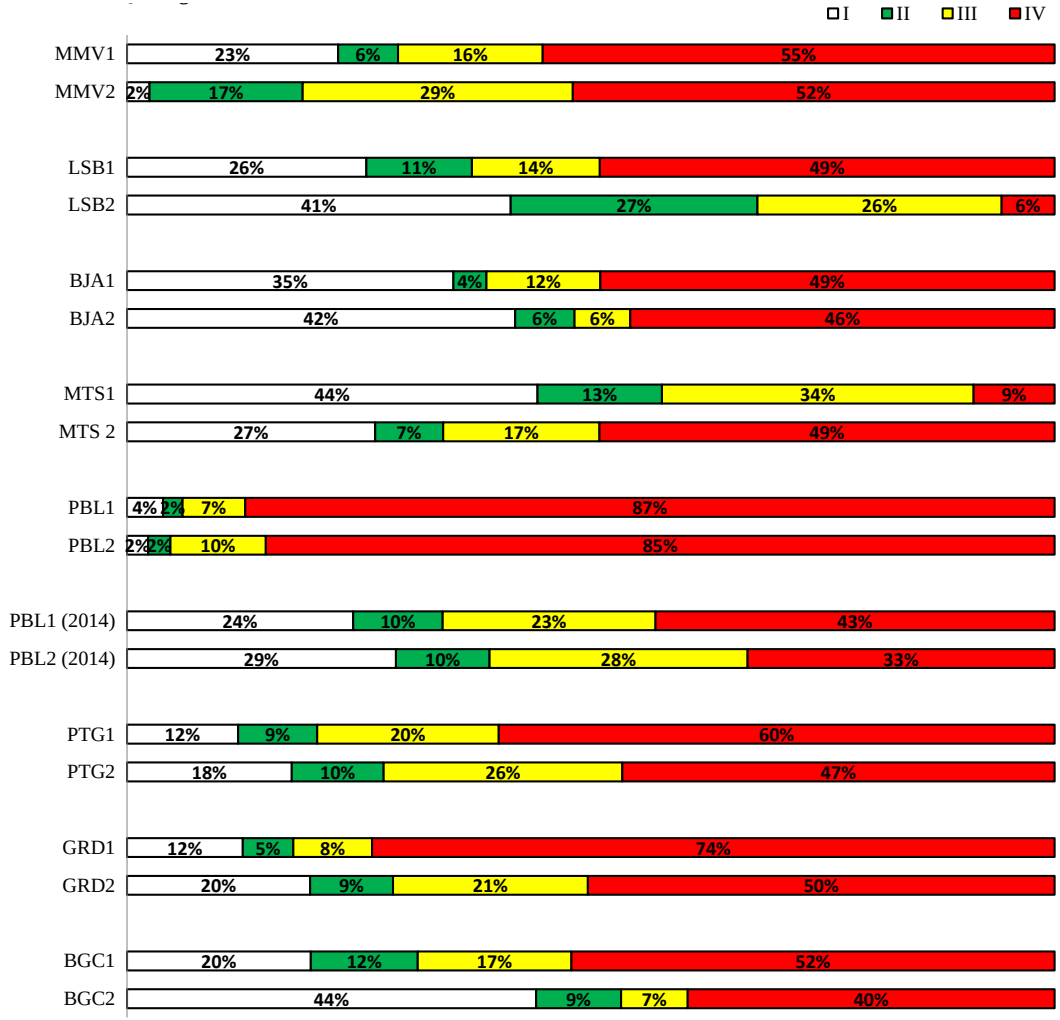
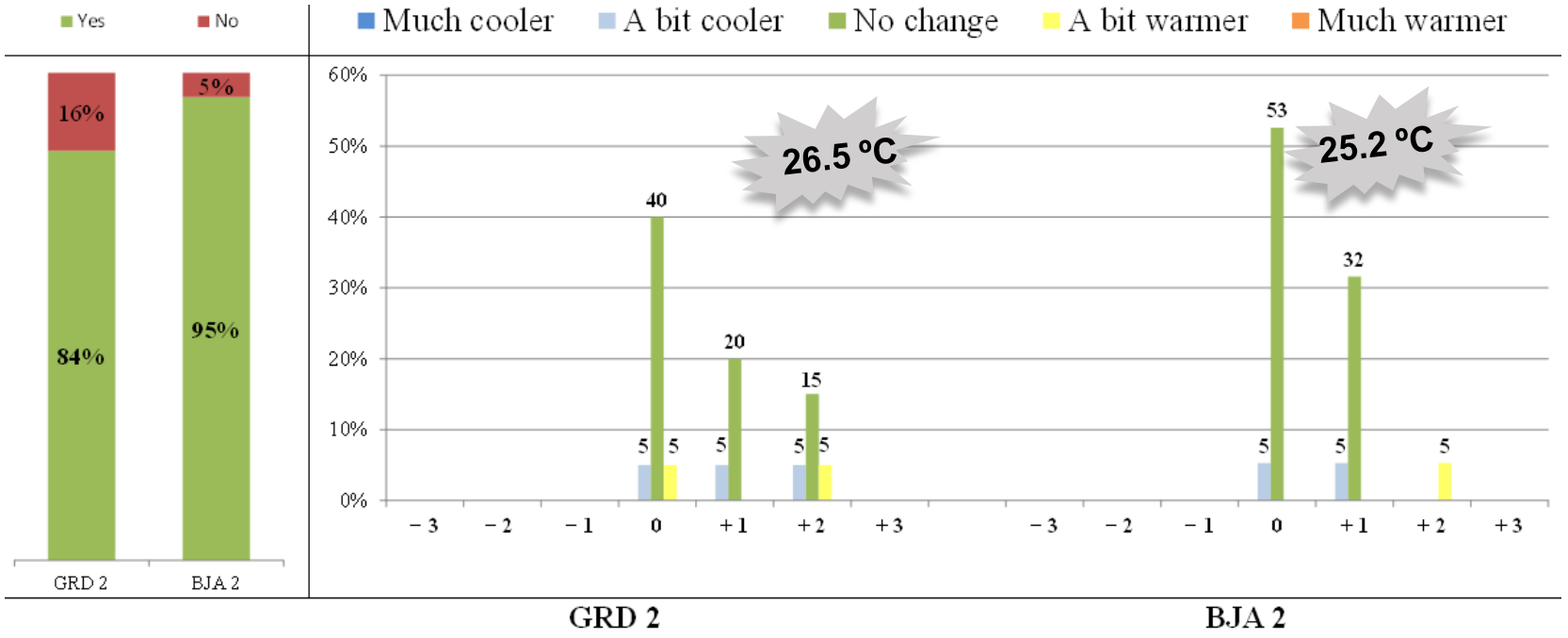


Figure 3 – Concentration evaluation expressed in percentage of time during occupancy periods in IAQ categories, according to the values of Table B4 in EN15251, expressed in concentration above outdoor concentration (considered 380 ppm)

schools should fit *cat. II* (new buildings & major renovations)

2 classrooms / school monitored

- Thermal Acceptability (TA) :
  - ✓ *Do you consider the thermal environment condition acceptable?*
- Thermal comfort (TC) :
  - ✓ *How do you feel at this moment?*
  - ✓ *How would you like to feel?*



energy efficiency plans for schools

This chapter aims at optimizing schools' Indoor Environmental conditions & improving HVAC systems operations »» optimizing energy use & costs

Method: focus on BMS: design / operation, users' behaviour & the EE-TC-IAQ dilemma (energy demand significantly lies on ventilation and temperature indoors)

Building Management System

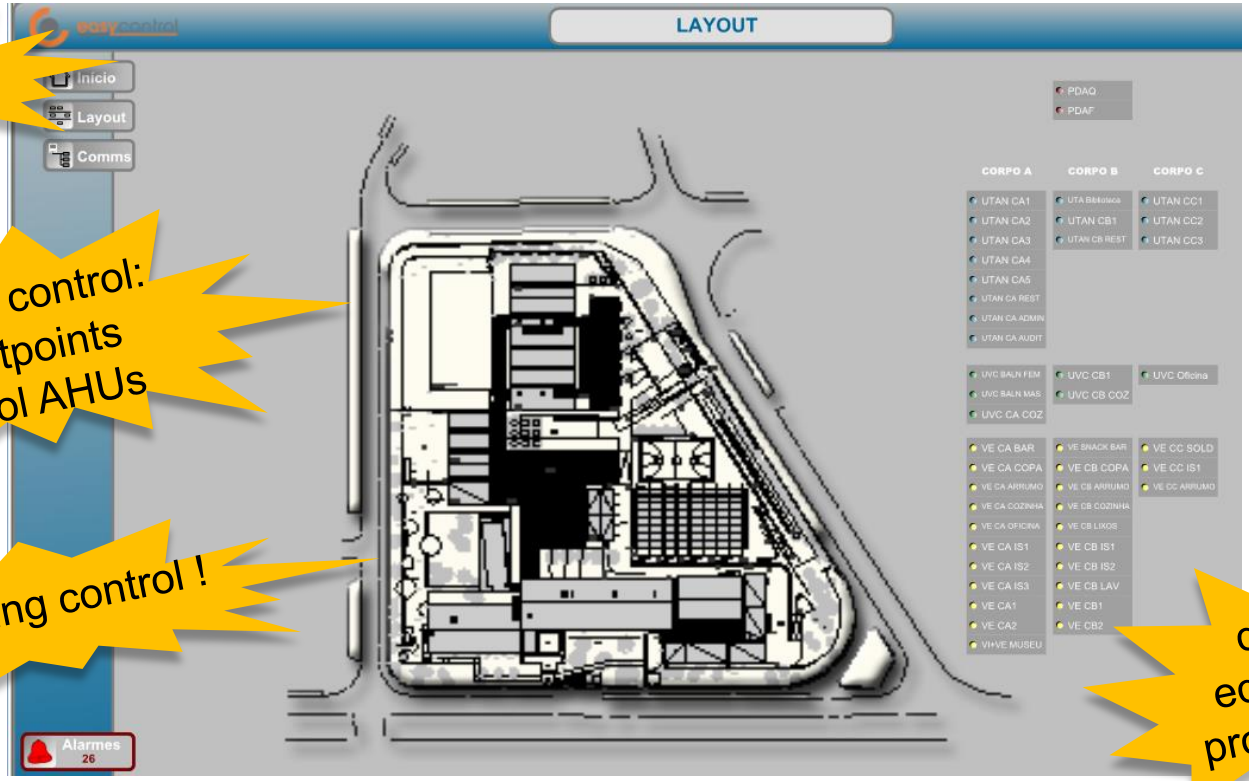
Case study 1

user friendly!

HVAC control: ºC setpoints Control AHUs

NO lighting control !

difficults equipments programming!



HVAC systems organized according to spatial distribution **BUT** when selecting one equipment, the plan & correspondent rooms signaled are NOT correct »» **conflict** between **project phase naming & current name** of the classrooms

*The equipment **operation time does not** always **take into account occupancy**, therefore adjustments can be made…*

Table 2 – Energy consumption of the AHUs serving classrooms (thermal heating energy)

AHU ID	BMS suggested schedule	Annual operation time (h/yr)		Energy consumption (kWh)			Energy Ratio (%)	
		Existing schedule	Suggested schedule	Existing schedule	Suggested schedule	Suggested sched + Proposed Q	Between sched (Suggest sched/ Existing sched)	(Suggest sched + Proposed Q) / Existing sched
AHU A2	07:00 – 18:00	2250	1626	28053	18913	14387	67.4	51.3
AHU A3	07:00 – 23:00	2250	2352	26471	24845	20029	93.9	75.7
AHU A4	07:00 – 18:00	2250	1626	35965	24248	19398	67.4	53.9
AHU A5	07:00 – 23:00	2250	2352	35965	33757	27006	93.9	75.1
AHU B1	07:30 – 18:00	2068	1535	15605	10856	8656	69.6	55.5
AHU C2	07:30 – 18:00	1689	1535	23676	18925	15551	79.9	65.7
AHU C3	07:30 – 18:00	1689	1535	18170	14524	12764	79.9	70.2

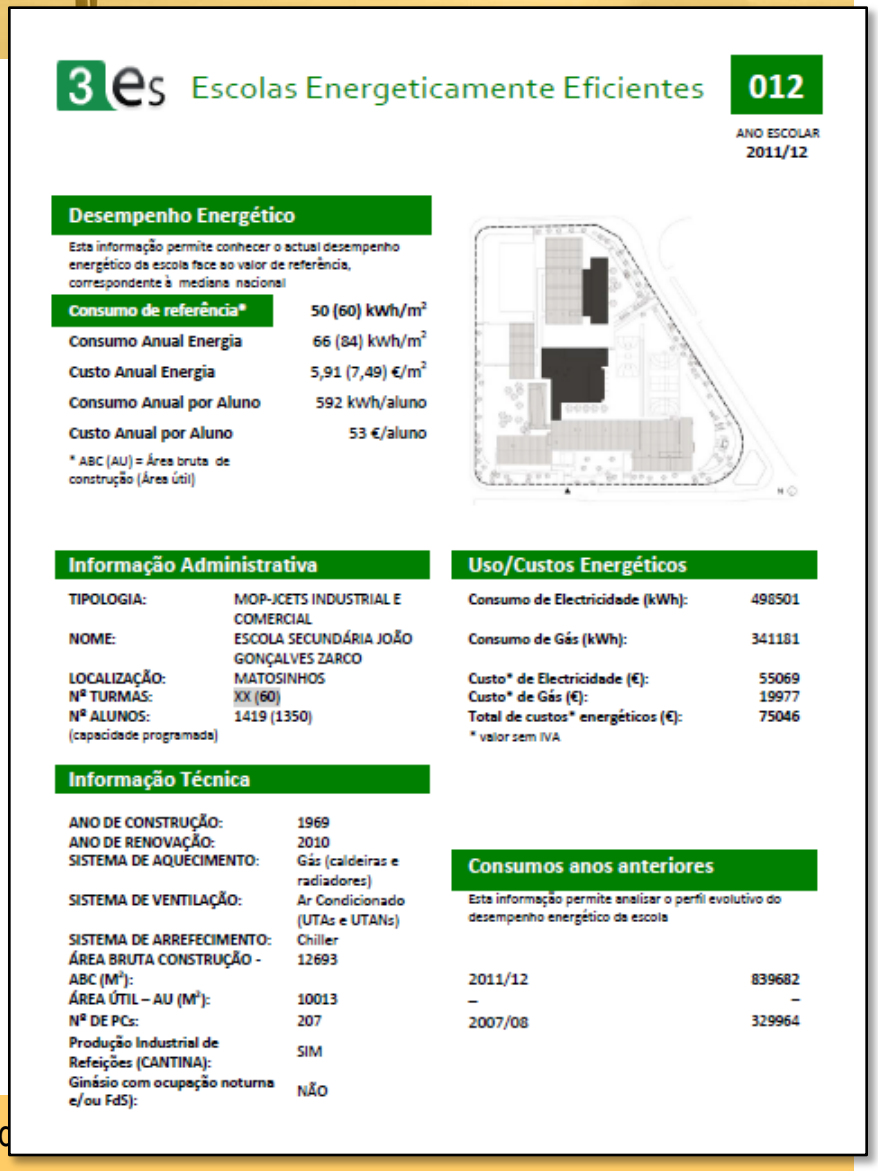
Note: for the present calculation pumps' electrical energy consumption was not considered. In CAV systems their contribution is very small when compared with the fan component.

Classroom activity was estimated based on the time-table occupancy (8h15-18h00 & 19h00-22h50 - max occupancy)

ventilation requirements adjustment

The EEP draft document

- List of Energy Efficiency Measures, based on the 2 case-studies *(today only one was shown)* & literature review
- The proposal of the S-EPC (School-Energy Performance Certificate) *(with energy consumption indicators & energy data consumption from previous school years)*
- The figure of the Energy Manager (EM) *(responsible for energy analysis, proposing energy saving initiaves, energy awareness campaigns, etc)*



3es Escolas Energeticamente Eficientes 012

ANO ESCOLAR 2011/12

Desempenho Energético

Esta informação permite conhecer o actual desempenho energético da escola face ao valor de referência, correspondente à mediana nacional

Consumo de referência*	50 (60) kWh/m²
Consumo Anual Energia	66 (84) kWh/m²
Custo Anual Energia	5,91 (7,49) €/m²
Consumo Anual por Aluno	592 kWh/aluno
Custo Anual por Aluno	53 €/aluno

* ABC (AU) = Área bruta de construção (Área útil)

Informação Administrativa

TIPOLOGIA:	MOP-JCETS INDUSTRIAL E COMERCIAL
NOME:	ESCOLA SECUNDÁRIA JOÃO GONÇALVES ZARCO
LOCALIZAÇÃO:	MATOSINHOS
Nº TURMAS:	XX (60)
Nº ALUNOS: (capacidade programada)	1419 (1350)

Uso/Custos Energéticos

Consumo de Electricidade (kWh):	498501
Consumo de Gás (kWh):	341181
Custo* de Electricidade (€):	55069
Custo* de Gás (€):	19977
Total de custos* energéticos (€):	75046

* valor sem IVA

Informação Técnica

ANO DE CONSTRUÇÃO:	1969
ANO DE RENOVAÇÃO:	2010
SISTEMA DE AQUECIMENTO:	Gás (caldeiras e radiadores)
SISTEMA DE VENTILAÇÃO:	Ar Condicionado (UTAs e UTANs)
SISTEMA DE ARREFECIMENTO:	Chiller
ÁREA BRUTA CONSTRUÇÃO - ABC (M²):	12693
ÁREA ÚTIL – AU (M²):	10013
Nº DE PCs:	207
Produção Industrial de Refeições (CANTINA):	SIM
Ginásio com ocupação noturna e/ou FdS):	NÃO

Consumos anos anteriores

Esta informação permite analisar o perfil evolutivo do desempenho energético da escola

2011/12	839682
–	–
2007/08	329964

conclusions
& contributions

Selection & characterization of **case-studies** was performed

- Definition several **SBI | Climate adjustment** showed to be **deceptive** (kWh/m² /yr/HDD)
- **Indicator** based on **TUFA** was generated (kWh/m²): **benchmark**
- **Typical** (median) & **good practice** (upper quartile) values were **defined**

IEQ analysis (**objective** & **subjective**) of **8 schools** (22 classrooms in total)

- **Higher temperatures** accepted than in the **standards** – 26.6ºC (**TA=84%)**

✓ TSV expressed ***No change***

✓ trend for ***Slightly warm*** environments in the **mid-season**

- IAQ (**CO_2 levels**) limits were being **exceeded**

✓**adaptive actions**, e.g. window(s) &/or door opening **should be promoted** to reduce CO_2 indoors

EEP strategy developed in **2 schools**.

- Classrooms **occupancy schedule crossed** with **systems operation** (mostly **BMS**)

✓One major EE consumption issue is the **pre-set heating / cooling** systems, operated by the **BMS** which was **not considering** the **energy tariff** or **occupancy**

✓Potential **energy savings** through **BMS rescheduling & *Q* adjustment**

Up to 32.6% useful thermal energy consumption reduction »» 14.1 – 24.7 kW/m^2 saved

(others, e.g. lighting & uncontrolled plug loads pointed out & should be explored)

✓These measures & other EEMs may be implemented at **low or negligible costs**

- **Good practice handbook** was drafted (accompanied of a list of **EEM)**

✓**Headed by a S-EPC**

✓The **Energy Manager** figure was suggested

✓It is hoped that the **applicability** of such **EE plan** would **spam to** the **other schools** of the project.

Modernised Portuguese Schools From IAQ and Thermal Comfort towards Energy Efficiency Plans

MANY THANKS!

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