Energy Saving Verification for an ISO 50001 in the RAE building

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ABSTRACT

The Regulatory Authority for Energy (“RAE”) building is the first in Greece to have an ISO 50001 standard installed, based on verification procedure for the energy savings, dated February 2014. To reduce natural gas consumption a number of interventions in the boiler room automation as well as redesign of the ventilation system have been made. To reduce electricity consumption various improvements such as interventions in the electrical panels as well as in the close circuit cooling units are applied. It is essential to mention that all the above retrofitting made in the building comprised low cost operations based on TAB, RD and TBM techniques. The new, after the verified reduction, energy consumptions in the building is decreased down to, in EP terms, 382 $kWh_{pr}/m2/y$, a value that needs high cost energy saving investment in order to reach the suggested one for the overall energy consumption in NZED Mediterranean buildings.

INTRODUCTION

Aim and objectives of the publication

The aim of this publication is to highlight the impact of the systematic energy management according ISO 50001 particularly in public buildings and show the optimization of this impact using customized mixture of energy services such as end use energy audits, engineering techniques (TAB, RD and MTB) and holistic Energy Management with targets & commitments. The publication must show further whether the ESCO’s potential market in buildings can walk on existing commercially applied methodologies of verification of the energy savings so that billing of these savings could be edited fairly and undoubtedly third part.

The publication will permit to reach the following objectives:

1. To localize actual energy savings, in matter of natural gas and electricity, by comparing the respective bills in yearly basis as well to correlate these savings to energy related interventions
2. To show how climatic data affect the above actual savings and to work out (applying the base line analysis) this impact with scope to reach the figures of the real savings
3. To establish modeled energy consumptions with scope to calculate the real energy savings and assess their cumulative effect on the energy bills throughout post-retrofit periods, by using state of the art regression methods

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4. To assess verification models for each of the various energy sources and for each of their tariff levels
5. To calculate rates of accuracy and uncertainty values for the above models be acceptable

State of the art in the M&V - Measurement and Verification of energy savings

To verify the energy savings the baseline analysis is the forecasting technique used since 1995 based mainly on billing data analysis, NAMVP 1996. According this, a linear base line forecasting model is suggested with an R^2 determination value above a threshold 0,85, value which was adopted by the Greek Regulation 1999. The state of art today applied mainly in USA, Canada and Australia is comprised in the EVO standard IPMVP 2012 adopted then in national M&V Guides, see respectively BPA and NSW. The main M&V design basics are included in IPMVP 2012 and the Guideline ASHRAE 14 - 2002. The above process supports the ISO 50001 (applied in the publication building) and the ISO 50006 system.

Following IPMVP 2012 and ASHRAE 14 the selection of the baseline period in a facility that operates on an annual cycle in response to weather should have a baseline period of a full year. Moreover, both summer and winter shall be consolidated in one base line model for evaluating the model confidence indices.

For the evaluation of regression models, as far as confidence 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 NDB to comply with the upper limit 5.10^{-5}, we must assess CVSTD and NMBE. The level of uncertainty then must be less than 50% of the annual reported savings, at a confidence level higher than 68%.

Methodology and procedure of the analysis

The methodology applied in the assessment comprises:

1. Collection of billing data in order to localize actual energy savings and working out average consumption values with reference to the number of days of each billing period (for both reference period and application period of the energy consumption)
2. Assessment of climatic data using the NASA weather data for Athens in terms of degree days with respect to an optimized indoor reference temperature for both heating and cooling, for both energy sources (gas and electricity) and for the above precise consumption periods
3. Plotting of the consumptions for both periods and modeling the reference period energy consumptions by using the base line as forecasting method, for each of the two energy sources and for each of their discrete tariff levels. Therefore three base lines are to be assessed (gas tariff, high price electricity tariff and low price electricity tariff)
4. Calculation of the accuracy and uncertainty figures [IPMVP 2012] for the above models be acceptable with scope to verify energy saving amounts

DESCRIPTION OF BUILDING

The headquarters of RAE is located at the center of Athens, at Piraeus Avenue 132.
The surface area of the building is:

- 5.411 m² (1st to 7th floor)
- 2.319 m² (2 basement levels)
- 84,60 m² (ground floor)

The RAE building has AC needs (heating and cooling), which are related to an area equal to 5.495,60 m².

The needs for heating are met by two boilers which use natural gas for heat production supplied to the spaces through a hydronic network comprising 251 local FCU. The electricity in the building mainly meets the following requirements:

1. AC-Air conditioning
2. Ventilation
3. Lightning
4. IP-Data Center
5. Devices

To assess both energy and economy evaluations, the total consumption of electricity is split into two categories: consumption at high price and at low price.

THE ENERGY MANAGEMENT PROCEDURE FOR AN ISO 50001

The Energy Management System (according to ISO 50001:2011 Energy Management System standard) planning and implementation methodology is based on the Plan-Do-Check-Act (PDCA) continuous improvement procedure of the standard.

The methodology for the design, implementation, test and optimization of the Energy Management System (EnMS) includes the use of various tools such as checklists, interviews and continuous interaction between stakeholders to ensure the development of a system that in an exemplary way fits the needs and specific challenges of the organization.

The flow chart diagram related to EnMS is as per the Figure 1.

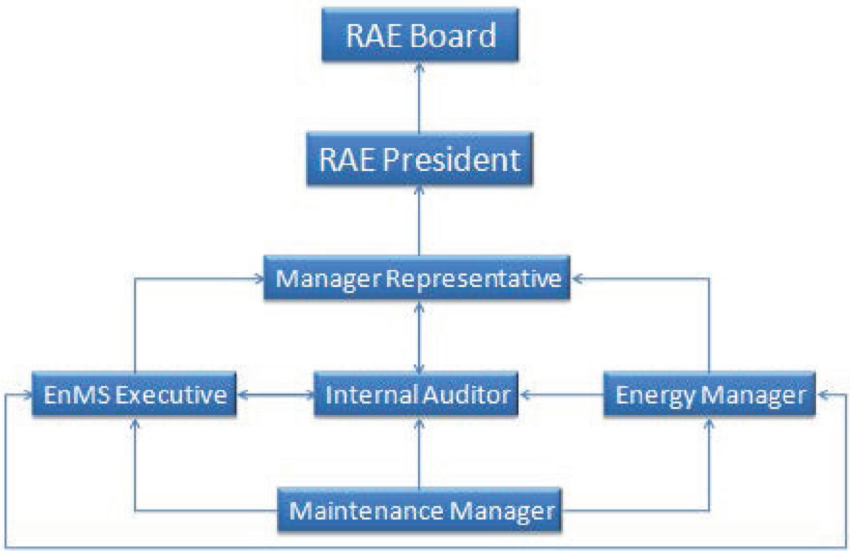

Figure 1: EnMS flow chart diagram.

The main steps followed to run all relevant procedures, day to day energy-related operational issues and documentation are:

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- Commitment of the organization's management for the implementation of EMS and the continuous improvement of the system to improve energy performance. This step includes the assignment of resources (Energy Management Team) to implement the system, the formation of an energy policy and training to the involved personnel for the implementation methodology.
- Analysis of past and present energy data in order to evaluate past and current patterns of energy consumption according to a thorough energy review compatible with European Directive 27/2012. All plans are monitored according to specific Energy Performance Indicators (EnPIs).
- Establishment of energy targets, objectives and energy management action plans. This step is of top importance since energy management action plans must be consistent and realistic over RAE's established energy policy, target and objectives.
- After the initial phase of EnMS planning, the implementation and pilot operation phase of the system is the next target to achieve. All documentation, training, communication and management of operational control.
- Checking of system's performance in terms of evaluating the conformance to ISO 50001:2011 requirements taking into consideration any corrective or preventive actions in order to handle non-conformities according to the standard.

NATURAL GAS CONSUMPTION

The consumption of natural gas in the building is collected from the GU invoices (Table 1)

Table 1. Heating Degree Days ($HDD_{18,77}$) and natural gas consumption

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	67212,65	1101,85
P2	24/11/2011	25/1/2012	63	412,74	6,55	157676,06	2502,79
P3	26/1/2012	23/3/2012	58	446,23	7,69	169617,54	2924,44
P4	24/3/2012	23/5/2012	61	78,17	1,28	36710,92	601,82
P5	24/5/2012	23/7/2012	61	0,00	0,00	0,00	0,00
P6	24/7/2012	24/9/2012	63	0,00	0,00	0,00	0,00
SUM				**1082,97**		**431217,17**	
P7	25/9/2012	22/11/2012	59	27,70	0,47	13559,69	229,83
P8	23/11/2012	23/1/2013	62	319,78	5,16	93064,15	1501,03
P9	24/1/2013	22/2/2013	30	185,31	6,18	44741,65	1491,39
P10	23/2/2013	26/3/2013	32	161,78	5,06	32932,46	1029,14
P11	27/3/2013	22/4/2013	27	84,30	3,12	11891,94	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	0,00	0,00	0,00	0,00
P14	25/7/2013	28/8/2013	35	0,00	0,00	0,00	0,00
P15	29/8/2013	25/9/2013	28	0,00	0,00	0,00	0,00
SUM				**783,38**		**196568,97**	
DIFF				**-27,7%**		**-54,4%**	

The natural gas consumption reduction by 54,4%, is explained in a significant part (24,8%, see table 3) by the weather change expressed from the decrease in the HDDs (by 27,7%). The remaining part (29,6%) is caused by a number of energy interventions made in the building.

ELECTRICITY CONSUMPTION

The invoiced electricity consumption in the building has two parts: the high priced zone and the low priced zone. In this article, we analyze only the high priced zone consumption but we present results from both zones. The high priced zone consumption is shown in Table 2 (source: EU invoices).

Table 2. Cooling Degree Days ($CDD_{20,7\,3}$) and electricity consumption (high priced zone)

Period Index	Starting Date	Ending Date	Number of Days	Total CDD (Kd)	Total Consumption (kWh)
P1	1/10/2011	31/10/2011	31	12,9	40825
P2	1/11/2011	30/11/2011	30	0	44856
P3	1/12/2011	31/12/2011	31	0	42196
P4	1/1/2012	31/1/2012	31	0	43918
P5	1/2/2012	29/2/2012	29	0	41572
P6	1/3/2012	31/3/2012	31	0	42421
P7	1/4/2012	30/4/2012	30	0,82	36169
P8	1/5/2012	31/5/2012	31	42,94	49041
P9	1/6/2012	30/6/2012	30	203,94	60805
P10	1/7/2012	31/7/2012	31	302,23	72667
P11	1/8/2012	31/8/2012	31	278,16	66656
P12	1/9/2012	30/9/2012	30	153,77	53545
SUM				**994,76**	**594671**
P13	1/10/2012	31/10/2012	31	64,69	53722
P14	1/11/2012	30/11/2012	30	4,29	41178
P15	1/12/2012	31/12/2012	31	0	32709
P16	1/1/2013	31/1/2013	31	0	39879
P17	1/2/2013	28/2/2013	28	0	35933
P18	1/3/2013	31/3/2013	31	0	34352
P19	1/4/2013	30/4/2013	30	0	36981
P20	1/5/2013	31/5/2013	31	20	42353
P21	1/6/2013	30/6/2013	30	96,36	46872
P22	1/7/2013	31/7/2013	31	178,47	60911
P23	1/8/2013	31/8/2013	31	187,08	52136
P24	1/9/2013	30/9/2013	30	123,22	48665
SUM				**674,11**	**525691**
DIFF				**-32,2%**	**-11,6%**

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The high price electricity consumption reduction by 11,6%, is explained later in a significant part (8,82%) by a number of energy interventions made in the building, while the remaining part is due to weather impact.

THE BASELINE ANALYSIS RESULTS

To verify the energy savings the baseline analysis is the forecasting technique used here based on billing data analysis. A linear base line forecasting model is assessed while the design basics are included in IPMVP 2012 and the Guideline ASHRAE 14 -2002.

The baseline related to the natural gas is assessed on mean daily values (for a twelve month period) and is detected throughout the reference period since no energy interventions occurred in the building and given by the equation:

$$y = 354{,}6\ x + 194{,}2 \qquad (1)$$

Where: y = average natural gas consumption (kWh/day)
x = average heating degree days (Kd/day)

Using the baseline we predict the natural gas consumption for the period of application next to reference period. Following IPMVP 2012 and ASHRAE 14 the selection of the baseline period in a facility that operates on an annual cycle in response to weather should have a baseline period of a full year. Since for the application period, energy interventions did occur in the building, it is easy to compare the actual consumption for the application period with the predicted one for the same application period in order to calculate the real energy savings due to these interventions.

Moreover, both summer and winter is consolidated in the base line model for evaluating further the model confidence indices. As shown in Figure 2, the values and the plot trend for the application period are lower than that of the baseline and this is due to the savings in natural gas consumption for the application, when energy interventions occurred. The application period (or post-retrofit period) according basic theory of the baseline) is not modeled.

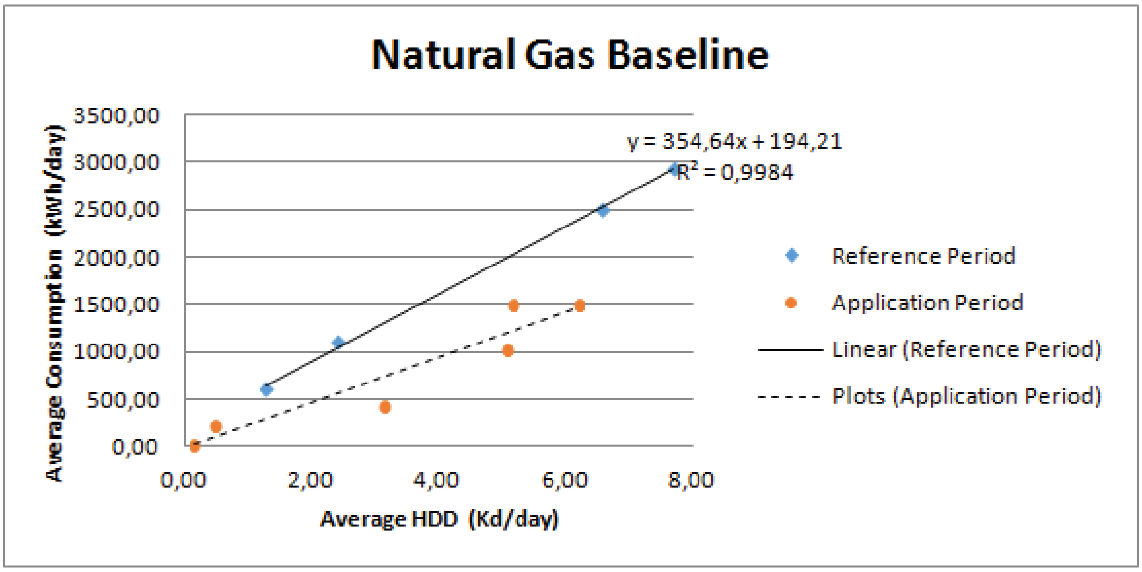

Figure 2: Graphic representation of daily natural gas consumption against average heating degree days for the reference (linear) and the application (plots) period.

Table 3. CUSUM Analysis of Natural Gas savings

Period Index	Total Consumption (kWh)	Total Modeled Consumption (kWh)	Savings (kWh)	Cumulative savings (kWh)
P1	67212,65	67212,65	0,00	0,00
P2	157676,06	157676,06	0,00	0,00
P3	169617,54	169617,54	0,00	0,00
P4	36710,92	36710,92	0,00	0,00
P5	0,00	0,00	0,00	0,00
P6	0,00	0,00	0,00	0,00
SUM	**431217,17**	**431217,17**		
P7	13559,69	21283,74	-7724,05	-7724,05
P8	93064,15	125435,36	-2371,21	-40095,26
P9	44741,65	71537,11	26795,45	-66890,72
P10	32932,46	63582,12	-30649,66	-97540,37
P11	11891,94	35137,12	-3245,18	-120785,56
P12	379,09	7427,13	-7048,04	-127833,59
P13	0,00	0,00	0,00	-127833,59
P14	0,00	0,00	0,00	-127833,59
P15	0,00	0,00	0,00	-127833,59
SUM	**196568,97**	**324402,57**	**-127833,59**	
DIFF	**-54,4 %**	**-24,8%**		

A CUSUM chart is elaborated with the help of which we can track the time that the real natural gas consumption savings start. In the Table 3, we observe that the real savings are equal to 127.833,6 kWh/y equivalent to 29,6% (= 54,4% - 24,8%) of the reference natural gas consumption. The related figure 3 shows that a large part of the energy savings starts in period 7 (October 2012). In this month a number of energy interventions occurred that are described in the following paragraphs.

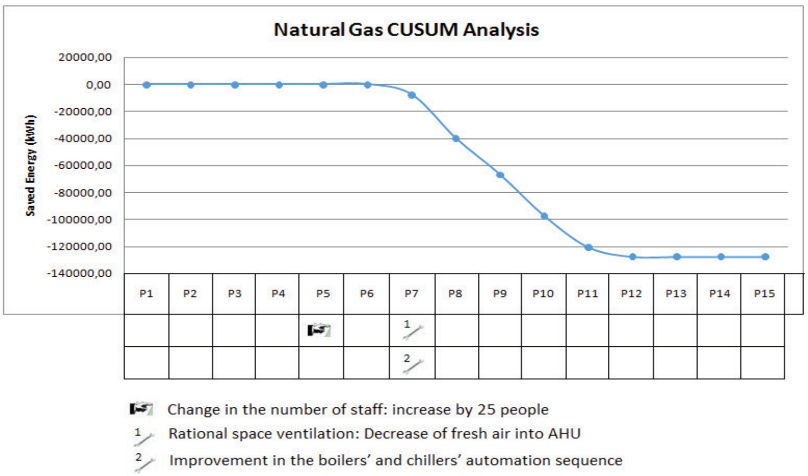

Figure 3: CUSUM analysis of the natural gas energy savings for the reference and the application period (kWh)

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To work on electricity evaluations, the total consumption has been split into two categories: consumption at high price and at low price. In the figure 4 the high price electricity baseline for the reference period is given.

The baseline of the high priced zone consumption is assessed on monthly values (for a twelve month period) and it is given by the equation:

$$Y = 94{,}48\ X + 41723{,}60 \qquad (2)$$

Where: Y = electricity consumption (kWh/month)
X = cooling degree days (Kd/month)

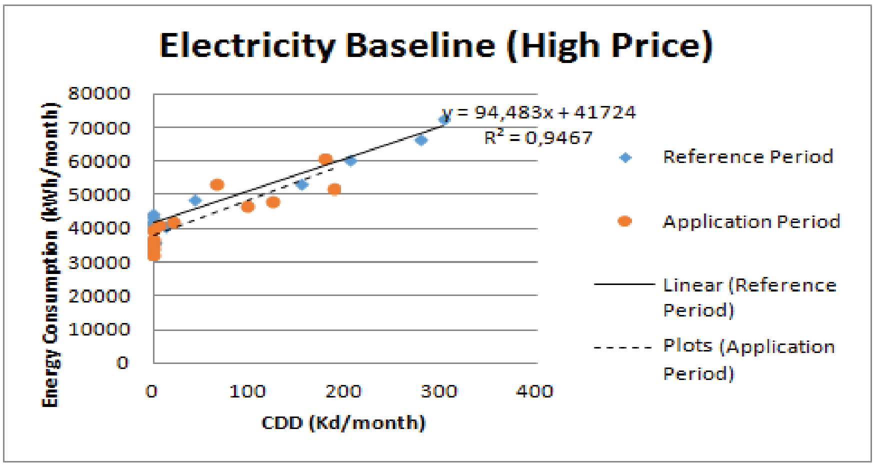

Figure 4: Baseline analysis of the electricity high price consumption for the reference and the application period (kWh/month).

As said, in the Table 3, we found the real gas savings equal to 127.833,6 kWh/y equivalent to 29,6% of the reference natural gas consumption. Using the electricity base line from the figure 4 and working out for the electricity similar tables to the table 3, we succeeded the correspondent figures that have been calculated equal to:

- Real savings of 83.929,3 kWh/y that represents a saving percentage of 8,82% for the high price zone.
- Real savings of 88.892,1 kWh/y that represents a saving percentage of 13,9% for the low price zone.

ENERGY SAVING VERIFICATION PROCEDURE

In the following we calculated seven regression parameters related to the verification procedure we applied [IPMVP 2012] as well as the uncertainty U [Ashrae 14/2002] for the prediction of the energy savings we achieved for three cost centers:

1. Natural Gas consumption
2. Highly invoiced electrical energy
3. Low invoiced electrical energy

The computed savings in energy and the monetary units are respectively kWh and Euro, while the energy price schedule of our EU used in the assessment is VitaGamma/MV(see Annex I). The whole building performance path is performed in our consumption building case study.

For the evaluation of 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 NDB with the upper limit 5.10^{-5}, we must assess CVSTD and NMBE.

The seven regression parameters R^2, t, SE, Net Determination Bias, CVSTD, CVRMSE, NMBE and the U are calculated bellow, as commonly, according statistical basics.

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

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

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

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

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

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

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

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

The Table 4 comprises the results of the regression model for the natural gas consumption baseline, showing acceptable values according to the implemented criteria. In the same table are also included the statistical calculations of both electricity consumption baselines.

Table 4. Results of the calculated regression on three baselines under confidence set at >95% (natural gas, highly invoiced zone and low invoiced zone electricity consumption)

REGRESSION RESULTS	NGas	High priced Electricity	Low priced Electricity	Criteria
R^2	0,998	0,947	1,000	>0,75
t-stat. CDD or HDD	36,88	13,333	n.a.	>2
t-stat. intercept	2,82	41,989	n.a.	>2
STANDARD ERROR	3343,75	2776,309	1332,060	the lower the better
Net Determination Bias	3,091E-08	0,000E+00	3,731E-06	<0,005%
CVSTD	1,083	0,231	0,157	
CV(RMSE)	0,04653	0,05602	0,04091	<0,25
NMBE	0,00%	0,00%	0,00%	
$U_{\text{total savings}}$	17,19%	33,53%	16,21%	

The level of uncertainty must be found less than 50% of the annual reported savings, at a confidence level higher than 68% [ASHRAE 14, 5.3.2.2f]. Table 4 complies, since at a confidence level higher than 95% the modeled uncertainty is found 17.19% and 33,53% of the annual reported savings (respectively for gas and high priced electricity).

ENERGY RELATED INTERVENTIONS IN THE BUILDING

In the building a number of occurrences happened and a series of interventions were built that presented a particular energy related impact. These facts can be classified in two categories.

Facts with an impact on:

- Natural gas savings
  1. Alteration of HDDs: 27,7% reduction from the reference to the application period
  2. Change in the building's staff number, who increased by 25.
- Electricity savings
  1. Alteration of CDDs: 32,2% reduction from the reference period to the application period.
  2. Change in the building's staff number, who increased by 25.

Moreover, a series of interventions related to both natural gas and electricity were built or are to be built, as per the Table 5 list:

Table 5. List of interventions built or to be built in the building to attain energy savings

Title of fact	Date of fact
To Reduce the Natural Gas	
Rational space ventilation: Redesign ventilation in 2 fresh air Air handlers	4/10/2012
Improvement in the boilers' and chillers' automation sequence	12/11/2012
Heat recovery from the boilers' flue gases	To be built
Geothermal use of phreatic well for fresh air preheating	To be built
Switch over from gas boiler to heat pump for space heating	planned
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
Rational space ventilation: Redesign ventilation in 2 fresh air Air handlers	10/10/2012
Replacement of CFLs (2x18W) to LEDs (10W) in the corridors	To be built

CONCLUSIONS

As far as natural gas consumption is concerned, the annual savings are localized to reach:

- Real savings 127.833,6 kWh/y that represent a saving percentage of 29,6%. The uncertainty U is 17,19% under a confidence level CL >95% (while U must be less than 50% at a CL higher than 68%)

The correspondent figures for the electricity are:

- Real savings 83.929,3 kWh/y that represent a saving percentage of 8,82% for the high price zone. The uncertainty is 33,53% under a confidence level >95% (while U must be less than 50% at a CL higher than 68%)

- Real savings 88.892,1 kWh/y that represent a saving percentage of 13,9% for the low price zone. The uncertainty is 16,21% under a confidence level >95%(while U must be less than 50% at a CL higher than 68%)

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The verification procedure applied to prove the announced energy savings gives excellent results since all criteria are highly satisfied. To succeed the savings analyzed above, a number of low cost interventions have been implemented in the building, TAB oriented, with an indicative payback period lower than one year.

Due to the retrofitting interventions, the total energy consumption indicator in the building, in EP terms, is decreased from 463,1 kWh_{pr}/m2/y (before) down to 382,0 kWh_{pr}/m2/y (after the retrofitting). With scope to reach a NZEB threshold of efficiency (this last is usually proposed for Mediterranean buildings to be about 210 kWh_{pr}/m2/y) a number of high cost retrofitting is planned such as efficient lighting installation, geothermal application, flue gas heat recovery and co-generation plant implementation.

Moreover, the publication showed that:

- Climatic data from one year period to the next altered by 27.7% (for the heating period) and affected the actual gas savings from 54,4% down to real savings leveled at 29,6% (this impact is different from 27,7%)
- Three baselines are indispensable to assess the case study (for the gas, high and low price electricity zone)
- Calculate the rates of accuracy and the uncertainty is complex but not difficult to assess. The energy saving percentage must be announced under the related level of uncertainty
- The developed modeling methodology based on the baseline technique and the verification procedure to assess the statistical efficiency of the above models based on the M&V international Protocol consists a valuable and reliable tool to prepare energy saving proofs in the framework of ISO 50001 and ISO 50006 for buildings
- The applied methodology of verification of the energy savings in the RAE building has been proved scientifically valuable and commercially tested in the building, therefore in the case that an ESCO is involved, it can walk on this methodology steadily since billing of savings are edited fairly and undoubtedly third part.

NOMENCLATURE

RAE = Regulatory Authority for Energy
TAB = Testing Adjusting Balancing,
RD = ReDesign,
TMB = Measuring, Targeting and Benchmarking
EP, pr = Energie Primaire
IPMVP = International Performance & Measurement Verification Protocol,
NZED = Near Zero energy Building
ESCO = Energy Services COmpany
HDD = Heating Degree Days, Kd
CDD = Cooling Degree Days, Kd
FCU = Fan Coil Unit
EU = Electric Utility
GU = Gas Utility
AC = Air Conditioning, IP: Information Power (of the data centers),
CUSUM = Cumulative SUM.

R^2 = coefficient of determination
SE = standard error of the prediction
CVSTD = the coefficient of variation of the standard deviation
t = statistic of a coefficient b
CVRMSE = the coefficient of variation of the root mean square error
NMBE = the normalized mean bias error
U = the overall savings uncertainty
y_i = data value i
$\hat{y}_i$ = predicted y_i
$\bar{y}$ = sample mean value
e_i = measured energy i
$\hat{e}_i$ = predicted e_i
n = number of periods of baseline
m = number of period in the post retrofit Savings reporting period
p = number of parameters in the baseline model of the baseline data
F = approximate percentage of the baseline energy use that is saved
t = t critical
NV = Medium voltage

REFERENCES

NAMVP, 1996, North American Energy Measurement and Verification Protocol, US Department of Energy, DOE/EE-0081

IPMVP 2012. January 2012. International Energy Measurement and Verification Protocol, USA Efficiency Valuation Organization.

BPA Regression for M&V. September 2011. Reference Guide, Version 1.0.

Ashrae 2009 Fundamentals.

Greek Regulation for energy inspections. 1999. (Δ6/Β/οικ 11038/FEK 1526/1999).

ASHRAE 14P. 2002. "Measurement of Energy and Demand Savings".

NSW Government. December 2012. Measurement and Verification Operation Guide, Whole Building Applications, Office of Environment and Heritage.

ANNEX I

The Vita Gamma MV (medium voltage) tariff of the Greek EU applies:

1. Annual power price
   - 7,10 (€/kW/month) (7:00-23:00 working days per year)
2. Annual energy prices
   - High price tariff: 0,06428 €/kWh (7:00 - 23:00 working days per year)
   - Low price tariff: 0,05062 €/kWh(23:00-7:00 working days per year, and 24hours at weekends-holidays per year)

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