



PERMANENT M&V Plan for Heating System Modernization

ABC Office Building, Croatia

Developed within the project Performance Risk Management for Energy Efficiency through
Training – PERMANENT – IEE/08/657/SI2.528420

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1. Description

ABC Office building is located in the business center of Zagreb, Croatia. It has 6 floors and a total heated area is 5.500 m². The building was built in 1990. It is occupied from 0800 to 2000 hours Monday to Friday. Gas fired boilers provide building heating and domestic hot water. The local gas distributor is responsible for gas supply and invoicing is monthly based on readings from the gas meter.

2. Description of ECMs

Three energy conservation measures were implemented by an ESCO, expecting to savings about 30% of annual gas use:

- a. Installation of heat recovery equipment in five air handling units regulating year round indoor temperature and humidity. The intention is to supply air of the same quality and quantity, but with less energy consumed. This will not change set point temperatures in office spaces. The installed heat exchangers are plate type, so there is no direct mixing of inlet and outlet air, which means no need for additional monitoring of air quality.
- b. Installation of solar panels on the building roof. Solar panels are connected to two large (5m³ each) buffer water tanks and are used to preheat domestic hot water.
- c. Reparation of indoor thermostats. About 20 of the 80 thermostats are not working. Temperature measurements in areas with broken thermostats showed that average temperature was 2-4C degrees higher than the 21°C setpoint. Repair of thermostats should reduce temperatures to 21°C in occupied periods and to 18°C in unoccupied periods.

3. Measurement Boundary

IPMVP Option B Retrofit Isolation: All Parameter Measurement will be used (IPMVP Volume I EVO 10000-1:2010). The measurement boundary is all equipment using natural gas for the heating and DHW systems.

The project will have slight interactive effects on the electricity using systems:

1. mechanical cooling energy *savings* from the sensible heat recovered in the heat exchangers in summer, and
2. fan energy *increases* to overcome the airflow resistance of the new heat exchangers.

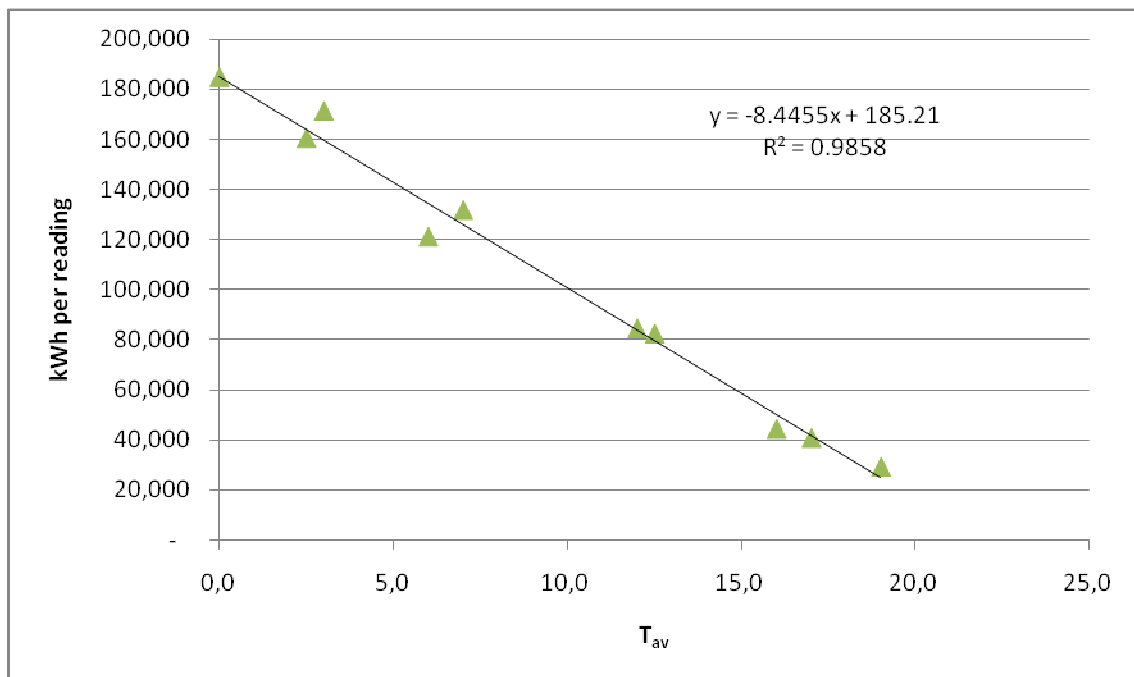
Though both of these effects are small, the savings of effect #1 is estimated to be significantly larger than the increases of effect #2. Since they are offsetting, and the savings enhancement of effect #1 is dominant, both effects can be ignored without fear of overstating the savings of the project.

4. Baseline Data

The baseline period is from January 1, 2008 to December 31, 2008. Baseline period energy and independent variable data (mean outdoor monthly temperature) are given in the following table. The data is from gas supplier invoices and an on-site temperature sensor. The utility reads the meter at the end of each month so the outdoor temperature was averaged for the same period. Data read from the gas bills in m³ is converted to the common energy units of equivalent kWh (ekWh) based on the reported energy content of the gas each month.

Month	2008 Natural Gas Consumption		T _{av} (°C)
	As Billed (m ³)	Converted to common units (ekWh)	
January	19.935	184.600	0,0
February	17.315	160.338	2,5
March	14.210	131.584	7,0
April	8.894	82.354	12,5
May	4.787	44.324	16,0
June	3.152	29.186	19,0
July	2.783	25.773	22,00
August	2.643	24.472	21,00
September	4.400	40.747	17,0
October	9.118	84.432	12,0
November	13.072	121.051	6,0
December	18.482	171.139	3,0
TOTAL	118.790	1.100.000	

The relationship of gas use and T_{av} for months where T_{av} is 19 degrees or less is shown below using linear regression analysis.



The mean value of gas use when T_{av} >19°C (July & August) is 25123 ekWh/month.

The overall equation describing the relationship of gas and T_{av} for all weather conditions is
(Equation 1):

$$\text{For } T_{av} \leq 19.0: \text{ Baseline [kWh]} = (-8445,5 * T_{av} + 185210)$$

$$\text{For } T_{av} > 19.0: \text{ Baseline [kWh]} = 25123$$

Static Factors during the baseline period are:

- Occupancy hours were 3.000 hours. The building was used Monday to Friday, 12 hours per day with full occupancy, for 50 weeks a year (two weeks in August were non-working for all employees).
- Number of employees working in the building was 200 on average (based on monthly figures).
- Measured indoor temperatures were: 23°C for offices, 22°C for meeting rooms, 20°C for halls, toilets and other spaces. Spaces were overheated since required temperatures are 21°C offices, 19°C for meeting rooms and 18°C for halls. After the project is completed, temperatures will drop to required levels. The number of air changes was 0,7 per hour, and will be unchanged due to air quality requirements.
- Total heated area was 5.500 m².
- Total electrical equipment load in the heated space was 10 kW. Lighting energy consumption is 25.000 kWh/year, based on sample load measurement and occupancy monitoring.
- Overall building electrical consumption, as determined from the utility bills. In the baseline it was 85.000 kWh.

5. Reporting Period

The savings reporting period is one year after commissioning of all new equipment. During that period, monthly bills for gas consumption will be collected and monthly savings reports prepared.

6. Basis For Adjustments

Savings will be reported on the basis of the conditions of the reporting period, so savings will be expressed as avoided energy or avoided cost.

7. Analysis Procedure

Avoided gas will be determined from **Equation 2:**

$$SAVINGS[ekWh] = \text{Baseline}[ekWh] - \text{Actual}[ekWh]$$

Where:

Baseline – adjusted baseline consumption calculated by Equation 1 using actual reporting period T_{av} (from outside temperature monitor)

Actual – actual billed gas consumption converted to ekWh

Static factors will be reviewed as follows:

- Indoor temperatures (measured once a year)
- Occupancy (logged by reception person)
- Lighting energy consumption (sample load measurement and occupancy monitoring). Total building electrical use shown on the utility bills will also be used to help identify changes in static factors

Non-routine baseline adjustments will be made for any changes observed in static factors at the end of the year.

8. Energy Prices

Calculations of savings will be determined using then current gas prices. Monetary savings (in Kuna) will change if price of gas changes based on **Equation 3**:

$$SAVINGS[Kn]_{before\ tax} = Actual\ Price \left[\frac{Kn}{ekWh} \right] * SAVINGS[ekWh]$$

Where actual price is the marginal price determined from the current utility bill.

9. Meter Specification

The utility bills will be used for measurement of actual consumption of natural gas (precision = +/-0% by definition).

Outside temperature T_{av} will be determined for a temperature sensor located on the north side of the building (precision +/-1%). The sensor will have a valid official certificate for calibration and shall be re-calibrated every 12 months. Sensor readings will be made every 15 minutes and saved in the building control system database.

10. Accuracy

The regression model (Equation 1) correlates gas and T_{av} well, since the R^2 is 98% and coefficient of variation is 7%. This model will report statistically meaningful savings since its standard error of 7200 ekWh is only 20% of the average expected monthly savings. Total savings reported with this model for a year, for the months of T_{av} equal to or below 19°C, will have a precision of +/-14%, at 95% confidence.

11. Monitoring Responsibilities

Monitoring of energy use, independent variables, and static factors will be as follows:

- Monthly gas and electric utility bills will be provided to the ESCO by the accounting department of ABC Building's owner.
- Outside temperature readings will be recorded by the building control system which can be accessed remotely by the ESCO and the building owner at any time.
- Occupant count will be performed by the building receptionist for one day each month. The ESCO will have continuous access to that information
- Air handler operating hours will be logged by the building management system. ESCO shall have continuous access to that information
- Heated area will be assessed by the ESCO once a year by visual audit.
- ESCO will review electrical equipment and usage annually

12. Budget

The initial budget for measurement equipment and installation is €1.000. Annual cost of M&V is €1.000.

13. Report Format

Reports shall be submitted by Email in .pdf format. A sample report is attached.

14. Quality Assurance

All raw data and savings reports will be confirmed by the ESCO's M&V engineer and project engineer.

15. Energy Savings Report - ABC Office Building

Reporting Period: January 1 - December 31, 2010.

The heating system retrofit project was commissioned December 31, 2009. For 2010 the avoided gas use was 38.570 m³ and avoided cost was 91.410 Kn. Data and calculations are shown below.

Reporting period observed data was:

Gas consumption (m ³)	Gas consumption (ekWh)	T _{av}
12.205	113.019	0,2
10.764	99.675	2,4
9.056	83.861	6,8
6.132	56.784	12,6
3.873	35.868	15,8
2.974	27.542	18,8
2.772	25.665	0*
2.772	25.665	0*
3.661	33.900	17,3
6.256	57.927	12,1
8.431	78.067	5,9
11.406	105.616	3
80.301	743.589	

* The temperature sensor was out of service for part of July and August, so temperature readings in these months are invalid. Fortunately it was summer and it is safe to assume the average temperature exceeded 19 degrees, so the T_{av} values were not needed for determining the adjusted baseline.

Static factors were reviewed

1. Indoor temperatures were the same as in base year.
2. Occupancy was the same as in base year.
3. Electricity consumption was the same as in base year
4. Lighting load and operation hours were the same as in the base year.

Therefore no non-routine baseline adjustments were needed.

Adjusted baseline values were computed using M&V Plan Equation 1 to be:

Month	Gas consumption (ekWh)
January	183.520
February	164.940
March	127.780
April	78.797
May	51.771
June	26.435
July	25.123
August	25.123
September	39.103
October	83.019
November	135.380
December	159.870
TOTAL	1.100.861

Total avoided energy and cost, using these adjusted baseline values and M&V Plan Equations 2 and 3, and a marginal gas price of 2.37 Kn/m³ are as follows:

Month	Avoided Gas (ekWh)	Avoided Gas (m ³)	Avoided Cost (Kn)
January	70.502	7.614	18.040
February	65.266	7.048	16.700
March	43.920	4.743	11.240
April	22.013	2.377	5.630
May	15.903	1.717	4.070
June	-1.107	-0.120	-0.28
July	-0.542	-0.059	-0.14
August	-0.542	-0.059	-0.14
September	5.203	0.562	1.330
October	25.092	2.710	6.420
November	57.315	6.189	14.670
December	54.258	5.859	13.890
TOTAL	357.279	38.570	91.410

Total savings are 48%.