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

Winter mode

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

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

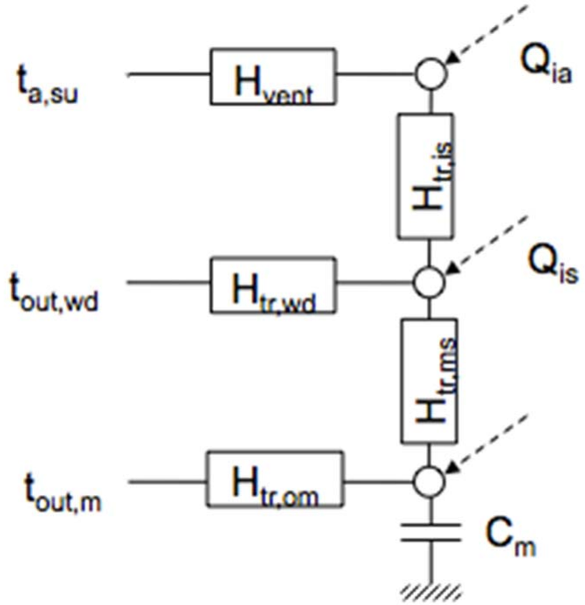
- 5 AHUs and the fan coils are working from 6am to 11pm only during WP, are shut off during PoP and restarted during the week of PrP.
- The 12 others (about 75% of the total supply air) are working round the clock during the WP.
  - 7 of those 12 even run round the clock during PrP and PoP,
  - the 5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

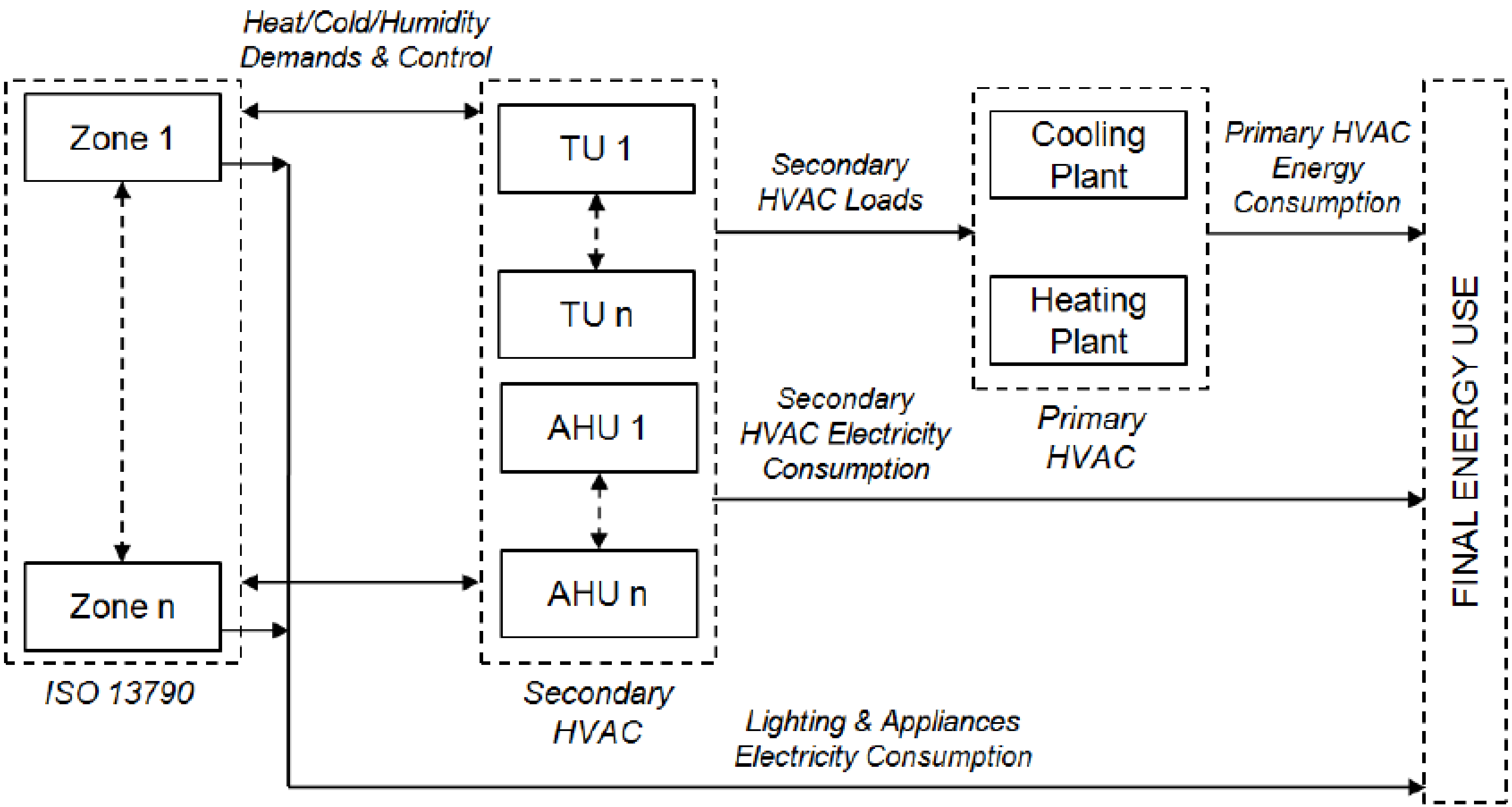
SIMPLIFIED BES MODEL : SIMAUDIT

- 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“

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

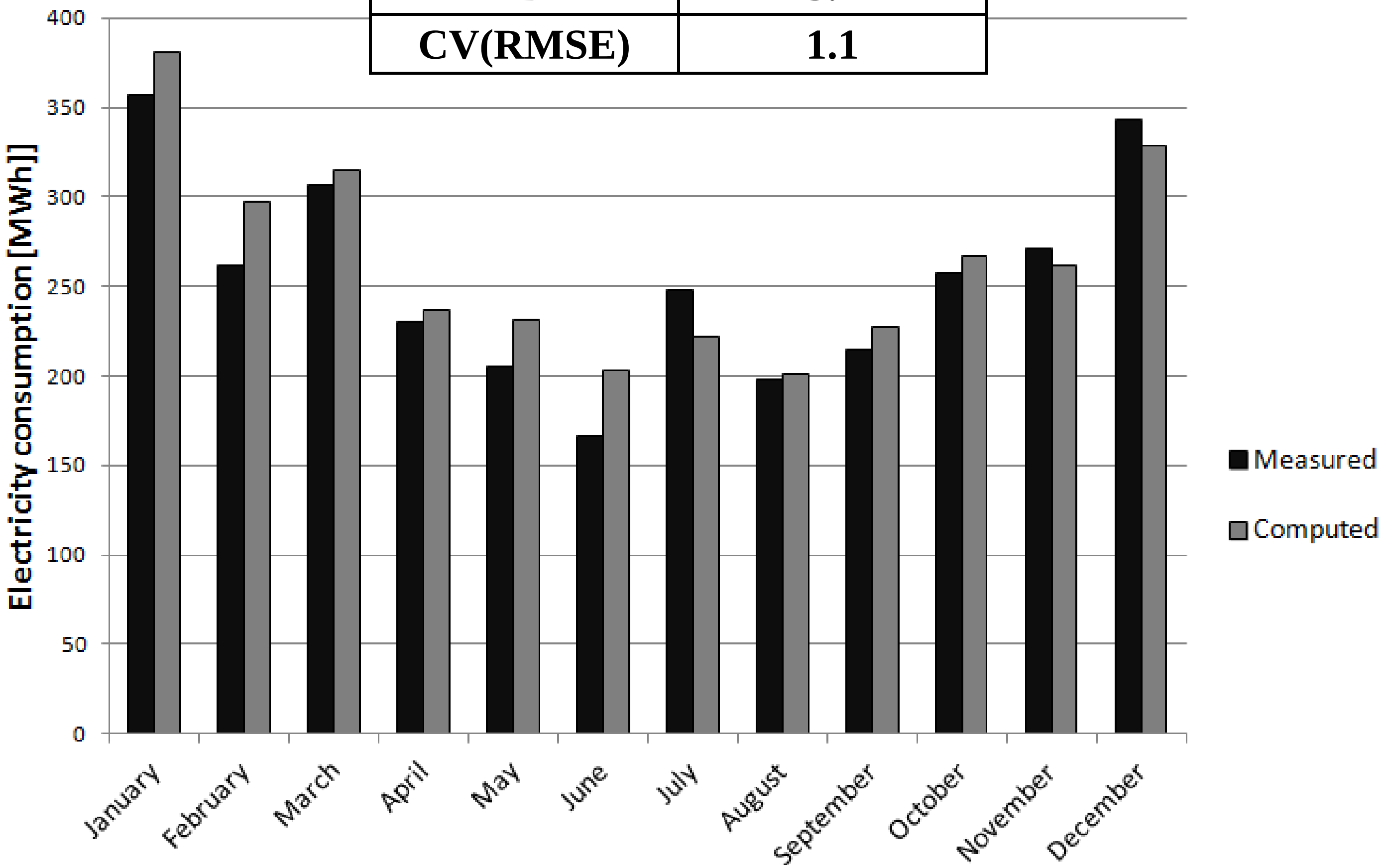
  - "Coefficient of Variation of the Root Mean Square Error“

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

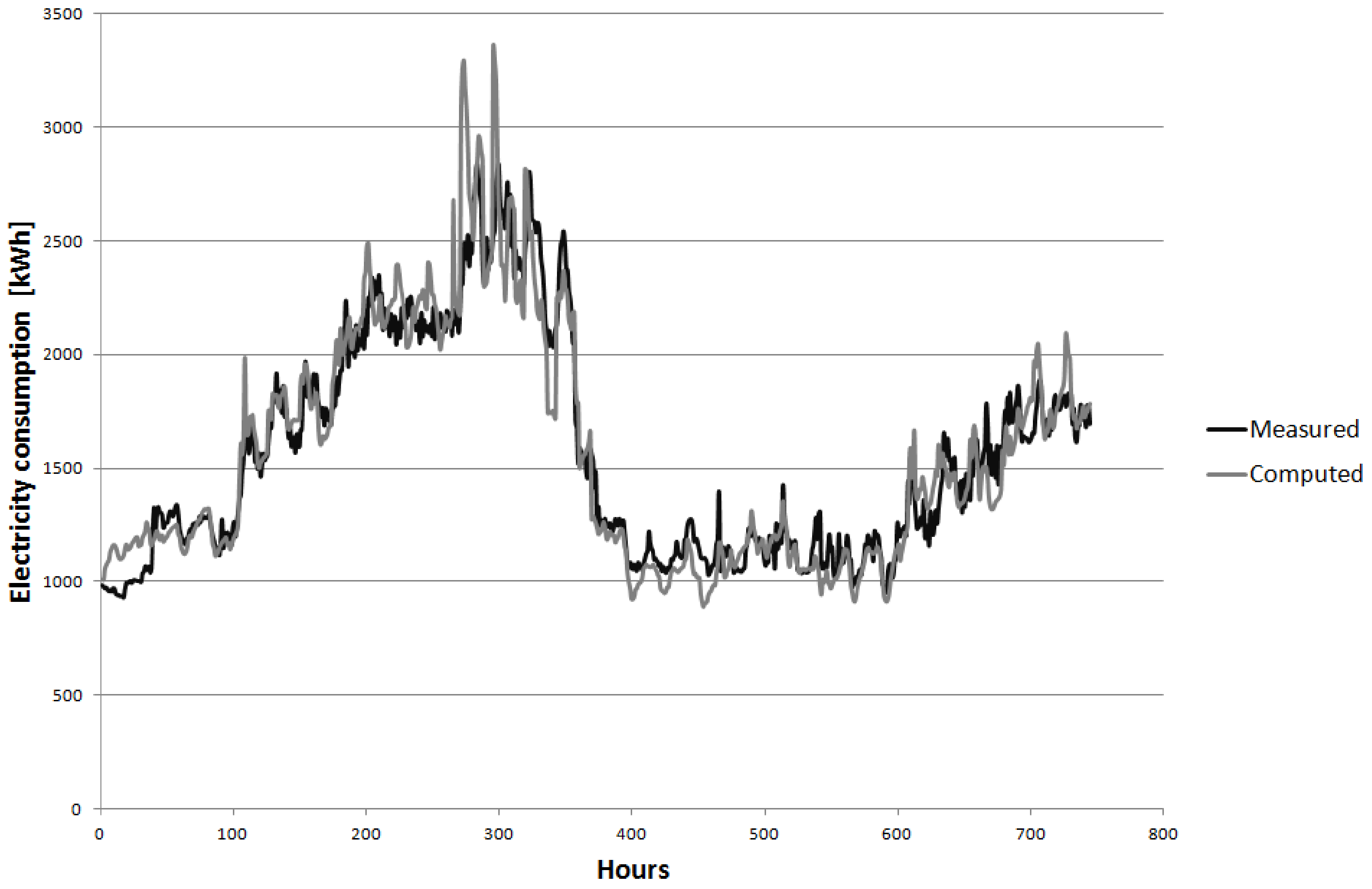
- In the case of an assessment on a monthly basis, ASHRAE recommends limits of +/- 5% for MBE and +/- 15% for the CV(RMSE)

CALIBRATED MODEL AND RESULTS

	[%]
MBE	3.7
CV(RMSE)	1.1

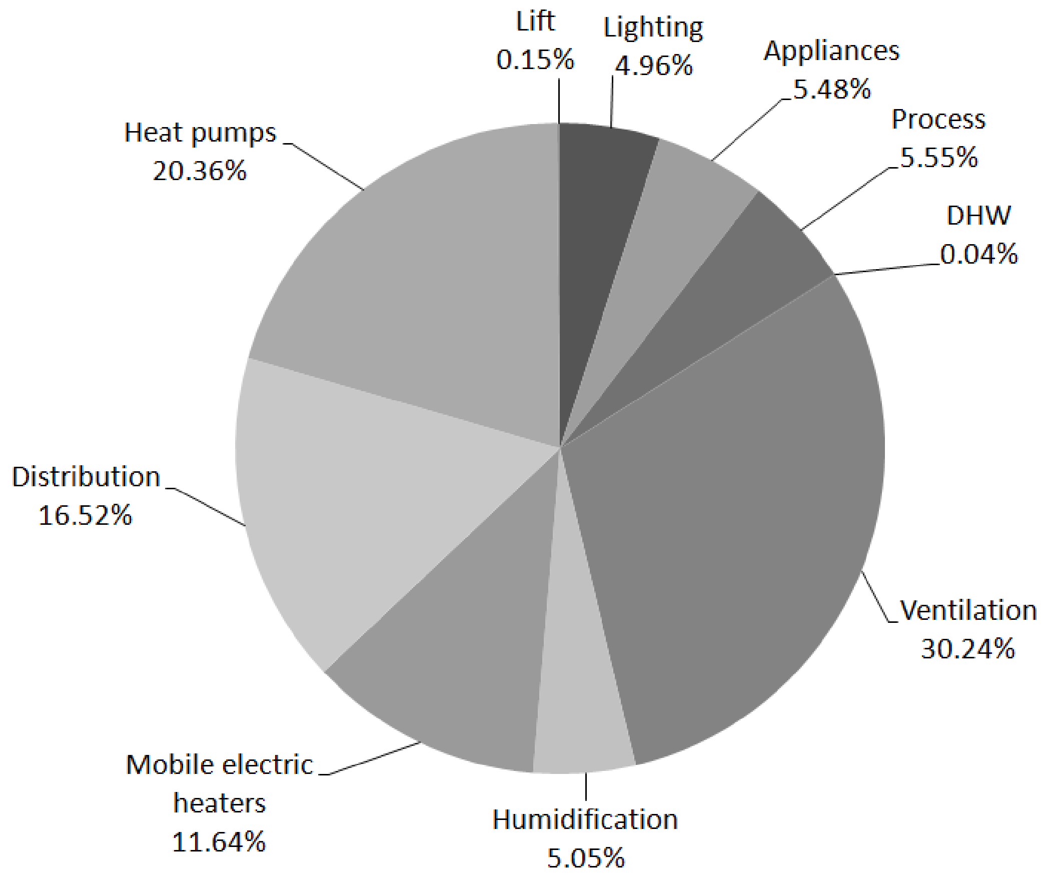


HOURLY COMPARISON (JANUARY)



ANNUAL ELECTRICITY CONSUMPTION

	MWh	kWh/m²
Total per year	**3172**	**166**



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!