TAB techniques within an EPC give high energy savings verified by IPMVP tool in the Greek Energy Regulator Building

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INTRODUCTION

The aims of the presentation are listed below:

- To highlight the potential TAB, RD and MVT techniques in energy projects (e.g. buildings)

- To demonstrate the importance of the systematic energy management for a project, under verification standards (eg IPMVP), which allowed us to evaluate an EPC

- To confirm whether and in what extent an ESCO may be based on existing experiences based on EPCs

- To show whether the energy saved can be billed reliably in order to run an EPC

BASIC NOMENCLATURE

- **TAB = Testing, Adjusting, Balancing**
  - Ventilation volume
  - Full/Partial load status
  - Lightning operation schedules
  - Operation schedules of ventilation, cooling and heating
- **RD = ReDesign**
  - Staff number
  - ASHRAE (50) ≠ KENAK (22)
- **MBT = Measuring, Benchmarking, Targeting**
  - Measuring through «continuous monitoring» using the BEMS
  - Calculation of indicators (kWh/m^2)
  - Benchmarking within the iSERV platform. Development of OPTIMUS platform
  - Introducing of new TARGET indicators according to the potential of energy savings of the EnMP program

REFERENCES

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- ASHRAE, 2012, «Performance Measuring Protocol, a Best Practice Guide»

- USA EVO-Efficiency Valuation Organization, IPMVP 2012, January 2012, «International Performance Energy Measurement and Verification Protocol»

- ASHRAE, 2002, ASHRAE Guideline 14-2002 «Measurement of Energy and Demand Savings»

DESCRIPTION OF THE BUILDING

The Headquarters of the Regulatory Authority for Energy [RAE] is located in the center of Athens, at Piraeus Avenue 132. The surface area of the building is:

- 5.411 m^2 (from the 1^{st} to the 7^{th} floor)
- 2.319 m^2 (2 basement levels)
- 85 m^2 (ground floor)
- KENAK category C

The energy consumption is directed to six cost centers:

- Heating (Natural Gas)
- AC-Air conditioning
- Ventilation
- Lightning
- IP-Data Center
- Devices

LIST OF ENERGY RELATED INTERVENTIONS IN THE BUILDING

Title of intervention	Date of commissioning
To Reduce the Natural Gas	
Ventilation Reduction: Redesign ventilation in 2 fresh air AHU	4/10/2012
Adjustments in automation to introduce free and night cooling in 2 fresh air AHU	4/10/2012
Improvement in the boilers' and chillers' automation sequence	12/11/2012
Geothermal use of phreatic well for fresh air preheating, reduction of water flow	11/07/2015
To Reduce the Electricity	
Change in the schedule of the building's facilities: Lightning, Ventilation, Air handlers	4/11/2012
Intervention in the closed control unit plenary CCU-S18 in the plenary room	19/06/2012
Intervention in the electric boards of the stairwells	05/07/2012
Intervention in the lighting of the -5 basement garage, with control via motion detectors	29/07/2012
Ventilation Reduction: Redesign ventilation in 2 fresh air Air handlers	10/10/2012

VENTILATION REDUCTION (1/2)

1. The existing two fresh air AHUs in the building, AHU01 and AHU02, used to have respectively air flows equal to 20.355 m^3/h and 11.960 m^3/h
2. The fresh air volume is highly oversized, since the population in the building is equal to 120 persons, a number that is very distant from the initial design value (of 500 people). Moreover, the standard for ventilation requirements has been reduced dramatically so far, down to 45% of the design year’s value, to apply a 65% of reduction potential
3. In order to redesign the ventilation system, the amount of fresh air that is necessary for the building has been recalculated, while ELOT EN15251:2007 and 3661/2010 (KENAK) regulations have been adopted
4. To achieve the proposed reduced ventilation, a redesign of the fan speed of the supply and return fans has been made
5. The reduction potential of 65% was proved inadequate due to poor air distribution
6. The flows of the AHU01 and AHU02 have been reduced down to 13.231 m^3/h and 7.774 m^3/h, achieving a reduction of 35%, introducing an acceptable distribution

VENTILATION REDUCTION (2/2)

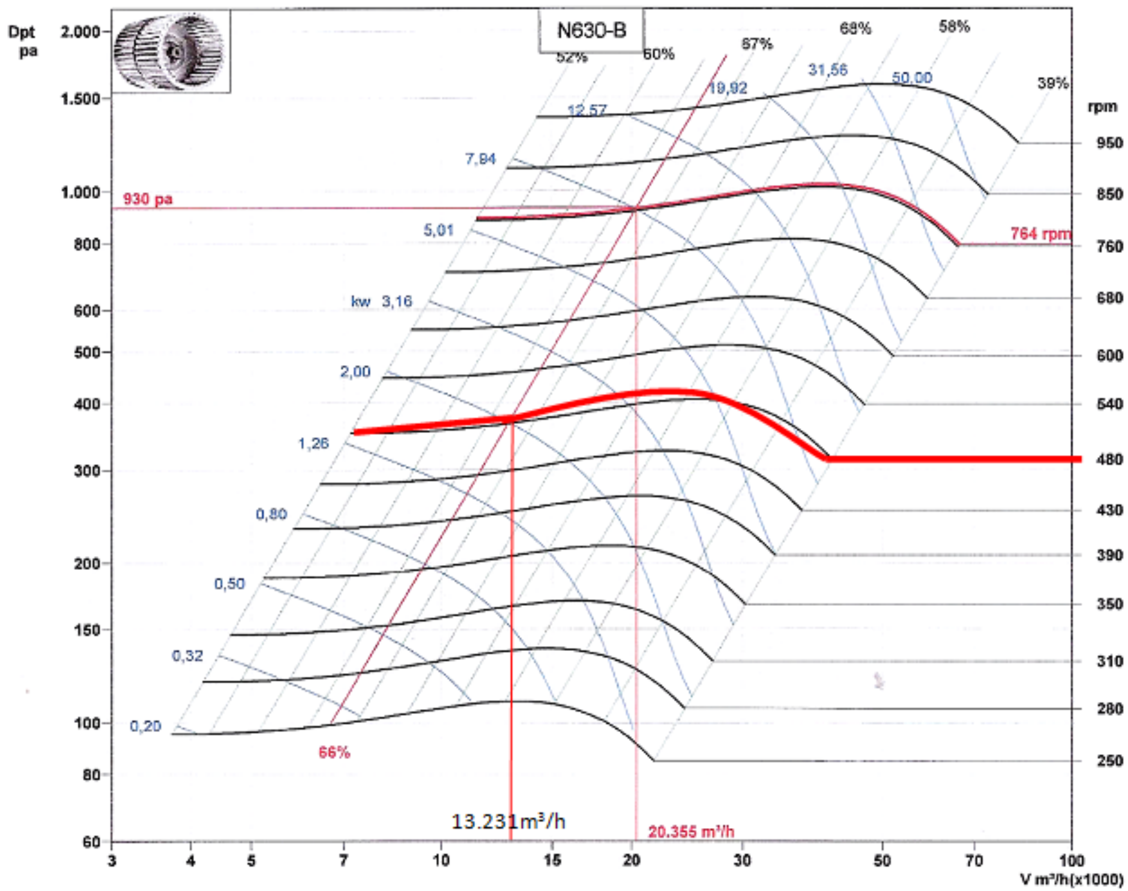
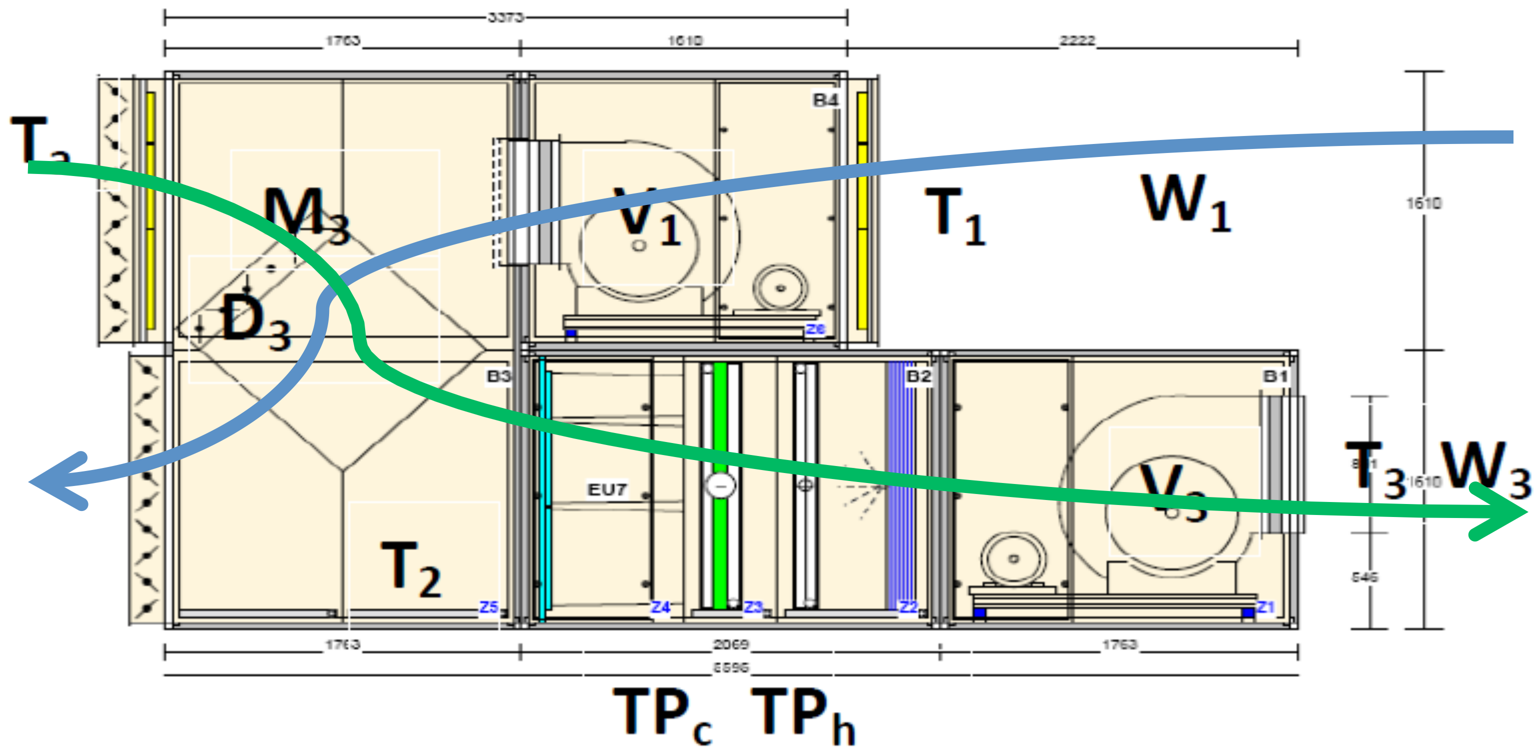


Chart that shows the redesign of the air supply fan for the AHU01

FREE AND NIGHT COOLING (1/2)

1. The free and night cooling technique offers space comfort conditions and saves the energy that would be consumed by the air-conditioning system if it was operating.
2. There were adjustments undertaken in minimum air flow supply temperature, in the difference between the ambient air and the room for the free cooling, in the ratio between the shell load and the total building load, in the mean ambient temperature for the start/end of the heating and cooling period (the last one was determined using simulation software).
3. Through calculations, it was estimated that the savings are in the order of 8.966 kWh_{el}/summer (for the compressors' operation) and saving a cost of 1.345 €/summer.
4. The cost of the extension of the BEMS network that was needed for the implementation of free and night cooling costed approximately 3.000 €.

AHU01 & AHU02 OPERATION



Plan of a standard preconditioned AHU. There is a bypass damper (A) while the automation system BMS based, has sufficient outputs.

AUTOMATION SEQUENCE

We focused on three main points:

1. Application of soft starting for the boiler cut-ins

2. Change of the automation sequence of the two boilers, 543 kW each, from parallel mode into cascade mode (in base load and peak load status, the peak load condition is found to occur only during February)

3. Work out a detailed process of testing for the combustion quality, showing an optimal length of 1,8 m for the flame and flue gas suction tuned down to an optimal value of -12 Pa (from the initial value of -50 Pa) via high rise chimney

VARIOUS INTERVENTIONS

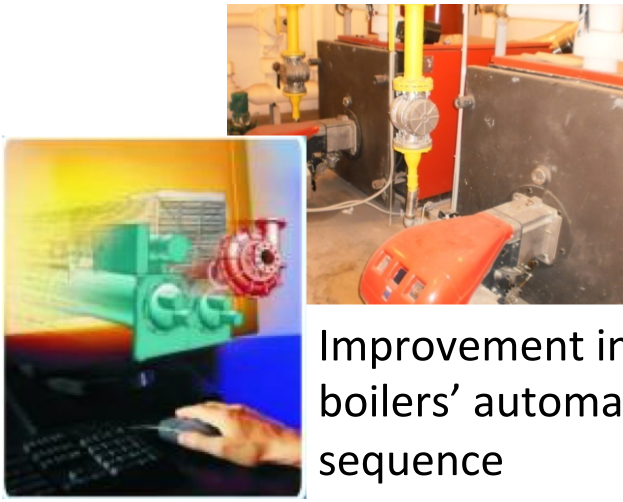
We focused on three main points:

1. The reduction of the oversized water flow rates of the pumps, based on ΔT optimal values, i.e. adjustment to the study optimal settings ΔT=2,5 K of the geothermal plant water flow, taking into consideration the role of the geothermal HX that was proved crucial

2. The installation of 8 electric switches in the electric boards of the stairwells, touch operated

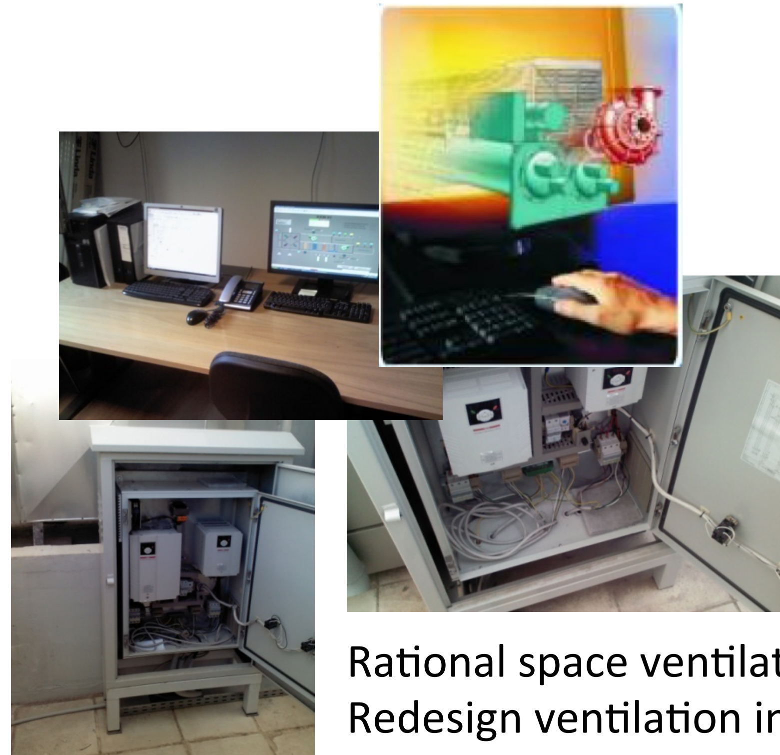
3. Implementation, in the -5 parking area, of zonal control, 30% of installed lighting power as safety zone plus 2 x 35% dual zoning as full load lighting power

VIEW OF TAB & RD INTERVENTIONS



Improvement in the boilers’ automation sequence

Intervention in the lightning of the -5 basement garage, with control via motion detectors



Rational space ventilation: Redesign ventilation in 2 fresh air handlers

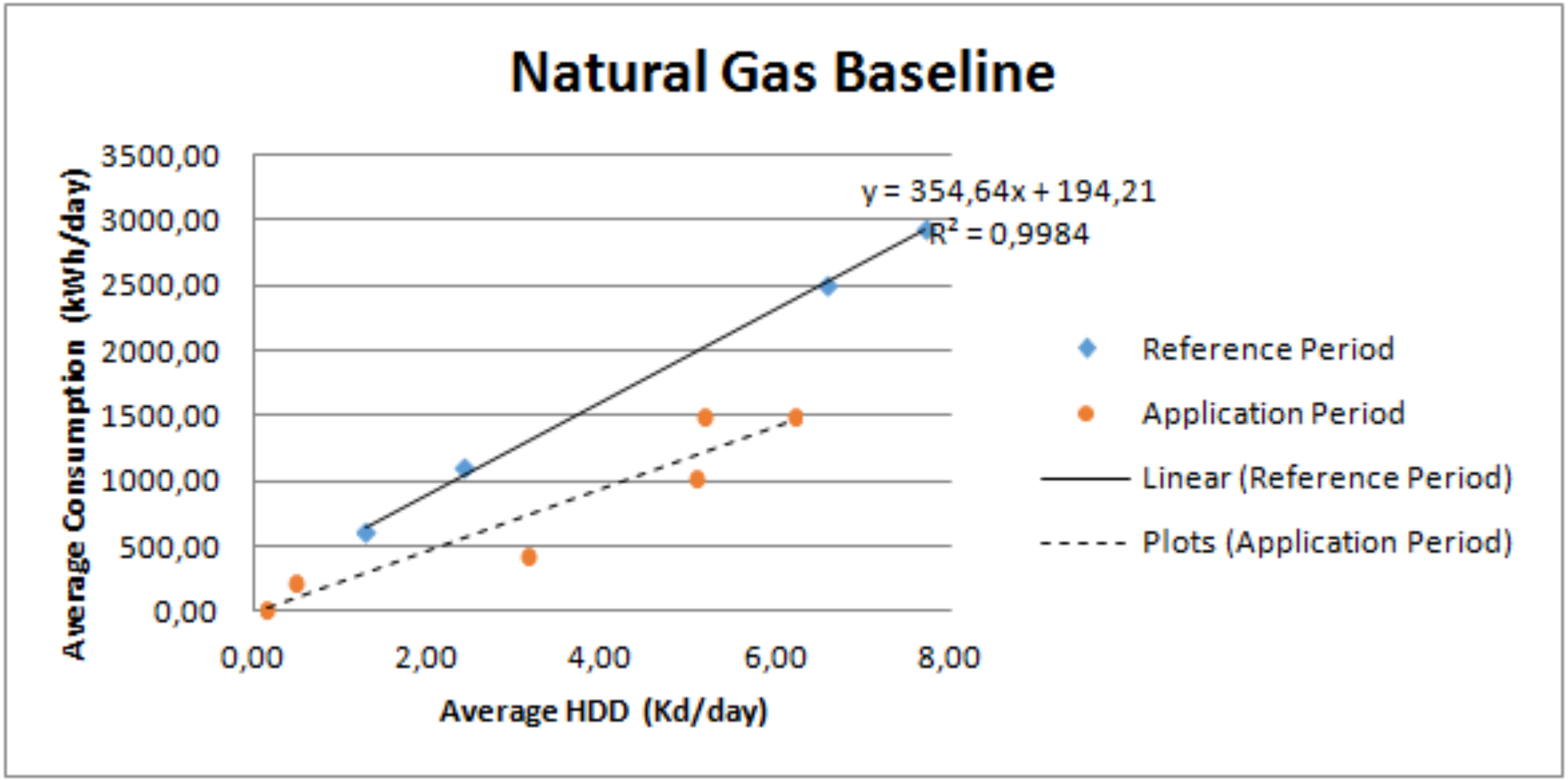
VERIFICATION PROCEDURE

1. BILLING, IPMVP OPTION C

Period Index	Starting Date	Ending Date	Number of Days	Total HDD (Kd)	Average HDD (Kd/Day)	Total Consumption (kWh)	Average Consumption (kWh/Day)
P1	24/9/2011	23/11/2011	61	145,83	2,39	67.212,65	1.101,85
P2	24/11/2011	25/1/2012	63	412,74	6,55	157.676,06	2.502,79
P3	26/1/2012	23/3/2012	58	446,23	7,69	169.617,54	2.924,44
P4	24/3/2012	23/5/2012	61	78,17	1,28	36.710,92	601,82
P5	24/5/2012	23/7/2012	61	0	0	0	0
P6	24/7/2012	24/9/2012	63	0	0	0	0
SUM				**1082,97**		**431.217,17**	
P7	25/9/2012	22/11/2012	59	27,7	0,47	13.559,69	229,83
P8	23/11/2012	23/1/2013	62	319,78	5,16	93.064,15	1.501,03
P9	24/1/2013	22/2/2013	30	185,31	6,18	44.741,65	1.491,39
P10	23/2/2013	26/3/2013	32	161,78	5,06	32.932,46	1.029,14
P11	27/3/2013	22/4/2013	27	84,3	3,12	11.891,94	440,44
P12	23/4/2013	22/5/2013	30	4,51	0,15	379,09	12,64
P13	23/5/2013	24/7/2013	63	0	0	0	0
P14	25/7/2013	28/8/2013	35	0	0	0	0
P15	29/8/2013	25/9/2013	28	0	0	0	0
SUM				**783,38**		**196.568,97**	
DIFF				**-27,70%**		**-54,40%**	

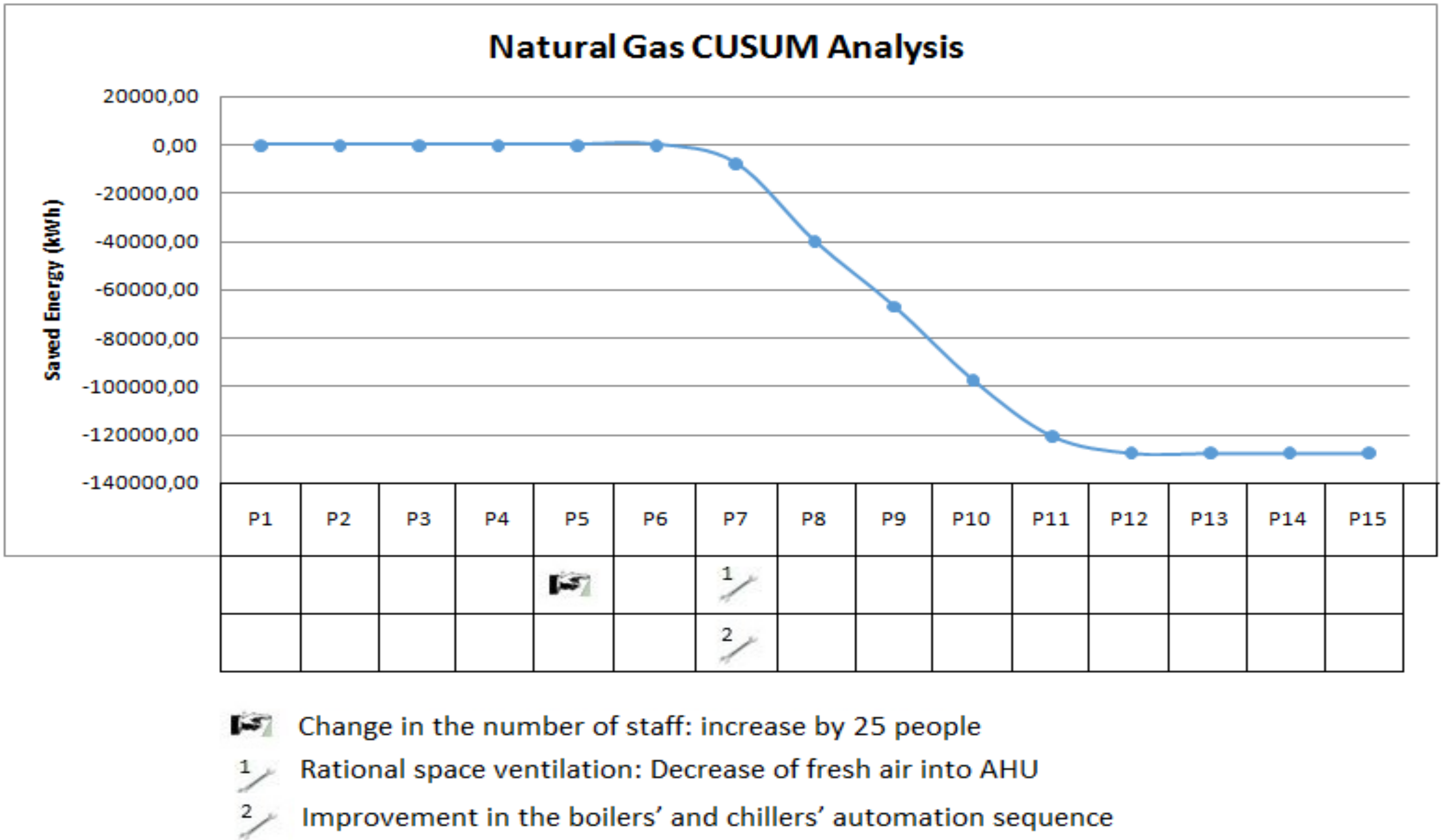
Heating Degree Days ($HDD_{18,77}$) and Natural Gas consumption

2.BASELINE ANALYSIS RESULTS (1/2)



Graphic representation of daily Natural Gas consumption against average Heating Degree Days for the reference (linear) and the application (plots) period

3.BASELINE ANALYSIS RESULTS (2/2)



CUSUM analysis of the natural gas energy savings before and after TAB intervention (kWh)

4.REGRESSION CRITERIA

- For the evaluation of the regression models, as far as accuracy and precision levels are concerned, according IPMVP 2012, we must assess R^2, SE and CVRMSE to comply with upper or lower limits

- Furthermore, since with each annual savings report it is indispensable to show at least the level of uncertainty and confidence interval in the savings determined during the post-retrofit period, according ASHRAE 14, besides the t statistic to comply with the lower limit (2) and the NDB with the upper limit ($5{,}10^{-5}$), we must assess CVSTD and NMBE

5.REGRESSION PARAMETERS & U FORMULAS

Statistic of Coefficient b

$$t - statistic = \frac{b}{SE_b}$$

$$Net\ Determination\ Bias = \frac{\sum(e_i - \hat{e}_i)}{\sum e_i} \times 100$$

Standard Error of the Prediction

$$SE_{\hat{y}} = \sqrt{\frac{\sum(\hat{y}_i - y_i)^2}{n - p - 1}}$$

Coefficient of Determination

$$R^2 = \frac{\sum(\hat{y}_i - \bar{y})^2}{\sum(y_i - \bar{y})^2}$$

Coefficient of Variation of the Standard Deviation

$$CVSTD = 100 \times \left[\sum(y_i - \bar{y})^2 / (n-1)\right]^{1/2} / \bar{y}$$

Normalized Mean Bias Error

$$NMBE = \frac{\sum(y_i - \hat{y}_i)}{(n - p) \times \bar{y}} \times 100$$

Coefficient of Variation of the Root Mean Square Error

$$CVRMSE = 100 \times \left[\sum(y_i - \hat{y}_i)^2 / (n-p)\right]^{1/2} / \bar{y}$$

Overall Savings Uncertainty

$$U = t \times \frac{1.26 \times CVRMSE}{F} \times \sqrt{\frac{n+2}{n \times m}}$$

VERIFIED ENERGY SAVINGS

Concerning the **Natural Gas** consumption, following the M&V procedure, the energy savings are:

- Real savings **of 127.833,6 kWh/y** representing a real saving percentage of **29,6%**.

Concerning the **Electricity** consumption, , following the M&V procedure, the energy savings are:

- Real savings of **60.061,8 kWh/y** representing a real saving percentage of **8,8**%
  for the high priced zone
- Real savings of **88.892,1 kWh/y** representing a real saving percentage of **13,9**%
  for the low priced zone

Total energy cost savings per year (before VAT): 36.000 €

<u>Uncertainty U is equal to 17% (<50%)</u>
<u>for a confidence index CL equal to 95% (>68%)</u>

CONCLUSIONS (1/2)

- The engineering techniques TAB, RD and MTB as well as the holistic Energy Management can give important energy savings through a number of low cost interventions with an indicative payback period lower than one year
- The EPCs potential market in buildings can rely on low cost interventions and operate on existing commercial energy saving methodologies, as well as on verification procedures of the energy savings that allow for billing of these savings to be accurately measured by third parties for the said TAB techniques
- These models were based on international M&V protocol and they consist a reliable and useful tool suitable for proofing of energy savings under the ISO 50001 and ISO 50006 building standards
- There are achieved significant savings (29.6% on natural gas, 8,8% and 13.9% on HPZ and LPZ electricity) due to a series of low-cost interventions (around 39.500 €) that have been made in the building (TAB, RD and MVT) **with a typical payback period of one year**

CONCLUSIONS (2/2)

- Due to the impact of the TAB techniques, the EnPI of the building, in terms of EP, decreased from 463,1 kWhpr/m²/y (before TAB) to 382,0 kWhpr/m²/y (after TAB). This fact contributed to the policy of the administration to reach the objective of a NZEB building and allowed the administration to make its definitive ESM investments in the fixed assets on a tuned building rather than an untuned one

- If we project the obtained results to a new Institution with 30 buildings, then the savings are expected to be 29.6% for natural gas and 14,0% for electricity and would require the same low-cost interventions (TAB, RD and MBT to reach a budget of 1.200.00 €) that may be implemented in the buildings and yield to a payback period of one year

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