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Energy Saving Verification for an ISO 50001 in the RAE building

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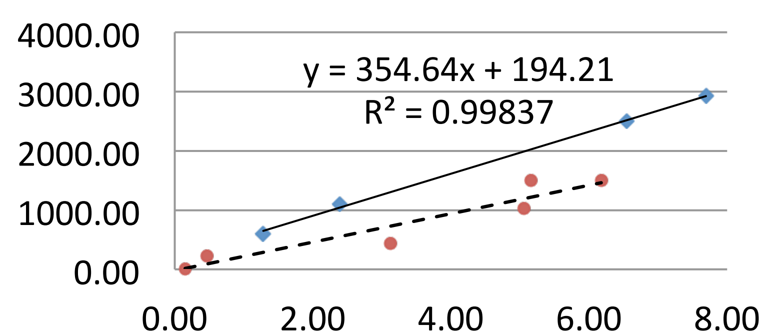

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INTRODUCTION

The 2 aims of the project are:

- to highlight the impact of the systematic energy management according ISO 50001
- to show whether the ESCO's potential market in buildings can walk on existing experience from commercially applied methodologies

The project permits to reach the following 5 objectives:

- To localize actual energy savings, in matter of natural gas and electricity
- To show how climatic data affect the above actual savings
- With scope to calculate the real energy savings, establish modeled energy consumptions
- To assess verification models for each of the various energy sources and for each of their tariff levels
- To calculate rates of accuracy values at an uncertainty level for the above models be acceptable

REFERENCES

- IPMVP 2012. January 2012. International Performance Energy Measurement and Verification Protocol, USA EVO-Efficiency Valuation Organization
- BPA-Bonneville Power Administration Regression for M&V- Measurement and Verification. September 2011. Reference Guide, Version 1.0
- Ashrae 2009 Fundamentals
- Greek Regulation for Energy Inspections. 1999. (D6/B/OIK 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

STATE OF THE ART IN THE M&V OF THE ENERGY SAVINGS

- The forecasting techniques used since 1995 is based mainly on billing data analysis: NAMVP 1996 (adopted then by the Greek Joint Ministerial Decision D6/B/OIK/11038/FEK1426/1999)
- The EVO standard IPMVP 2012 is adopted in national **M&V** (Measurement & Verification) Guides, see respectively BPA and NSW
- The main M&V design basics are included in IPMVP 2012 as well as in the Guideline ASHRAE 14 -2002
- The selection of the baseline period in a facility should have a period of a full year
- For evaluating the model confidence indices, both summer and winter shall be consolidated in one base line model
- According IPMVP 2012 we must assess R^2, SE and CVRMSE to comply with upper or lower limits
- According ASHRAE 14, besides NDB to comply with the upper limit 5.10^-5, we must further assess the CVSTD and NMBE values

METHODOLOGY & PROCEDURE OF OUR ANALYSIS

- Collection of billing data in order to localize actual energy savings and work out average consumptions along set periods
- Assessment of climatic data using the NASA weather data for Athens in terms of degree days
- Plotting of the consumptions for the reference period (before retrofitting) and modeling these energy consumptions
- With scope to localize the real energy savings, plotting of the consumptions for the post - retrofitting period
- Calculation of the accuracy and uncertainty figures [IPMVP 2012] for the above models be acceptable

THE RAE 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 1st to the 7th floor)
- 2.319 m^2 (2 basement levels)
- 84,60 m^2 (ground floor)

The RAE building has AC needs (heating and cooling), which are related to an area equal to 5.495,60 m^2. 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

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NATURAL GAS CONSUMPTION

Period Index	Starting Date	Ending Date	Number of Days	Total HDD (Kh)	Average HDD (Kh/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	0,00
P6	24/7/2012	24/9/2012	63	0,00	0,00	0	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	0,00
P14	25/7/2013	28/8/2013	35	0,00	0,00	0	0,00
P15	29/8/2013	25/9/2013	28	0,00	0,00	0	0,00
SUM				**783,38**		**196568,97**	
DIFF				**-27,7%**		**-54,4%**	

The natural gas actual energy savings by 54,4%, are explained in a significant part (24,8%, see next) by the weather change expressed from the decrease in the HDDs (by 27,7%). The remaining part is the real energy savings (29,6%) and is caused by a number of energy related retrofitting made in the building

HPZ ELECTRICITY CONSUMPTION

Period Index	Starting Date	Ending Date	Number of Days	Total CDD (Kh)	HPZ 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%**

in a significant part (real savings=10,1%) by a number of energy retrofitting made in the building

GAS BASELINE ANALYSIS (1/2)

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

  $$y = 354{,}6\ x + 194{,}2$$

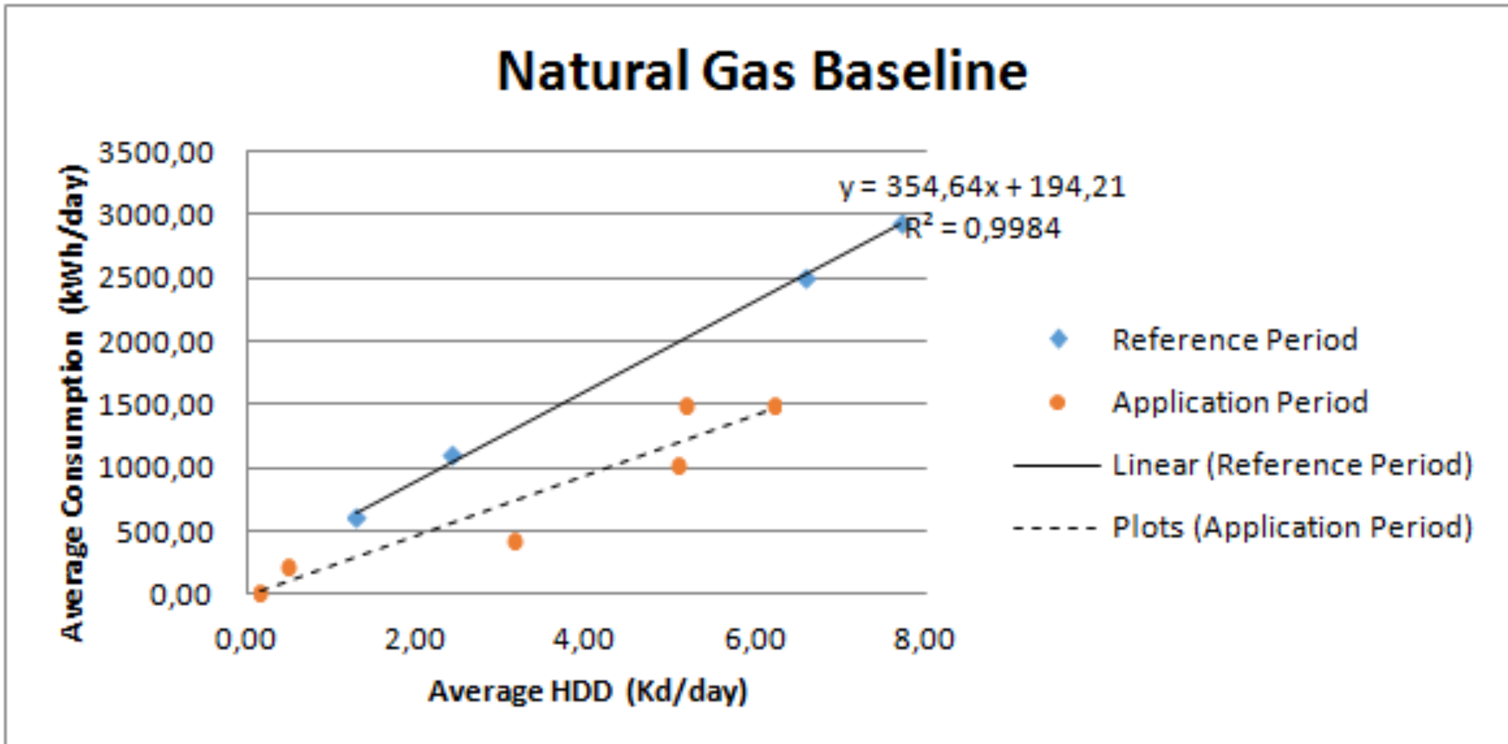
  Where: y = average natural gas consumption (kWh/day)

  x = average heating degree days (Kd/day)

- Using the baseline we predict the natural gas consumption for the period of application (the said post-retrofitting period) next to reference period. Since for the post-retrofitting period, energy interventions did occur in the building, it is easy to compare the actual consumption for the post-retrofitting period with the predicted one in order to verify the real energy savings due to these interventions.

GAS BASELINE ANALYSIS (2/2)

As shown in the figure, the values and the slope for the application period are lower than that of the baseline and this is due to the savings in natural gas consumption for the post-retrofitting, since energy interventions occurred



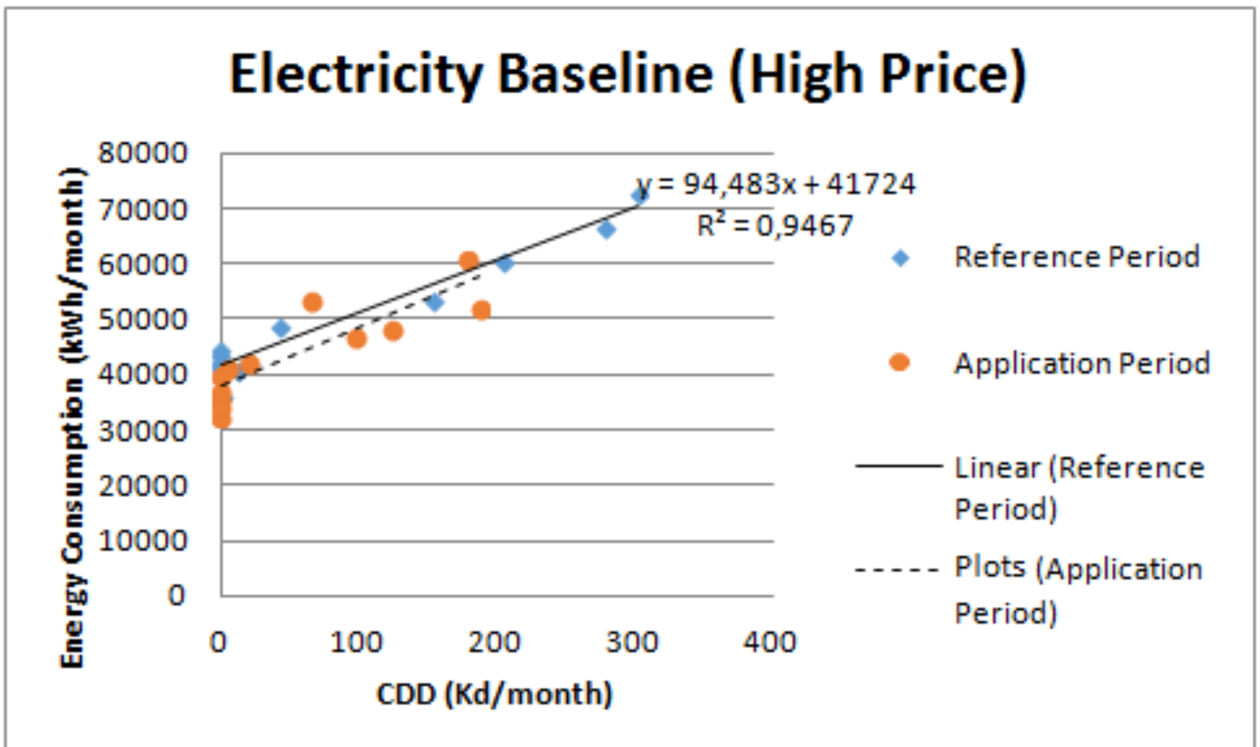
ELECTRICITY BASELINE ANALYSIS

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:

$$Y = 94{,}48\ X + 41.723{,}60$$

Where: Y = electricity consumption (kWh/month)

X = cooling degree days (Kd/month)



ENERGY SAVING VERIFICATION PROCEDURE

- In the following steps, for three cost centers, we calculated seven regression parameters related to the verification procedure we applied [Ashrae 14/2002] .Also the uncertainty U for the prediction of the energy savings [IPMVP 2012] we achieved:
  a) Natural Gas consumption
  b) Highly invoiced electrical energy
  c) Low invoiced electrical energy
- The computed savings in energy and the monetary units are respectively kWh and €, while the energy price schedule of our EU used in the assessment is VitaGamma/MV
- 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 <u>with each annual savings report it is indispensable to show at least the level of uncertainty and confidence interval in the savings</u> 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.

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

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

Coefficient of Determination

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

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

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

REGRESSION RESULTS

- The table comprises the regression results for the natural gas consumption baseline, showing accepted values according to the implemented criteria
- Both electricity consumption baselines statistical assessment is also included in the same table

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%	

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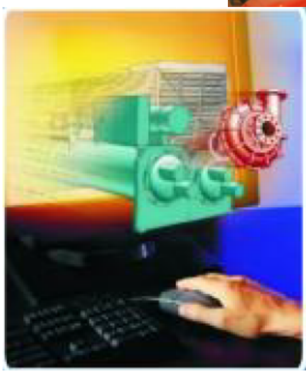
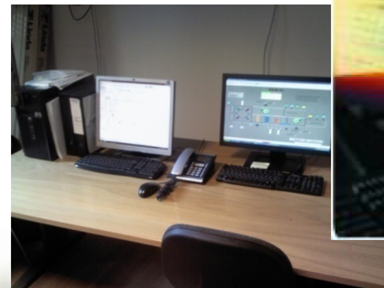
ENERGY RELATED INTERVENTIONS IN THE BUILDING

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

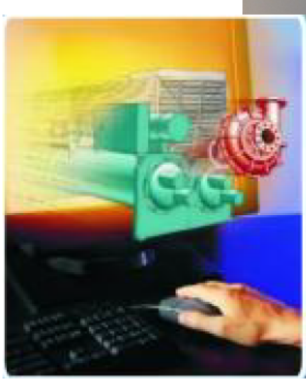
VIEWS OF INTERVENTIONS



Improvement in the boilers' automation sequence



Rational space ventilation:
Redesign ventilation in 2 fresh air handlers



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

RESULTS

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%

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%
- 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%

U must be less than 50% at a CL = 68%

CONCLUSIONS (1/2)

- 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 to assess.
- 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
- On this methodology and in the case that an ESCO is involved, *it can walk steadily* since *billing of savings are edited fairly and undoubtedly third part*.

CONCLUSIONS (2/2)

- The verification procedure applied to prove the announced energy savings gives excellent results since *the set criteria are highly satisfied.* The savings proved above are due to a number of low cost interventions implemented in the building, TAB & RD 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 kWhpr/m²/y (before) down to 382,0 kWhpr/m²/y (after the retrofitting).
- With scope to reach down to a *NZEB threshold of efficiency (this last is usually proposed for Mediterranean buildings to be about 250 kWhpr/m²/y*) a number of high cost retrofitting is planned such as switch overs gas/electric heating/cooling heat pumping, high efficient lighting installation, geothermal applications, flue gas heat recovery and co-generation plant implementation

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