ISP

IES

Evaluation and optimised control of energy processes in indoor swimming pools

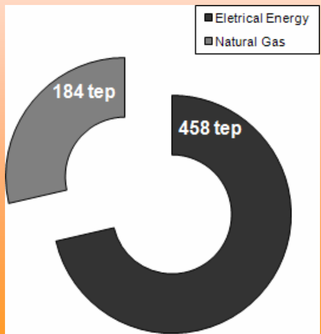
HVAC system management

1

Introduction I

IES

- Increase the number of Indoor Swimming Pools (ISP).
- High energetic processes.



2

Introduction II

- Directive 2006/32/EC and law 79/2006 => minimise the energy consumption.

- Energetic Efficiency Index (EEI):
  - 35 kgep/m2.year - reference,
  - 95.7 kgep/m2.year - case study.

3

Introduction III

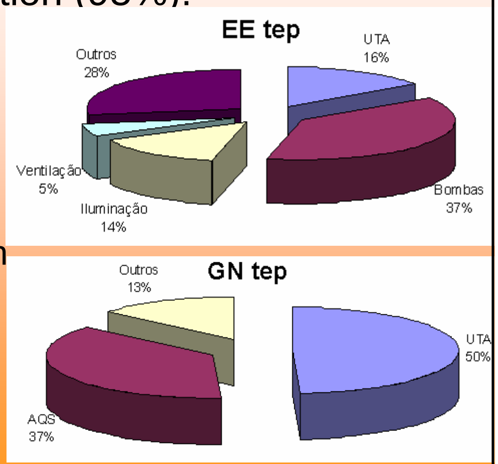
- Implementation of optimised control strategies.

- Rational Use of Energy (RUE) measures:
  - cogeneration,
  - renewable energy systems,
  - recovery of energy in the rejected air,
  - **pool cover.**

4

Introduction IV

- ISP energy consumption (95%):
  - HVAC system,
  - Pumping system,
  - Pool water treatment,
  - Water heating for bath
  - Lighting.



Introduction V

- In this work:
  - Approach to control strategies of HVAC system,
  - Pool cover such RUE measure.

6

Case study I

- Sports complex with:
  - olympic pool of 50x25 m2,
  - children pool of 25x12.5 m2.
- HVAC system - Air Handling Unit (AHU) with dehumidifying and heating capacities.
- A building automation system controls all main process.

7

Case study II

- Olympic pool:
  - water temperature varies between 27ºC and 28ºC,
  - air temperature between 28ºC and 29ºC,
  - relative humidity between 50% and 55%.
- Children pool:
  - the water temperature varies between 29ºC and 30ºC,
  - air temperature between 30ºC and 31ºC,
  - relative humidity between 60% and 65%.

8

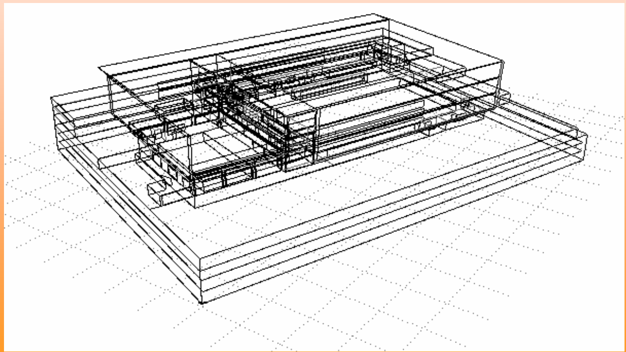
Building Performance Simulation I

- The building energy simulation programs is the better way to study of measures to reduce the energy consumption.
- Energy simulation programs work with three main groups of variables:
  - Climatic variables,
  - Design variables,
  - Use and occupancy variables.

9

Building Performance Simulation II

- Several building energy simulation programs such as: **ESP-r**, ENERGYPLUS, TRNSYS and DOE.



10

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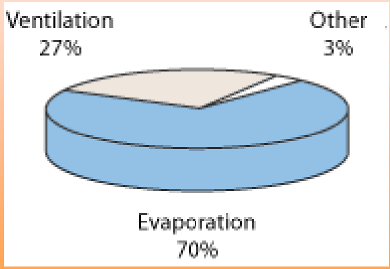
Variable I

- AHU > high evaporation in ISP complex.



11

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Variable II

- Environmental variables associated to AHU control:
  - *Tap* - Pool water temperature (ºC),
  - *Tamb* - Ambient air temperature (ºC),
  - ϕ - Relative humidity (%),
  - *Qe* - Latent load associated with the evaporation from the pool (W).

12

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Variable III

- Fundamental variable - mass of evaporated water (*me*):

$$m_e = A_{pool}\left[0{,}113 - \frac{0{,}0000175 \times A_{pool}}{N} + 0{,}000059(P_s - P_a)\right]$$

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Case study

- Reference values during 2006:

Olympic pool

Variable	Value
Tap	27,5ºC
Tamb	28,3ºC
ϕ	52,3%
Qe	180.009W

Children pool

Variable	Value
Tap	28,9ºC
Tamb	30,5ºC
ϕ	52,7%
Qe	45.168W

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Control strategies I

- Variation of the environmental variables at night (8PM to 8AM).
- with two distinct criteria:
  - wet-bulb temperature,
  - dew point temperature.

15

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Control strategies II

- 1st criteria

Olympic pool

	CS-1	CS-3
Tap	27,5ºC	27,5 ºC
Tamb	26,0 ºC	24,5 ºC
ϕ	65,0%	75,0%
Qe	171.765W	165.458W

Children pool

	CS-1	CS-3
Tap	28,9ºC	28,9 ºC
Tamb	28,0 ºC	26,5 ºC
ϕ	65,0%	75,0%
Qe	43.341W	41.660W

16

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Control strategies III

- 2nd criteria

Olympic pool

	CS-2	CS-4
Tap	27,5ºC	27,5 ºC
Tamb	25,0 ºC	22,5 ºC
ϕ	65,0%	75,0%
Qe	178.336W	179.632W

Children pool

	CS-2	CS-4
Tap	28,9ºC	28,9 ºC
Tamb	27,0 ºC	24,5 ºC
ϕ	65,0%	75,0%
Qe	45.152W	45.435W

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Control strategies IV

- Pool Cover simulation

Olympic pool

	CS-5	CS-6
Tap	27,5ºC	27,5 ºC
Tamb	28,3 ºC	Free float
ϕ	52,7%	Free float
Qe	18.001W	18.001W

Children pool

	CS-5	CS-6
Tap	28,9ºC	28,9 ºC
Tamb	30,5 ºC	Free float
ϕ	52,7%	Free float
Qe	4.517W	4.517W

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Results I

- Three major losses in process, quantified by building thermal simulations, are:
  - Building envelope losses to environment quantified by simulation,
  - Energy spent associated with the reduction of building latent load,
  - Losses associated with energy heating water that is necessary to compensate evaporation.

19

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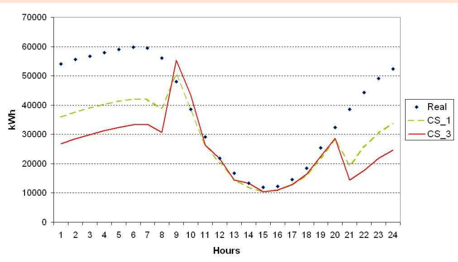
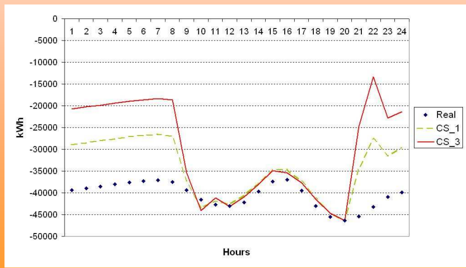
Results II

- Olympic pool - 1st criteria:



sensible energy



latent energy

20

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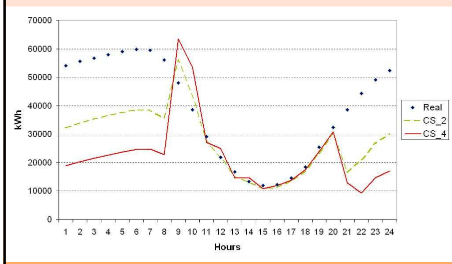
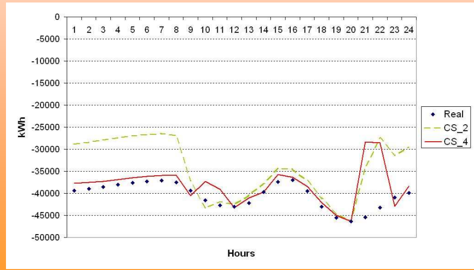
Results III

- Olympic pool - 2nd criteria:



sensible energy



latent energy

21

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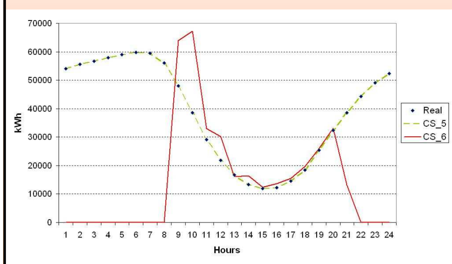
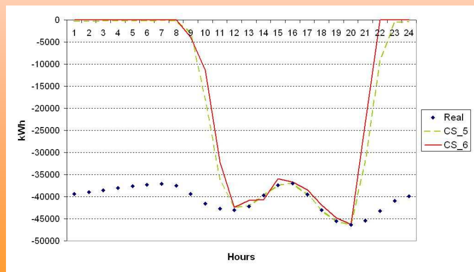
Results IV

- Olympic pool - pool cover simulation:



sensible energy



latent energy

22

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Results IV

- EEI quantification:

	Electrical Energy (tep)	Natural Gas (tep)	EEI
Real	427,0	203,0	95,7
CS-1	420,3	195,5	93,5
CS-2	427,0	177,0	91,7
CS-3	414,2	174,6	89,4
CS-4	423,9	169,1	90,0
CS-5	392,5	202,2	90,3
CS-6	391,1	148,3	81,9

23

Conclusion I

- CS-1, CS-2, CS-3 and CS-4:
  - Reduction of sensible energy, linked to the natural gas consumption;
  - Latent energy associated to the decrease of water evaporation, linked to the electrical energy consumption.

24

Conclusion II

- CS-3 - best control strategy for EEI:
  - reduction of 41,2 tep/year (6,5%),
  - Represents 29.000€ in 2006 energy price savings.

- CS-4 - best control strategy for money saving:
  - reduction of 37,0 tep/year (5,9%),
  - Represents 31.000€ in 2006 energy price savings.

Conclusion III

- CS-6, in conjunction with pool cover at night:
  - Reduction of 90 tep/year (14,4%),
  - Represents 60.000€ in 2006 energy price savings,
  - Four month payback for pool cover.

Tank you