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

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

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:

\[
\begin{align*}
\text{Savings}_{\text{Campus Electricity}} &= \text{Savings}_{\text{Pre Campus}} - \text{Savings}_{\text{Post Campus}} \\
\text{Savings}_{\text{Pre Campus}} &= (E_{\text{Pre Campus Weekday}, \text{kWh}} + E_{\text{Pre Campus Weekend}, \text{kWh}}) \times \text{Rate}_{\text{Campus Baseline, kWh}} + (E_{\text{Pre Campus, \text{kWh}}} \times \text{Rate}_{\text{Campus Baseline, kwh}}) \\
\text{Savings}_{\text{Post Campus}} &= (E_{\text{Post Campus, \text{kWh}}} - E_{\text{Post Campus New Bldg, \text{kWh}}} - E_{\text{Campus Adjust, \text{kWh}}} - E_{\text{Post Campus New Building,CHW,\text{kWh}}} \times \text{Rate}_{\text{Post Campus, kwh}})
\end{align*}
\]

In this set of equations, the basic savings are calculated using the Option C, before-after calculation technique. “$E_{\text{Pre Campus}}$” 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.

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Energy Systems Laboratory
Texas Engineering Experiment Station
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.

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

* 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. A summary of the total estimated metering costs are presented in Table A.

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.

<table>
<thead>
<tr>
<th>Description</th>
<th>Equipment Required</th>
<th>Output Signal</th>
<th>Metering Equipment Cost</th>
<th>Installation T&amp;M</th>
<th>Data Acquisition Hardware Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Campus kWh</td>
<td>City Utility Meter</td>
<td>Contact Pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Plant kWh (feeds standby chillers, MCCs)</td>
<td>City Utility Meter</td>
<td>Contact Pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Plant Heating Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW Supply Temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW Return Temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Plant Gas (feeds boilers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satellite Plant kWh 4160V Feed (3 Chillers) 480V MCCs Subfeed (pumps, cooling towers, lighting)</td>
<td>City Utility Meter</td>
<td>Watt-Hour Meter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satellite Plant Heating Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW Supply Temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW Return Temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satellite Plant Gas (feeds boilers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satellite Plant CHW CHW Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHW Supply Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHW Return Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chilled Water Supply to Campus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHW Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHW Supply Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHW Return Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Plant Data Logger</td>
<td>Synergistics C120EANI /Signal Splitters</td>
<td>Modern</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satellite Plant Data Logger</td>
<td>Synergistics C140EANI /Signal Splitters</td>
<td>Modern</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table xxx Planned Metering Equipment and Estimated Costs

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

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:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metering Equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Acquisition Hardware</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EMCS Programming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Weather Service Hourly Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verification of Metering Instrumentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Management (labor, travel, etc)</td>
<td>labor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>travel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>

Table xxx Total Estimated Metering Equipment Installation Costs
Figure Electrical Monitoring Diagram

Legend
KWh - kилоWatt-hour Meter or Pulse from Utility Meter
D - Digital Pulse Signal to Data Logger

Central Energy Plant

Satellite Energy Plant

New Building

Adjustments (Typical)

Building (Typical)

MCC

Chillers

Swim Center

Facilities Bldg

CAMPUS
Figure Chilled Water Monitoring Diagram
Figure Hot Water Monitoring Diagram

Legend
HWS - Hot Water Supply
HWR - Hot Water Return
T - Temperature
F - Flow Rate
BTU - British Thermal Unit
A - Analog Output Signal
D - Digital Pulse Signal
CCF - Gas (100 Cubic Ft)

Central Energy Plant
- HWR
- HWS
- Boilers
- CCF
- D

Gas Company
- D
- CCF

Satellite Energy Plant
- HWR
- HWS
- Boilers
- F
- T

Satellite Plant Loads
- F
- T

New Building
- Adjustments (Typical)

Campus Loop
- HWR
- HWS

BTU Calculation
- T
- A
- A
- A

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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

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

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.

\[
\text{Savings}_{\text{Total}} = \text{Savings}_{\text{Campus Electricity}} + \text{Savings}_{\text{Swim Center/Facilities Bldg Electricity}} - \text{Increases}_{\text{Thermal Plant Electricity}} - \text{Increases}_{\text{Thermal Plant Gas}} + \text{Savings}_{\text{Purchased C&H}} + \text{Savings}_{\text{Purchased HW}} - \text{Increases}_{\text{Thermal Plant Domestic Water}} - \text{Increases}_{\text{O&M}}
\]
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.

<table>
<thead>
<tr>
<th>Month</th>
<th>Percentage of Total Annual Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>5.7%</td>
</tr>
<tr>
<td>February</td>
<td>6.5%</td>
</tr>
<tr>
<td>March</td>
<td>6.7%</td>
</tr>
<tr>
<td>April</td>
<td>7.7%</td>
</tr>
<tr>
<td>May</td>
<td>9.1%</td>
</tr>
<tr>
<td>June</td>
<td>10.5%</td>
</tr>
<tr>
<td>July</td>
<td>10.7%</td>
</tr>
<tr>
<td>August</td>
<td>10.1%</td>
</tr>
<tr>
<td>September</td>
<td>9.5%</td>
</tr>
<tr>
<td>October</td>
<td>9.1%</td>
</tr>
<tr>
<td>November</td>
<td>7.7%</td>
</tr>
<tr>
<td>December</td>
<td>6.6%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

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.

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

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:

\[
\$E_{\text{Pre Campus}} = (E_{\text{Pre Campus Weekday, kWh}} + E_{\text{Pre Campus Weekend, kWh}}) \times \text{Rate}_{\text{Campus Baseline, kWh}} + \\
(E_{\text{Pre Campus, kW}} \times \text{Rate}_{\text{Campus Baseline, kW}})
\]

\[
\$E_{\text{Post Campus}} = (E_{\text{Post Campus, kWh}} - E_{\text{Post Campus New Bldg, kWh}} - E_{\text{Campus Adjust, kWh}} - \\
E_{\text{Post Campus New Building(CHW,kWh)}}) \times \text{Rate}_{\text{Post Campus, kWh}}
\]

\[
\$\text{Savings}_{\text{Campus Electricity}} = \$E_{\text{Pre Campus}} - \$E_{\text{Post Campus}}
\]

where

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

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

\[
\text{Rate}_{\text{Campus Baseline, kWh}} = \text{Campus electric baseline consumption utility rate ($/kWh)}
\]

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

\[
\text{Rate}_{\text{Campus Baseline, kW}} = \text{Campus electric baseline demand utility rate ($/kWh)}
\]

\[
\$E_{\text{Pre Campus}} = \text{Predicted pre-retrofit Campus electricity cost}
\]
Pre-Retrofit Baseline Campus Usage Models: 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 than 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

Pre-Retrofit Baseline Cost: 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.

\[
\begin{align*}
E_{\text{Post Campus, kWh}} &= \text{Measured monthly post-retrofit campus electric consumption (kWh)} \\
E_{\text{Post Campus New Bldg, kWh}} &= \text{Campus consumption of metered new buildings (kWh)} \\
E_{\text{Post Campus New Bldg/CHW, kWh}} &= \text{Electrical consumption of additional chilled water production for new buildings at a plan kW/ton rate to be reported quarterly (kWh)} \\
E_{\text{Campus Adjust, kWh}} &= \text{Monthly baseline adjustments to campus electric consumption (kWh)} \\
\text{Rate}_{\text{Post Campus, kWh}} &= \text{Campus electric consumption rate at time of construction ($/kWh)} \\
SS_{\text{Post Campus}} &= \text{Post-retrofit campus electricity cost} \\
SS_{\text{Savings Campus Electricity}} &= \text{Calculated campus electricity cost savings}
\end{align*}
\]

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

\[
\begin{align*}
\text{Rate}_{\text{Campus Baseline, kWh}} &= $0.03269 \text{ per kWh} \\
\text{Rate}_{\text{Campus Baseline, kW}} &= $19.25 \text{ per kW}
\end{align*}
\]

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

\[
\begin{align*}
\text{Rate}_{\text{Post Campus, kWh}} &= $0.0565 \text{ per kWh}
\end{align*}
\]

Pre-Retrofit Baseline Campus Usage Models: 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 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

Pre-Retrofit Baseline Cost: 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.
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.

<table>
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<tr>
<th>Date</th>
<th>9/4/95</th>
<th>12/25/95</th>
<th>12/28/95</th>
<th>1/15/96</th>
<th>7/4/96</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td>12/27/95</td>
<td>1/1/96</td>
<td>5/27/96</td>
<td></td>
</tr>
<tr>
<td>September-95 Weekdays</td>
<td>September-95 Weekends</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hour</strong></td>
<td><strong>Avg (kWh)</strong></td>
<td><strong>Min (kWh)</strong></td>
<td><strong>Max (kWh)</strong></td>
<td><strong>Std Dev</strong></td>
<td><strong>Hour</strong></td>
</tr>
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<table>
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<tr>
<th>October-95 Weekdays</th>
<th>October-95 Weekends</th>
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</thead>
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<td>2659</td>
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<td>7</td>
<td>4914</td>
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<td>5742</td>
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<td>4663</td>
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<td>4046</td>
</tr>
<tr>
<td>23</td>
<td>3576</td>
</tr>
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</table>

Table Sept-Oct 1995 Weekday/Weekend Hourly Campus Electrical Usage Models (kWh vs. Hour of Day)
Historical Peak Campus Electric Demand for Baseline Year

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Peak kW</td>
<td>7051</td>
<td>7122</td>
<td>6955</td>
<td>6789</td>
<td>6517</td>
<td>6618</td>
<td>6875</td>
<td>6688</td>
<td>7106</td>
<td>6814</td>
<td>6779</td>
<td>6970</td>
</tr>
<tr>
<td>Off-Peak kW</td>
<td>7036</td>
<td>7071</td>
<td>7043</td>
<td>6703</td>
<td>6592</td>
<td>6532</td>
<td>6819</td>
<td>6643</td>
<td>6990</td>
<td>6804</td>
<td>6814</td>
<td>6930</td>
</tr>
</tbody>
</table>

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:

\[
\begin{align*}
\$E_{Pre} & = \text{Zero Dollars (paid by } \text{)} \\
\$E_{Post} & = E_{Post\, On\, Peak,\, kWh} \times Rate_{Post\, On\, Peak,\, kWh} \\
& \quad + E_{Post\, Off\, Peak,\, kWh} \times Rate_{Post\, Off\, Peak,\, kWh} \\
\text{Increases} & = \$E_{Post} \\
\text{where} & \\
\$E_{Pre} & = \text{Pre-retrofit electricity cost at Central Plant (Zero Dollars)} \\
E_{Post\, On\, Peak,\, kWh} & = \text{Measured monthly post-retrofit on-peak electricity consumption of both thermal plants (kWh)} \\
E_{Post\, Off\, Peak,\, kWh} & = \text{Measured monthly post-retrofit off peak electricity consumption of both thermal plants (kWh)} \\
\$E_{Post} & = \text{Post-retrofit period electricity cost} \\
Rate_{Post\, On\, Peak,\, kWh} & = \text{On-Peak electric consumption rate at time of construction ($/kWh)} \\
Rate_{Post\, Off\, Peak,\, kWh} & = \text{Off-Peak electric consumption rate at time of construction ($/kWh)} \\
\text{Increases} & = \text{Increased electricity cost to run}
\end{align*}
\]
both thermal plants

**Electricity Rate Structure at Time of Construction**

The Thermal Plant Electricity rate at time of construction is as 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 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

<table>
<thead>
<tr>
<th>Date</th>
<th>Energy (kWh)</th>
<th>Demand (kW)</th>
<th>Load Factor</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
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<td>64,500</td>
<td>195</td>
<td>43%</td>
<td>$6,222</td>
</tr>
<tr>
<td>09/05/97</td>
<td>63,000</td>
<td>195</td>
<td>45%</td>
<td>$6,145</td>
</tr>
<tr>
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<td>$62,969</td>
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</table>

### Savings Calculations:

\[
S_{E_{Pre\ Fac}} = E_{Pre\ Fac, kWh} \times (0.01388/kWh \times b + 13.00 + E_{Pre\ Fac, kW} \times 0.1275/kWh + \\
(0.04878/kWh \times \min(200 \times E_{Pre\ Fac, kW}, E_{Pre\ Fac, kWh})) + \\
(0.03819/kWh \times \min(E_{Pre\ Fac, kW}, 150) \times \max(0, E_{Pre\ Fac, kWh} - 200 \times E_{Pre\ Fac, kW})) + \\
(0.02440/kWh \times \max(0, E_{Pre\ Fac, kWh} - 350 \times E_{Pre\ Fac, kW}))
\]

\[
S_{E_{Post\ Fac}} = \max(E_{Post\ Fac, kW} \times \text{nhours/month} \times 0.65, E_{Post\ Fac, kWh}) \times 0.07/kWh
\]

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)
- $S_{E_{Pre\ Fac}}$ = 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)
- $S_{E_{Post\ Fac}}$ = 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

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<th>Demand (kW) $E_{Pre, Swim, kW}$</th>
<th>Load Factor</th>
<th>Cost</th>
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<td>68%</td>
<td>$5,781</td>
</tr>
<tr>
<td>07/07/97</td>
<td>66,000</td>
<td>147</td>
<td>58%</td>
<td>$5,435</td>
</tr>
<tr>
<td>06/05/97</td>
<td>63,000</td>
<td>144</td>
<td>61%</td>
<td>$5,261</td>
</tr>
<tr>
<td>05/05/97</td>
<td>71,100</td>
<td>159</td>
<td>58%</td>
<td>$5,866</td>
</tr>
<tr>
<td>04/04/97</td>
<td>55,800</td>
<td>165</td>
<td>49%</td>
<td>$5,372</td>
</tr>
<tr>
<td>03/06/97</td>
<td>75,300</td>
<td>166</td>
<td>67%</td>
<td>$6,165</td>
</tr>
<tr>
<td>02/06/97</td>
<td>71,400</td>
<td>162</td>
<td>63%</td>
<td>$5,937</td>
</tr>
<tr>
<td>01/06/97</td>
<td>64,800</td>
<td>144</td>
<td>57%</td>
<td>$5,330</td>
</tr>
<tr>
<td>12/08/96</td>
<td>76,200</td>
<td>153</td>
<td>67%</td>
<td>$5,943</td>
</tr>
<tr>
<td>11/05/96</td>
<td>69,600</td>
<td>153</td>
<td>65%</td>
<td>$5,691</td>
</tr>
<tr>
<td>Totals</td>
<td>835,500</td>
<td></td>
<td></td>
<td>$69,118</td>
</tr>
</tbody>
</table>

### Savings Calculations:

\[
$E_{Pre, Swim} = E_{Pre, Swim, kWh} \times 0.01388/kWh + 13.00 + E_{Pre, Swim, kW} \times 12.75/kW + 
\left(\frac{0.04878/kWh \times \min(200 \times E_{Pre, Swim, kW}, E_{Pre, Swim, kWh})}{E_{Pre, Swim, kWh}}\right) + 
\left(\frac{0.03819/kWh \times \min(150 \times E_{Pre, Swim, kW}, \max(0, E_{Pre, Swim, kWh} - 200 \times E_{Pre, Swim, kW}))}{E_{Pre, Swim, kWh}}\right) + 
\left(\frac{0.02440/kWh \times \max(0, E_{Pre, Fac, kWh} - 350 \times E_{Pre, Fac, kWh})}{E_{Pre, Swim, kWh}}\right)
\]

\[
E_{Post, Swim} = \max(E_{Post, Swim, kW} \times \text{nhours/month} \times 0.65, E_{Post, Swim, kWh}) \times 0.07/kWh
\]

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)
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:

\[
\begin{align*}
$G_{\text{Pre Satellite}} &= G_{\text{Pre Satellite}} \times \text{Rate}_{\text{Pre Gas}} + \text{Facility}_{\text{Pre Charge}} \\
$G_{\text{Pre Central Plant}} &= \text{Zero Dollars (paid by)} \\
$G_{\text{Pre}} &= $G_{\text{Pre Satellite}} \\
$G_{\text{Post}} &= (G_{\text{Post Satellite}} + G_{\text{Post Central Plant}}) \times \text{Rate}_{\text{Post Gas}} + \text{Facility}_{\text{Post Charge}} \\
\text{Increases} &= \text{Thermal Plant Gas} = $G_{\text{Post}} - $G_{\text{Pre}} - $G_{\text{Post New Building Gas HW}}
\end{align*}
\]

where

$G_{\text{Pre Satellite}} =$ Stipulated monthly Satellite Plant baseline gas usage (CCF)
\text{Rate}_{\text{Pre Gas}} =$ Gas usage rate during the Pre-Retrofit baseline period
\text{Facility}_{\text{Pre Charge}} =$ Facility charge during the baseline period
\text{Rate}_{\text{Post Gas}} =$ Gas rate at the time of construction
\text{Facility}_{\text{Post Charge}} =$ Facility charge during the post-retrofit period

Texas Energy Coordinating Council, and the Texas General Services Commission, State Energy Conservation Office

Energy Systems Laboratory

Texas Engineering Experiment Station
$\text{Increases Thermal Plant Gas}$ = Increased gas costs

**Gas Rate During Baseline Period**
The gas rate during the baseline period is as follows:

- **Facility Charge:** $14$/month
- **Usage Charge:** $0.292$ per CCF for all CCF

Where $1$ CCF = 100 cubic feet

**Gas Rate at Time of Construction**
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

**Pre-Retrofit Baseline Cost:** The central plant was operated by 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

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

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:

\[
\begin{align*}
&W_{\text{Post Satellite Plant}} = W_{\text{Pre Satellite Plant}} \times \text{Rate Water} \\
&W_{\text{Pre Central Plant}} = \text{Zero Dollars (paid by) } \\
&W_{\text{Pre}} = W_{\text{Pre Satellite Plant}} \\
&W_{\text{Post}} = (W_{\text{Post Satellite Plant}} + W_{\text{Post Central Plant}}) \times \text{Rate Water} \\
&S\text{Increases Thermal Plant Domestic Water} = W_{\text{Post}} - W_{\text{Pre}}
\end{align*}
\]

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)
- \( \text{Rate Water} \) = Water rate at time of construction
- \( W_{\text{Post}} \) = Post-retrofit period water cost
- \( S\text{Increases Thermal Plant Domestic Water} \) = 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.

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

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:
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

<table>
<thead>
<tr>
<th>B_0 (y-intercept)</th>
<th>-26667 (Ton-Hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B_1 (slope)</td>
<td>987.0 (Ton-Hrs/°F)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.91</td>
</tr>
<tr>
<td>CV-RMSE</td>
<td>11.5%</td>
</tr>
</tbody>
</table>
The baseline model developed is:

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

Where

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

![Graph showing the relationship between Chilled Water Usage (Ton-Hrs) and Average Daily Temperature. The graph is a scatter plot with a linear trend line.](image)

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

### Weekend Purchased Chilled Water Model Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_C$ (change point)</td>
<td>62.5 (°F)</td>
</tr>
<tr>
<td>$Y_C$ (change point)</td>
<td>27712 (Ton-Hrs)</td>
</tr>
<tr>
<td>$B_0$ (left slope)</td>
<td>655.3 (Ton-Hrs/°F)</td>
</tr>
<tr>
<td>$B_1$ (right slope)</td>
<td>989.2 (Ton-Hrs/°F)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.91</td>
</tr>
<tr>
<td>CV-RMSE</td>
<td>12.1%</td>
</tr>
</tbody>
</table>

The baseline model developed is:

If Avg Temp $< X_C$

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

If Avg Temp $> X_C$

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

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

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: $0.12061/\text{Ton-Hr}$

Production Charge: $31,492/\text{month}$
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:

\[
SH_{\text{Pre Purchased Hw}} = (H_{\text{Pre Purchased Hw Weekdays}} + H_{\text{Pre Purchased Hw Weekends}} + H_{\text{Adjust}}) \times \text{Rate}_{\text{HW}} + \text{Production Charge}
\]

\[
SH_{\text{Post Purchased Hw}} = \text{Zero Dollars (purchases will be eliminated)}
\]

**Savings** \(\text{Purchased HW} = SH_{\text{Pre Purchased Hw}}\)

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

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 below.
Weekday Purchased Hot Water Model Statistics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_C$ (change point)</td>
<td>75.96 (°F)</td>
</tr>
<tr>
<td>$Y_C$ (change point)</td>
<td>98.91 (MMBTU)</td>
</tr>
<tr>
<td>$B_0$ (slope)</td>
<td>-8.715 (MMBTU)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.92</td>
</tr>
<tr>
<td>CV-RMSE</td>
<td>15.6%</td>
</tr>
</tbody>
</table>

The baseline model developed is:

If $\text{Avg Temp} < X_C$

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

If $\text{Avg Temp} > X_C$

$$E_{\text{MMBTU}} = Y_C$$

Where

$X_C$ = Model Change Point (°F)
$Y_C$ = Model Change Point (MMBTU)
$E_{\text{MMBTU}}$ = Predicted Daily Usage (MMBTU)
$B_0 = -8.715$ MMBTU/°F
$\text{Avg Temp}$ = Average Daily Temperature (°F)
Weekend Purchased Hot Water Model Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X_C (change point)</td>
<td>74.29 (°F)</td>
</tr>
<tr>
<td>Y_C (change point)</td>
<td>101.1 (MMBTU)</td>
</tr>
<tr>
<td>B_0 (slope)</td>
<td>-8.83 (MMBTU)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.91</td>
</tr>
<tr>
<td>CV-RMSE</td>
<td>16.2%</td>
</tr>
</tbody>
</table>

The baseline model developed is:

If Avg Temp < X_C
E_{MMBTU} = Y_C + (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 |
|                            | $297,000 |
| Annual Operating Cost      | $ 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 (chilled 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

\[
E_{\text{Campus Adjust, kWh}} = \text{Additional electricity consumption due to baseline adjustment}
\]
\[
E_{\text{Post Campus New Bldg, kWh}} = \text{Measured electricity consumption of any metered new buildings}
\]
\[
E_{\text{Post Campus, kWh}} = \text{Measured electricity consumption during post-retrofit period}
\]
E_{\text{Post Model, kWh}} = \text{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:

\[ C_{\text{Adjust}} = C_{\text{Post Total CHW}} - C_{\text{New Buildings}} - C_{\text{Post Model}} \]

where

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

\[ C_{\text{Post Model}} = C_{\text{Post Total CHW}} - C_{\text{Undergrad Learning Center CHW}} \]

\[ C_{\text{Undergrad Learning Center CHW}} = \text{measured chilled water use of the new undergraduate learning center (Ton-hrs)} \]

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:

\[
H_{\text{Adjust}} = H_{\text{Post Total HW}} - H_{\text{New Buildings}} - H_{\text{Post Model}}
\]

where

- \( H_{\text{Adjust}} \) = Hot water usage adjustment due to campus changes (MMBTU)
- \( H_{\text{Post Total HW}} \) = Measured total hot water usage during post-retrofit period
- \( H_{\text{New Buildings}} \) = Measured hot water usage of new buildings (MMBTU)
- \( H_{\text{Post Model}} \) = 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.