EFFECTIVE IMPLEMENTATION OF "IPMVP OPTION C- WHOLE BUILDING MEASUREMENT" MEASUREMENT AND VERIFICATION PLANS

PREPARED
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INTRODUCTION

This document describes the Measurement and Verification (M&V) methodology for Phase One of the Texas Health and Human Services Commission (HHSC) energy savings performance contracting (ESPC) project. TAC-Tour Andover Controls was the energy service company (ESCO) chosen by HHSC to implement the ESPC. The M&V plan is based on the International Performance Measurement and Verification Protocol (IPMVP) Option C "Whole Building Measurement" and provides the methodology that will be used to measure and verify savings for this project. *The description of this procedure and an example of it's application will be useful for anyone utilizing the IPMVP Option C for measuring energy savings. There is also a discussion of how the procedure will be used in the contract between HHSC and TAC.*

Option C was chosen by HHSC as the best IPMVP option to meet the following needs of HHSC:

1. Actual utility savings would be used to pay for the project
2. If the guaranteed savings did not occur, the ESCO would pay the shortfall
3. The performance risk of the ESPC would be with the ESCO, not HHSC

The five facilities that are included in the Phase One project are the Austin State Hospital/Central Office site consisting of 861,013 square feet of space, Austin State School consisting of 446,127 square feet of occupied space, Kerrville State Hospital consisting of 330,918 square feet of space, San Antonio State Hospital consisting of 544,100 square feet of occupied space, and San Antonio State School consisting of 235,888 square feet of occupied space. The total square footage of the facilities in the project is 2,418,046 square feet.

The savings generated by the Utility Cost Reduction Measures (UCRMs) proposed in this project will be verified by the various methods shown in detail in this report. The gas and electric utility savings from the following UCRMs will be verified according to the Whole Meter Method explained in Section I: Lighting Upgrades, Window Film, Mechanical Replacements, and the Energy Management System.

HHSC and TAC will mutually agree upon any required modifications or adjustments, in accordance with this Measurement and Verification plan. This includes, but is not limited to, modifications and/or adjustments to the baseline that may be required to account for changes in building use, weather fluctuations, or any other events that materially change the energy consumption of the facilities included in this project. In the event that HHSC and TAC cannot agree, a mutually agreeable, third party, Professional Engineer will be utilized to assist in the determination of an acceptable solution. In the further event that HHSC and TAC cannot agree, the procedures for Dispute Resolution contained in the contract will be utilized.

SECTION I – WHOLE METER METHOD DESCRIPTION

A. Whole Meter Method Description

The method of determining utility savings described in this section uses "Option C – Main Meter Measurement" as described in the International Measurement and Verification Protocol (IPMVP). In brief, the utility savings resulting from this project will be measured as follows:

Utility savings will be measured by comparing the guarantee period's total utility consumption and demand to the total utility consumption and demand for the same area in the base year period. Base year energy and demand will be adjusted for differences in weather, facility operation and facility modifications to estimate how much energy would have been used in the guarantee period if the utility conservation measures had not been implemented. The utility consumption saved is the difference between the adjusted base year consumption and the guarantee period consumption. The demand saved is the difference between the adjusted base year demand and the guarantee period demand. Utility cost savings is the difference between the cost of the base year consumption and demand and the guarantee period consumption and demand. Baseline adjustments will be performed each year starting from the original baseline, i.e. the baseline adjustments will not be cumulative. This process will be followed for each fuel type and water involved in the guarantee.

B. Baseline Definition

The base year is the period of time, as described in this document, establishes the pre-retrofit conditions used as the point of reference for determining guaranteed savings. The baseline is that set of parameters that describes both the utility consumed in the base year and the conditions that caused that consumption to occur. This set of parameters includes utility consumption, facility use information, weather data and other information as may be necessary to describe the base year conditions. Weather data used to generate the HHDs and CDDs, will be supplied in an hourly format for the baseline year (8760 outside temperature values). In addition, the baseline includes certain mathematical values, calculated by a model, that are used to correlate the base year utility consumption with the factors that caused that consumption. HHSC agrees to accept modifications to this baseline that are necessary to account for changes in the facilities and their use which may have occurred prior to the execution of this agreement but come to the attention of TAC after the execution of this agreement. **<u>These modifications will be implemented only on approval from both TAC and HHSC.</u>**

C. Determination of Adjusted Baseline

Base year consumption is adjusted to estimate what the current guarantee period consumption would have been if no utility conservation measures had been implemented. This is accomplished by adjusting for these factors:

- Changes in the number of days between the base year and guarantee year billing periods
- Changes in weather between the base year and guarantee year billing periods
- Changes in facility use between the base year and guarantee year billing periods
- Modifications to the facility between the base year and guarantee year periods

TAC will clearly document the baseline conditions for the above items in all buildings TAC will be guaranteeing savings on. This includes defining the baseline year, defining the specific weather of the baseline year, identifying the use and number of people in each facility (to the level of detail that TAC will want to adjust the use in later years) and the current status of each facility. For example, if HHSC changes a library to a hospital ward area, this would be an appropriate adjustment.

Adjusted base year consumption is calculated as follows for each fuel type:

$$Q = C_D * (T_i - T_{i-1}) + C_H * HDD_i + C_C * CDD_i + O_i + M_i,$$

or

Adjusted Base Year Consumption = Weather Independent Consumption + Weather Dependent Consumption + Offset + Use and Modification Adjustments

Where:

Q = adjusted base year consumption
C_D = a constant representing units of consumption per billing period day as calculated by model
T_i = ending date of current billing period
T_{i-1} = ending date of previous billing period
C_H = a constant representing units of consumption per heating degree day as calculated by model
HDD_i = heating degree days in the current billing period
C_C = a constant representing units of consumption per cooling degree day as calculated by model
CDD_i = cooling degree days in the current billing period
O_i = offset for the current billing period (O_i is described in detail below)
M_i = other adjustments for the current billing period (M_i is described in detail below)

Adjusted base year demand is calculated with a slightly different formula as follows:

$D = D_D * (T_i - T_{i-1}) + D_H *(HDD_i / (T_i - T_{i-1})) + D_C * (CDD_i / (T_i - T_{i-1})) + O_i + M_i$, or
Adjusted Base Year Demand = Weather Independent Demand + Weather Dependent Demand + Offset + Use and Modification Adjustments

Where:

D = adjusted base year demand
D_D = a constant representing units of demand per billing period day as calculated by model
D_H = a constant representing units of demand per heating degree day as calculated by model
D_C = a constant representing units of demand per cooling degree day as calculated by model

1. Daily Consumption

This component of consumption can be regarded as base-load, or non-HVAC consumption. Because utility meters are not always read on the same day of the month, the number of days in a meter's billing period frequently varies. The term, $C_D * (T_i - T_{i-1})$, in the above equation is used to account for this difference, where $(T_i - T_{i-1})$, gives the number of days in the guarantee year billing period. Thus, Daily Consumption is the base load consumption per day times the number of days in the guarantee year billing period. The approach is identical for demand, except that the term D_D is substituted for C_D.

2. Weather Dependent Consumption

The change in weather between the base year and guarantee year periods is accounted for with the terms, $C_H * HDD_i + C_C * CDD_i$. Weather Dependent Consumption is consumption per degree-day times the number of degree-days in the guarantee year billing period. A cooling degree-day is the difference between the average daily temperature and the balance point (or degree day base) temperature (AvgTemp – BalanceTemp). A heating degree-day is the difference between the balance point (or degree day base) temperature and the average daily temperature (BalanceTemp – AvgTemp). Degree-days are always greater than or equal to zero. If the degree-day calculation yields a negative number, the period is considered to have zero degree-days of that type. The balance point temperature is different for each building and for each fuel type.

Demand is treated similarly. The exception being that "total degree-days per month" is substituted for "degree-days per day." This provides a measure of average daily weather intensity.

3. Offset

The weather dependent and daily consumption (or demand) terms in the baseline equation result from the least-squares regression of actual consumption (or demand) quantities against independent variables such as cooling degree-days (CDD) or heating degree-days (HDD). The equations produced by this method do not exactly predict the base period consumption or demand quantities. Additional variation, not accounted for by the daily or weather-sensitive consumption (or demand) terms, exists. This is especially noticeable in facilities such as schools which may be occupied for only nine months of the year.

To account for this variation in a given meter, an "offset" is determined for each month. This offset represents the difference between the equation-predicted meter quantity and the actual meter quantity. Thus, for a 12-billing-period baseline, there would be 12 unique offset values that are used along with the other terms in the baseline equation for that meter to exactly reflect the baseline meter usage quantities for each month. The resulting baseline equation thus allows for prediction of meter consumption or demand in years after the baseline year with adjustment terms for varying weather, billing period days, and facility usage. Since the guarantee period may overlap two or more base year billing periods, the guarantee period offset will be the weighted average of the base year offset for the corresponding guarantee year period.

Offset for the guarantee period is determined with this equation:

$$O_i = O_1 * dG_1/dB_1 + O_2 * dG_2/dB_2 + \ldots O_n * dG_n/dB_n$$

Where:

O_i = current guarantee period offset
O_1 = base year period 1 offset
O_2 = base year period 2 offset

O_n = base year period n offset
dG_1 = days in guarantee period that overlap base year period 1
dG_2 = days in guarantee period that overlap base year period 2
dG_n = days in guarantee period that overlap base year period n
dB_1 = days in base year period 1
dB_2 = days in base year period 2
dB_n = days in base year period n
n = number of base year periods overlapped by guarantee year period

For the HHSC contract, TAC did not employ offset in the calculation of the Adjusted Base Consumption (or Demand). However, offsets are included the savings calculation example in Section II to illustrate how offsets can be used.

4. Other Adjustments

Additional adjustments to the base year may be made to compensate for modifications and additions to a facility or to compensate for changes in how a facility is used. A list of known Causes for Adjustment is shown in the M&V Plan along with means to determine the magnitude of these adjustments.

The total adjustment for any given period will be determined with this equation:

$$M_i = Adj_1 + Adj_2 + \dots Adj_n$$

Where Adj_1, Adj_2 and Adj_n are all of the adjustments determined to be necessary for the guarantee period. The sign of the adjustment will be positive when the change will cause an increase in utility and the sign of the adjustment will be negative when the change will cause a decrease in utility. Upon request, TAC will provide an explanation of the derivation of these adjustments to HHSC.

If additional changes occur, other than those listed in the M&V Plan, TAC will document to HHSC how adjustments will be determined for said changes. Any such adjustment will be added to the term M_i in the equation above.

Both TAC and HHSC must approve adjustments. Either party may reject proposed adjustments by providing a mutually agreeable alternative.

D. Determination of Utility Units Saved

Energy and demand units saved will be determined by the following equation:

$$E = E_B - E_G$$

Where;

E = Utility (or demand) Units Saved
E_B = Adjusted Base Year Consumption
E_G = Guarantee Period Consumption

E. Determination of Utility Dollars Saved

For the purposes of this contract's guarantee, utility dollars saved will be determined as follows:

$$\$ = (\$_B - \$_G) + \$s + \$_M$$

Where:

\$ = Utility Dollars Saved
$\$_B$ = Cost of Adjusted Base Year Utility, for All Fuel Types
$\$_G$ = Cost of Guarantee Period Utility, for All Fuel Types
\$s = Short Term Measurement (Option A) Savings
$\$_M$ = Stipulated Rate Change Savings

The cost of utility in any period will be determined by applying the utility rates, as defined in the M&V Plan.

F. Meter Tuning Summary

The purpose of meter tuning is to evaluate the relationship between utility consumption and demand, as measured by a particular meter, and the variables effecting utility consumption and demand on that meter. The "baseline equation" is the product of the meter tuning process. The coefficients of the baseline equation will be derived using linear regression of consumption against the variables in question. To be included in the baseline equation, the linear regression must meet the following criteria:

1. R^2 for the regression must be greater than 0.75
2. T-statistic for each variable must be greater than or equal to 2.0

The linear regression will be performed using the Metrix utility accounting software available from Abraxas Energy Consulting, which has been accepted as meeting the requirements of the (IPMVP) International Performance Measurement and Verification Protocol. For additional information about the linear regression in this application see the References.

Section II- Savings Calculation Example

This document provides an example of TAC's savings calculation methodology in accordance with Option C, the Whole Meter Method, of the International Measurement and Verification Protocol (IPMVP). This calculation methodology is documented in detail in the Measurement and Verification (M&V) Plan document and is applied to two specific meters at one specific site for illustration and clarification in this document. The site used for this example is CAPS, a 30,401 square foot facility on the Austin State Hospital campus. The electric meter to be used in this example is:

Meter Name	Account Number	Meter Number	Utility Co.	Rate	Units
ASH-CAPS	0632106-1	81655	Austin Energy	State Primary	KWh/kW

A. Meter Tuning Methodology

The method of determining utility savings described in this section uses "Option C – Main Meter Measurement" as described in the International Measurement and Verification Protocol (IPMVP). Utility savings will be calculated for each meter by subtracting the current, actual guarantee-period consumption (or demand) from the adjusted base consumption (or demand) for that meter. This calculation will be made for each billing period and is described by Equation 1 for consumption and Equation 2 for demand.

For Consumption:

(1) $E = E_B - E_G$

For Demand:

(2) $D = D_B - D_G$

Adjusted base year consumption is calculated using Equation 3 for each fuel type:

(3) $E_B = [C_D * (T_i – T_{i-1})] + [C_H * HDD_i] + [C_C * CDD_i] + O_i + M_i$,

Adjusted base year demand is calculated with a slightly different formula as shown in Equation 4:

(4) $D_B = D_D * (T_i – T_{i-1}) + D_H *(HDD_i / (T_i – T_{i-1})) + D_C * (CDD_i / (T_i – T_{i-1})) + O_i + M_i$,

These equations for adjusted base consumption and adjusted base demand seek to answer the question, "how would this meter have performed under the current conditions had no conservation measures been implemented?" The coefficients used in these equations, along with the balance-point temperatures used to calculate the degree-day variables, are determined through a process called “meter tuning.” This process explores the relationship between utility use (consumption or demand) and the variables that drive that use.

This process begins by graphing the variable in question against time. For example, plotting the consumption on Austin Energy Account number 0632106 against time revealed by Figure 1.

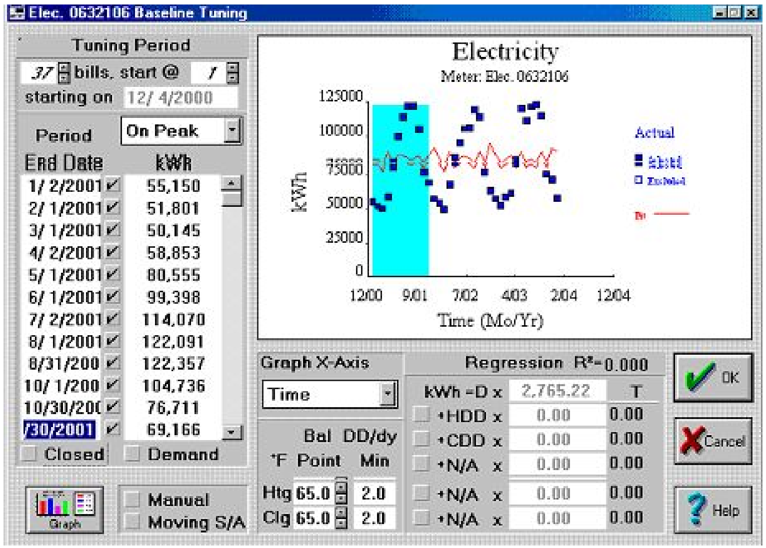

Figure 1. All Consumption Data vs Time

From this plot we can observe that, over the three years of data under consideration, the consumption pattern is similar year to year. Plotting a twelve-month moving sum, as shown in Figure 2, provides another view that verifies this observation.

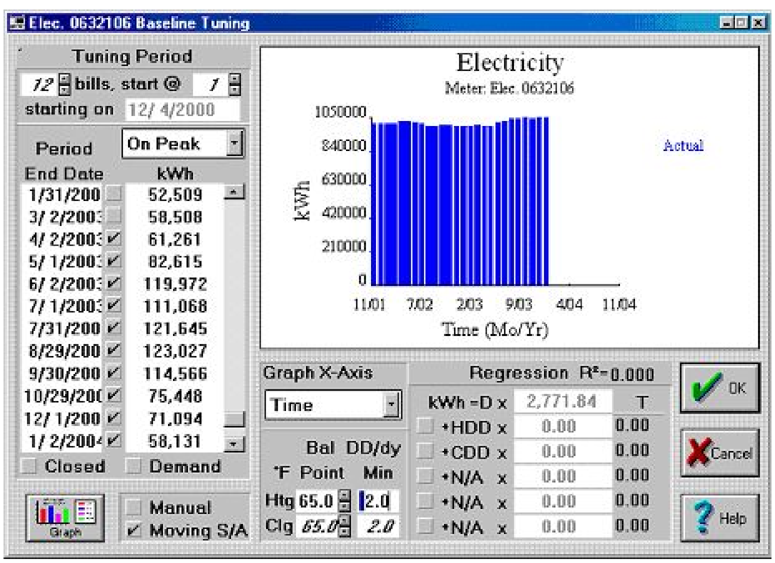

Figure 2. Running 12-Month Sum of Consumption Data

Each bar in the Figure 2 graph represents the sum of consumption over twelve months. If this graph revealed dramatic changes, it would suggest areas for investigation before finalizing the selection of the base year. In this case, no such changes appear, and we have a previously agreed to base year corresponding to the calendar year of 2003.

The next step is to plot consumption against average outside air temperature for each billing period, as shown in Figure 3.

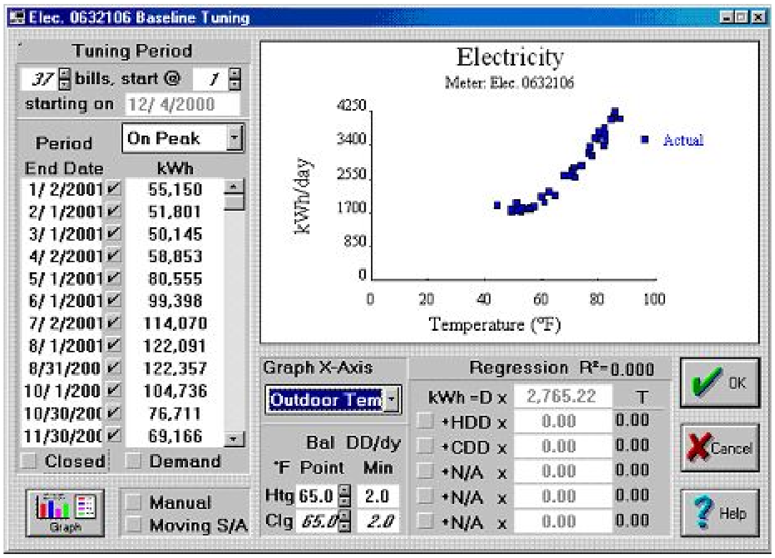

Figure 3. Consumption Data vs Outdoor Air Temperature

From Figure 3, we can observe whether the weather is the primary driving variable, or if there are other significant variables in play. The plot in this case shows a strong, consistent correlation between cooling load and electrical consumption. This correlation persists over the course of all three years included in the data set, indicating that the cooling load is, in fact, the primary driving variable. It is also important to note that this effect dissipates when the average outdoor air temperature is below approximately 60 °F. That means that our choice of a balance point temperature, from which cooling degree-days will be calculated, should be in the neighborhood of 60 °F. Finally, the lack of a strong, consistent negative correlation between consumption and average outside air temperature below 60 °F indicates that there is no significant heating load served by this meter.

To summarize, this cursory survey of the raw utility data available leads to the following conclusions:

- the balance point for the areas served by this meter is around 60 °F
- there is a significant cooling load on this meter, so cooling degree-days should be included as a regression variable
- there is not a significant heating load on this meter, so heating degree-days should not be included as a regression variable

The next step is to plot the data against cooling degree-days per day. This plot is Figure 4.

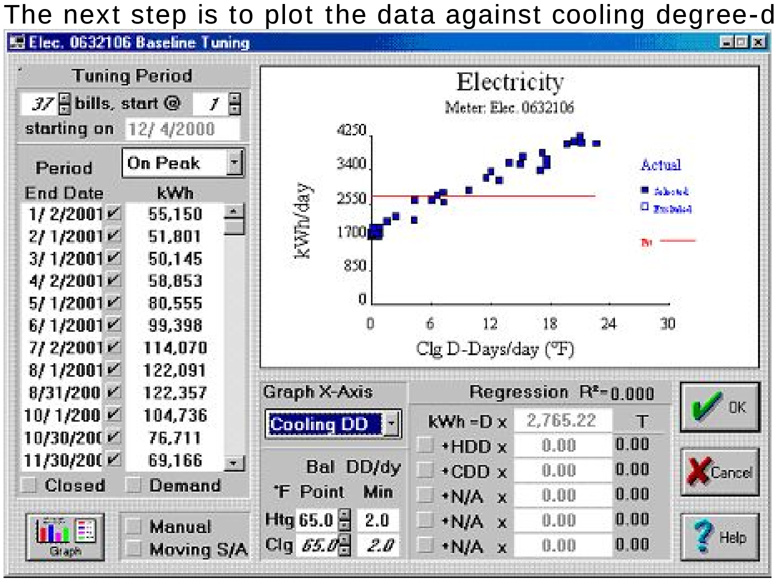

Figure 4. Consumption Data vs Cooling Degree-days per Day

The y-intercept of the implied line in Figure 4 also provides a fair indication of what we should expect C_D, consumption per billing period day constant, to be. In this case, when the tuning is complete, we expect to find C_D around 1,700 kWh per billing period day.

Next we check the "CDD" box, instructing Metrix to perform a linear regression of consumption against cooling degree-days. Doing this, and adjusting the cooling balance point temperature to maximize R^2, produces the result in Figure 5.

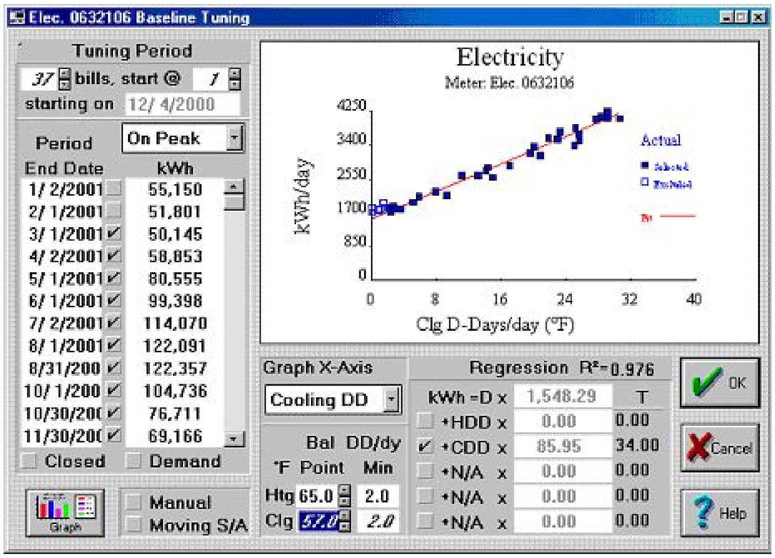

Figure 5. Consumption vs CDD / Day with 57 °F Balance Point Temperature

Our criteria for acceptable tuning are:

1. R^2, which indicates the extent to which the regression explains the variation in consumption, must be greater the 0.75
2. T, which indicates the significance of an individual regression variable, must be greater than 2.0 for each variable included in the regression.

In this case, R^2=0.976 and T_{CDD}=34.00, both of which meet the minimum criteria.

The tuning view pictured in Figure 5 is still considering all 37 available bills. However, our agreed-upon base year is the calendar year 2003. Therefore, we need to restrict the regression to only those twelve bills. The exercise of tuning all available data, however, is necessary to provide a reality check for the ultimate tuning. This helps identify whether in variations peculiar to the base year are affecting the final tuning.

The same settings, applied only to the twelve bills covering the calendar year 2003, are pictured in Figure 6. Here, the value of R^2 increases slightly to 0.983. Note, however, that our daily consumption coefficient, C_D, is 1,413.08 kWh/billing period day, which is lower than the 1,700 kWh/billing period day discussed above.

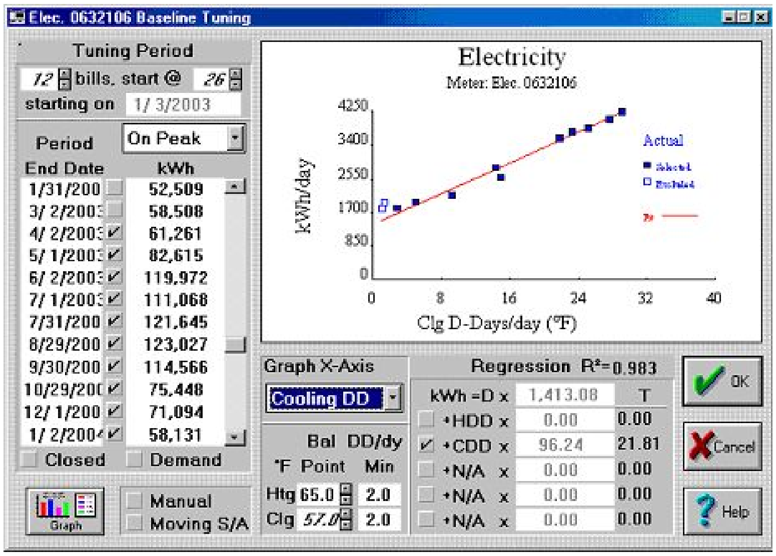

Figure 6. Consumption vs CDD / Day for 12-month Base Period

Readjusting the balance point temperature to maximize R^2 in this case produces Figure 7.

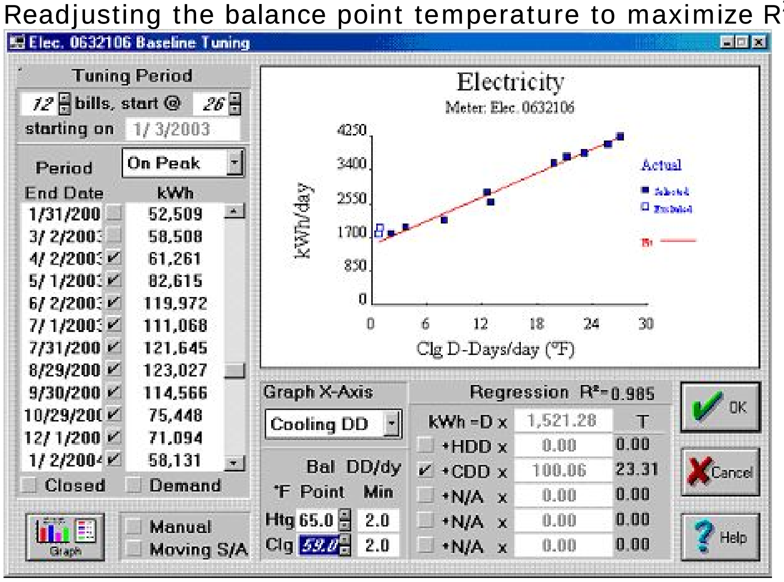

Figure 7. Consumption vs CDD / Day for 12-month Base Period, 59 °F Balance Point

This raises C_D slightly to 1,521.28 kWh/billing period day. This is still lower than seemed appropriate from our initial survey with all the data displayed. Notice that the 1/31/03 and 3/2/03 (ending read date) bills are excluded from the regression equation. This is indicated by the empty check box next to the date in the table on the left, and also by the hollow data points on the graph. These points have been automatically excluded from the regression based on the minimum degree-day per day threshold of 2.0 (set adjacent to the cooling balance point temperature). Changing this to 1.0 and readjusting the balance-point to maximize R^2 yields Figure 8.

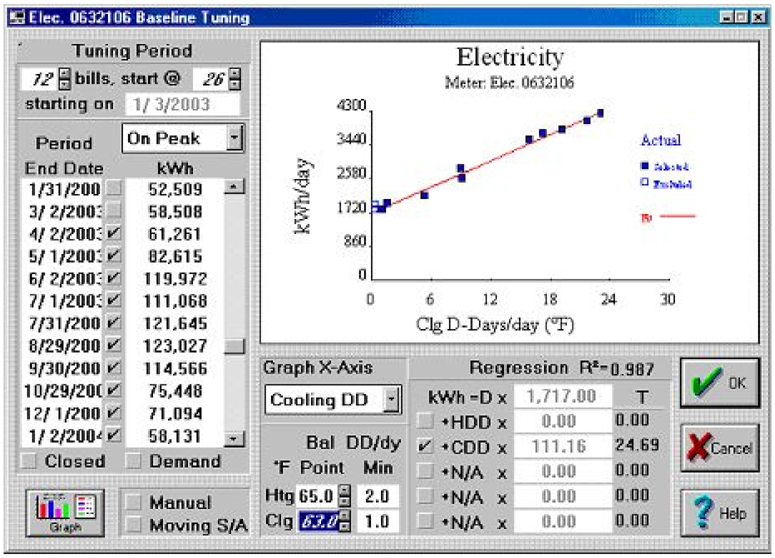

Figure 8. Consumption vs CDD / Day for 12-month Base Period, 63 °F Balance Point

The 1/31/2003 and 3/2/2003 bills are still automatically excluded in this case, but that is appropriate since they have less than 1 cooling degree-day per day in their respective periods. With no need for cooling present, it is better not to force them into a regression that is relating consumption to cooling load.

The tuning above meets the minimum requirements for both R^2 and the T statistic for cooling degree-days. Its daily consumption coefficient, C_D is consistent with the expected value. The final cooling balance-point temperature is in the neighborhood of 60 °F. The only step that remains is to compare this tuning to that including all available data. Figure 9 displays the result.

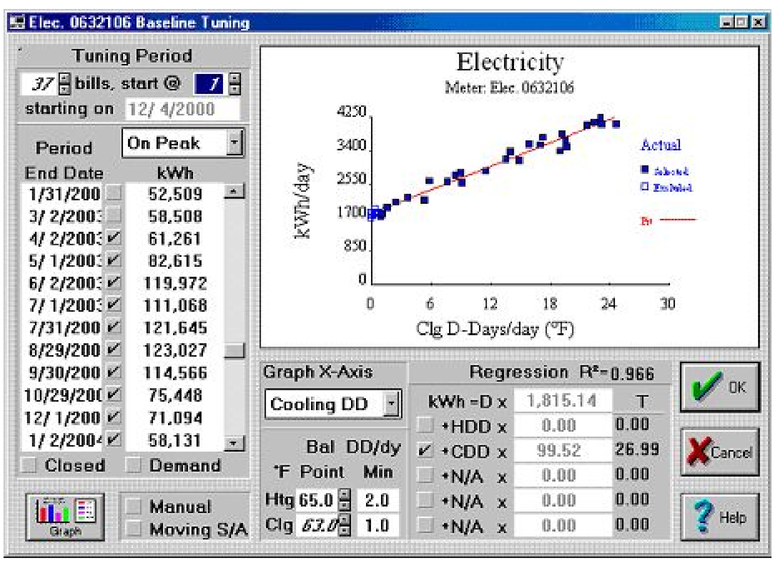

Figure 9. Consumption vs CDD / Day for 37-month Base Period, 63 °F Balance Point

Here, both R^2 and the T statistic are still acceptable and C_D, though higher than the initial guess obtained from Figure 4, is still of the same order of magnitude. The conclusion, then, is that we have arrived at an acceptable tuning.

Equation 5 is the resulting baseline equation.

(3) $E_B = [C_D * (T_i - T_{i-1})] + [C_H * HDD_i] + [C_C * CDD_i] + O_i + M_i$,

Yielding:

(5) $E_B = [1,717 \text{ kWh/day}*(T_i - T_{i-1})]+[0 \text{ kWh/HDD}*HDD_i]+[111.16 \text{ kWh/CDD}*CDD_i]+ O_i + M_i$,

The result of this process is documented in the Metrix "Meter Tuning Report," shown as Tuning Summary 1.

Tuning Summary 1

Project :HHSC Site :HHSC: ASH/CAPS Area: HHSC: ASH/CAPS
Meter: Elec. 0632106 Unit: Qty On-pk (kWh)Account: Austin Energy 0632106

From	To	# Days	Reading	HtgDD	ClgDD	Multiplier	Offset	Baseline	Deviation
1/3/03	1/31/03	29	52,509	451	11	1.0	0	50,960	-2.9%
2/1/03	3/2/03	30	58,508	424	10	1.0	0	52,566	-10.2%
3/3/03	4/2/03	31	61,261	147	49	1.0	0	58,674	-4.2%
4/3/03	5/1/03	29	82,615	23	260	1.0	0	78,695	-4.7%
5/2/03	6/2/03	32	119,972	0	553	1.0	0	116,360	-3.0%
6/3/03	7/1/03	29	111,068	0	557	1.0	0	111,654	0.5%
7/2/03	7/31/03	30	121,645	0	651	1.0	0	123,875	1.8%
8/1/03	8/29/03	29	123,027	0	669	1.0	0	124,159	0.9%
8/30/03	9/30/03	32	114,566	0	507	1.0	0	111,247	-2.9%
10/1/03	10/29/03	29	75,448	11	265	1.0	0	79,250	5.0%
10/30/03	12/1/03	33	71,094	148	176	1.0	0	76,170	7.1%
12/2/03	1/2/04	32	58,131	314	34	1.0	0	58,668	0.9%
Total or Average		**365**	**1,049,844**	**1,517**	**3,739**	**1.0**	**0**	**1,042,276**	**-0.7%** **±3.9%**

Below is the equation used to calculate the Baseline values for the tuning period and all future periods:

Baseline (kWh) = 1,717.00 x #Days + 111.1601 x ClgDD + Offset

This Baseline Equation has a Net Mean Bias of -0.7% and a Monthly Mean Error of ±3.9%. The underlying regression has a R^2=0.987

Explanations and Assumptions:

- HtgDD=Heating Degree-Days calculated for AUSTIN, TX for a 65.0°F balance point.
- ClgDD=Cooling Degree-Days calculated for AUSTIN, TX for a 63.0°F balance point. Periods under 1.0°F-days/day are excluded from regression, but are still used in applying the Baseline Equation.

The actual consumption, listed in the "Reading" column of the above table, and the calculated consumption, listed in the "Baseline" column, are plotted together in Figure 11. The calculated consumption, listed in the "Baseline" column above, is the result of applying the variable data from the base year, listed in the above table, to the Baseline kWh equation on a monthly basis.

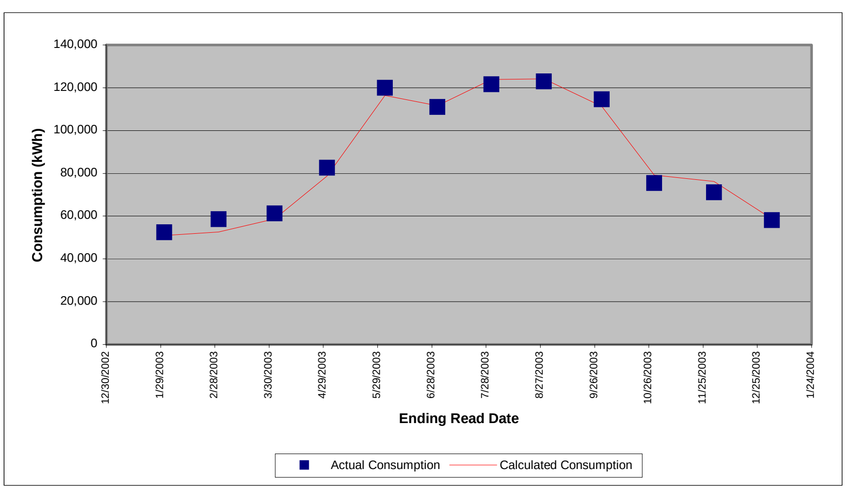

Figure 11. Actual and Adjusted Base Consumption Without Offsets for the 12-month Base Year

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Since the baseline equation was created to model the consumption pattern of the base year, calculating consumption using the same billing period length and weather variables as the base year should produce the same number in the "Baseline" column as in the "Reading" column for a given month. Comparison of the two columns above, however, reveals that this is not the case. The "Deviation" column documents the extent of the difference on percent. The difference is visible on the graph as the distance of each "Actual Consumption" data point from the baseline, "Calculated Consumption," line. These variations are the result of consumption not accounted for by the daily term, the heating load-dependent term, or the cooling load-dependent term of the baseline equation.

The "Offset" term of the baseline equation, O_i, exists to account for these variations. Applying a "Bill Matching" modification to the meter in Metrix generates a series of 12 offsets, one for each billing period in the base year. These offsets are used to force the model to match the actual data exactly. These twelve offset values, like the coefficients of the baseline equation, are then fixed for the life of the project. The savings calculation each month incorporates the appropriate offset from the base year, prorating if necessary to match the current billing period. In using the offsets in this way, we make the following assumptions:

1. Whatever variables produced the variation accounted for in the offset will either:
    a. Continue to occur, or
    b. Be changed by the installation of the resource conservation measures to produce savings.
2. Any randomness (noise) aggregated in the offset will become inconsequential over the 10 to 15 year life of the project.

Applying the bill-matching modification produces the offsets listed below. This addition results in a baseline model that exactly matches the base year source data, as evidenced by the 0% deviation in Tuning Summary 2 and Figure 12.

Tuning Summary 2

Project :HHSC Site :HHSC: ASH/CAPS Area: HHSC: ASH/CAPS
Meter: Elec. 0632106 Unit: Qty On-pk (kWh)Account: Austin Energy 0632106

rom	To	# Days	Reading	HtgDD	ClgDD	Multiplie r	Offset	Baseline	Deviation
1/3/2003	1/31/2003	29	52,509	451	11	1.0	1,548.90	52,509	0.0%
2/1/2003	3/2/2003	30	58,508	424	10	1.0	5,942.06	58,508	0.0%
3/3/2003	4/2/2003	31	61,261	147	49	1.0	2,587.24	61,261	0.0%
4/3/2003	5/1/2003	29	82,615	23	260	1.0	3,920.45	82,615	0.0%
5/2/2003	6/2/2003	32	119,972	0	553	1.0	3,612.12	119,972	0.0%
6/3/2003	7/1/2003	29	111,068	0	557	1.0	-585.54	111,068	0.0%
7/2/2003	7/31/2003	30	121,645	0	651	1.0	-2,230.16	121,645	0.0%
8/1/2003	8/29/2003	29	123,027	0	669	1.0	-1,132.05	123,027	0.0%
8/30/2003	9/30/2003	32	114,566	0	507	1.0	3,319.49	114,566	0.0%
10/1/2003	10/29/200	29	75,448	11	265	1.0	-3,802.36	75,448	0.0%
10/30/200	12/1/2003	33	71,094	148	176	1.0	-5,075.51	71,094	0.0%
12/2/2003	1/2/2004	32	58,131	314	34	1.0	-536.78	58,131	0.0%
Total or Average		**365**	**1,049,844**	**1,517**	**3,739**	**1.0**	**7,567.86**	**1,049,8 44**	**0.0%**

Below is the equation used to calculate the Baseline values for the tuning period and all future periods:

Baseline (kWh) = 1,717.00 x #Days + 111.1601 x ClgDD + Offset

This Baseline Equation has a Net Mean Bias of 0.0% and a Monthly Mean Error of ±0.0%. The underlying regression has a R^2=0.987

Explanations and Assumptions:

- HtgDD=Heating Degree-Days calculated for AUSTIN, TX for a 65.0°F balance point.
- ClgDD=Cooling Degree-Days calculated for AUSTIN, TX for a 63.0°F balance point. Periods under 1.0°F-days/day are excluded from regression, but are still used in applying the Baseline Equation.
- Offset is derived from Modification(s) in effect during the tuning period and is replicated annually for all future periods.

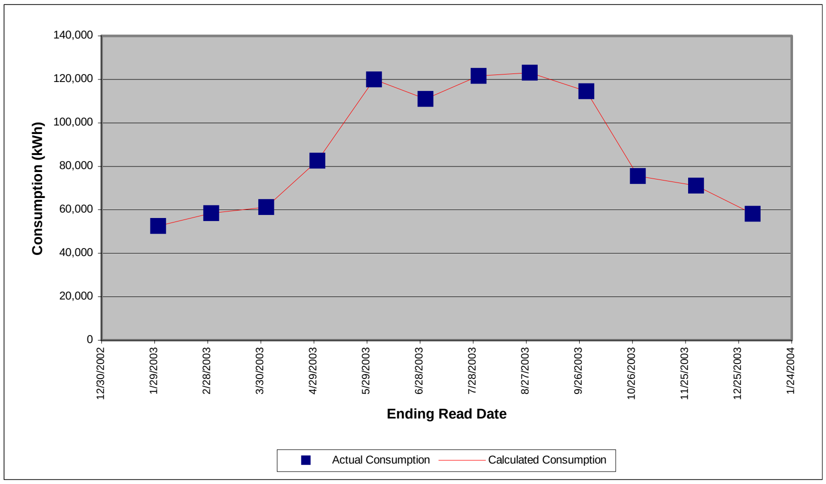

Figure 12. Actual and Adjusted Base Consumption With Offsets for the 12-month Base Year

B. Example Savings Calculation

Having arrived at a baseline equation for consumption, it is now possible to calculate energy savings. Assume that the weather data for this year is the TMY2 data for Austin. For purposes of illustration only, assume the utility data in Table 1.

Table 1. Hypothetical Performance-period Data

Beginning Read Date	Ending Read Date	Days in Billing Period	kWh	KW	HDD (65 °F Bal pt)	CDD (63 °F Bal pt)
1/3/2004	1/31/2004	29	10094.00	88.00	397.65	30.45
2/1/2004	2/29/2004	29	16502.00	43.00	366.50	21.50
3/1/2004	3/31/2004	31	18892.00	92.00	203.00	102.50
4/1/2004	4/30/2004	30	37726.00	133.00	20.00	218.50
5/1/2004	5/31/2004	31	52247.00	141.00	0.00	367.50
6/1/2004	6/30/2004	30	63288.00	128.00	0.00	537.00
7/1/2004	7/31/2004	31	72824.00	127.00	0.00	652.50
8/1/2004	8/31/2004	31	75274.00	141.00	0.00	666.50
9/1/2004	9/30/2004	30	60028.00	151.00	0.00	458.50
10/1/2004	10/31/2004	31	65075.00	130.00	14.00	268.50
11/1/2004	11/30/2004	30	15657.00	122.00	163.00	121.00
12/1/2004	12/31/2004	31	7173.00	57.00	422.00	35.50

Our example savings calculation will be for the billing period from 7/1/2004 through 7/31/2004. Recall that consumption savings is calculated according to Equation 1 is:

(1) $E = E_B - E_G$

Where:

E = Utility Consumption Units Saved
E_B = Adjusted Base Year Consumption
E_G = Current, Actual, Guarantee-Period Consumption

E_G is the simpler of the two terms to determine. It is simply consumption recorded on the utility bill for the billing period in question, which, in this case is 7/1/2004 through 7/31/2004. The consumption recorded on that imaginary bill, from the table above, is 72,824 kWh. The value of E_B requires slightly more work to determine. It arises from the Equation 3:

(3) $E_B = [C_D * (T_i - T_{i-1})] + [C_H * HDD_i] + [C_C * CDD_i] + O_i + M_i$,

Specifically, for this meter the equation is:
(5) E_B = [1,717 kWh/day * ($T_i – T_{i-1}$)] + [0 kWh/HDD * HDD_i] + [111.16 kWh/CDD * CDD_i]+ O_i + M_i,

To calculate E_B, we will address each of the terms. The daily consumption term is:
(6) [1,717 kWh/day * ($T_i – T_{i-1}$)]
Where:
T_i = ending date of current billing period, i = 7/31/2004
T_{i-1} = ending date of previous billing period, i-1 = 6/30/2004

The difference in these two dates reveals a 30-day billing period. Plugging these values into Equation 6 yields:
[1,717 kWh/day * ($T_i – T_{i-1}$)] = [1,717 kWh/day * (7/31/2004 – 6/30/2004)]
= [1,717 kWh/day * 31 days]
= 53,227 kWh

The coefficient for heating load dependent consumption is zero, so that term immediately goes to zero. The cooling load dependent term is calculated as follows:
(7) [111.16 kWh/CDD * CDD_i]

Cooling degree days (CDD) for any billing period are calculated according to Equation 8:

$$(8) \quad CDD_i = \sum_{n=T_{(i-1)}}^{T_i} \left[\left(\frac{HiTemp_n + LowTemp_n}{2} \right) - BalPtTemp_{clg} \right]^+$$

Where:
$HiTemp_n$ = High temperature for day *n* between T_{i-1} (7/31/04) and T_i (6/30/04)
$LowTemp_n$ = Low temperature for day *n* between T_{i-1} (7/31/04) and T_i (6/30/04)
$BalPtTemp_{clg.}$ = Cooling Balance Point Temperature = 63 °F.
NOTE: only values greater than 0 are included in the summation

The result is that there are 652.5 cooling degree-days in this billing period, so Equation 7 becomes 72,531.9 kWh

The offset term, O_i, is shown in Table 2:

Table 2. Monthly Offset Values in Base Year

From	To	# Days	Offset	Offset/Day
1/3/2003	1/31/2003	29	1,548.90	53.41
2/1/2003	3/2/2003	30	5,942.06	198.07
3/3/2003	4/2/2003	31	2,587.24	83.45
4/3/2003	5/1/2003	29	3,920.45	135.17
5/2/2003	6/2/2003	32	3,612.12	112.88
6/3/2003	7/1/2003	29	-585.54	-20.21
7/2/2003	7/31/2003	30	-2,230.16	-74.33
8/1/2003	8/29/2003	29	-1,132.05	-39.03
8/30/2003	9/30/2003	32	3,319.49	103.72
10/1/2003	10/29/2003	29	-3,802.36	-131.10
10/30/2003	12/1/2003	33	-5,075.51	-153.82
12/2/2003	1/2/2004	32	-536.78	-16.78
Total or Average		**365**	**7,567.86**	

The current billing period for which we need an offset is 6/30/04 through 7/31/04. However, the July billing period in the base year is 7/2/03 through 7/31/03. To accommodate this difference, we simply use the offset per day from the pertinent base year billing periods and multiply it by the number of current-year days in that billing period, as describe by Equation 9.

(9) $O_i = O_1 * dG_1/dB_1 + O_2 * dG_2/dB_2 + ... O_n * dG_n/dB_n$

Which yields:

$$O_i = \left[O_1 * \frac{dG_1}{dB_1}\right] + \left[O_2 * \frac{dG_2}{dB_2}\right] = \left[-586\text{kWh} * \frac{1\text{days}}{29\text{days}}\right] + \left[-2{,}230\text{kWh} * \frac{30\text{days}}{30\text{days}}\right]$$
$$= \left[-586\ \text{kWh} * 0.03448\right] + \left[-2{,}230.16\ \text{kWh} * 1\right] = -20.2069 - 2{,}230.16 = -2{,}250.37$$

Recall that the objective here is to calculate the adjusted base consumption, E_B. This is given by the Equation 3:

(3) $E_B = [C_D * (T_i - T_{i-1})] + [C_H * HDD_i] + [C_C * CDD_i] + O_i + M_i$,

At this point, there are no other adjustments, so:
(10) $M_i = 0$

Yielding:
(5) $E_B = [1{,}717 \text{ kWh/day} * (T_i - T_{i-1})] + [0 \text{ kWh/HDD} * HDD_i] + [111.16 \text{ kWh/CDD} * CDD_i] + O_i + M_i$,

Which, substituting all the values just calculated, becomes:
$E_B = [1{,}717 \text{ kWh/day} * 31 \text{ days}] + [0 \text{ kWh/HDD} * HDD_i] + [111.16 \text{ kWh/CDD} * 652.5 \text{ CDD}] + -225$
kWh + 0
= 123,508.55 kWh

We can now return to the initial savings calculation
(1) $E = E_B - E_G$

Substituting the 123,508.55 kWh – 72,824 kwh
= **50,685 kWh Saved**

The dollar savings resulting from this energy savings is the subject of a separate document.

References

IPMVP 2001. IPMVP Committee, *International Performance Measurement & Verification Protocol: Concepts and Options for Determining Energy and Water Savings*, Vol. 1, U.S. Dept. of Energy, DOE/GO-102001-1187, 86 pp., January.

Sonderegger, Robert C, Ph.D., 1998. *A Baseline Model for Utility Bill Analysis Using Both Weather and Non-Weather-Related Variables*, ASHRAE Transactions, paper #TO-98-12-2