PERMANENT
M&V Plan for Lighting Efficiency Improvement

At ABC Manufacturing, Romania

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

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CONTENTS

1. Introduction

Purpose: The project aimed to improve the efficiency of the lighting system in part of XYZ Manufacturing's plant in Romania. The lighting retrofit will maintain light levels at specified levels.

IPMVP Option: The lighting retrofit affected only a portion of the plant electrical load, so the M&V plan follows IPMVP Vol I, 2010 Option A Retrofit Isolation: Key Parameter Measurement.

Measurement Boundary: Project savings will be determined within a measurement boundary that encompasses only the light fixtures in the five areas subject to the retrofit project.

Interactive Effects: Only the lighting equipment will be measured, though the retrofit has an interactive effect of reducing the amount of heat generated by the lights in the retrofitted areas. The reduction of space heat gain: a) increases the heating required in the winter, and b) decreases the cooling required in summer. These interactive effects only occur in the retrofitted spaces which are temperature controlled by the plant's heating and cooling system. All retrofitted spaces except the warehouse are temprature controlled.

Every kWh of electricity saved in the lights in the conditioned spaces requires a kWh of heat to be delivered from the gas boilers. It is assumed that the overall efficiency of the heating delievery system is 85%. It is also assumed that the heating system operates during only 5 months of the year. Therefore the interactive gas energy increase (ΔGas, in Nm^3) associated with the lighting energy reduction ($\Delta kWh_{lighting}$), in the heating season, is estimated to be (1 Nm^3 = 10 kWh):

$$\Delta Gas = \frac{\Delta kWh_{lighting} \times 5}{0.85 \times 12 \times 10} = \Delta kWh_{lighting} \times 0.0490 \qquad Equation\ 1$$

Similarly every kWh of electricity saved in the lights will reduce mechanical cooling energy needed for the conditioned spaces. It is assumed that the coefficient of performance of the chiller plant in delivering cooling to the space is 3.0, and that the chiller operates 4 months of the year. Therefore the interactive cooling electrical savings ($\Delta E_{cooling}$, in kWh) associated with the lighting energy reduction, in the cooling season, is estimated to be:

$$\Delta E_{cooling} = \frac{\Delta kWh_{lighting} \times 4}{3.0 \times 12} = \Delta kWh_{lighting} \times 0.111 \qquad Equation\ 2$$

Assumed Value: The purpose of the lighting retrofit was to imporve lighting efficiency, so lighting power reduction will be measured instantaneously. However lighting operating periods are very regular and not related to the purpose of the project. The lighting periods are reported by the production supervisor of each area as shown in Table 1.

Room	Hrs/day	Days/mo	Months/year	Hours/year
Hard Injection Production	12	22	12	3,168
First Injection 2 Production	12	22	12	3,168
Second Injection 2 Production	24	22	12	6,336
Salomon Injection Production	24	22	12	6,336
Warehouse	8	22	12	2,112

Table 1 - Lighting Periods

These periods match the production hours since the supervisors of each production area report tight control of the lighting periods. The supervisors may turn the lights on a few minutes before production periods and off slightly after production periods, possibly totalling an additional 15 minutes per day (2% of 12 hour daily time where nearly half of the load reduction will occur). About half of the lighting load reduction is expected to ocur in areas where 24 hour/day operation is involved for weekdays so there will be even less impact of slight extensions of operating periods. By ignoring the possible impacts of these small additions to operating hours, savings will be under-reported, but by a negligible amount.

Therefore it is conservatively assumed that the operating hours of the lighting system after retrofit will be as shown in Table 1.

Independent Variables: There are no independent variables influencing the energy use within the measurement boundary.

Static Factors: Non-routine adjustments will be made if necessary for changes in static factors since the baseline measurements. The only static factors relevant are the number of burned out lamps and the light levels. The lamp burnout factor is discussed below under Basis for Adjustment.
To verify that any light level change is within the agreed project design, light level measurements will be made by the plant engineer at randomly selected work surfaces in each area after retrofit.

Basis for Adjustments: Savings will be reported assuming the same lamp burnout fraction that was observed during the baseline measurements.

Calculations: Avoided energy calculations will follow IPMVP Vol I 2010 Equation 1d.
Avoided Energy = Estimated operating hours (Table 1) *
[Measured baseline lighting power (Appendix)
- Measured post-retrofit lighting power corrected for the lamp burnout fraction observed during the baseline]

A sample of the savings report is attached.

Measurement Equipment: Power use of the lighting systems will be determined by XYZ independent electrical contractor's portable true RMS wattmeter. The meter manufacturer reports an accuracy of ±3% for this meter.

Measurement Process: Power will be measured by XYZ independent electrical contractor instanteously for each lighting circuit in the five rooms. The number of operating lamps on each circuit will be noted at the time of measurement. Baseline measurements will be made and recorded immediately before implementation of the retrofits, and then after 100 hours of operation of the new lighting. Baseline data will be added to the Appendix, and post-retrofit data will be shown in the savings report (sample attached) after retrofit.
Accuracy: The plausible error in the estimated lighting operating periods is trivial and it is conservative to ignore it. The +/-3% meter accuracy will yield a +/-5% uncertainty in the final savinsg number.

Energy Prices: Current marginal energy prices are €0.081/kWh of electricity and €0.3/Nm^3 of gas. These prices will be multiplied by the calculated energy amounts to determine net avoided costs.

M&V Cost: The independent electrical contractor's charges for doing all measurements will be €500.

Quality control: Measurements of electric power and light level will be sotred in the project file in the plant engineering department for further inspection. The calibration report for the wattmeter will be filed in the same place.

2. APPENDIX - Baseline Data

Gathered Nov 1-3, 2009

Circuit	Lamp Type	Number of fixtures	Number of lamps		Measured Circuit Power [W]
			Operating	Non-Operating	
Hard Injection Production Room					
1	300 W Incand-escent	15	15	0	4500
2	400 W Mercury	11	11	0	4631
3		11	11	0	4631
4		11	11	0	4631
5		11	11	0	4631
6		11	11	0	4631
7		11	11	0	4631
8		11	11	0	4631
9		11	11	0	4631
10		11	11	0	4631
11		3	3	0	1263
				Total	**47442**
First Injection 2 Production Room					
	250 W Mercury	17	17	0	4607
2		13	7	0	3523
				Total	**8130**
Second Injection 2 Production Room					
1	250 W Mercury	17	17	0	4607
2		17	17	0	4607
3		17	17	0	4607
4		17	17	0	4607
5		17	17	0	4607
6		17	17	0	4607
7		17	17	0	4607
8		17	17	0	4607
9		17	17	0	4607
10		15	15	0	4065
				Total	**45528**
Salomon Injection Production Room					
1	250 W Mercury	17	17	0	4607
2		17	17	0	4607
3		15	15	0	4065
				Total	**13279**
Warehouse					
1	150 W Mercury	27	27	0	4509
2		28	28	0	4676
				Total	**9185**

3. Lighting Savings Report

ABC Manufacturing

Feb 9, 2010

Avoided energy use associated with the lighting retrofit is determined following IPMVP Vol I 2010 Option A, from measurements taken between January 27 and January 29, 2010. This report follows the M&V Plan dated September 21, 2009 and updated with pre-retrofit data on November 6, 2009.

Based on this information:

- *Avoided* electric energy is estimated to be 420 MWh/year
- *Increased* gas energy is estimated to be 18000 Nm^3/year
- Total annual cost avoidance is conservatively estimated to be €28000, a net of a €34000 electricity cost avoidance and a €6000 gas cost increase.

The measured data are shown in Tables A and B. Calculations supporting the reported cost and energy avoidance are presented in Table C.

Table A Post-Retrofit Data (gathered by XYZ Electrical Contractor January 27-29, 2010)

Circuit	Lamp Type	Number of fixtures	Number of lamps		Measured Circuit Power [W]
			Operating	Non-Operating	
Hard Injection Production Room					
1	150 W Metal Halide	7	7	0	1190
2	250 W Metal Halide	14	14	0	3780
3		14	14	0	3780
4		14	14	0	3780
5		14	14	0	3780
				Total	16310
First Injection 2 Production Room					
1	250 W Metal Halide	15	15	0	4125
				Total	4125
Second Injection 2 Production Room					
1	250 W Metal Halide	12	12	0	3420
2		12	12	0	3420
3		12	12	0	3420
				Total	10260
Salomon Injection Production Room					
1	250 W Metal Halide	12	12	0	3300
2		13	13	0	3575

				Total	6875
Warehouse					
1	250 W Metal Halide	12	12	0	3300
2		6	6	0	1650
				Total	4950

All lamps were operating during the baseline tests (see M&V Plan), as in the post-retofit tests. Therefore no adjustment was needed for burnouts.

Table B Light Level Data (gathered by plant engineer January 27, 2010)

Room	Average Light level at working surfaces (lux)
Hard Injection	258
First Injection 2	208
Second Injection 2	281
Salomon Injection	255
Warehouse	185

All post-retrofit light levels met the requirements for the space. Therefore no adjustment was needed.

Table C - Avoided Energy/Cost

Area	Assumed Operating Hours per year (M&V Plan Table 1) A	Measured kW		Calculated Lighting Load Change (kW) D	Annual Lighting Energy Avoided (kWh) E	Annual Cooling Energy Avoided (kWh) (M&V Plan Eq 2) F	Total Annual Electricty Avoided (kWh)	Annual Gas Increase (Nm^3) (M&V Plan Eq 1)
		Baseline Power (M&V Plan Appendix) B	Post Retrofit Power (Table A) C					
	Calculation:			B - C	D * A	E * 0.111	E + F	E * 0.0490
Hard injection	3168	47,44	16,31	31,13	98620	10947	109567	4832
First injection 2	3168	8,13	4,13	4,00	12672	1407	14079	621
Second injection 2	6336	45,53	10,26	35,27	223471	24805	248276	10950
Salomon injectionhttp://hallo.ro/se	6336	13,28	6,88	6,40	40550	4501	45051	1987
Warehouse (Unconditioned) e	2112	9,19	4,95	4,24	8955	0	8955	0
Total		123,57	42,53	81,04	384268	41660	**425928**	**18390**
Marginal energy price (from M&V Plan)							€0.081	€0.30
Avoided Cost							**€34500**	**(€5517)**
Net Avoided Cost							**€28983**	