
SIMULATION-ASSISTED EVALUATION OF POTENTIAL ENERGY SAVINGS: APPLICATION TO AN ADMINISTRATIVE BUILDING IN FRANCE

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GENERAL PURPOSE OF THE STUDY

- ✘ Feasibility studies for improving energy and environmental efficiency of administrative buildings in France and Belgium
- ✘ Study split in 2 phases:
 - + In the first phase for each building, analysis of the operation of the buildings
 - + In the second phase for each building, feasibility studies to determine the concrete possibilities of adaptation of the building and its systems to reduce energy needs

PARTNERS IN THE PROJECT

- ✘ Project is conducted by OTE/TTE, private consulting firms from France/Belgium
- ✘ University of Liege team has participated to the study in term of Building Energy Simulation modeling:
 - + 1st Phase : Calibration of the model
 - + 2nd Phase : Use calibrated building model to simulate various individual technical solutions or ECOs at first, and then some overall concept scenarios.

BUILDING DESCRIPTION

- ✘ Situated in France
- ✘ Built in the 80s
- ✘ Floor area of 19,000 m²
- ✘ 11 levels
- ✘ Curtain walls façade made of aluminum and glass.
- ✘ Houses offices, a few conference rooms that can accommodate around hundred people, bathrooms and a nursery.



BUILDING HVAC DESCRIPTION

- ✘ Main HVAC production system is composed of reversible geothermal heat pumps:
 - + Produce hot and chilled water simultaneously, when needed, to satisfy
 - ✘ the cooling needs of IT rooms all year and
 - ✘ heating and/or cooling of all other spaces throughout the seasons
- ✘ Meeting rooms and the other large volumes are only served by CAV air handling units
- ✘ Office spaces are served by CAV air handling units and fan coil terminal units

BUILDING HVAC DESCRIPTION (GEOHP)



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BUILDING HVAC DESCRIPTION (GEOHP)

- ✘ Production of HW/CW fully provided by 3 similar geothermal heat pumps on groundwater (2005)
- ✘ Machine composed of 2 screw compressors with refrigerant R134a
- ✘ Nominal performances in winter and summer mode listed below:

Condenser		
<i>Heating capacity</i>	<i>Water in-out temperature</i>	<i>EER "hot"</i>
758 kW	50/40°C	<u>4.10</u>
Evaporator		
<i>Cooling capacity</i>	<i>Water in-out temperature</i>	<i>EER "cold"</i>
582 kW	6/11°C	3.15

Winter mode

Condenser		
<i>Heating capacity</i>	<i>Water in-out temperature</i>	<i>EER "hot"</i>
772 kW	20/30°C	5.68
Evaporator		
<i>Cooling capacity</i>	<i>Water in-out temperature</i>	<i>EER "cold"</i>
643 kW	6/11°C	<u>4.73</u>

Summer mode

BUILDING HVAC DESCRIPTION (AHU)

- ✘ 17 AHUs : approx. 200 000 m³/h (supply air)
 - + 16 of them are running since 1987
 - + some allow partial recirculation
 - + some other are equipped with heat pipe energy recovery systems
 - From inspection, in poor shape or even removed from AHUs



OCCUPANCY AND OPERATING PROFILES

- ✘ Administrative building with atypical occupancy and operating profiles
- ✘ Number of occupant can vary from 135 to more than 600 depending on the period:
 - + work period (WP),
 - + pre-work period (PrP)
 - + post-work period (PoP)
- ✘ Major challenge in term of potential savings especially during the PrP and PoP (20% normal occupancy)

OCCUPANCY AND OPERATING PROFILES

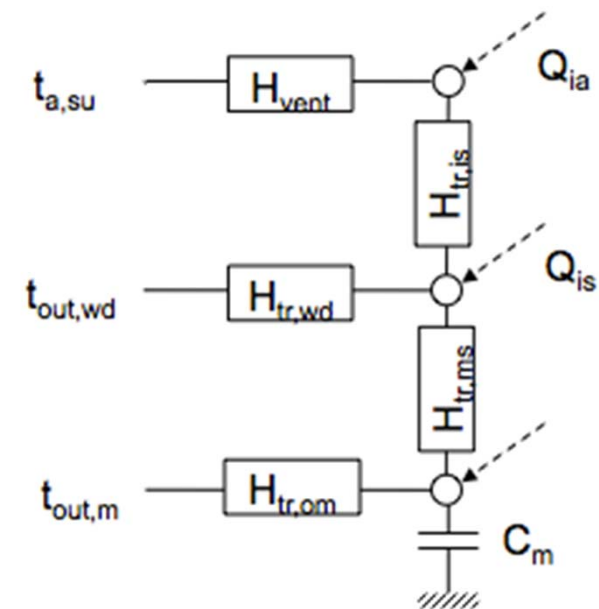
- ✘ 5 AHUs and the fan coils are working from 6am to 11pm only during WP, are shut off during PoP and restarted during the week of PrP.
- ✘ The 12 others (about 75% of the total supply air) are working round the clock during the WP.
 - + 7 of those 12 even run round the clock during PrP and PoP,
 - + the 5 other being started during the PrP week and stop at the end of the WP.

CONTROL STRATEGY

- ✘ From inspection a first observation can be made regarding the control strategy:
 - Building management systems BMS is poorly utilize!
- ✘ Indoor setpoint fixed 21°C in winter and 22°C in summer (in theory during occupation hours)
 - Each office is equipped with potentiometer on terminal units allowing a -3°C or +3°C deviation of the setpoint
 - No inoccupation hour's setpoint were found during inspection (in as-built 16°/28°C in theory)
 - Mobile electric heater were in 1/3 of the office (winter)

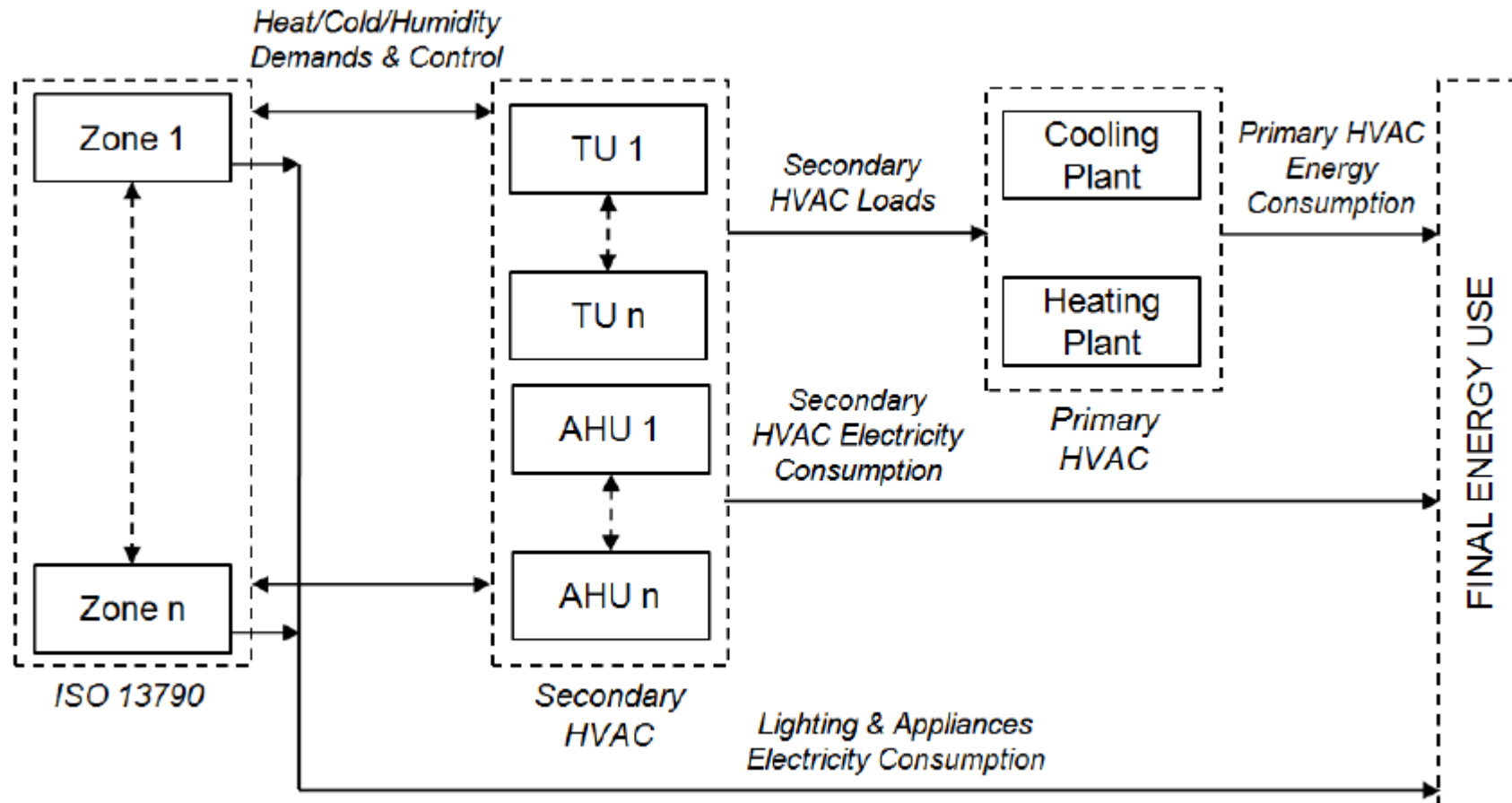
SIMPLIFIED BES MODEL : SIMAUDIT

- ✘ Simple multizone building model (simple hourly method ISO/EN 13790), by S. Bertagnolio
- ✘ Moisture balance: Water capacitance method
- ✘ Secondary HVAC system
 - + All Air (CAV+RH/VAV+RH)
 - + Air / Water (CAV+TU)
 - + All Water (TU)
- ✘ Primary HVAC system
 - + Hot water boiler
 - + Air or water cooled chillers
 - + Heat rejection devices



Sensible thermal zone model

SIMAUDIT MODEL



CALIBRATION CRITERION

- ✘ 2 criterion were used to define calibration quality:

- + "Mean Bias Error"

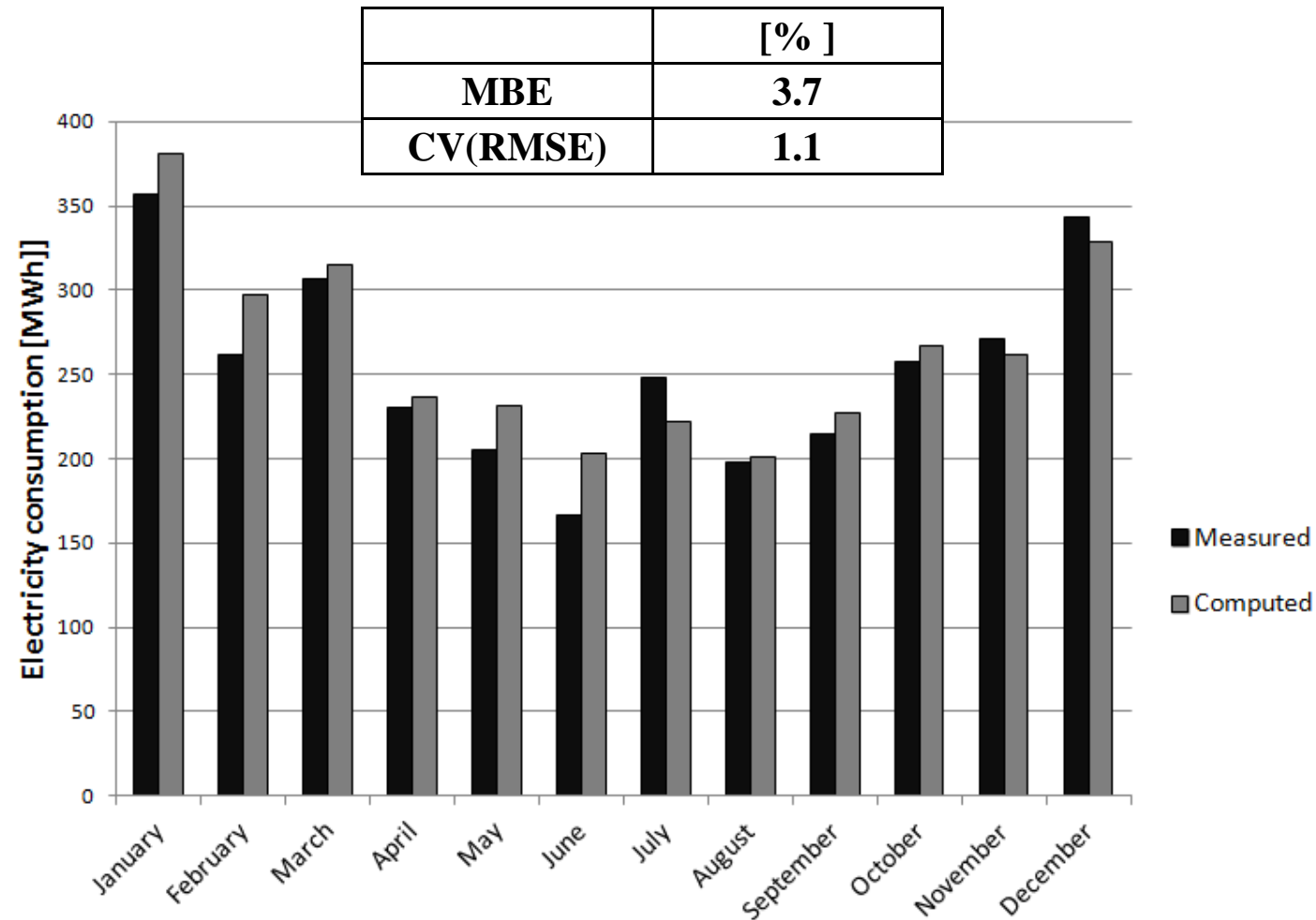
$$MBE = \frac{\sum_{i=1}^n (Q_{pred,i} - Q_{data,i})}{n Q_{data}}$$

- + "Coefficient of Variation of the Root Mean Square Error"

$$CV(RMSE) = \frac{\sqrt{\frac{\sum_{i=1}^n (Q_{pred,i} - Q_{data,i})^2}{n}}}{Q_{data}}$$

- ✘ In the case of an assessment on a monthly basis, ASHRAE recommends limits of +/- 5% for MBE and +/- 15% for the CV(RMSE)

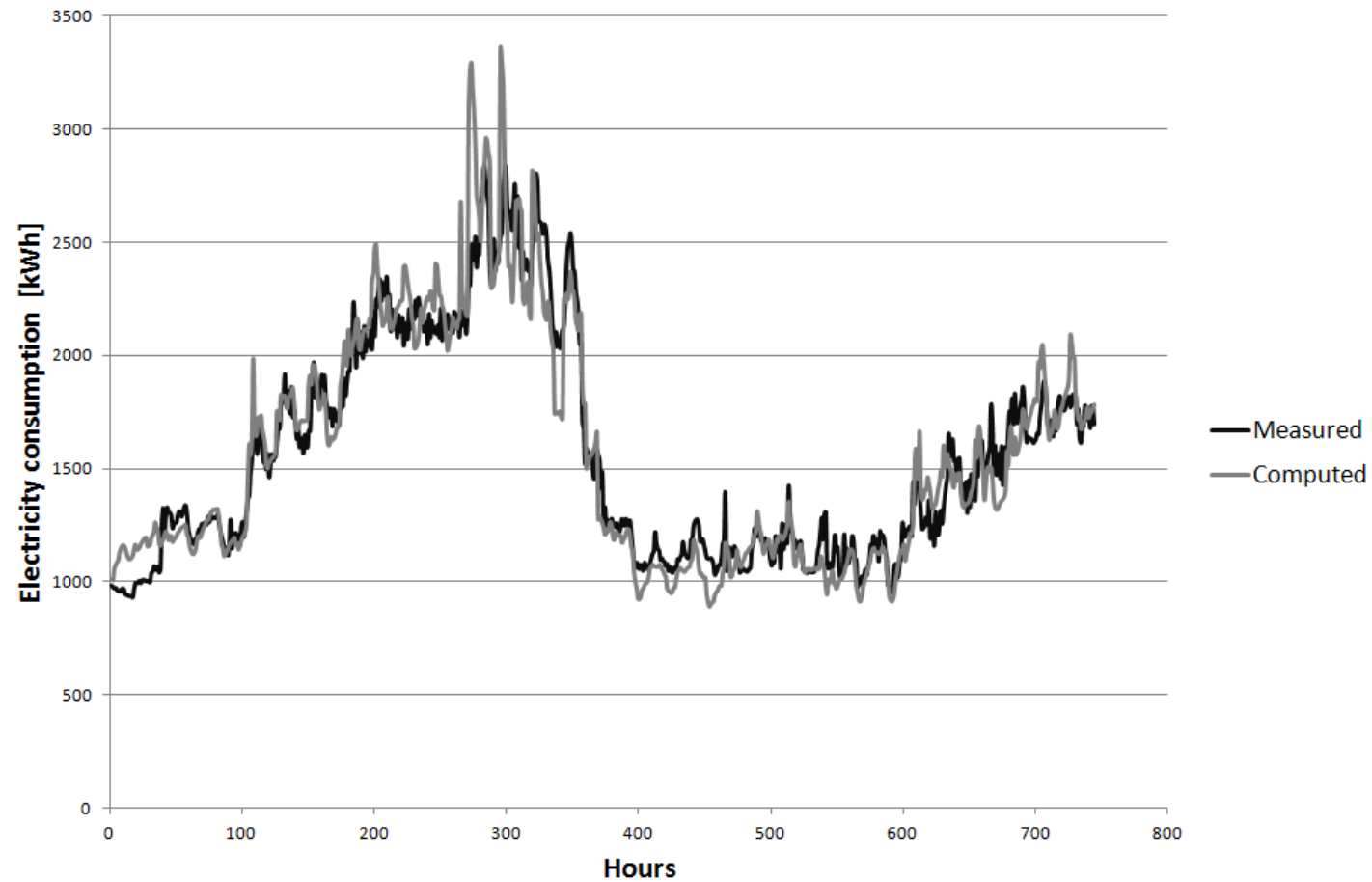
CALIBRATED MODEL AND RESULTS



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HOURLY COMPARISON (JANUARY)

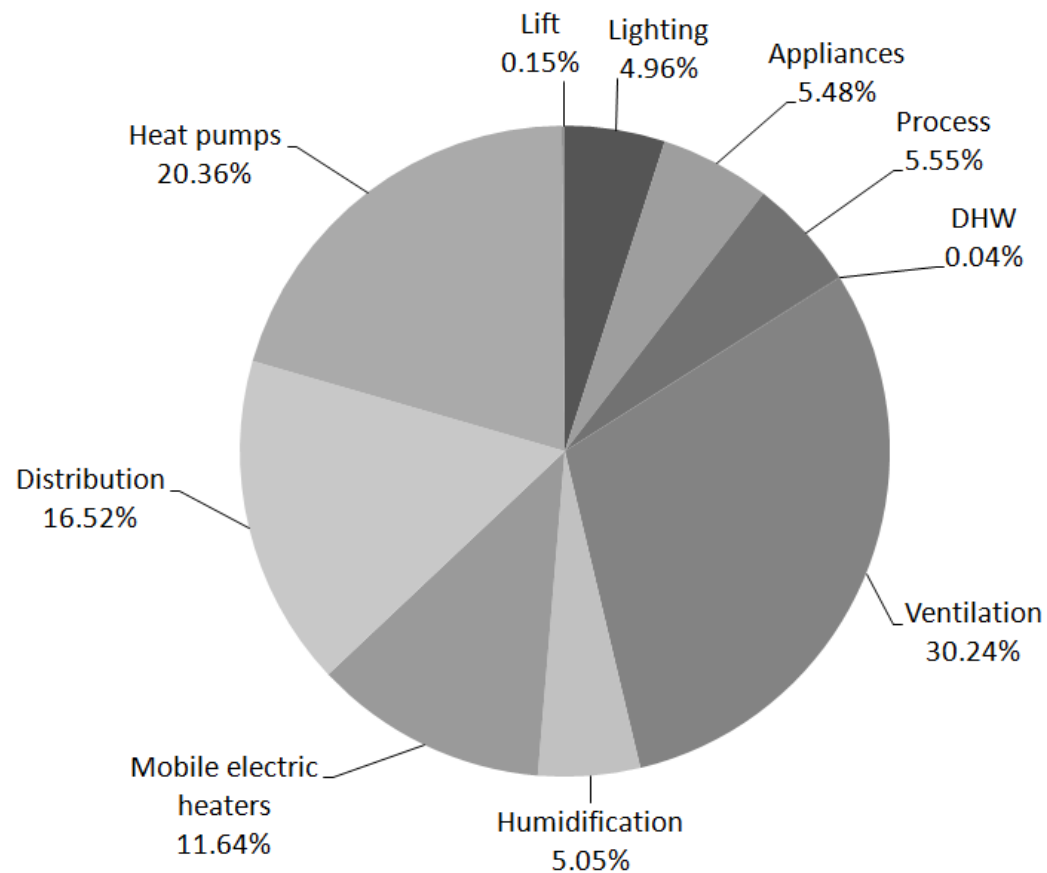


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ANNUAL ELECTRICITY CONSUMPTION

	MWh	kWh/m ²
Total per year	3172	166



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RETROFIT OPTIONS SIMULATION (1)

- ✘ Implementation of energy efficient schedule, fresh air rate and new setpoint for air handling units and fan coils into the BMS:
 - + New indoor setpoint (*occ* 20°C/24°C and *nocc* 16°/26°C)
 - + Lowering fresh air percentage in supply air especially during PrP and PoP when
 - + Automatic schedule for all AHU and fan coils implemented in BMS based on WP and PrP/PoP

RETROFIT OPTIONS SIMULATION (2)

- Allow a significant reduction of energy especially for the PrP and PoP where some of the HVAC systems were still working 24/7.

	Unit	Reference	Solution	Relative Gain
Total electricity consumption	MWh	3 770.18	2972.74	21.2%
High peak electricity consumption	MWh	180.49	140.08	22.4%
Winter peak electricity consumption	MWh	1 042.33	842.35	19.2%
Winter off-peak electricity consumption	MWh	730.57	531.28	27.3%
Summer peak electricity consumption	MWh	1 098.85	904.61	17.7%
Summer off-peak electricity consumption	MWh	717.94	554.41	22.8%

OVERALL SCENARIO

- ✘ The scenario presented here is the last scenario asked by the private consultant to model. It regroups an important amount of retrofit options like
 - + Adapt indoor setpoints depending on occupation and WP
 - + Replace over 25years old AHU
 - + Adapt BMS schedule for AHU and TU
 - + Change some of the lightings equipments
 - + Optimize office organization in term of PrP/PoP occupation regrouping
 - + Other more small or specific ECO solution

OVERALL SCENARIO (2)

	Unit	Reference	Solution	Relative Gain
Total electricity consumption	MWh	3 770.18	1 932.64	48.7%
High peak electricity consumption	MWh	180.49	92.36	48.8%
Winter peak electricity consumption	MWh	1 042.33	538.50	48.3%
Winter off-peak electricity consumption	MWh	730.57	309.28	57.7%
Summer peak electricity consumption	MWh	1 098.85	661.26	39.8%
Summer off-peak electricity consumption	MWh	717.94	331.25	53.9%

CONCLUSION

- ✘ The most sensitive point in this type of study is the calibration of the BES Model and therefore the quality and the quantity of data needed
- ✘ It is important when you see such results to improve energy performance rules and certification
- ✘ **Continuous monitoring** of the main consumers in a building could serve such purpose of “pre-inspection” and highlight possible ECO

THANK YOU FOR YOUR ATTENTION!