



PERMANENT M&V Plan for Heating Pump Efficiency Improvement

In an Office Building, Czech Republic



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

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1. Introduction

Purpose - An office building's space heating pumping system will be improved by replacing the pumps with more efficient pumps. The building is used as a call center working 24 hours per day, 7 days a week. The new pumps have the same flow capacity as the old ones. The system operates at variable flow during the heating season (October to May), and is off for the summer.

IPMVP Option – IPMVP Vol. 1 2010, Option A Retrofit Isolation: Key Parameter Measurement was selected.

Measurement Boundary – Electrical power will be measured for the 10 heating system circulation pump motors (nominal power input of 5 kW each) at the single electrical power feed to all of the motors. There are no interactive effects of this retrofit on other building energy using systems.

Independent Variables – The load on the heating system significantly affects the pumping energy. The heat consumed by the system is the only independent variable used in analysis of pump motor energy.

Static Factors - Factors affecting pumping energy are:

- the size of the heat circulation system - the number of heat delivery coils or devices connected. 163 heating devices are attached to the distribution system during the baseline.
- the programmed relationship between outdoor temperature and heating system water delivery temperature. In the baseline period it was noted that the system:
 - provides heat when outdoor temperature is below 15°C for more than 12 continuous hours, and the system is enabled by the building operator.
 - distribution temperatures ranged from 65°C to 85°C over an outdoor temperature range from 15°C to -15°C.

Measurement Equipment – electricity consumption (in kWh) will be measured by a freshly calibrated true RMS wattmeter with logging capabilities. This meter has a rated accuracy of +/-1% of reading. The electrical measuring equipment is owned by the independent consultant hired for this M&V work.

The independent variable of heat consumption will be measured using the district heating utility's energy supply meter, with an accuracy of +/-0% by definition.

Measurement Process – the consultant will continuously measure electricity consumption during test periods before and after retrofit. These periods will be long enough to span the full range of heat delivery rates normally found for the building. Electrical consumption will be continuously recorded and totaled for each day.

Heat consumption of the heating system (in equivalent kWh, or ‘ekWh’) will be manually read from the utility meter at the district heating substation. The readings will be made and recorded each day at midnight, by building maintenance staff.

Baseline Data – The baseline data was collected over the period from October 1 2008 to February 10, 2009 and is shown in Figure 1. This data was felt to reasonably reflect the full range of heat consumption levels of a typical heating season, since it included the full range of typical load conditions plus some common conditions of heat supply shortage.

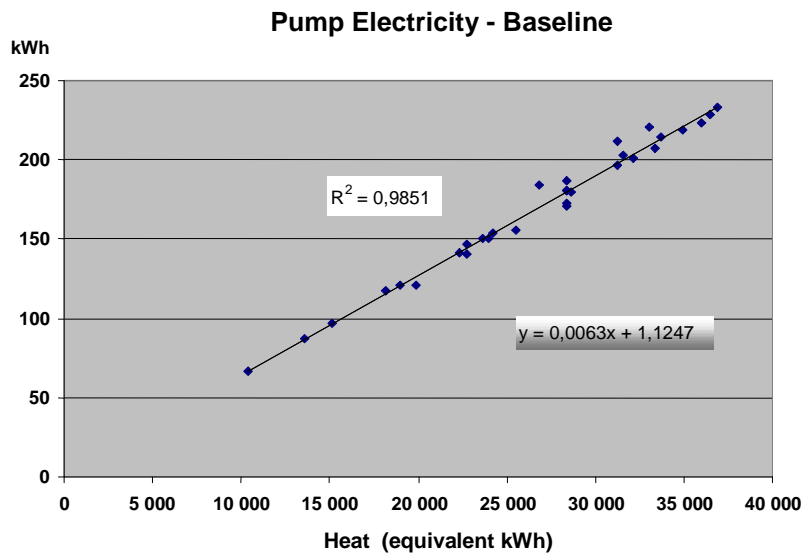


Figure 1. Baseline Daily Electrical and Heat Energy Data

Regression analysis of the baseline data determined that the monthly pump electricity use in the baseline period is:

$$\begin{aligned} \text{Pump Motor Monthly Electricity Use (kWh)} = & \\ & (1.1247 * \text{Number of days in the month when the heating system is on}) \\ & + (.0063 * \text{Daily Heat Consumed (ekWh)}) \end{aligned} \quad \text{Equation 1}$$

Since the regression analysis had a good R^2 (98%), it was decided that the behavior of the system was linear over the whole range of heating loads. Equation 1 will be used to determine the adjusted baseline pump energy when determining the savings.

Calculation Method and Assumed Value - Normalized savings will be determined for this project using IPMVP Vol I 2010 equation 1c, namely:

$$\begin{aligned} \text{Normalized Savings (kWh)} = & \text{Adjusted Baseline Energy} \\ & - \text{Adjusted Reporting Period Energy} \end{aligned} \quad \text{Equation 2}$$

Adjustment of both baseline and reporting period energy will be made to the average heating requirements over the period 2005-2008. These requirements are derived from utility heat deliveries as shown in Table 1, below. Though the average monthly values do not reflect the actual for any year, it was decided that such recent four year average was an appropriate basis

for reporting savings. The average number of days of heating in each month was also determined by inspection.

Adjustments will be made using the baseline and reporting period pump/heat regression equations. The baseline equation for pump/heat energy is Equation 1, above. A similar equation will be derived for the new pumps after retrofit.

	Purchased Heat (MWh)				Average Year	
	2005	2006	2007	2008	kWh	Days of Heating
January	651	474	756	784	666,313	31
Ferbruary	367	352	372	491	395,396	28
March	450	322	568	208	386,806	31
April	226	200	166	143	183,435	30
May	91	88	246	75	125,042	22
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	65	84	52	70	67,667	13
October	154	295	108	197	188,500	31
November	378	409	322	334	360,708	30
December	418	549	268	403	409,458	31
Total	2,800	2,771	2,857	2,705	2,783,324	247

Table 1: Average Energy Consumption For Space Heating

The Table 1 average year’s heating load and heating days for each month will be inserted into the pump/heat regression equations determined for the baseline and reporting periods. The results of these calculations will be the adjusted energy amounts for in Equation 2. A sample of the planned normalized savings calculation is shown in the attached sample Savings report.

Any changes in static factors will also be considered before computing final savings.

Reporting Period Test – A reporting period test will be conducted for an entire month after retrofit when there is significant heating load. Since the baseline test showed that a linear relationship can be expected between pump energy and heat energy, the full range of heating loads does not need to be monitored to permit proper determination of the new pump/heat relationship for all months. The test will be the similar to the baseline test, and reported in the same form as the baseline in Figure 1.

Energy Price - The normalized cost savings of the project will be computed using the current marginal electricity price of 5.4 CZK/kWh.

Measurement Cost - The consultant’s fee for developing the M&V Plan, making measurements, performing savings computation and preparing the final savings report will be xx CZK.

Accuracy – The baseline regression analysis showed good correlation of pump energy and heating consumption ($R^2 = 98\%$). The electricity meter had reasonable accuracy of +/-1%.

Quality Control – The pump motor energy observations will be open for the building manager to inspect as they are being taken. The data will be recorded in MS Excel spreadsheet as readings are being taken and provided with the consultant’s report on the project.

2. Energy Savings Report - Pump Replacement

March 1, 2010

Based on a performance test throughout January of 2010, it is conservatively estimated that the heating pump replacement project would create a normalized savings of 1600 kWh/year and 8900 CZK/year under average conditions of 2005-2008. These estimated amounts follow IPMVP Vol I 2010 Option A, and the M&V Plan dated March 27, 2009.

Measured Data

Data gathered and analysis is shown below, following the M&V Plan.

Date	Heating equivalent kWh	Pump Motor Electricity kWh
1	19,880	110
2	25,560	125
3	24,140	139
4	21,300	117
5	11,360	58
6	14,484	84
7	19,880	112
8	34,080	174
9	28,400	161
10	27,690	141
11	24,140	135
12	29,820	151
13	26,412	147
14	21,584	111
15	15,620	81
16	15,940	87
17	13,100	75
18	14,200	84
19	12,780	78
20	14,200	74
21	19,880	115
22	22,720	126
23	28,400	147
24	28,400	150
25	31,240	164
26	28,400	158
27	33,086	183
28	28,400	149
29	26,838	146
30	28,400	157
31	25,560	131
Total	715,894	3,870

Table 1: Measured Daily Data, January 2010

This data was analyzed by regression analysis, as shown in Figure 1, below.

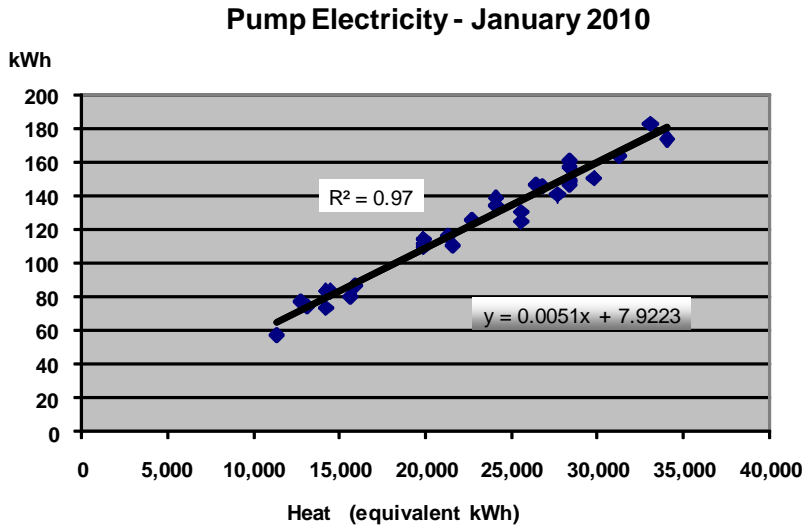


Figure 1: Regression analysis – Reporting-period energy

The regression model for the new pumps on a monthly basis is:

$$\begin{aligned} \text{New Pump Motor Monthly Electricity Use (kWh)} = & \\ & (7.9223 * \text{Number of days in the month when the heating system is on}) \\ & + (0.0051 * \text{Daily Heat Consumed (ekWh)}) \end{aligned}$$

Since the regression model has a good R^2 (97%), like that of the baseline, it was decided that this one month model is acceptable for characterizing the operation of the new pumps throughout a heating season.

During the January test all Static Factors were the same as listed in the M&V Plan.

Normalized Savings Calculation

Using the regression models of the baseline period (in the M&V Plan) and that of the new pumps (immediately above) for the assumed four year average heating load in the M&V Plan, the normalized pump motor electricity savings are determined for each month, as defined in Equation 2 of the M&V Plan and shown below.

	Heat- ing Days	Assumed Average Heat Load (equiv kWh)	Electricity Adjusted to 2005-2008 Average (kWh)						Normalized Electricity Savings (kWh)
			Adjusted Baseline			Adjusted Reporting Period			
			Fixed Comp- onent	Load Sens- itive	Total	Fixed Comp- onent	Load Sens- itive	Total	
			A	B	C	D	E	F	
		From M&V Plan	1.1247*A	.0063*B	C + D	7.9223*A	.0051*B	F + G	E - H
Jan	31	666313	35	4198	4233	246	3398	3644	589
Feb	28	395396	31	2491	2522	222	2017	2238	284
Mar	31	386806	35	2437	2472	246	1973	2218	253
Apr	30	183435	34	1156	1189	238	936	1173	16
May	22	125042	25	788	813	174	638	812	1
Jun		0		0	0		0	0	0
Jul		0		0	0		0	0	0
Aug		0		0	0		0	0	0
Sep	13	67667	15	426	441	103	345	448	-7
Oct	31	188500	35	1188	1222	246	961	1207	15
Nov	30	360708	34	2272	2306	238	1840	2077	229
Dec	31	409458	35	2580	2614	246	2088	2334	281
Total	247	2783324			17813			16152	1661

Table 1: Calculation Of Normalized Electricity Savings

Since there was no change in Static Factors non-routine baseline adjustments were not needed.

At 5.4 CZL/kWh, the normalized savings are valued at 8969 CZK.

Final savings shown at the beginning of this report are rounded down to 2 significant digits because there are as few as two significant digits in the key element of the regression equations.