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SAMPLE M&V PLAN FROM THE TEXAS WORKSHOP: *"PREPARING AND EVALUATING MEASUREMENT AND VERIFICATION PLANS FOR ENERGY PERFORMANCE CONTRACTS IN TEXAS"*

Sponsored by

the Texas Energy Coordinating Council (TECC)
and
the Texas General Services Commission
State Energy Conservation Office (SECO)

Presented by

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PREFACE

This document contains a sample M&V plan that has been prepared in accordance with the Texas Guidelines for Measurement and Verification for Energy Performance Contracts. This sample M&V plan was extracted from the March 1999 workshop, entitled: "Preparing and Evaluating Measurement and Verification Plans for Energy Performance Contracts in Texas", Sponsored by the Texas was developed by the Texas State Energy Coordinating Council, and the General Services Commission, State Energy Conservation Office. The M&V plan represents an actual Performance Contract that was approved by the TECC/SECO.

This document is a public domain document that is intended to serve as an example document of an M&V plan. Certain manufacturer's trade names are mentioned in this document for the purpose of describing the types of equipment used to measure energy use. Such reference does not constitute an endorsement or recommendation of such equipment, and is provided for informational purposes only.

Description of sample M&V plan.

The sample M&V plan begins with a table of contents that contains the material that is required to be in the M&V plan in accordance with the Texas Guidelines.

Following this table of contents is an Introduction section that provides a narrative that describes what is contained in the M&V plan. In this narrative specific information is mentioned about the type of Performance Contract, retrofits, etc. The Introduction also contains important information about the baseline period and post retrofit period. It contains an important table that relates the Energy Conservation Retrofit Measures (ECRMs) with the metering and analysis methods. This is followed by a narrative about the instrumentation and estimated costs.

There are also several tables in the Introduction that contain the cost information about the Performance Contract as it pertains to the M&V and cost of M&V for the life of the contract. The dollar values have been removed from this table for the purpose of protecting the participants in the actual Performance Contract that this applies to.

The instrumentation accuracy in the table is an important feature since it can be used to determine the uncertainty of the M&V plan using the equations provided by ASHRAE's Guideline 14.

The electrical, chilled water, hot water and domestic water monitoring diagrams are an important feature of the M&V plan since this gives the reader a visual understanding of the placement of meters, etc. with regard to building locations, etc.

The primary equation that is used to calculate savings is given by

$$\begin{aligned} Savings_{Total} = {} & Savings_{Campus\ Electricity} + Savings_{Swim\ Center/Facilities\ Bldg\ Electricity} \\ & - Increases_{Thermal\ Plant\ Electricity} - Increases_{Thermal\ Plant\ Gas} + Savings_{Purchased\ CHW} \\ & + Savings_{Purchased\ HW} - Increases_{Thermal\ Plant\ Domestic\ Water} - Increases_{O\&M} \end{aligned}$$

This equation is the heart of the M&V plan and every term in the equation must be explained and understood by all parties for the M&V plan to work properly. This equation contains (+) positive and (-) negative values that represent costs or savings expected from the retrofits. Operation and maintenance savings are also included.

Construction and checking of every term in this equation is a painstaking process that is vital to the integrity of the M&V plan. For example, the "$Savings_{Campus\ Electricity}$" term is explained by another set of equations:

$$\$E_{Pre\ Campus} = (E_{Pre\ Campus\ Weekday,\ kWh} + E_{Pre\ Campus\ Weekend,\ kWh}) * Rate_{Campus\ Baseline,\ kWh} + (E_{Pre\ Campus,\ kW} * Rate_{Campus\ Baseline,\ kW})$$

$$\$E_{Post\ Campus} = (E_{Post\ Campus,\ kWh} - E_{Post\ Campus\ New\ Bldg,\ kWh} - E_{Campus\ Adjust,\ kWh} - E_{Post\ Campus\ New\ BuildingCHW,kWh}) * Rate_{Post\ Campus,\ kWh}$$

$$\$Savings_{Campus\ Electricity} = \$E_{Pre\ Campus} - \$E_{Post\ Campus}$$

In this set of equations, the basic savings are calculated using the Option C, before-after calculation technique. "$\$E_{Pre\ Campus}$" is basically a set of weekday-weekend 24 hour profiles that are multiplied by electric rate plus the pre-retrofit campus demand time the corresponding demand rate. A sample description of the profiles is provided and the method used to calculate the profiles is also included.

In general, in each equation, all values are provided and an example equation so that someone reading the equation can actually calculate a sample value. This same format is followed for each of the values in the main equation.

Adjustments to the equations are also provided where a reasonable method for calculating the adjustments can be provided. Otherwise, a place holder is provided where a "future" adjustment will be proposed and approved.

It is the intent that this document will provide enough information so that a knowledgeable person can read and understand how to construct an M&V plan that is in compliance with the Texas Guidelines. Questions regarding this document can be forwarded to: Jeff S. Haberl Ph.D. P.E., Associate Professor, Energy Systems Laboratory, Department of Architecture, Texas Engineering Experiment Station, Texas A&M University System, College Station, TX, 77843-3581, ph# 979-845-6065, fax#979-862-2457, jhaberl@tamu.edu, http://www-esl.tamu.edu.

EXAMPLE SAVINGS CALCULATION METHODOLOGY.

The material contained in this section of the report is an M&V plan that is provided as an example of the proper format and detail that is expected from an M&V plan that is meant to comply with the Texas M&V Guidelines. It contains actual equations and language that was extracted from an M&V plan for an ESPC performed on a large university campus in Texas. Specific names and references have been removed to allow for this document to be freely distributed as an example.

Introduction.

The proposed M&V plan was developed to provide substantial proof that implementation of the performance contract provides the savings guaranteed in the contract. The plan was developed following the guidelines for monitoring energy savings from performance contracts as presented in the Draft Texas State Performance Contracting Guidelines. A sample quarterly report to be submitted to the Facility Owner and third party audit firm has been developed and is attached for review.

Energy metering equipment will be installed at the University to measure energy usage during the Post-Retrofit period. Data from this metering equipment will be logged by a data logger/EMCS and reviewed weekly. It will be used to calculate utility cost savings, ensure efficient operation, identify potential O&M opportunities, and make adjustments to the calculated baseline energy usage when appropriate.

Baseline costs are calculated by applying utility rates during the baseline period to the predicted baseline usage. The usage is predicted based on statistical models developed using baseline period utilities usage. Baseline adjustments will be made to the predicted baseline usage when warranted to account for new construction, extended operating schedules, and changes in building use. A discussion of the baseline adjustment procedure and required approval process is provided in Section XXX. These baseline costs represent the predicted cost of utilities assuming the ECRMs had not been constructed.

Baseline Period Operations

Chilled water and hot water was produced at the Central Plant and a small Satellite Plant during the baseline period. The Central Plant was operated by the Utility Company where chilled water and high temperature hot water was produced and sold to the University.

The satellite plant was operated by XXX during the baseline period. The plant served the special events center and two other classroom buildings. No energy metering equipment was installed on this satellite plant and no historical energy usage data is available.

The campus electrical load was served by the XXX Electric Company. Campus electricity costs were paid by the Central plant electricity costs were paid by the XXX Electricity Company.

Baseline period Energy Consumption

Electricity, natural gas, domestic water, and personnel costs to operate the Central Plant during the baseline period were paid by the XXX Energy Company and are not addressed in this plan. Statistical regression models for central plant chilled water and high temperature hot water purchased by XXX have been generated to identify baseline period usage. These daily models were developed using 12 months of historical hourly consumption data during the base year (Sept 1995 – Oct 1996) and average hourly temperatures from the National Weather Service, XXX Airport weather station. These models are used to project baseline utilities usage into the post-retrofit period.

Base year campus electricity usage has been obtained from the XXX Electric Company. Electrical consumption (kWh) for each 30-minute time interval during the base year was provided and summed to hourly data. Peak and off-peak demand for each monthly billing period was also provided. Statistical models of hourly electricity consumption have been developed using this data to project the baseline campus electrical usage into the post-retrofit period. The campus electrical load includes the loads resulting from satellite plant operations.

The satellite plant domestic water consumption and boiler gas consumption during the base year were not metered and are not available. These utilities have been estimated using a Trane TRACE simulation model of the buildings served by the plant.

Post-Retrofit Period Operations

XXX has taken over the operation of the Central Plant from the XXX Energy Company and will no longer purchase chilled water and hot water. XXX will purchase electricity, water, and natural gas to produce chilled and hot water, and provide personnel to operate both thermal plants.

Two of the four pre-retrofit chillers will be removed from the Central Plant as part of this project. The two chillers that remain will be operated only during emergency or abnormal operating conditions, and during weekend periodic maintenance intervals. New chillers will be installed and located near the existing Satellite Plant location. New chilled water piping will be installed to connect these new chillers to the existing campus chilled water loop. All campus cooling loads will be satisfied by these new chillers.

The existing high-temperature high-pressure boilers located at the Central Plant will continue to serve the buildings located on the existing central plant hot water loop. The existing boilers located at the Satellite Plant will continue to serve the buildings located on the existing satellite plant hot water loop.

The Satellite Plant will be removed from the campus electric load. A new transformer will be installed to serve the new chillers and accessory equipment at the Satellite Plant. The new Cool Storage time-of-day electric rate will be applied to both the Central Plant and Satellite Plant electric consumption.

ENERGY METERING EQUIPMENT AND ESTIMATED COSTS

The performance contract consists of the following ECRMs. The metering equipment used to measure the utility usage for each ECRM is also presented.

ECRM	METERING EQUIPMENT*
1) Installation of new chillers to cool the entire campus 2) Installation of Chilled Water Thermal Energy Storage Tank	1) Satellite Plant Electric Meter 2) Central Plant Electric Meter 3) Chilled water flow & temperatures on Campus feed 4) Chilled water flow & temperatures on new Chillers 5) Domestic Water Meters
3) Retrofit of Boilers	1) Central Plant Gas Meter 2) Satellite Plant Gas Meter 3) Domestic Water Meters 4) Hot water flow & temperatures on Central Plant Boilers 5) Hot water flow & temperatures on Satellite Plant Boilers
4) Building chilled water loop modifications including variable speed pumping.	1) Campus Electric Meter 2) Central Plant Electric Meter 3) Satellite Plant Electric Meter

* Weather data is hourly temperature from the NWS,- XXX Airport Weather Station

Table xxx Listing of ECRMs and Proposed Metering to Capture Savings

Instrumentation and Estimated Costs

The installation of energy metering equipment will occur during the construction phase of the project. A data logger/EMCS will trend data from the energy metering devices at hourly intervals. These data will be retrieved weekly and reviewed.

The XXX EMCS will trend signals from the proposed energy metering equipment. A Synergistic Control Systems data logger will be installed in parallel with the EMCS in an effort to demonstrate that the EMCS is capable of accurately recording time-series energy usage data. Recorded energy usage from both systems will be compared and presented to THECB and SECO along with documentation of logger configuration and data channel types. Upon successful demonstration of the EMCS capabilities, the Synergistics Control Systems data logger will be removed and used on other energy metering projects.

Hourly outdoor air temperature data will be purchased from the National Weather Service, XXX Airport weather station. The planned metering points, metering equipment required and estimated installation costs are presented in Table xxx

Manufacturer's specifications on the chilled and hot water flow sensors are presented in Table A summary of the total estimated metering costs are presented in Table

Energy monitoring diagrams for the electrical, chilled water, and hot water systems are presented in Figures xxx ,and xxx respectively on the following pages. These diagrams show the locations of the planned metering equipment and the type of output signal provided to the data logger/EMCS.

Description	Equipment Required	Output Signal	Metering Equipment Cost	Installation T&M	Data Acquisition Hardware Cost
Main Campus kWh	City Utility Meter	Contact Pulse			
Central Plant kWh (feeds standby chillers, MCCs)	City Utility Meter	Contact Pulse			
Central Plant Heating Water					
HW Flow	Ultra-Sonic Flow Meter	4-20 ma			
HW Supply Temp	500 ohm RTD/Xmittr	4-20 ma			
HW Return Temp	500 ohm RTD/Xmittr	4-20 ma			
Central Plant Gas (feeds boilers)	City Utility Meter	Contact Pulse			
Satellite Plant kWh					
4160V Feed (3 Chillers)	City Utility Meter	Contact Pulse			
480V MCCs Subfeed (pumps, cooling towers, lighting)	Watt-Hour Meter	Contact Pulse			
Satellite Plant Heating Water					
HW Flow	Insertion Flow Meter	4-20 ma			
HW Supply Temp	100 ohm RTD/Xmittr	4-20 ma			
HW Return Temp	100 ohm RTD/Xmittr	4-20 ma			
Satellite Plant Gas (feeds boilers)	City Utility Meter	Contact Pulse			
Satellite Plant CHW					
CHW Flow	Insertion Flow Meter	4-20 ma			
CHW Supply Temperature	100 ohm RTD/Xmittr	4-20 ma			
CHW Return Temperature	100 ohm RTD/Xmittr	4-20 ma			
Chilled Water Supply to Campus					
CHW Flow	Insertion Flow Meter	4-20 ma			
CHW Supply Temperature	100 ohm RTD/Xmittr	4-20 ma			
CHW Return Temperature	100 ohm RTD/Xmittr	4-20 ma			
Central Plant Data Logger	Synergistics C120EANI /Signal Splitters	Modem			
Satellite Plant Data Logger	Synergistics C140EANI /Signal Splitters	Modem			
TOTALS					

Table xxx Planned Metering Equipment and Estimated Costs

Description	**Model**	**Flow Range**	**Accuracy**
Insertion Flow Meter	Data Industrial 225B with Transmitter	1-30 feet/sec	+/- 1% Full Scale
Ultra-Sonic Flow Meter	Pana-Metrics DF868	1-40 feet/sec	2% of Reading
City Gas Meters	Pressure and Temperature corrected		

Table xxx Manufacturer's Flow Meter Specifications

Notes:

1) An Ultra-Sonic flow meter was selected for use on the High Temperature Hot Water feed at the Center Plant. The harsh operating conditions (350°F) make the less expensive Data Industrial flow sensor unsuitable for use (221°F max).

2) Both the Synergistic Controls Data Logger and the xxx EMCS are capable of calculating chilled and hot water production rates using the flow and temperature sensors.

A summary of the total estimated monitoring costs are shown below:

Description	Cost	Comments
Metering Equipment		
Installation		
Data Acquisition Hardware		
EMCS Programming		
National Weather Service Hourly Data		
Verification of Metering Instrumentation		
Project Management (labor, travel, etc) labor travel		
TOTAL		

Table xxx Total Estimated Metering Equipment Installation Costs

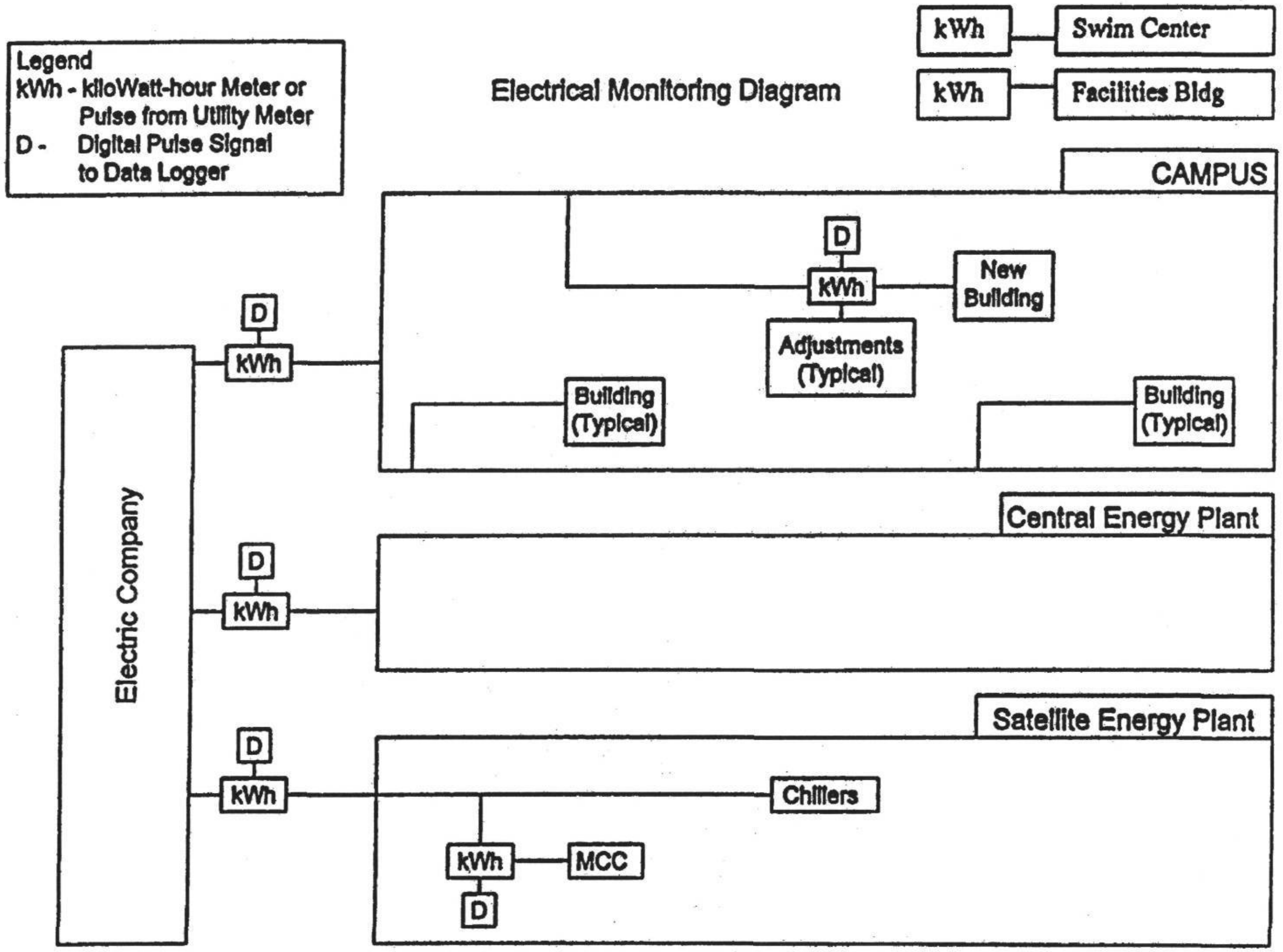

Figure Electrical Monitoring Diagram

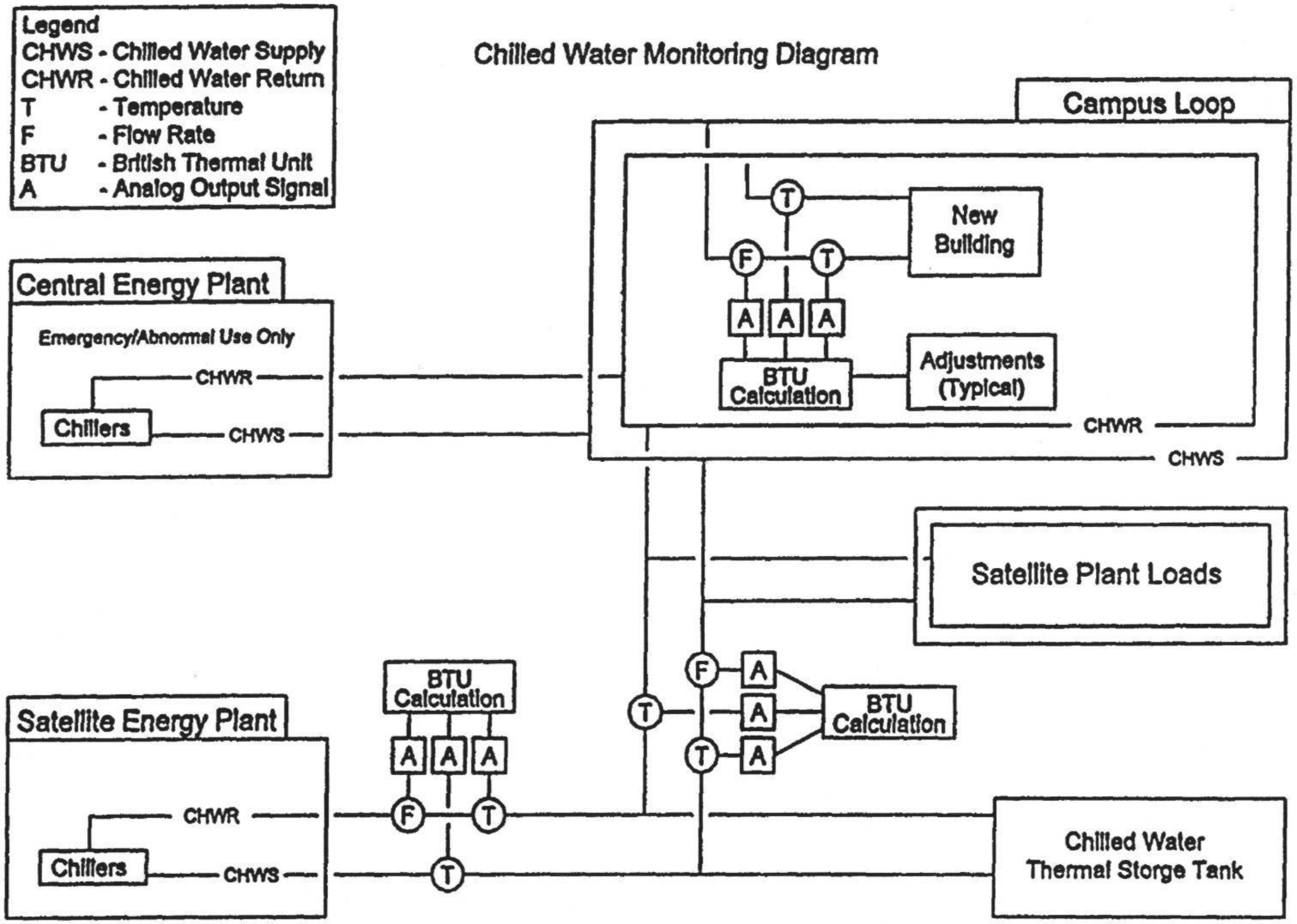

Figure Chilled Water Monitoring Diagram

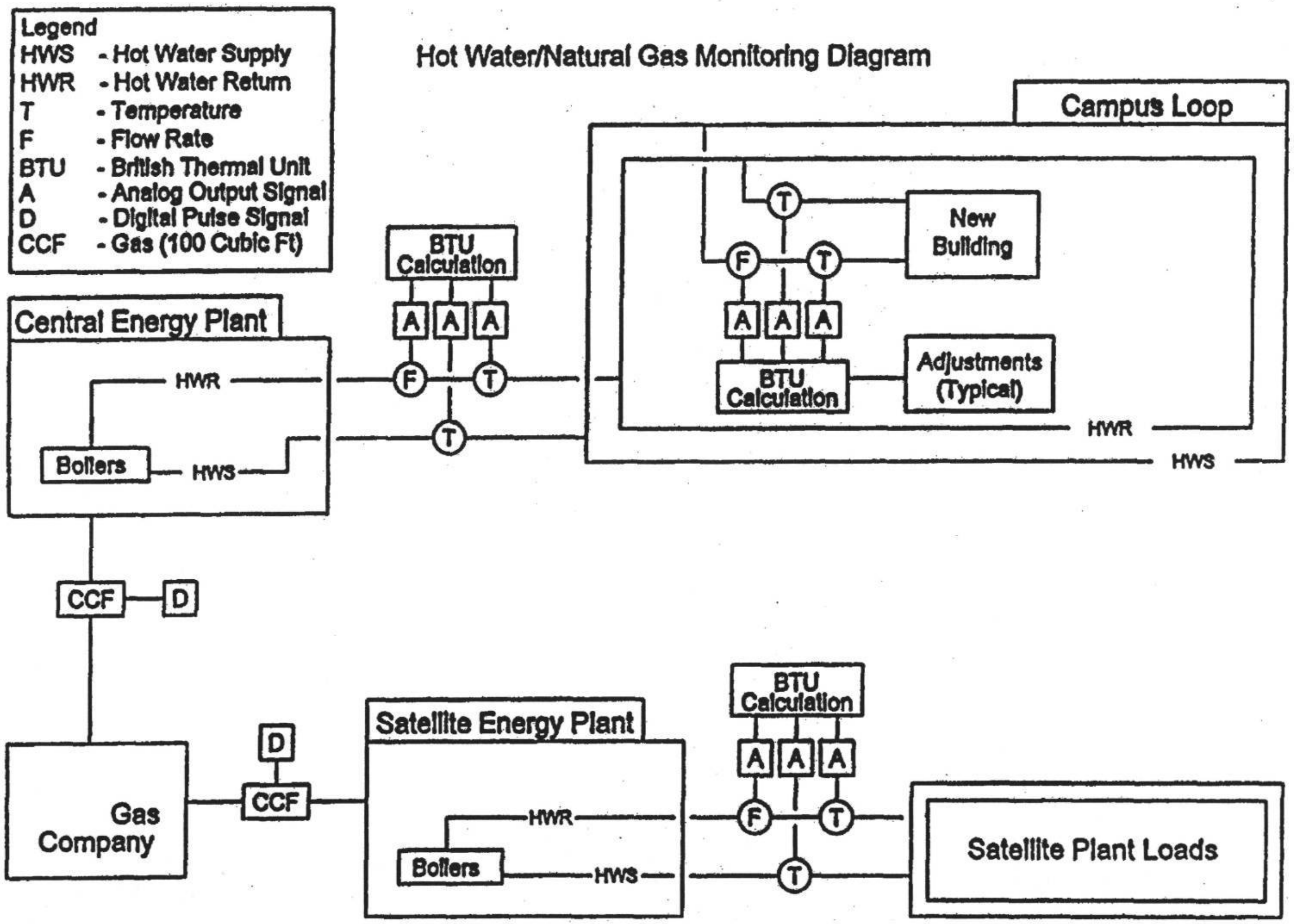

Figure Hot Water Monitoring Diagram

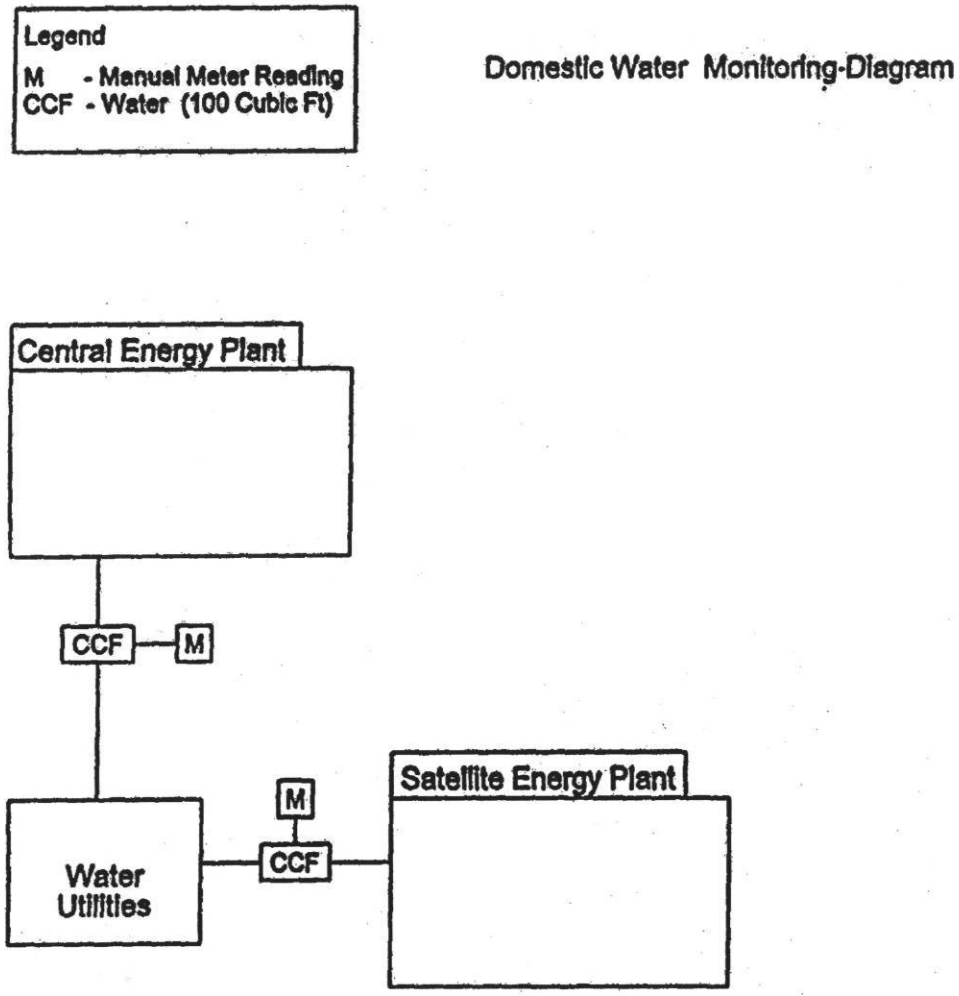

Figure Domestic Water Monitoring Diagram

Verification Plan, Instrumentation Maintenance, and Estimated Costs

Costs for implementing the verification and maintenance portion of the plan are presented below.

Instrumentation Inspection, Maintenance, and Re-Calibration Costs

Description	10 Year Cost	Procedure
Campus CHW Flow Sensor		Inspect Annually Calibration Expense (Bi-Annually) Failed Sensor Replacement Expense/Maintenance
Campus CHW Temperature Sensors		Inspect Annually Calibration Expense (Bi-Annually) Failed Sensor Replacement Expense/Maintenance
Satellite Chillers CHW Flow Sensor		Inspect Annually Calibration Expense (Bi-Annually) Failed Sensor Replacement Expense/Maintenance
Satellite Chillers CHW Temp Sensors		Inspect Annually Calibration Expense (Bi-Annually) Failed Sensor Replacement Expense/Maintenance
Satellite Plant Hot Water Flow Sensor		Inspect Annually Calibration Expense (Bi-Annually) Failed Sensor Replacement Expense/Maintenance
Satellite Plant Hot Water Temp Sensors		Inspect Annually Calibration Expense (Bi-Annually) Failed Sensor Replacement Expense/Maintenance
Central Plant Hot Water Flow Sensor		Inspect Annually Failed Sensor Replacement Expense/Maintenance
Central Plant Hot Water Temp Sensors		Inspect Annually Calibration Expense (Bi-Annually) Failed Sensor Replacement Expense/Maintenance
Satellite Plant 480V Watt-Hour Meter		Inspect Annually
Metering Equipment Troubleshooting		hours/year
Weekly Collection & Review of Utilities Usage Data Preparation of Weekly, Monthly, Quarterly and Annual Reports		
Project Management Labor Travel, Misc		hours/year
TOTAL		

Maintenance and Calibration of Energy Metering Equipment

Many of the meters used to verify savings are city-owned utility meters. Maintenance and calibration of these city-owned utility meters are not included in this performance contract. The chilled water and hot water flow sensors and temperature sensors, and satellite plant watt-hour meter will be inspected annually. New flow sensors will be purchased with calibration certificates indicating successful calibration using a NIST-traceable procedure. The satellite plant chilled water flow sensors and hot water flow sensor will be re-calibrated every two years. The ultra-sonic flow meter on the high temperature hot water system will be inspected annually by performing manufacturer recommended diagnostic procedures. Inspections will consist of a visual inspection of signal wiring, an accuracy check comparing sensor readings to readings from NIST-traceable calibrated portable metering equipment, and the weekly inspection of collected data polled from the data logger/EMCS. Sensor failures will be identified during the weekly inspection of trend log data from the data logger/EMCS.

VERIFICATION PLAN

The verification process consists of utilities usage data collection, calculation of cost savings, and periodic reportings of project performance to the Owner and third party audit firm ( ).

Measurement of Utilities Usage

Data from the data logger/EMCS will be polled on a weekly basis and stored in an ASCII flat file for analysis. Data from multiple weeks will be merged to create monthly datasets. Utility bills will be collected monthly.

Calculation of Total Savings

Cost savings will be determined for each utility. The overall project savings will be the sum of the savings/increases from each utility minus operational and maintenance cost increases.

$$\begin{aligned} \text{Savings}_{\text{Total}} = {} & \text{Savings}_{\text{Campus Electricity}} + \text{Savings}_{\text{Swim Center/Facilities Bldg Electricity}} \\ & - \text{Increases}_{\text{Thermal Plant Electricity}} - \text{Increases}_{\text{Thermal Plant Gas}} + \text{Savings}_{\text{Purchased CHW}} \\ & + \text{Savings}_{\text{Purchased HW}} - \text{Increases}_{\text{Thermal Plant Domestic Water}} - \text{Increases}_{\text{O\&M}} \end{aligned}$$

Guaranteed Monthly Savings

The savings estimated in the Energy Assessment Report depend on outdoor weather conditions and vary each month. A percentage of total savings for each month has been developed and is listed below. These percentages will be applied to the annual guaranteed savings when developing the quarterly savings reports.

Month	Percentage of Total Annual Savings
January	5.7%
February	6.5%
March	6.7%
April	7.7%
May	9.1%
June	10.5%
July	10.7%
August	10.1%
September	9.5%
October	9.1%
November	7.7%
December	6.6%
TOTAL	100.0%

Reporting

Quarterly reports of measured savings will be submitted to the Owner, third party audit firm ( ), and for information only, the Texas Energy Coordination Council and the State Energy Conservation Office. The reports will be presented in printed and electronic format. The data collected from the data logger and purchased from the National Weather Service will also be provided. An annual reconciliation report will be presented to the Owner. A sample quarterly report has been developed and is attached for review.

SAVINGS CALCULATION METHODOLOGY

The savings resulting from the combined effect of all ECRMs will be determined by summing the savings or subtracting the increases from each utility service minus operational and maintenance increases due to xxx plant operations as shown in Equation 6.0.1 below.

$$Savings_{Total} = Savings_{Campus\ Electricity} + Savings_{Swim\ Center/Facilities\ Bldg\ Electricity} + Savings_{Purchased\ CHW} - Savings_{Purchased\ HW} - Increases_{Thermal\ Plant\ Electricity} - Increases_{Thermal\ Plant\ Gas} \; Increases_{Thermal\ Plant\ Domestic\ Water} - Increases_{O\&M}$$

Equation 6.0.1 Total Savings Equation

The calculation methodology for each utility service is presented in this section.

Campus Electricity

Related ECRMs: Savings will result from a Cool Storage Electric Rate from the Electric Company for installing the Thermal Energy Storage system. Pumping energy on the building chilled water pumps will be reduced by installing variable speed pumping. Thermal plant consolidation will also reduce campus electrical energy usage.

Electricity Cost Savings: Saving are the predicted Pre-Retrofit baseline campus electricity cost minus the measured Post-Retrofit period campus electricity cost as shown in the following equations:

$$\$E_{Pre\ Campus} = (E_{Pre\ Campus\ Weekday,\ kWh} + E_{Pre\ Campus\ Weekend,\ kWh}) * Rate_{Campus\ Baseline,\ kWh} + (E_{Pre\ Campus,\ kW} * Rate_{Campus\ Baseline,\ kW})$$

$$\$E_{Post\ Campus} = (E_{Post\ Campus,\ kWh} - E_{Post\ Campus\ New\ Bldg,\ kWh} - E_{Campus\ Adjust,\ kWh} - E_{Post\ Campus\ New\ BuildingCHW,kWh}) * Rate_{Post\ Campus,\ kWh}$$

$$\$Savings_{Campus\ Electricity} = \$E_{Pre\ Campus} - \$E_{Post\ Campus}$$

where

$E_{Pre\ Campus\ Weekday,\ kWh}$ = Monthly predicted baseline campus weekday electric consumption (kWh)

$E_{Pre\ Campus\ Weekend,\ kWh}$ = Monthly predicted baseline campus weekend electric consumption (kWh)

$Rate_{Campus\ Baseline,\ kWh}$ = Campus electric baseline consumption utility rate ($/kWh)

$E_{Pre\ Campus,\ kW}$ = Predicted monthly On-Peak baseline electric demand (kW)

$Rate_{Campus\ Baseline,\ kW}$ = Campus electric baseline demand utility rate ($/kWh)

$\$E_{Pre\ Campus}$ = Predicted pre-retrofit Campus electricity cost

$E_{Post\ Campus,\ kWh}$ = Measured monthly post-retrofit campus electric consumption (kWh)
$E_{Post\ Campus\ New\ Bldg,\ kWh}$ = Campus consumption of metered new buildings (kWh)
$E_{Post\ Campus\ New\ BldgCHW,kWh}$ = Electrical consumption of additional chilled water production for new buildings at a plan kW/ton rate to be reported quarterly (kWh)
$E_{Campus\ Adjust,\ kWh}$ = Monthly baseline adjustments to campus electric consumption (kWh)
$Rate_{Post\ Campus,\ kWh}$ = Campus electric consumption rate at time of construction ($/kWh)
$\$E_{Post\ Campus}$ = Post-retrofit campus electricity cost
$\$Savings_{Campus\ Electricity}$ = Calculated campus electricity cost savings

<u>Electricity Rate Structure During Baseline Period:</u>
The electricity rate during the baseline period is as follows:

$Rate_{Campus\ Baseline,\ kWh}$ = $0.03269 per kWh
$Rate_{Campus\ Baseline,\ kW}$ = $19.25 per kW

<u>Electricity Rate Structure at Time of Construction:</u>
The electricity rate at time of construction is listed below:

$Rate_{Post\ Campus,\ kWh}$ = $0.0565 per kWh

<u>Pre-Retrofit Baseline Campus Usage Models:</u> Hourly electricity usage data for the base year (September 1995 – October 1996) was used to create 24 hour daytype usage profiles. Historical 30-minutes electrical usage data for the base year was provided by the Electric Company and summed to hourly intervals. Data were grouped by month for weekdays and weekends resulting in 24 datasets. Data for holidays were grouped into the weekend categories.

The mean and standard deviation were calculated for each hourly time interval for each dataset. The data file was then reprocessed, and data points deviating from the mean by more then two standard deviations were identified as "bad" data points. The mean, minimum, maximum, and standard deviation were again calculated on the "good" data points. The resulting pre-retrofit baseline models are presented in Tables through

A graphical display of the September 1995 Weekday model is shown in Figure below. Hourly kWh are shown for each hour of the day. The model consists of the kWh mean, minimum, maximum, and standard deviation for each hour.

The peak demand recorded during the baseline period for each month plus demand due to baseline adjustments will be used as the baseline period demand. The On-Peak and Off-Peak demand for each baseline month is shown in Table

<u>Pre-Retrofit Baseline Cost:</u> The daily usage predicted by the Pre-Retrofit baseline models summed for the monthly period will be used as the baseline usage. The baseline cost will be calculated by applying the rates in place during the baseline period to the predicted baseline usage.

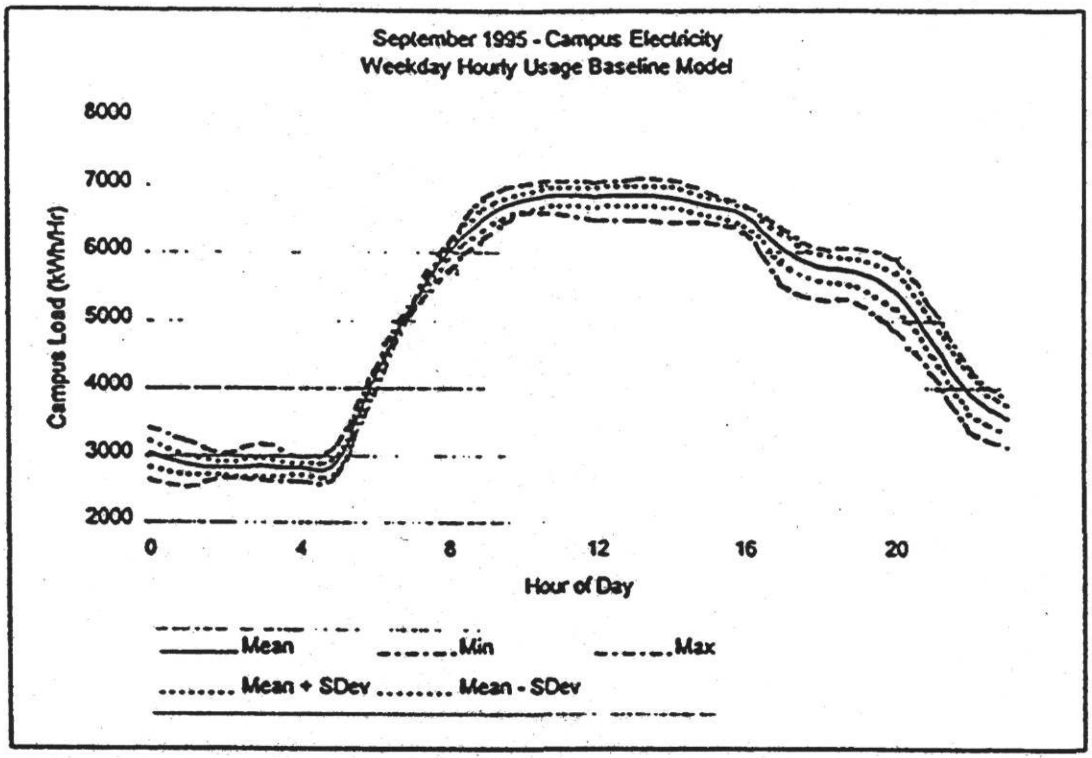

Figure Campus Electrical Usage by Hour of Day

Holidays: The following weekdays were identified as holidays during the baseline period. Data on these days were grouped with weekend data when determining hourly profile models for Campus Electricity usage.

9/4/95	12/25/95	12/28/95	1/15/96	7/4/96
11/23/95	12/26/95	12/29/95	3/22/96	
11/24/95	12/27/95	1/1/96	5/27/96	

September-95 WeekDays				
Hour	Avg (kWh)	Min (kWh)	Max (kWh)	Std Dev
0	3033	2649	3427	201
1	2865	2538	3231	152
2	2823	2674	3029	95
3	2833	2654	3185	124
4	2809	2638	2981	86
5	2901	2701	3160	119
6	4083	3871	4274	99
7	5152	5065	5262	64
8	5972	5718	6111	93
9	6501	6199	6807	159
10	6760	6587	7011	126
11	6840	6577	7056	131
12	6820	6487	7041	140
13	6846	6492	7081	149
14	6828	6469	7081	163
15	6697	6456	6915	133
16	6547	6287	6731	138
17	6074	5544	6381	227
18	5781	5315	6063	202
19	5708	5274	6073	192
20	5414	4808	5889	266
21	4706	4201	5161	259
22	3920	3372	4299	269
23	3536	3132	3858	175

September-95 Weekends				
Hour	Avg (kWh)	Min (kWh)	Max (kWh)	Std Dev
0	2939	2772	3236	179
1	2891	2704	3193	201
2	2849	2664	3132	180
3	2826	2656	3125	170
4	2800	2636	3107	170
5	2835	2674	3117	156
6	3289	3079	3601	185
7	3685	3352	4143	243
8	3886	3420	4521	389
9	4046	3430	5101	552
10	4191	3457	5312	639
11	4420	3818	5484	575
12	4512	3926	5612	563
13	4419	3969	5017	375
14	4508	3959	5302	428
15	4463	3954	5090	392
16	4446	3934	5136	404
17	4373	3914	5032	369
18	4180	3861	4763	270
19	4282	3767	5131	418
20	3952	3520	4526	271
21	3657	3284	4045	207
22	3341	2923	3841	256
23	3115	2878	3440	193

October-95 WeekDays				
Hour	Avg (kWh)	Min (kWh)	Max (kWh)	Std Dev
0	3059	2775	3515	220
1	2859	2583	3306	168
2	2793	2563	3246	164
3	2759	2530	3231	163
4	2726	2460	3160	151
5	2755	2457	3057	139
6	3844	3188	4319	231
7	4914	4249	5166	228
8	5844	5496	6076	156
9	6317	5975	6648	173
10	6601	6368	6824	114
11	6702	6494	6993	136
12	6678	6446	6915	125
13	6713	6441	6940	143
14	6717	6446	6902	130
15	6595	6240	6804	148
16	6466	6071	6698	152
17	6067	5549	6446	223
18	5798	5232	6255	221
19	5742	5350	6076	169
20	5389	4947	5811	189
21	4663	4266	5244	245
22	4046	3573	4541	241
23	3576	3175	4045	239

October-95 Weekends				
Hour	Avg (kWh)	Min (kWh)	Max (kWh)	Std Dev
0	2915	2578	3256	221
1	2899	2540	3417	268
2	2776	2447	3062	212
3	2805	2311	3417	312
4	2774	2250	3402	322
5	2778	2255	3281	296
6	3058	2641	3440	225
7	3331	2404	4070	467
8	3590	2462	4511	614
9	3706	2475	4803	716
10	3890	2548	5247	831
11	4145	2951	5491	755
12	4310	3465	5615	666
13	4295	3916	4975	407
14	4320	3944	4919	353
15	4390	3876	4906	349
16	4530	3828	5395	476
17	4387	3770	4962	394
18	4270	3614	4791	377
19	4255	3596	4682	364
20	3960	3420	4410	336
21	3720	3359	4274	307
22	3491	3100	4145	323
23	3091	2810	3432	212

Table Sept-Oct 1995 Weekday/Weekend Hourly Campus Electrical Usage Models (kWh vs. Hour of Day)

Peak Demand	9/95	10/95	11/95	12/95	1/96	2/96	3/96	4/96	5/96	6/96	7/96	8/96
On-Peak kW	7051	7122	6955	6789	6517	6618	6875	6688	7106	6814	6779	6970
Off-Peak kW	7036	7071	7043	6703	6592	6552	6819	6643	6990	6804	6814	6930

Table Historical Peak Campus Electric Demand for Baseline Year

Post-Retrofit Cost: Total Campus electricity usage as measured using the city utility meters will be recorded at hourly intervals using that data logger/EMCS. Baseline adjustments and electricity usage of metered new buildings will be subtracted from this total usage to determine the adjusted post-retrofit usage. The Post-Retrofit cost is determined by applying the utility rates at time of construction to the adjusted post-retrofit usage.

Thermal Plant Electricity

Related ECRMs: The takeover of thermal plants operations from the Company by personnel will increase thermal plant electric utility costs. New high efficiency chillers, cooling towers, a primary/secondary pumping arrangement and a new time-of-day Cool Storage Electric Rate for installing the TES will reduce thermal plant electric utility costs. Electricity costs to run the satellite plant in the baseline period are included in the campus electricity load and are addressed in Section Electricity costs to run both thermal plants will be metered separately from the campus load in the post-retrofit period.

Electricity Cost Increases: Increases are the measured Post-Retrofit electricity cost as shown in the following equations:

$\$E_{Pre}$ = Zero Dollars (paid by)

$$\$E_{Post} = E_{Post\ On\ Peak,\ kWh} * Rate_{Post\ On\ Peak,\ kWh} + E_{Post\ Off\ Peak,\ kWh} * Rate_{Post\ Off\ Peak,\ kWh}$$

$$\$Increases_{Thermal\ Plant\ Electricity} = \$E_{Post}$$

where

$\$E_{Pre}$ = Pre-retrofit electricity cost at Central Plant (Zero Dollars)

$E_{Post\ On\ Peak,\ kWh}$ = Measured monthly post-retrofit on-peak electricity consumption of both thermal plants (kWh)

$E_{Post\ Off\ Peak,\ kWh}$ = Measured monthly post-retrofit off peak electricity consumption of both thermal plants (kWh)

$\$E_{Post}$ = Post-retrofit period electricity cost

$Rate_{Post\ On\ Peak,\ kWh}$ = On-Peak electric consumption rate at time of construction ($/kWh)

$Rate_{Post\ Off\ Peak,\ kWh}$ = Off-Peak electric consumption rate at time of construction ($/kWh)

$\$Increases_{Thermal\ Plant\ Electricity}$ = Increased electricity cost to run both thermal plants

Electricity Rate Structure at Time of Construction

The Thermal Plant Electricity rate at time of construction is a follows:

On-Peak Period:	11 am to 7 pm Monday through Friday	
Summer:	May through October	
Winter:	November through April	
Energy Charge:	Summer On-Peak	\$0.14418/kWh
	Winter On-Peak	\$0.11000/kWh
	Off-Peak	\$0.03955/kWh
Demand Charge:	\$0/kW	

Pre-Retrofit Baseline Cost: The central plant was operated by the Company. The central plant electricity cost to was zero dollars. The satellite plant baseline electricity was included as part of the campus electrical load and is addressed in Section Total Pre-Retrofit baseline cost is zero dollars.

Post-Retrofit Cost: The cost is determined by applying the utility rates at time of construction to the measured usage as metered using the city utility meters and recorded using the data logger/EMCS. City utility meters at the central plant and the satellite plant will provide kWh pulse output signals that will be recorded by the data logger/EMCS at hourly intervals.

Swim Center & Facilities Building Electricity

ECRMs: Improved load profile by installing controls to limit building demand.

An improved billing rate structure has been offered by the Electric Company to reduce billing demand and improve the load profile. The load profile is defined as the average monthly kW divided by the peak kW. The utility rate structure to be implemented is still under negotiation. The specific ECRMs for improving the load profiles will be determined during the construction period. If a favorable utility rate cannot be negotiated, or the required building controls needed to improve the load profile are not cost-effective, this portion of the savings equation presented in Section will not be implemented.

The Swim Center and Facilities Building are located on the main campus, but are metered and billed separately. They do not receive heating or chilled water from the thermal plants.

Actual electricity usage as reported on the utility bills for the period November 1996 through October 1997 will be used at the baseline usage.

Facilities Building Electricity Baseline

Date	Energy (kWh) $E_{Pre\ Fac,\ kWh}$	Demand (kW) $E_{Pre\ Fac,\ kW}$	Load Factor	Cost
10/07/97	64,500	195	43%	$ 6,222
09/05/97	63,000	195	45%	$ 6,145
08/06/97	66,000	195	47%	$ 6,299
07/07/97	68,000	205	43%	$ 6,550
06/05/97	60,000	195	43%	$ 5,991
05/05/97	53,500	185	58%	$ 5,509
04/04/97	44,000	130	49%	$ 4,203
03/06/97	41,000	125	49%	$ 3,975
02/06/97	41,000	125	47%	$ 3,975
01/06/97	41,500	125	42%	$ 4,001
12/08/96	46,000	180	34%	$ 5,050
11/05/96	46,000	180	37%	$ 5,050
Totals	634,500			$ 62,969

Savings Calculations:

$$\$E_{Pre\ Fac} = E_{Pre\ Fac,\ kWh} * \$0.01388/kWh + \$13.00 + E_{Pre\ Fac,\ kW} * \$12.75/kW + (\$0.04878kWh * \min(200 * E_{Pre\ Fac,\ kW}, E_{Pre\ Fac,\ kWh})) + (\$0.03819/kWh * \min(150 * E_{Pre\ Fac,\ kW}, \max(0, E_{Pre\ Fac,\ kWh} - 200 * E_{Pre\ Fac,\ kW}))) + (\$0.02440/kWh * \max(0, E_{Pre\ Fac,\ kWh} - 350 * E_{Pre\ Fac,\ kWh}))$$

$$\$E_{Post\ Fac} = \max(E_{Post\ Fac,\ kW} * nhours/month * 0.65, E_{Post\ Fac,\ kWh}) * \$0.07/kWh$$

Note: Post-Retrofit period rate structure subject to change.

where

$E_{Pre\ Fac,\ kWh}$ = Facilities Building monthly Pre-Retrofit electric consumption (kWh)
$E_{Pre\ Fac,\ kW}$ = Facilities Building monthly Pre-Retrofit electric demand (kW)
$\$E_{Pre\ Fac}$ = Facilities Building monthly Pre-Retrofit cost.
$E_{Post\ Fac,\ kWh}$ = Facilities Building monthly Post-Retrofit electric consumption (kWh)
$E_{Post\ Fac,\ kW}$ = Facilities Building semi-annual Post-Retrofit electric demand (kW)
$\$E_{Post\ Fac}$ = Facilities Building monthly Post-Retrofit cost.

nhours/month = number of hours within the billing period.

When and if any adjustments to consumption (kWh) or demand (kW) are required, they will be submitted for approval.

Facilities Building Electricity Baseline

Date	Energy (kWh) $E_{Pre\ Swim,\ kWh}$	Demand (kW) $E_{Pre\ Swim,\ kW}$	Load Factor	Cost
10/07/97	78,000	159	64%	$6,130
09/05/97	70,800	177	56%	$6,209
08/06/97	73,500	150	68%	$5,781
07/07/97	66,000	147	58%	$5,435
06/05/97	63,000	144	61%	$5,261
05/05/97	71,100	159	58%	$5,866
04/04/97	55,800	165	49%	$5,372
03/06/97	75,300	166	67%	$6,165
02/06/97	71,400	162	63%	$5,937
01/06/97	64,800	144	57%	$5,330
12/08/96	76,200	153	67%	$5,943
11/05/96	69,600	153	65%	$5,691
Totals	835,500			$69,118

Savings Calculations:

$\$E_{Pre\ Swim} = E_{Pre\ Swim,\ kWh} * \$0.01388/kWh + \$13.00 + E_{Pre\ Swim,\ kW} * \$12.75/kW +$
$(\$0.04878kWh * min(200 * E_{Pre\ Swim,\ kW}, E_{Pre\ Swim,\ kWh})) +$
$(\$0.03819/kWh * min(150 * E_{Pre\ Swim,\ kW}, max(0, E_{Pre\ Swim,\ kWh} - 200 * E_{Pre\ Swim,\ kW}))) +$
$(\$0.02440/kWh * max(0, E_{Pre\ Fac,\ kWh} - 350 * {}_{E\ Pre\ Fac,\ kWh}))$

$\$E_{Post\ Swim} = max\ (E_{Post\ Swim,\ kW} * nhours/month * 0.65, E_{Post\ Swim,\ kWh}) * \$0.07/kWh$

Note: Post-Retrofit period rate structure subject to change.

where

$E_{Pre\ Swim,\ kWh}$ = Swim Center monthly Pre-Retrofit electric consumption (kWh)
$E_{Pre\ Swim,\ kW}$ = Swim Center monthly Pre-Retrofit electric demand (kW)
$\$E_{Pre\ Swim}$ = Swim Center monthly Pre-Retrofit cost.
$E_{Post\ Swim,\ kWh}$ = Swim Center monthly Post-Retrofit electric consumption (kWh)
$E_{Post\ Swim,\ kW}$ = Swim Center semi-annual Post-Retrofit electric demand (kW)

$\$E_{Post\ Swim}$ = Swim Center monthly Post-Retrofit cost.
nhours/month = number of hours within the billing period.

$\$E_{Pre} = \$E_{Pre\ Swim} + \$E_{Pre\ Phy}$
$\$E_{Post} = \$E_{Post\ Phy} + \$E_{Post\ Swim}$
$\$Savings_{Swim\ Center/Phy\ Electricity} = \$E_{Pre} - \$E_{Post}$

When and if any adjustments to consumption (kWh) or demand (kW) are required, they will be submitted for approval.

Natural Gas

Related ECRMs: The takeover of thermal plant operations from the Company by personnel will increase gas utility costs. Boiler refurbishments at the central plant and the satellite plant will reduce gas utility costs.

Natural Gas Cost Increases: Increases are the measured Post-Retrofit gas cost minus the Stipulated Pre-Retrofit baseline gas as shown in the following equations:

$\$G_{Pre\ Satellite} = G_{Pre\ Satellite} * Rate_{Pre\ Gas} + Facility_{Pre\ Charge}$
$\$G_{Pre\ Central\ Plant}$ = Zero Dollars (paid by)
$\$G_{Pre} = \$G_{Pre\ Satellite}$
$\$G_{Post} = (G_{Post\ Satellite} + G_{Post\ Central\ Plant}) * Rate_{Post\ Gas} + Facility_{Post\ Charge}$
$\$Increases_{Thermal\ Plant\ Gas} = \$G_{Post} - \$\ G_{Pre} - \$G_{Post\ New\ Building\ Gas\ HW}$

where

$G_{Pre\ Satellite}$ = Stipulated monthly Satellite Plant baseline gas usage (CCF)
$Rate_{Pre\ Gas}$ = Gas usage rate during the Pre-Retrofit baseline period
$Facility_{Pre\ Charge}$ = Facility charge during the baseline period
$\$G_{Pre\ Satellite}$ = Stipulated Satellite Plant monthly pre-retrofit gas cost
$\$G_{Pre\ Central\ Plant}$ = Pre-Retrofit Central Plant gas cost (zero dollars)

$\$G_{Post\ New\ Building\ Gas\ HW} = G_{Post\ New\ Building\ Gas\ HW} * Rate_{Post\ Gas}$

$\$G_{Post\ New\ Building\ Gas\ HW}$ = Gas usage needed to produce hot water for new buildings at a
ccf/mmbtu = Rate to be determined quarterly
$\$G_{Pre}$ = Stipulated pre-retrofit gas cost
$G_{Post\ Satellite}$ = Measured monthly Satellite Plant post-retrofit gas usage (CCF)
$G_{Post\ Central\ Plant}$ = Measured monthly Central Plant post-retrofit gas usage (CCF)
$Rate_{Post\ Gas}$ = Gas rate at the time of construction
$Facility_{Post\ Charge}$ = Facility charge during the post-retrofit period
$\$G_{Post}$ = Post-retrofit period gas cost

$\$\text{Increases}_{\text{Thermal Plant Gas}}$ = Increased gas costs

<u>Gas Rate During Baseline Period</u>
The gas rate during the baseline period is a follows:

Facility Charge: $14/month

Usage Charge: $0.292 per CCF for all CCF

Where 1 CCF = 100 cubic feet

<u>Gas Rate at Time of Construction</u>
The gas rate at time of construction is as follows:

Facility Charge: $14/month

Usage Charge: $0.226 per CCF for all CCF

Where 1 CCF = 100 cubic feet

<u>Pre-Retrofit Baseline Cost:</u> The central plant was operated be the Company. The central plant gas cost was paid by and the cost to was zero dollars. The satellite plant gas was not metered and has been estimated using a Trane TRACE computer simulation model of the buildings served by the satellite plant. The predicted monthly usage and cost is presented below

	GAS On Peak (mmbtu)	Gas CCF	Gas Cost
JAN	2,532	24,582	$ 7,192
FEB	2,605	25,286	$ 7,398
MAR	3,144	30,523	$ 8,927
APR	1,609	15,618	$ 4,575
MAY	0	0	$ 14
JUN	0	0	$ 14
JUL	0	0	$ 14
AUG	0	0	$ 14
SEP	0	0	$ 14
OCT	1,677	16,278	$ 4,767
NOV	2,819	27,372	$ 8,007
DEC	2,330	22,618	$ 6,619
TOTAL	16,715	162,279	$ 47,553

Table Predicted Satellite Plant Gas Usage and Cost.

Post-Retrofit Cost: The cost is determined by applying the utility rates at time of construction to the measured usage as metered using the city utility meters and recorded using the data logger/EMCS.

Thermal Plant Domestic Water

Related ECRMs: The takeover of thermal plant operations from the Company by personnel will increase water utility costs. Water usage will be metered using existing city water meters.

Domestic Water Cost Increases: Increases are the measured Post-Retrofit period water cost minus the predicted Pre-Retrofit baseline water cost as shown in the following equations:

$\$W_{\text{Pre Satellite Plant}} = W_{\text{Pre Satellite Plant}} * \text{Rate}_{\text{Water}}$
$\$W_{\text{Pre Central Plant}} = \text{Zero Dollars (paid by} \qquad)$
$\$W_{\text{Pre}} = \$W_{\text{Pre Satellite Plant}}$
$\$W_{\text{Post}} = (W_{\text{Post Satellite Plant}} + W_{\text{Post Central Plant}}) * \text{Rate}_{\text{Water}}$
$\$\text{Increases}_{\text{Thermal Plant Domestic Water}} = \$W_{\text{Post}} - \$W_{\text{Pre}}$

where

$W_{\text{Pre Satellite Plant}}$ = Stipulated monthly Satellite Plant baseline water usage (CCF)
$\$W_{\text{Pre Satellite Plant}}$ = Predicted Satellite Plant monthly pre-retrofit water cost
$\$W_{\text{Pre Central Plant}}$ = Pre-Retrofit Central Plant water cost (zero dollars)
$\$W_{\text{Pre}}$ = Predicted pre-retrofit water cost
$W_{\text{Post Satellite Plant}}$ = Measured monthly Satellite Plant post-retrofit water usage (CCF)
$W_{\text{Post Central Plant}}$ = Measured monthly Central Plant post retrofit water usage (CCF)
$\text{Rate}_{\text{Water}}$ = Water rate at time of construction
$\$W_{\text{Post}}$ = Post-retrofit period water cost
$\$\text{Increases}_{\text{Thermal Plant Domestic Water}}$ = Calculated increased water cost

Note: Sewage costs are a fixed monthly cost and are not based on water consumption. Sewage costs will not increase or decrease as a result of this project, and will therefore not be included in the savings calculations.

Water Rate at Time of Construction
The water rate at time of construction is as follows:

Facility Charge: $33.45/month

Usage Charge: $0.80/CCF for the first 1781 CCF

$1.48/CCF for the next 2295 CCF
$1.85/CCF for all excess CCF

where 1 CCF = 100 cubic feet

Pre-Retrofit Baseline Cost: The water usage of the satellite plant during the baseline period will be used as the baseline usage. The satellite plant water usage was not metered and has been estimated using a Trane TRACE computer simulation model of the buildings served by the satellite plant. The predicted monthly usage and cost is presented below

	WATER (1000 Gal)	Water (CCF)	WATER Cost
JAN	0	0	$ 33
FEB	74	99	$ 216
MAR	91	122	$ 259
APR	154	206	$ 414
MAY	430	575	$ 1,097
JUN	457	611	$ 1,164
JUL	462	618	$ 1,176
AUG	412	551	$ 1,052
SEP	308	412	$ 795
OCT	163	218	$ 437
NOV	88	118	$ 251
DEC	6	8	$ 48
TOTAL	2,645	3,536	$ 6,943

Table Predicted Satellite Plant Water Usage and Cost

Post-Retrofit Cost: The cost is determined by applying the utility rates at time of construction to the measured usage as reported on the monthly utility bill. Usage will include the central plant and satellite plant.

Purchased Chilled Water

Related ECRMs: The takeover of thermal plant operations from the Company by personnel will eliminate all chilled water purchases.

Purchased Chilled Water Cost Savings: Savings are the predicted Pre-Retrofit baseline chilled water cost minus the Post-Retrofit period water cost as shown in the following equations:

$$\$C_{Pre\ Purchased\ Chw} = (C_{Pre\ Purchased\ Chw\ Weekdays} + C_{Pre\ Purchased\ Chw\ Weekends} + C_{Adjust}) * Rate_{CHW} + Production_{Charge}$$

$$\$C_{Post\ Purchased\ Chw} = \text{Zero Dollars (purchases will be eliminated)}$$

$$Savings_{Purchased\ CHW} = \$C_{Pre\ Purchased\ Chw}$$

where

$C_{Pre\ Purchased\ Chw\ Weekdays}$ = Predicted baseline weekday chilled water usage (Ton-Hrs)
$C_{Pre\ Purchased\ Chw\ Weekends}$ = Predicted baseline weekend chilled water usage (Ton-Hrs)
C_{Adjust} = Adjustments to predicted baseline chilled water usage (Ton-Hrs)
$Rate_{CHW}$ = Baseline period purchased chilled water energy charge
$Production_{Charge}$ = Baseline period purchased chilled water production charge
$\$C_{Pre\ Purchaed\ Chw}$ = Predicted baseline purchased chilled water cost
$Savings_{Purchased\ CHW}$ = Purchased chilled water cost savings

Pre-Retrofit Baseline Purchased Chilled Water Usage: A statistical model of purchased chilled water consumption as a function of outdoor temperature was developed to predict the baseline usage. Historical chilled water usage during the baseline period (September 1995 – August 1996) from the Company and average daily temperatures were used to develop this model. Temperature data will be collected from the National Weather Service during the Post-Retrofit period and used with this baseline model to predict daily usage.

Weekday and weekend baseline models were developed to predict the chilled water usage of the facility. Chilled water usage in the baseline period was correlated to average daily temperatures. A simple linear regression model for Weekday usage was developed using Emodel software from the Energy Systems Laboratory, Texas A&M University. A four-parameter changepoint model for Weekend usage was also developed using Emodel. Model statistics and graphical displays of baseline data and model predictions are shown in Figures and below.

Weekday Purchased Chilled Water Model Statistics

B_0 (y-intercept)	-26667 (Ton-Hrs)
B_1 (slope)	987.0 (Ton-Hrs/°F)
R squared	0.91
CV-RMSE	11.5%

The baseline model developed is:

$$E_{Ton\text{-}Hrs} = B_0 + B_1 * \text{Avg Temp}$$

Where

$E_{Ton\text{-}Hrs}$ = Predicted Daily Usage (Ton-Hrs)
B_0 = -26667 (Ton-Hrs)
B_1 = 987.0 (Ton-Hrs/°F)
Avg Temp = Average Daily Temperature (°F)

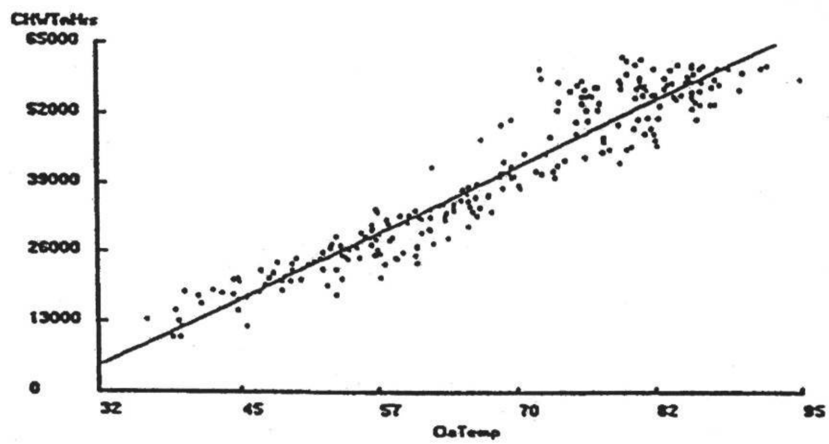

Figure Weekday Model – Daily Chilled Water Usage (Ton-Hrs) as a function of Average Daily Temperature.

Weekend Purchased Chilled Water Model Statistics

X_C (change point)	62.5 (°F)
Y_C (change point)	27712 (Ton-Hrs)
B_0 (left slope)	655.3 (Ton-Hrs/°F)
B_1 (right slope)	989.2 (Ton-Hrs°F)
R squared	0.91
CV-RMSE	12.1%

The baseline model developed is:

If Avg Temp < X_C

$$E_{Ton\text{-}Hrs} = Y_C + (\text{Avg Temp} - X_C) * B_0$$

If Avg Temp > X_C

$$E_{Ton\text{-}Hrs} = Y_C + (\text{Avg Temp} - X_C) * B_1$$

Where

X_C = Model Change Point (ºF)
Y_C = Model Change Point (Ton-Hrs)
$E_{Ton\text{-}Hrs}$ = Predicted Daily Usage (Ton-Hrs)
B_0 = 655.3 (Ton-Hrs/ºF)
B_1 = 989.2 (Ton-Hrs/ºF)
Avg Temp = Average Daily Temperature (ºF)

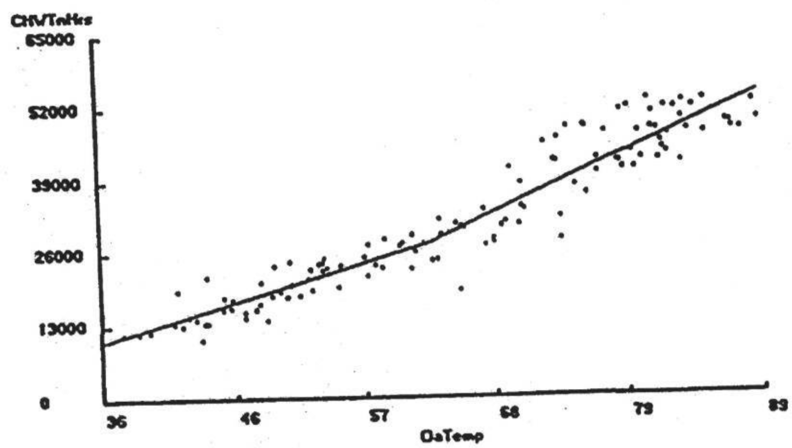

Figure Weekend Model – Daily Chilled Water Usage (Ton-Hrs) as a function of Average Daily Temperature

Pre-Retrofit Baseline Purchased Chilled Water Cost: Baseline chilled water cost will be determined by applying the rate structure in place during the baseline period to the predicted chilled water usage plus usage due to mutually agreed upon baseline adjustments. This rate includes a production and distribution charge and an energy charge.

Purchased Chilled Water Rate During Baseline Period
The purchased chilled water rate during the Baseline Period is as follows:

Energy Charge: $0.12061/Ton-Hr

Production Charge: $31,492/month

Post-Retrofit Purchased Chilled Water Cost: Chilled water purchases and costs will be eliminated.

Purchased Hot Water

Related ECRMs: Boiler operations by personnel will eliminate all hot water purchases.

Purchased Hot Water Cost Savings: Savings are the predicted Pre-Retrofit baseline hot water cost minus the Post-Retrofit period water cost as shown in the following equations:

$\$H_{\text{Pre Purchased Hw}} = (H_{\text{Pre Purchased Hw Weekdays}} + H_{\text{Pre Purchased Hw Weekends}} + H_{\text{Adjust}}) * \text{Rate}_{\text{HW}} + \text{Production}_{\text{Charge}}$
$\$H_{\text{Post Purchased Hw}}$ = Zero Dollars (purchases will be eliminated)
$\text{Savings}_{\text{Purchased HW}} = \$H_{\text{Pre Purchased Hw}}$

where

$H_{\text{Pre Purchased Hw Weekdays}}$ = Predicted baseline weekday hot water usage (MMBTU)
$H_{\text{Pre Purchased Hw Weekends}}$ = Predicted baseline weekend hot water usage (MMBTU)
H_{Adjust} = Adjustments to predicted baseline hot water usage (MMBTU)
Rate_{HW} = Baseline period purchased hot water energy charge ($/MMBTU)
$\text{Production}_{\text{Charge}}$ = Baseline period purchased hot water production charge
$\$H_{\text{Pre Purchased Hw}}$ = Predicted baseline purchased hot water cost
$\text{Savings}_{\text{Purchased HW}}$ = Purchased hot water cost savings

Pre-Retrofit Baseline Purchased Hot Water Model: A statistical model of purchased hot water consumption as a function of outdoor temperature was developed to predict the baseline usage. Historical hot water usage during the baseline period which is September 1995 to August 1996 from the Company and average daily temperature were used to develop this model. Historical usage from the Company and average daily temperatures were used to develop this model. Outdoor air temperature data will be collected from the National Weather Service during the Post-Retrofit period and used with this baseline model to predict usage.

Weekday and weekend baseline models were developed to predict the hot water usage of the facility. A three-parameter changepoint heating model was developed for Weekday and Weekend usage using Emodel software from the Energy Systems Laboratory, Texas A&M University. Hot water usage in the baseline period was correlated to average daily temperatures. Model statistics and graphical displays of baseline data and model predictions are shown in Figures and below.

Weekday Purchased Hot Water Model Statistics	
X_C (change point)	75.96 (ºF)
Y_C (change point)	98.91 (MMBTU)
B_0 (slope)	-8.715 (MMBTU)
R squared	0.92
CV-RMSE	15.6%

The baseline model developed is:

If Avg Temp < X_C

$$E_{MMBTU} = Y_C + (\text{Avg Temp} - X_C) * B_0$$

If Avg Temp > X_C

$$E_{MMBTU} = Y_C$$

Where

X_C = Model Change Point (ºF)
Y_C = Model Change Point (MMBTU)
E_{MMBTU} = Predicted Daily Usage (MMBTU)
B_0 = -8.715 MMBTU/ºF
Avg Temp = Average Daily Temperature (ºF)

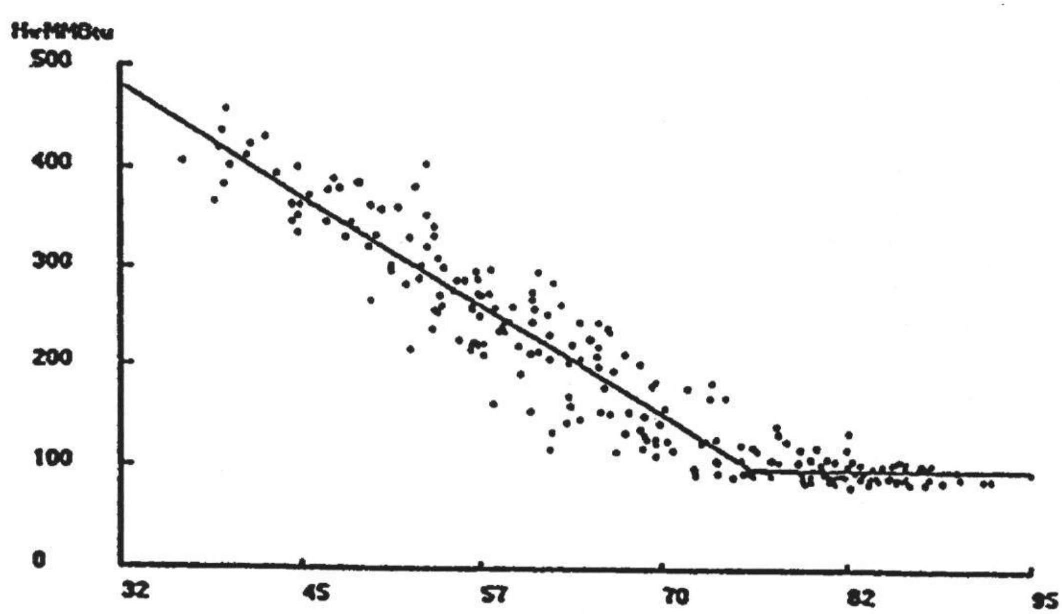

Figure Weekday Model – Daily Hot Water Usage (MMBTUs) as a function of Average Daily Temperature.

Weekend Purchased Hot Water Model Statistics

X_C (change point)	74.29 (°F)
Y_C (change point)	101.1 (MMBTU)
B_0 (slope)	-8.83 (MMBTU)
R squared	0.91
CV-RMSE	16.2%

The baseline model developed is:

If Avg Temp < X_C

$$E_{MMBTU} = Y_C + (\text{Avg Temp} - X_C) * B_0$$

If Avg Temp > X_C

$$E_{MMBTU} = Y_C$$

Where

X_C = Model Change Point (°F)
Y_C = Model Change Point (MMBTU)
E_{MMBTU} = Predicted Daily Usage (MMBTU)
B_0 = -8.83 MMBTU/°F
Avg Temp = Average Daily Temperature (°F)

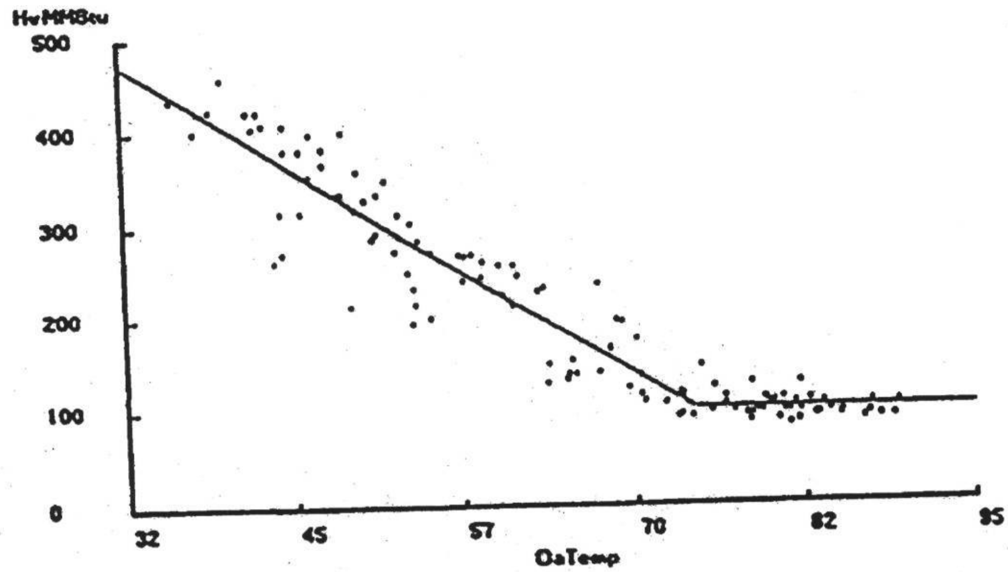

Figure Weekend Model – Daily Hot Water Usage (MMBTUs) as a function of Average Daily Temperature.

Pre-Retrofit Baseline Purchased Hot Water Cost: Baseline Hot Water Costs will be determined by applying the rate structure in place during the baseline period to the predicted Hot water usage. This rate includes a production and distribution charge and an energy charge.

Purchased Hot Water Rate During Baseline Period:
The purchased chilled water rate during the Baseline Period is as follows:

Energy Charge: $8.90210/MMBTU

Production Charge: $3,650/month

Post-Retrofit Purchased Hot Water Cost: Hot water purchases and costs will be eliminated.

Operation and Maintenance Costs

Water treatment costs and operating costs due to the takeover of the thermal plant will increase operating costs. The combined operational and maintenance cost savings and expenditures are presented below using the Option O&M-C Budget Comparison method. The numbers were provided by personnel.

Annual Water Treatment Cost	$35,000
Annual Operating Cost	$297,000
Annual Cost Adjustment	$0
Total Additional Annual Operating Cost	$332,000

The net additional monthly operating cost is $27,667.
The net additional quarterly operating cost is $83,000.
The actual annual operating cost will be adjusted annually.

POST-RETROFIT MODELS AND FUTURE BASELINE ADJUSTMENTS

Energy metering equipment will be installed at the Campus to measure energy usage during the Post-Retrofit period. Data from this metering equipment will be logged by the data logger/EMCS and reviewed weekly. It will be used to calculate utility cost savings, ensure efficient operation, identify potential O&M opportunities, and make adjustments to the calculated baseline energy usage when appropriate.

Post-Retrofit Baseline energy usage-models will be generated using the collected hourly data once construction is complete and the systems are operating normally. Data from the first year of operation will be used to generate these models, assuming no changes in facility operation have occurred. These models represent the facility utilities usage before any new construction or changes in use occur. Revised Post-Retrofit baseline models may be developed during the term of the contract to capture additional savings resulting from continuous commissioning efforts.

The addition of any new buildings will increase the load on the physical plant. Therefore, energy metering equipment must be installed on each new building to record electrical usage, chilled water usage, and hot water usage. This measured usage will be subtracted from the post-retrofit whole campus usage (campus electricity) or added to the predicted pre-retrofit baseline usage (chillied or hot water) before applying the appropriate utility rate structures.

It will be the responsibility of to install, maintain, and calibrate this metering equipment. In the event that does not install this additional metering equipment, baseline adjustments will estimated by subtracting the loads predicted using the post-retrofit baseline models from the measured campus loads. Baseline adjustments will only be made when the measured loads exceed the predicted loads using the post-retrofit baseline models.

Data collection will continue throughout the term of the performance contract. Increases in utilities usage will be identified by comparing monthly measured usage to the predicted usage from the Post-Retrofit Baseline models. When and if an increase in usage is detected, the cause of the increase will be investigated. If the increase is determined to be the result of new construction, extended operating hours, or other changes in owner-directed building activities, an appropriate adjustment will be calculated. Any baseline adjustments resulting in a cost adjustment excess of 10% of the guaranteed savings amount will be submitted to SECO and THECB for approval. Baseline adjustment in an amount less than 10% of the guaranteed savings amount will be reviewed by the third party audit firm (   ) during the quarterly savings report review.

Decreases in measured utilities usage will result in lower utility bills and increased savings to the building owner. Baseline adjustments will not be made when utilities usage decreases. A description of the post-retrofit baseline models that will be developed is presented below.

Campus Electricity Post-Retrofit Baseline Model

A 24 hour daytype Post-Retrofit model will be developed upon project completion to characterize electrical usage. Changes in operation during the term of the performance contract will be identified by comparing measured usage to the predicted usage from this model. A sample 24 hour daytype profile is shown in figure 6.1.1. Each quarterly report will include the quarter's measured electrical usage, and a comparison to the usage as predicted using the Post-Retrofit model once these models have been developed.

Baseline Adjustments: Increases in electrical usage will be identified by comparing measured usage to the predicted usage from the Post-Retrofit baseline model. The sum of the mean of the post-retrofit weekday-weekend daytype model will be compared to the sum of the mean for the weekday-weekend measured usage and the "positive only differences" will be charged as an adjustment. The additional adjusted kWh used will be summed for each month. The usage adjustments will be calculated as shown below.

$$E_{\text{Campus Adjust, kWh}} = E_{\text{Post Campus, kWh}} - E_{\text{Post Campus New Bldg, kWh}} - E_{\text{Post Model, kWh}}$$

where

$E_{\text{Campus Adjust, kWh}}$ = Additional electricity consumption due to baseline adjustment

$E_{\text{Post Campus New Bldg, kWh}}$ = Measured electricity consumption of any metered new buildings

$E_{\text{Post Campus, kWh}}$ = Measured electricity consumption during post-retrofit period

$E_{Post\ Model,\ kWh}$ = Predicted electricity consumption from Post-Retrofit model

Note: Only positive adjustments will be made.

Chilled Water Post-Retrofit Baseline Model

The chilled water production supplied to the campus will be metered using a flow meter and supply and return temperature sensor. A BTU calculation will be performed by the data logger/EMCS and trended on an hourly basis and summed daily. A Post-Retrofit Baseline model of chilled water usage versus average daily temperature will be developed using this measured data.

Baseline Adjustments: Increases in chilled water usage will be identified by comparing measured daily usage to the predicted usage from the Post-Retrofit model. The additional chilled water consumption (actual-model) will be calculated for each day, and summed for each month. Increases in chilled water usage will be investigated to determine the cause of increased usage. Increases due to new construction, increased operating hours, or changes in building operations may require a baseline adjustment. The usage adjustments will be added to the baseline usage as predicted using the baseline models.

Adjustments to the baseline chilled water consumption will be made on a daily basis for usage according to the following equation:

$$C_{Adjust} = C_{Post\ Total\ CHW} - C_{New\ Buildings} - C_{Post\ Model}$$

where

C_{Adjust} = Chilled water usage adjustment due to campus changes
$C_{Post\ Total\ CHW}$ = Measured total campus chilled water usage during post-retrofit period
$C_{New\ Buildings}$ = Measured chilled water usage of new buildings (Ton-Hrs)
$C_{Post\ Model}$ = Predicted chilled water usage from Post-Retrofit baseline model using the first twelve months of post retrofit chilled water consumption data (excludes new buildings)

$C_{Post\ Model} = C_{Post\ Total\ CHW} - C_{Undergrad\ Learning\ Center\ CHW}$
$C_{Undergrad\ Learning\ Center\ CHW}$ = measured chilled water use of the new undergraduate learning center (Ton-hrs)

Note: Only positive adjustments will be made.

Heating Hot Water Post-Retrofit Baseline Model

The hot water production supplied to the campus will be metered at both the central plant and satellite plant using flow meters and supply and return temperature sensors. A BTU calculation will be performed by the data logger/EMCS and trended on an hourly basis and summed daily. Models of hot water usage versus average daily temperature will be developed for each boiler plant using this measured data.

Baseline Adjustments: Increases in hot water usage will be identified by comparing measured daily usage to the predicted usage from the Post-Retrofit models. The additional hot water consumption (actual-model) will be calculated for each day, and summed for each month. Increases in hot water usage will be investigated to determine the cause of increase usage. Increases due to new construction, increased operating hours, or changes in building operations may require a baseline adjustment. The usage adjustments will be added to the baseline usage as predicted using the baseline models.

Adjustments to the baseline hot water consumption will be made on a daily basis for usage according to the following equation:

$$H_{Adjust} = H_{Post\ Total\ HW} - H_{New\ Buildings} - H_{Post\ Model}$$

where

H_{Adjust} = Hot water usage adjustment due to campus changes (MMBTU)
$H_{Post\ Total\ HW}$ = Measured total hot water usage during post-retrofit period
$H_{New\ Buildings}$ = Measured hot water usage of new buildings (MMBTU)
$H_{Post\ Model}$ = Predicted hot water usage from Post-Retrofit baseline model using the first twelve months of post-retrofit consumption data (excludes new buildings)

Note: Only positive adjustments will be made.

CURRENT BASELINE ADJUSTMENTS

Building operations relative to the baseline period have already been modified, thus requiring a baseline adjustment to the savings calculation equations. The undergraduate Learning Center is a new building that was built on the campus after the baseline period. It is now occupied, and receives chilled and hot water from the thermal plants. The electricity load is metered through the campus electric meter.

The installation of whole building metered or electricity, chilled water, and hot water are recommended for this building. The energy usage data would be polled weekly. The additional usage would be used to make the baseline adjustments using procedures presented in Section 6 and 7.