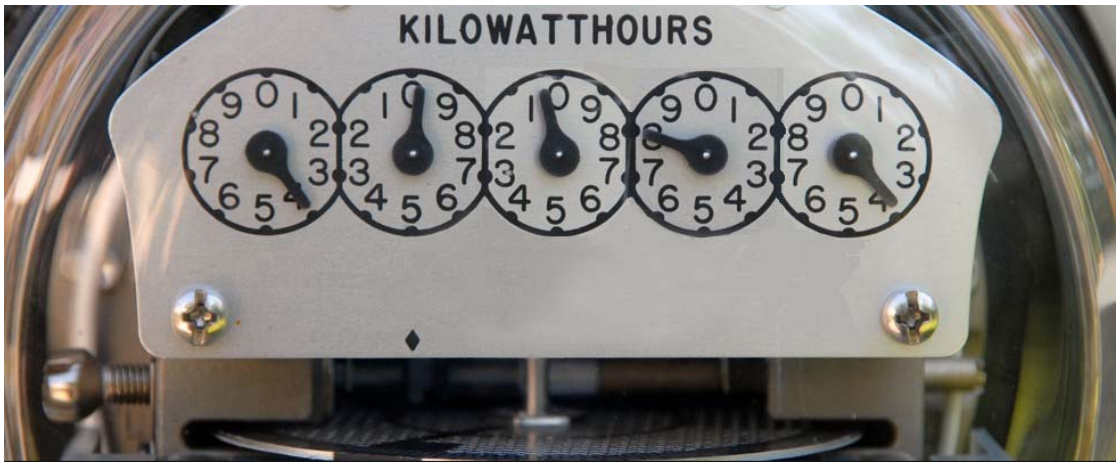
Energy & Water Audit Field Guide

US ARMY Corps of Engineers



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1. OVERVIEW

1.1 Introduction

The basic purpose of any energy and water audit is to find viable methods to reduce overall energy and potable water consumption. Due to the vast variances in facilities, there is no "one-size-fits-all" protocol for conducting energy audits. The protocol presented herein is intended as a general guide to cover the majority of circumstances. However, the audit team must exercise a certain amount of flexibility based on sound engineering principles for those circumstances where deviations may be required.

The America Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) postulated three specific levels of audit protocols:

- Level I Analysis – Walk-Through Analysis
- Level II Analysis – Energy Survey and Analysis
- Level III Analysis – Detailed Analysis of Capital-Intensive Modifications.

The scope of each Level is amplified in following sections.

While there are numerous protocols structured around the ASHRAE models, the methodology detailed in this guide is built around a modified Level II, for compliance with Energy Independence and Security Act of 2007 (EISA 2007) Section 432, with strong emphasis on pre-audit data analysis. The fundamental intent of this guide is to minimize the required "on-site" time and to pre-determine specific areas where conservation measures may be effective.

The goal is to reduce costs, such that smaller facilities can afford an audit, while maintaining the highest standards and accountability. In addition, the collected and calculated data is to be presented in a report format that covers several facets of the facility. This report is intended to fulfill the audit requirements stipulated in EISA 2007 Section 432 and provide a useful document on the facility for use by the facility manager and energy manager.

The cost of an audit varies greatly depending on location, number of buildings, number of stories, square feet, etc. However some fundamental guides can be approximated. In general, the minimum cost would be about $21,500.00. Again, there could be adjustments necessary for multi-building facilities and the number of stories.

While pre-audit analysis is a useful tool, it is not intended to replace the actual on-site inspections, measurements or findings. Pre-audit analysis is strictly a guide for better time utilization during the physical audit. It does however allow certain renewable

energy sources to be evaluated. These may include solar PV, solar water heating, solar space heating, natural light harvesting potentials, wind power and ground source heat pumps. Most often evaluations of renewable energy systems will lead to a level III study, unless eliminated by the initial findings.

2. EXECUTIVE SUMMARY

This Energy & Water Audit Protocol Field Guide is provided as a road map on "how to conduct a successful energy and water audit." It draws upon successful audit protocols and "lessons learned," to establish a low cost alternative to a traditional ASHRAE Level II audit, which requires less field time, and meets specific goals and objectives without detracting from its technical correctness, consistency and completeness.

It is intended to provide the necessary steps, tools, evaluation techniques and report generating guide lines for persons with reasonable energy and water knowledge to be able to conduct a successful audit. It has been specifically designed to be a "living" document which should be reviewed and amended periodically to assure the most up to date techniques and technologies are applied. This will be accomplished by a selected team representing Military Missions, Civil Works, and Interagency support provided by USACE.

This guide is presented in logical sequential steps with measurable milestones to assure completeness and accuracy of an audit. The last section of this guide lists some of the EISA 2007 Section 432 requirements to illustrate this guide's compliance with its requirements.

3. THE ASHRAE AUDIT PROTOCOLS

This covers USACE Energy and Water Audit Level Protocols.

3.1 The ASHRAE Level I Audit

3.1.1 Purpose

The Level I ASHRAE audit is intended to be a quick view to determine the basic potential for energy conservation measures as well as water conservation opportunities. It does not detail economic benefits, but rather points out potential opportunities. It is fundamentally the gateway to more detailed audits.

3.1.2 Protocol

The ASHRAE Level I audit is essentially a "*Walk-Through Analysis"* in which certain fundamental data is collected for a preliminary assessment of the facility. It is the basic starting point for building energy optimization. It also involves brief interviews with site personnel (both pre and post audit).

As with all audit levels, ascertaining a minimum of 12 consecutive months of all utility billing is essential. In addition, the utility specific rate structures are mandatory in determining potential viable energy conservation projects.

3.2 The ASHRAE Level II Audit

3.2.1 Purpose

An ASHRAE Level II audit is conducted to identify Energy Conservation Measures (ECM) and Water Conservation Measures (WCM), and to conduct a fundamental economic analysis to validate potential savings. More detail is presented in the findings to assess potential savings based on recommendations.

3.2.2 Protocol

The Level II project starts with the findings from a Level I audit or a pre-audit survey, and evaluates the building energy systems in detail to define a variety of potential energy efficiency improvements. In this case, the Level I (essentially a walk through inspection) is to be included in the audit and will be used to help create a Level II. As an example, systems such as Controls, Automation Systems, Re-Commissioning, Building Envelope, Lighting, Heating, Ventilation, and Air Conditioning (HVAC), Motors, Domestic Hot Water (DHW), Plug Loads, Renewable Energy Systems and others will be evaluated.

The study starts with a detailed analysis of energy consumption to quantify base loads, seasonal variation, and effective energy costs. From there, the study will include an evaluation of lighting, air quality, temperature, ventilation, humidity, and other conditions that may affect energy performance and occupant comfort. The process also includes detailed discussions with the building occupants to explore potential problem areas.

The Level II audit will result in a clear and concise report and out briefing, detailing findings and subsequent ECMs and WCMs. The out briefing is conducted at the conclusion of the site visit and presented to the facility manager(s). A presentation of findings is provided by each team member.

Identified ECM's will be categorized into no/low-cost, moderate cost and potential significant cost projects requiring capital (see Table 1 for cost categories). Other categories may include Maintenance items, Renewable Energy Projects, and Work in Progress. The findings will include general costs, economic and performance measures to assist in project evaluation.

Some of the ECMs and WCMs revealed during the ASHRAE Level II audit can be implemented quickly with rapid or immediate financial payback. Some ECMs may require more detailed analysis of benefits and costs. Other ECMs, may involve a more detailed engineering study to determine potential benefits. Typically, these also require capital investments. This is where the ASHRAE Level III audit becomes essential.

3.3 The ASHRAE Level III Audit

3.3.1 Purpose

The Level III audit is intended to evaluate potential conservation projects by performing detailed engineering studies. Typically, it is reserved for items of significant cost which require substantial capital investment and show promise of good economic returns.

3.3.2 Protocol

Often referred to as an "investment grade" audit, the Level III analysis is an expansion of the previous audit levels and focuses on the facility representative's selection of measures to analyze further. It is a detailed engineering analysis with implementation (designs), performance Measurement and Verification (M&V), and fully instrumented diagnostic long-term measurements.

The anticipated results of a Level III audit are complete designs for implementation, including costs and economic indicators. The completed study should support decisions to proceed after gathering sufficient funding.

4. A BASIC AUDIT GUIDE

4.1 Purpose and Scope

This Energy Audit Protocol consists of pre-audit data collection and analysis, combined with a modified ASHRAE Level II audit. The ASHRAE Level I is essentially replaced with an in-depth study of pre-audit data of the facility. See 5.2 for details on pre-audit data. Recommendations may be made for a Level III or Investment Grade Audit (IGA), for specific identified conservation measures.

Under normal circumstances, this audit consists of approximately 40% pre-audit information gathering and analysis (Phase I & II), 20% on site data collection (Phase III), 40% final calculations and report generation (Phase IV). As previously noted, different facilities may require modifications to any postulated protocol, and thus this guide is general in nature. It will be up to the audit team to determine any required additions and deletions based on the specific circumstances.

The initial phase of an energy audit will require the facility manager (or logistics personnel) to gather and organize the requested information about the facility (per 5.2.3 Facility Basic Data). This information is used by the assessment team in planning the audit, determining areas of focus, preliminarily assessing specific systems and determining an approximate overall standing. It is very important that the assessment team have adequate time to analyze the gathered information. Timely receipt of requested data is important for proper pre-audit analysis.

An example copy of a final audit report is included in Appendix I, to illustrate the scope and depth of this audit protocol. The fundamental objectives are:

i.) Fulfill government requirements
ii.) Provide constancy from audit to audit (Including ECM/WCM numbering)
iii.) Provide a useful document which can function as a reference for future projects
iv.) Establish a baseline for audit updates as required by EISA 2007 Section 432

In addition, the scope of work should include observations from operational audits, safety audits, maintenance practices, housekeeping and minor energy issues which may be solved locally.

Identified ECM and WCM are categorized as follows:

1. No to low cost (<25k)
2. Moderate cost (25 to 150k)
3. Significant cost (>150k)
4. Renewable technologies

5. Not economical feasible
6. Requires further study
7. In progress

4.2 Required Tools

There are certain required tools associated with conducting energy audits. The following list is not intended to be fully encompassing, but rather as a guide to typical items required. Individual team members may choose to add other items to aid in their assessment.

- Tape Measure
- Flashlight
- Infrared Temperature Sensor
- Light Meter
- Humidity Sensor
- Clipboard pens and forms
- Compass (Primarily for PV, Solar Panels and building orientation)
- Map of the installation if not familiar with location of all buildings
- Probe Type Temperature Sensors
- Airflow Velocity Sensor
- Pliers
- Screwdrivers
- Nut Drivers
- Barometer
- Infrared or other remote thermometer(s)
- Magnifying Glass
- Camera (Digital)
- Multi-meter
- Infrared camera
- Stop watch
- Volumetric container for plumbing flow rates
- Ladder (available at site)
- Mechanical and Electrical Room Keys (Available on site)
- Laser measuring device (Optional)

4.3 Audit Forms

Every commercial flight finds the pilot reviewing a pre-flight check list to assure nothing is overlooked. The use of audit forms provides a similar method to assure all potential items were checked. The use of audit forms similar to those available in Appendix I.

5. PERFORMING THE AUDIT

5.1 Introduction

This energy and water audit protocol field guide is broken out in four distinct phases, collection of pre-audit data (Phase I), preliminary analysis (Phase II), site visit (Phase III), and preparing the final report (Phase IV). The pre-audit data and the preliminary analysis may assist in forming a team with the most desired skill sets to meet the specific facility requirements. The energy audit team must be composed of at least one Professional Engineer, a Certified Energy Manager (may be the same person), and additional professionals (mechanical engineer, electrical engineer, and architect) with proven skill sets in assessing specific systems identified in the facility. These skill sets include, but may not be limited to:

- Electrical Systems
- Building Envelope
- Lighting and Control Systems
- Plumbing Systems
- HVAC Systems
- Energy Measurement, Monitoring, and Analysis
- Energy Conservation Measures
- Water Conservation Measures

The audit process starts with contacting the facility and initiating the basic requirements for data collection, prior to the actual site visit. During these initial stages, the basic work hours, availability of area, restrictions, permission to take photographs, safety protocols, and personal safety equipment requirements, points of contact, access to mechanical and electrical rooms and availability of required items such as ladders should be discussed and recorded. In addition, the request for basic “as-built” drawings and utility data including name, rate structure and a minimum of twelve consecutive months of actual bills should be requested.

Other discussion items may include any recent modifications, planned modifications and any known issues. Obtaining as much information in advance as possible will greatly assist in determining the focus and the fundamental skill sets required for the audit team, as well as assist in reducing the required time on site.

Once the preliminary information has been analyzed, it may point to specific areas where conservation measures may be viable, as well as where specialized skills would be beneficial.

Next, a physical inspection of the facility is performed. Adequate measurements, item counts, photographs and data recording are performed to assure a complete assessment of the various systems. Sketches showing locations of windows, doors, light fixtures and major equipment are recommended. When as-built drawings are available, they can be used as a base for creating field sketches while verifying actual conditions. Take notes of all findings, counts, name plate data, flows, sizes etc. This becomes invaluable when assembling the audit report. Take as many photographs as required to illustrate all findings and recommendations. It is far better to over photograph than to under photograph.

Infrared thermography should be used for detecting leaks around doors and windows. In addition, inadequate insulation can also be detected. Infrared thermography should also be employed for all electrical breakers and panels. This will determine any overloads or loose connections.

Identified potential ECM's are generally placed into one of seven categories (as seen below in Table 1). This classification is useful in setting priorities and obtaining budgetary funding. The summary of conservation measures must also include estimated savings to assist in the decision making process. This information should be presented in the Executive Summary of the final report, including the total percent energy reduction potential.

Category	Description	Investment
1	No to Low Cost	<25k
2	Moderate Cost	25 - 150k
3	Significant Cost	>150k
4	Renewable Technologies	N/A
5	Not Economically Feasible	SIR<1.2
6	Requires Further Study	N/A
7	In Progress	N/A

Table 1 ECM Categories

Conducting an effective energy audit must employ these specific sequential phases to assure the desired end results. Each specific Phase of the audit process is discussed in more detail in the following sections.

5.2 Phase I – Collection of Pre-Audit Data

The initial phase of an energy audit must be the preliminary collection of basic data. Arguably the most important part of the entire audit process, this phase allows an initial assessment of the facility condition. In addition, these preliminary data can assist in identification of potential high energy use areas, which can be more closely scrutinized during the actual site visit. This information may also assist in determining the makeup of the audit team to assure the proper skill sets are available.

The most important group of data consists of a minimum of one continuous years' worth of actual utility billing from each utility provider. In addition, the names of the specific providers and their rate structures are required. Most electrical rate structures are designed such that the actual unit cost [$/kWh] varies during the year. Certain energy conservation measures are seasonal as well and thus it is imperative that the actual rate be calculated for each month to achieve the true savings. The use of averages or "blended" rates can cause errors as much as 50% in extreme cases.

Many electrical utilities have a demand charge based on the highest peak demand set during any 15-minute or 30-minute interval of the billing period. Some rates have a ratchet clause which charges a percent of the highest summer demand regardless of the current demand usage. This is important in that not all reductions in energy reduce the actual peak demand, and thus the savings can only be attributed to the energy portion of the bill, and no credit can be taken for demand. A comprehensive understanding of the specific rate structure is mandatory for postulating savings.

Natural gas and propane costs vary monthly as well. Fundamentally there is a delivery charge and the cost of the commodity (cost of gas COG). The commodity costs vary monthly based on the market value. Typically, delivery rates are long term rates filed with public utility commissions. The delivery rates can become quite convoluted and like electrical rates the specific rate structure must be secured and scrutinized. Energy reduction will come from the highest tier, which is the least expensive. This rate must be applied to calculate actual savings. Normally, savings in consumption will come off the highest tier (lowest cost), further emphasizing the need to know the specific rate structure.

The general purpose of the pre-audit information gathering is to establish an energy baseline, determine potential areas for improvement, and to analyze any noted consumption anomalies. Further, follow-up requests can be made to attempt to resolve noted issues.

Additional data to be collected in this phase should include, but may not be limited to:

5.2.1 Basic Information

1. Point(s) of contact, including phone numbers and email addresses
2. Facility operating hours (when can audit personnel be on site)
3. Permission for taking photographs
4. Personal safety equipment requirements
5. Noted restrictions

6. Availability of an electrician, ladders, keys to mechanical, electrical rooms, access to HVAC systems, roof access, etc.
7. Scheduled dates and time for the physical audit

5.2.2 Site location data (Items 1-5 lookup, 6 provided by location):

1. Longitude
2. Latitude
3. Elevation
4. Fuel region
5. ASHRAE climate zone
6. Surrounding terrain type (i.e. open water, desert, rolling hills with trees, urban, tall buildings etc.) This will determine the wind shear factor.

5.2.3 Facility basic Data (Provided by location):

1. Number of buildings, type, use and square footage of each
2. Year(s) constructed, added to or refurbished
3. Date of last commissioning
4. All utilities (energy sources) utilized
5. What utility meters are provided
6. As built drawings
7. Number of occupants and occupancy schedules
8. Construction type (As many details as possible)
9. Occupancy schedules
10. Operational hours
11. Buildings to be demolished, abandoned, and any historical structures
12. Any planned re-commissioning, remodeling and other modifications
13. Any un-conditioned space (sq. ft.) by building.

5.2.4 Weather data (Obtain from listed sources and used per UFC 3-400-02 Design Engineering Data):

1. Average monthly temperatures. (highs, lows and overall average)
2. Heating and cooling degree days by month.
3. Monthly wind speed @ 10 meters.
4. Monthly average high and low relative humidity.
5. Monthly average rain fall.
6. Prevailing wind direction.

NOTE: Weather data for a specific location can be obtained from available sources such as:

https://www.climate.af.mil/

5.2.5 Utility data (Request from facility):

1. All Utility Providers (Names) and their Rate Schedules (Include any rate changes and dates for the billing information provided)
2. A minimum of recent twelve consecutive months of actual bills for each utility and meter
3. If utility data for the facility is not readily available use portable data loggers with CTs and PTs to record electrical usage.

5.2.6 Geological data*:

1. Soil depth
2. Average ground temperature
3. Average ground water temperature
4. Bed rock type and depth
5. Soil thermal conductivity
6. Soil diffusivity

**** This data may be difficult to obtain, but it is helpful for evaluating potential ground source heat pump applications. Previous test well data from the area and USGS files may help. This may require further study to be completed on in a Level III Audit.***

Once this information has been received and verified, the preliminary analysis phase can begin. Upon completion of Phase I, the required skill sets, time on site, and potential conservation measures should have been identified and conveyed to the facility manager.

5.3 Phase II – Preliminary Analysis

5.3.1 Introduction

The second phase of this protocol organizes and evaluates the preliminary data to assist in focusing on areas of potential energy conservation and planning the field visit. Weather data can be compared with utility consumptions to look for seasonal trends and noted anomalies. Some of the useful pre-audit analysis tools are discussed below.

It is important to note these methods are for preliminary analysis only and the onsite data may alter some of the conclusions. They are however, useful in assessing areas of high energy use and potential areas where energy may be conserved, and can greatly reduce the required time spent onsite.

5.3.2 Heating and Cooling Degree Day (HDD & CDD) Assessment

In figure 1, heating and cooling degree days are displayed to determine the balance between heating and cooling loads. Most readily available data is based on 65°F.

Balanced loads may indicate a potential for ground source heat pumps. In addition, this data can be used to determine the loads on cooling and heating systems, and compared with annual energy consumption trends.

There are typically two "cross-over" points where the HDD and CDD are equal. They can be used to determine the approximate summer and winter durations. They are also useful in determining approximate base line energy consumptions.

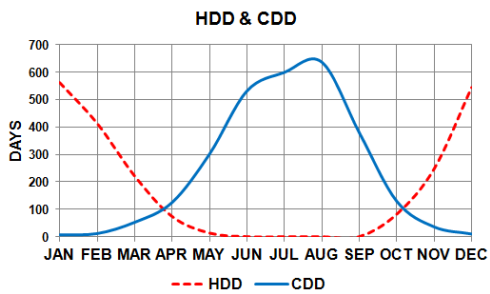


Figure 1 Heating and Cooling Degree Days.

By adjusting the energy scale, the energy consumption can be overlaid on the CDD curve to indicate the effect the cooling load has on overall energy consumption. In the figure below (Fig. 2), the increase in summer energy use tracks the CDD trend fairly well and can be considered as the driving force behind the summer electrical consumption increases.

In certain colder climate zones, overlaying the consumption over the HDD may provide useful information about heating energy trends. This may require trending different utility consumptions if natural gas, propane or other non-electric energy sources are used for space heating.

5.3.2 Approximating Heating Loads

In turn, the amount of heating and cooling annual energy use can be approximated. These can be scrutinized to determine any potential excessive energy consumption and to determine if any added focus on these systems is warranted.

As an example, in figure 2 the electrical usage (kWh) was multiplied times .01833 so that the maximum value was about equal to the maximum CDD data. The maximum CDD is about 650 and the maximum kWh was about 7800, thus 650/7800 = 0.0833. Note this is just for trending and thus the exact numbers are not important.

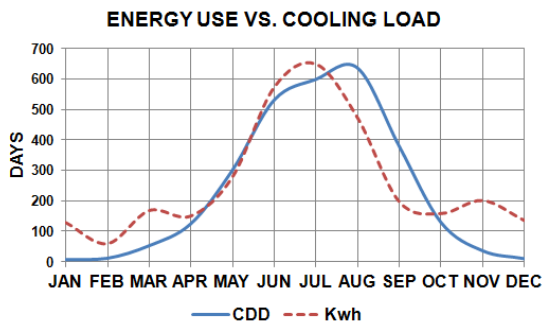


Figure 2 Trending Cooling Loads against Electrical Energy Consumption.

The overall electrical use trend in Figure 2 would suggest that the major driving factor for electrical energy consumption is due to the cooling load. In this case, heating was via natural gas. The same technique is applicable regardless of the energy source used for space heating. The consumption profile is overlaid on the HDD trend curve. Figure 2 is from a location in Texas and thus the cooling load is considerably greater than locations in the Northern states.

Note that the displayed monthly consumption is based on billing dates and not calendar days. This partially explains the apparent lag in the curves, July through October. In addition, the overall load factors as seen in Figure 3 below, are quite different which further contributes to the offset.

5.3.3 Effects of Load Factors

The load factor is simply the actual consumed kWh divided by the total time multiplied by the peak (billed) demand. Although not all utility rates include demand charges or tiered energy charges based on demand, the practice is relatively common. Demand and demand weighted energy charges are one of the fundamental methods electric utility companies recover their capital investments. How this affects the facility billing is illustrated in the following example. This example stresses the need to obtain the exact rate structure to determine the unit costs.

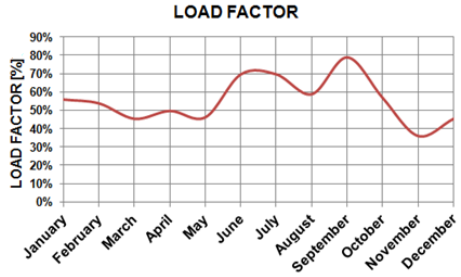


Figure 3 Load Factor.

As an example a rate structure may consist of the following components:

Customer Service Charge: $50.00 per month

Demand Charge:	$12.75 per kW based on the 15-minute monthly peak.
Energy Charge:	$0.0325 times the first 100 kWh times the demand. $0.0275 for all remaining kWh.
Fuel Charge:	$0.02612 for all kWh.

This is a 2 tiered energy rate that is demand weighted. Assuming a 30-day billing cycle; a peak demand of 208 kW; and an energy usage of 120,678 kWh, the Load Factor is 120678 kWh/(208 kW*24 hrs.*30 days) or 80.58%

The bill would be [Excluding any applicable taxes]

Customer Service Charge:	$50.00	
Demand Charge:	$2,652.00	[208 kW x $12.75]
Energy Tier 1:	$676.00	[100 hr. x 208 kW x $0.0325]
Energy Tier 2:	$2,746.65	[120678 kWh-(100 x 208 kW) x $0.0275]
Fuel Charge:	$3,152.11	[120678 x $0.02612]
Total Bill:	$9,276.72	
Unit Cost:	$0.07687 / kWh	[$9,276.72 / 120678 kWh]

Using the same rate structure and kW and altering the load factor to 50% yields a use of 74,880 kWh. This bill would be:

Customer Service Charge:	$50.00	
Demand Charge:	$2,652.00	[208 kW x $12.75]
Energy Tier 1:	$676.00	[100 hr. x 208 kW x $0.0
325]		
Energy Tier 2:	$1,487.20	[74880 kWh-(100 x 208 kw) x $0.0275]
Fuel Charge:	$1,955.87	[74880 x $0.02612]
Total Bill:	$6,821.07	
Unit Cost:	$0.09109 / kWh	[$6,821.07 / 74880 kWh]

It is easy to see that for this example, the higher the Load Factor the lower the unit cost. If equal amounts of energy were consumed, the demand would be 335 kW and thus the demand charge would be $4,271.25, the actual total bill would be $10,959.51 for a unit cost of $0.090816. There are countless ways for utility companies to create rates which favor higher load factors. This again emphasizes the need to understand the exact rate structure and not just “blended or average” rates which are applied to the facility.

Certain recommended ECM’s may be seasonal i.e. space heating load reduction. The actual savings could be dependent upon the winter load factors and greatly influenced if a “blended” or average cost is applied.

Once the billing data has been analyzed and the rate structure modeled, specific consumption graphs are useful in analyzing trends and looking for abnormalities. Load factor, power factor, demand, consumption, cost and unit cost are some of the data which can be graphed and analyzed.

5.3.4 Estimating Equivalent Square Footages

Appendix D is included to address a method of estimating the facility EUI. While other methods may be available, this example indicates potential issues when multi-buildings are served by single meters. Sub-metering would be the best solution.

5.3.5 Estimating Cooling and Heating Loads as a Percent of Consumption

The approximate percent of electrical energy consumed by heating and cooling systems can be estimated by subtracting the estimated base load from the total summer consumption. This is illustrated in Figure 4. The base (dashed) line is subtracted from the total electrical consumption (solid) line for the summer months. Again, this is only used to estimate the percentage of energy consumed in space cooling. The figure below is for a facility with gas space heating.

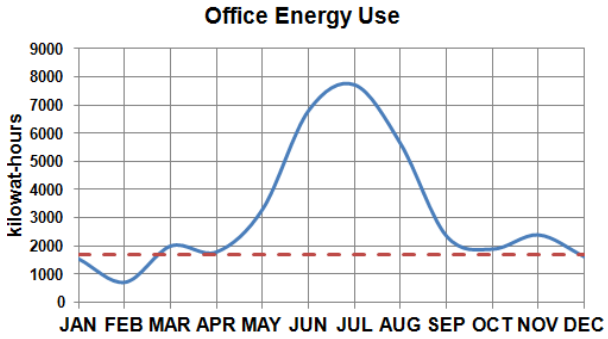


Figure 4 Approximate HVAC energy consumption.

The rough approximate base line is estimated as follows. From the crossover points in Figure 1, the average use for (Jan.-Mar.) + (80% of Apr.) + (20% of Oct.) + (Nov.-Dec.) is calculated as 1,680 kWh. This represents an approximate non HVAC base line. By overlaying the actual consumption, the approximate HVAC contribution is displayed (Fig. 4). Since the annual consumption for this meter was 37,802 kWh, the HVAC portion is 37,802-(12*1,680) or 17,642 which represents 46.67%.

NOTE: This is an approximation only for the purpose of identifying potential savings.

If electrical energy was used for space heating, the base would be subtracted from the winter totals as above. Regardless of the fuel type used for heating, a similar approach can be utilized.

5.3.6 Lighting Loads as a Percent of Consumption

The approximate lighting loads can be obtained from the number and type of connected fixtures, and the reported number of operating hours per day. Once again, this is for a general usage only. Utility billings are rarely on a monthly basis, but rather readings are taken at approximate dates. That is some billing periods may run from the 14th to the following months' 16th. Billing periods can be from 27 to 35 days in duration and could even fall outside these limits. Thus the estimated lighting load is just a reference point. Note the use factor (operational hours per year) will be an estimate from the facility. Annual consumptions will tend to provide more accurate results than monthly figures.

Summing the connected lighting times their wattage, and the hours of use annually, will provide an annual kWh value which can be divided by the total consumption to calculate and approximate percent of overall electric consumption attributable to lighting.

5.3.7 Ancillary Loads as a Percent of Consumption

Ancillary loads can also be estimated by their name plate data and use factor (Percent of the time they operate and average load). Once again, it must be emphasized that these percentages of overall load are strictly to gain insight as to potential areas of excessive usage.

5.3.8 Plug Loads as a Percent of Consumption

Once the major plug load items are identified, ASHRAE publishes tables which indicate their approximate annual power consumption. Summing these will indicate an approximate plug load percent. Some of these items include refrigerators, freezers, ice machines, vending machines,, fans, lamps, radios, computer systems, coffee machines, microwaves, toaster ovens etc.

NOTE: The sum of the above loads should be within +/- 10% of the annual billing. If the sum of these values is less than 10%, there are apparent discrepancies in the time of use assumptions, wattage or the percent load. This should trigger further investigation into these loads.

5.3.9 Energy Use Intensity (EUI) and the Building Energy Quotient (bEQ)

A preliminary energy use intensity and subsequent building energy quotient can be postulated and used to compare the initial standing against similar building types. While the intent is to determine a general standing, the EUI is also useful in determining the extent of potential conservation measures required to bring the facility to an acceptable energy use level.

ASHRAE introduced a scale for evaluating the energy consumption based on the square footage without predominate use. This rating, in terms of kBTU/yr./sq.ft., is modified in the bEQ, which is usage specific. This is shown in the following table.

Scale Range	Rating	Description
≤0	A+	Net Zero Energy
1-25	A	High Performance
26-50	A-	Very Good
51-75	B	Good
76-100	C	Fair
101-125	D	Poor
>125	F	Unsatisfactory

Table 2 The ASHRAE Building Rating (EUI) Scale.

Table 2 shown in graphic form is illustrated below.

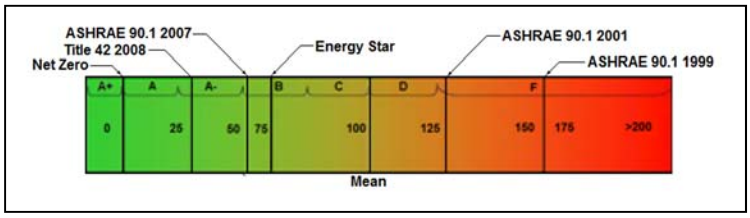


Figure 5 Charting the "As Is" Energy Use Intensity.

Figure 5 is simply the total consumed annual energy expressed in kBTU divided by the square footage of the facility. This should include all types of energy consumed at the facility. Some Energy Use Intensity (EUI) values are shown in Table 2A, others may be found at the following Energy Star web site.

https://portfoliomanager.**energystar**.gov/.../US%20National%20Median%

Building Type	National Medium EUI	Building Type	National Medium EUI
Admin.	61	College/University	97
Bank/Financial	87	Primary Schools	55
Government Office	77	High School	71
Medical Office	52	Preschool/Day Care	71
Mixed-use Office	71	Other Classrooms	40
Other Office	59	Fast Food	419
Laboratory	266	Restraunts/Cafeteria	229
Dist./Shipping	34	Othe Food Service	125
Warehouse	16	Hos[ital	199
Convience Store	232	Nursing Home	126
Convience Store w/gas	187	Dormitory	74
Grocery Store	193	Hotel	76
Food Sales	58	Motel	74
Fire/Police Station	98	Other Lodging	71
Other Public Order	89	Car Sales	82
Medical Office (diagnostic)	44	Retail Store	47
Outpatient Clinic	67	Other Retail	82
Refrigerated Warehouse	103	Post Office	64
Religious Worship	35	Repair Shop	43
Entertainment	35	Vehicle Repair	49
Library	92	Vehicle Storage	21
Recreation	40	Other Service	90
Social meeting	41	Strip Mall	94
Other Public Assembly	42	Enclosed Mall	90

Table 2A Average EUI Values.

The building energy quotient is the calculated EUI divided by the medium EUI for the specific building type.

It is unfortunate that the bEQ measurement does not account for the various climate zones. The factors shown in Table 2B reflect a multiplier for the average bEQ, to adjust for the specific climate zone. Table 2C shows the correction for specific building types. This information was calculated by the Department of Energy (DoE) and the National Renewable Energy Laboratory (NREL).

Table 2D reflects adjustment factors by building type for different climate zones.

Climate Zone	City	Factor
1A	Miami	0.95
2A	Houston	0.94
2B	Phoenix	0.91
3A	Atlanta	0.94
3B*	Los Angles	0.79
3B^	Los Vegas	0.89
3C	San Francisco	0.85
4A	Baltimore	1.04
4B	Albuquerque	0.93
4C	Seattle	0.96
5A	Chicago	1.12
5B	Denver	1.01
6A	Minneapolis	1.25
6B	Helena	1.14
7	Duluth	1.35
8	Fairbanks	1.79

*(Coast)
^(Other)

Table 2C bEQ Average Adjustment Factors.

DOE/NREL EUI to Zonal Benchmark Ratio																
	Miami	Houston	Phoenix	Atlanta	Los Angles	Los Vegas	San Francisco	Baltimore	Albuquerque	Seattle	Chicago	Denver	Minneapolis	Helena	Duluth	Fairbanks
	1A	2A	2B	3A	3B	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8
Medium Office	0.92	0.98	0.94	0.95	0.77	0.87	0.89	1.06	0.90	0.98	1.11	0.96	1.26	1.11	1.32	1.79
Warehouse	1.44	0.92	0.95	0.90	0.70	0.87	0.75	1.02	0.96	0.90	1.19	1.11	1.42	1.30	1.63	2.55
Stand-Alone Retail	0.90	0.90	0.87	0.89	0.64	0.80	0.71	1.04	0.88	0.94	1.17	0.99	1.35	1.20	1.50	2.10
Strip Mall	0.83	0.87	0.85	0.93	0.66	0.85	0.79	1.11	0.95	1.03	1.26	1.08	1.47	1.33	1.65	2.33
Primary School	0.98	0.97	0.94	0.94	0.78	0.89	0.87	1.04	0.93	0.92	1.12	0.99	1.27	1.12	1.35	1.92
Secondary School	0.87	0.89	0.86	0.89	0.65	0.83	0.77	1.06	0.89	0.95	1.17	0.99	1.38	1.19	1.51	2.19
Supermarket	0.87	0.93	0.88	0.94	0.84	0.88	0.92	1.02	0.93	1.00	1.08	0.99	1.15	1.09	1.23	1.47
Fast Food	0.91	0.93	0.91	0.95	0.84	0.92	0.89	1.03	0.96	0.97	1.11	1.02	1.21	1.12	1.30	1.61
Restraunt	0.86	0.90	0.87	0.94	0.80	0.89	0.88	1.04	0.95	1.00	1.12	1.02	1.22	1.13	1.31	1.63
Hospital	1.00	1.02	0.96	0.98	0.95	0.94	0.98	1.02	0.88	0.96	1.02	0.90	1.06	0.95	1.07	1.29
Outpatient	1.03	1.02	1.02	1.00	0.93	1.02	0.88	1.02	1.00	0.91	0.99	0.99	1.03	1.01	1.02	1.19
Motel	0.95	0.95	0.93	0.95	0.83	0.91	0.86	1.01	0.94	0.93	1.07	0.99	1.17	1.07	1.24	1.51
Hotel	0.81	0.89	0.82	0.95	0.86	0.87	0.92	1.05	0.98	1.02	1.14	1.07	1.23	1.18	1.34	1.61
Mid-Rise Appartment	0.95	0.95	0.93	0.94	0.77	0.89	0.80	1.04	0.92	0.94	1.16	1.02	1.34	1.19	1.46	1.87
Average Factor	0.95	0.94	0.91	0.94	0.79	0.89	0.85	1.04	0.93	0.96	1.12	1.01	1.25	1.14	1.35	1.79
Government Office	0.92	0.95	0.91	0.90	0.74	0.83	0.82	0.99	0.86	0.91	1.06	0.92	1.18	1.04	1.23	1.68

Table 2D Individual Building Adjustment Factors.

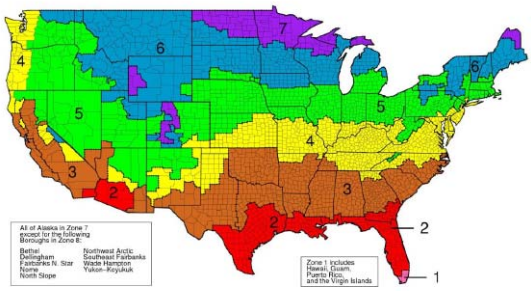


Figure 7 International Energy Conservation Code (IECC) Climate Codes for the U.S.

Many multi-building facilities are metered via a single meter. This creates a problem in resolving a true energy quotient. One postulated solution is presented in Appendix B, which calculates an equivalent facility square footage based on building types and individual square footages. Once again, this calculation is used only for comparison purposes and to assist in determining the level to which energy may be reduced.

5.3.10 Available Sunlight and Natural Light Harvesting

Solar radiation levels can be used to determine the viability of natural lighting potentials as well as solar energy potentials. The following three figures are examples of data used for this preliminary analysis. These are site specific.

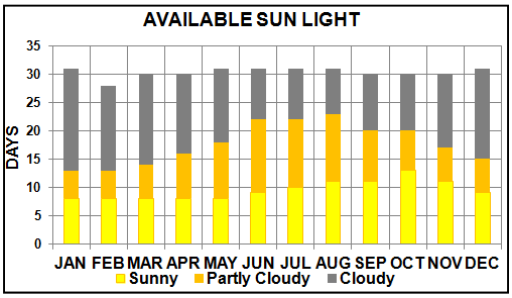


Figure 8 Weather Conditions.

Figure 8 illustrates the local distribution of cloud cover. This data can be helpful in determining potential daylight harvesting in the amount of available watts per square meter and/or available lumens.

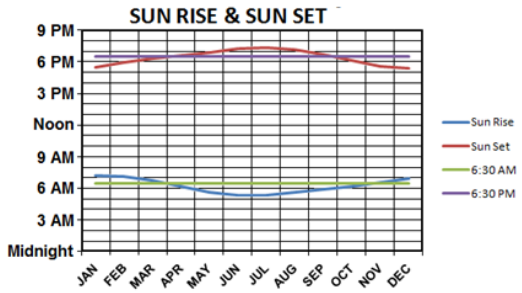


Figure 9 Sun rise & sun set overlaid on office hours.

In Figure 9, the sun rise and sun set times are over laid on the occupied hour lines. This graph is a good indicator of the availability of sun light for harvesting.

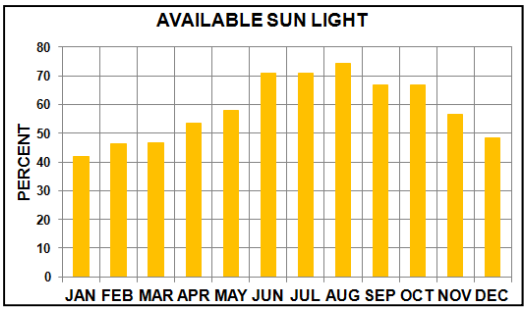


Figure 10 Percent of Sun Light Striking the Surface.

Figure 10 illustrates the effect of cloud cover on the amount of solar radiation that strikes the PV panels for the specified location, as well as indicating the intensity of natural light available.

5.3.11 Solar Radiant Energy

There are a host of factors that influence the amount of recoverable energy from the sun. These include the site location, time of day, time of year, panel angle, local weather patterns, etc. Determining the annual harvesting potential is best handled through the use of available daylighting simulation programs, such as Relux.

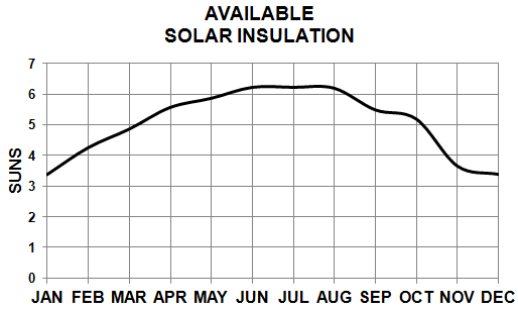


Figure 11 Solar Potential.

Figure 11 illustrates the actual amount of solar radiation (average per month) that is available at the specified location.

NOTE: A sun is defined as 1kWh per square meter. The sum of the daily irradiation defines the total suns for that day.

This information is available through the NREL PVWATTS program. If using PVWATTS, a fixed tilt array, set to the latitude, should be selected.

www.pvwatts.nrel.gov

5.3.12 Wind Energy

In general, wind potentials are best left to persons familiar with determining energy production potentials. Determine average wind speed and temperatures for the site from weather data collected. Wind velocities, average temperatures and humidity values are required to produce potential wind power generation data. Rayleigh and Weibull distribution curves are calculated and the specific manufacturer's output curve is used, to develop the anticipated annual output potential.

Fundamentally, if the average wind speed is less than 10 MPH small turbines may not be viable. This increases to about 12 MPH for larger utility scale units.

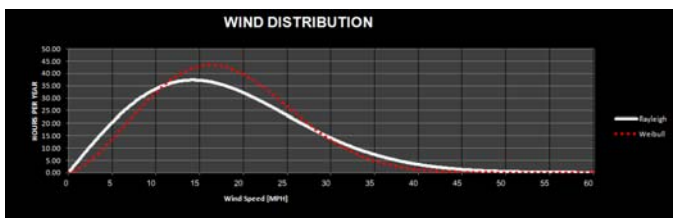


Figure 12 Weibull and Rayleigh Wind Speed Distribution Curves.

Figure 13 Turbine Output vs. Wind Speed Curve.

Figure 13 shows the specific output for a Jacobs J31-20 wind turbine. Note that the wind needs to be about 26 MPH for the unit to produce its name plate rating. The hours per year for a given wind speed, from the distribution curves (Figure 12) are multiplied by the output for that speed (Figure 13). The results are summed to provide the total annual potential output.

There many are other factors which influence wind turbines such as the hub height, air density and the wind shear exponent. Potential issues with tower height and noise levels may also restrict their use. If wind conditions are favorable, this is usually deferred to a Level III study. Wind averages below the stated minimums above would eliminate this renewable energy source.

5.3.13 Ground Source Heat Pumps (GSHP)

The ability for the earth to absorb or input energy in a GSHP application is quite complex. The soil depth, bed rock, heat transfer coefficients, ground water flows, diffusivity local average temperatures and the balance between HDD and CDD all influence the viability of these systems. It is always best to have data from an actual test well.

Check with local contractors to determine if there are any successful GSHP installations in the area. This may assist in determining if further study is warranted. Again, the evaluation is best left to knowledgeable persons in the industry. A fundamental disqualification is a large difference between HDD and CDD.

5.3.14 Analysis Summary

It is important not to lose sight of the basic objective, which is to get an overall idea of potential excessive energy consumption. This is not meant to quantify specific uses, but rather to gain an overview of the driving forces in the overall energy consumption.

Specific energy consumptions can be compared to DoE average values to determine if a category is considerably over or under the average. This may be useful in directing focus to certain systems. Building specific percentages can be utilized for a more detailed investigation.

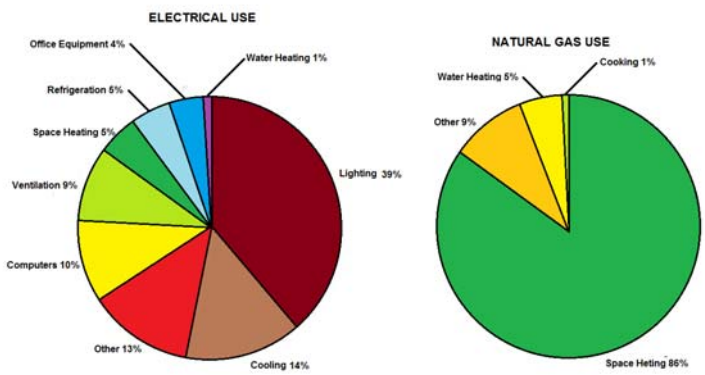


Figure 14 DoE Average Commercial Building Use.

It is important to note that comparing the audited facility against the above averages is only for reference purposes. Again, these data are not tempered for climate zones or unusual occupancy levels. Use this as a guide to determine excessive or deficient energy consumptions to focus on potential problem areas.

Note: Variations will exist between climate zones, occupancy types, and year of construction.

5.4 Phase III – The Site Visit

5.4.1 Introduction

All team members should fully understand the overall Scope of Work (SOW), and have reviewed the facility provided data. They should also have participated in the Phase I analysis. Each member should then be assigned to specific task areas (see details following). The audit leader should be familiar with the specific skill sets of individual team members and assign leads accordingly. Every effort should be made to cross train members within different task areas as time permits.

The initial meeting with facility personnel should detail what is to take place, access to photography, address specific safety concerns, identification protocols, personal protective equipment use and specified work hours. The proper personnel should be asked about specific area access, ladders, unlocking of areas, the need for an electrician etc.

Training and assurance of skill levels for the use of specific tools should be provided prior to the site visit. Daily reviews with the entire team should be held to assure all are keeping with the schedule and to determine if additional support is required.

Proper maintenance will assist in preserving system efficiency. All systems degrade with time, and thus the efficiency usually decreases. Proper maintenance can reduce the amount of efficiency losses. As an example, regular changing of air filters, either on a calendar period or based on pressure drop across the filter will consume less energy.

During an audit, housekeeping items such as obstructions, boxes or furniture restricting return or supply ducts, high partitions or obstructions to natural light, all can add to wasted energy. While not direct energy reduction methodologies, these items should be identified as potential factors in increased energy consumption, and as a professional, you are obligated to report any observed deficiency.

5.4.2 Detailed Task Areas

While the lists located below are not meant to be totally encompassing of all potential issues, they do provide guidelines into the fundamental scope of work. Photographic documentation is essential. Each conservation measure should be documented with supporting photographs. Other checks, measurements and evaluations may apply. Some items fall under the umbrella of maintenance, safety or housekeeping. They are included since professionals are obligated to report any findings detrimental to the overall operation.

Not every item listed will be applicable at each site, and the intended purpose is to cause the auditor to “stop, look and ask questions.”

5.4.2.1 General (Safety & Housekeeping)

1. Assure all major equipment is placed on a properly designed “housekeeping” pads
2. Assure all equipment is properly fastened to its’ pad
3. Assure all rotating equipment is properly guarded (i.e. coupling guards etc.)
4. Determine if all proper safety and warning signs are in place (No smoking, caution equipment starts automatically etc.)
5. Assure all exits are properly marked, and clear of obstructions that would impair a safe exit
6. All emergency doors should open outward and include panic hardware
7. Inspect for fire extinguisher placement. Inspect tags and dates they were inspected for proper charge
8. Note any housekeeping deficiencies, such as dirty filters and light covers, etc.
9. Check for trip hazards such as extension cords.
10. Identify all unusual plug load devices such as fans, radios, lights, heaters, personal refrigerators, etc.
11. Note clutter and blockage of vents and electrical panels
12. Check for doors and windows that are propped open
13. Record the closing time for entrance doors
14. Note any failure of doors to completely close on their own (Exterior or to non-conditioned spaces)

5.4.2.2 Mechanical

Inspect for proper operation, noting load, operating times, efficiencies, fuel type, size, models and other characteristics. (Record all name plate data and photograph if practical.)

1. Inspect and record name plate data for:
   a. Pumps
   b. Fans
   c. Blowers
   d. Motors
   e. Boilers
   f. Heaters
   g. Water Heaters
2. Check for minimum water storage temperature
3. Inspect all air compressors
4. Inspect all air system components and piping
5. Inspect all supply air paths
6. Inspect all Exhaust systems
7. Inspect for secure hold downs
8. Check for excessive noise or vibrations
9. Check for pressure drop across filters and exhaust systems

5.4.2.3 Electrical

1. Locate, photograph and record data for all:
   a. Transformers (Identify Utility that owns each)
   b. Meters, Utility (including any multipliers used)
   c. Meters, Sub-metering and what loads are measured
   d. All panel board breakers (include IR photograph)
2. Record light levels by room, include lamp count, type, and wattage. Record time and height of light level reading and with/without artificial light.
3. Note any non-operating lighting
4. Record/note any natural lighting opportunities, or shading to reduce solar heat gain
5. Record any control systems used for lighting control
6. Inspect and record all MCC panel data and condition
7. Note any safety issues
8. Note any code violations
9. Note any need for upgrade or repairs
10. Record plug load equipment including office equipment, lighting, copiers, Printers, water coolers, refrigerator, stoves, microwaves, coffee makers, monitors, PC's, etc. by building and room
11. Note if unoccupied equipment is left in the "on" mode
12. Note any excessive plug load equipment, wattage and type
13. Photograph all supporting evidence to enhance the all identified issues.
14. Record exterior lighting, its controls and condition
15. Recommend any alterations, upgrades or enhancements that would reduce energy consumption. Include any safety improvements.
16. Record any backup generator data, including type, size, manufacturer, ratings (Volts/Amps/Phase). Determine "exercise" period, maintenance condition and what the unit is connected to
17. Note and solar photovoltaic and domestic hot water equipment installed, including capacity, inverter size capacity, manufactured, condition etc.
18. Record data for any electrically powered heaters and water heating equipment, including all name plate data and overall operating condition
19. Record all electric motor name plate data, service, and condition (See 5.4.2.2 Mechanical)

Note: Photographic evidence is required for the final report as well as a reference tool to record data.

5.4.2.4 Lighting & Controls (Also See Electrical)

1. External lighting and controls
2. Interior lighting type, number, lumens, controls estimated load factor (hours of use)
3. Inspect fixtures and skylights for cleanliness

5.4.2.5 Building Envelope

1. Note type and condition of roof
2. Determine roof (ceiling) and wall insulation
3. Determine if structure is pier and beam or slab construction
4. Determine a window count and the ratio of window to wall areas
5. Determine window type to include SHGC, U value, single/double glazing, and condition
6. Inspect for shading, natural or manmade (awnings etc.)
7. Photograph all findings
8. Determine condition of all seals.
9. Inspect all exterior doors for proper closing, seals and weather stripping.
10. Note condition of exterior
11. Note any damage to the structure to include broken windows, concrete sidewalks condition, trip hazards, paint and finish of exterior walls, gutters and down spouts, any mold, etc.
12. Record date of construction and any major upgrades, additions or modifications made and when they were implemented
13. Record IR photographs of exterior for thermal leaking, poor insulation etc.

5.4.2.6 HVAC

1. Inspect unit condition and record nameplate data. Note any rust, and other damage
2. Inspect all filter and record pressure drop across filter systems
3. Inspect for mold
4. Determine building zoning and controls. Note if the building(s) has Supply and Return Ducts and condition
5. Record all set points
6. Record all VAV locations and function ability
7. Note any DOA system(s) employed and their operation
8. Assure all exterior condensers and packaged units are free from obstructions that would impair proper air circulation including vegetation.
9. Assure exterior condensers and packaged units refrigerant lines are properly insulated and protected
10. Thermostats, Type, Settings, Off hour setbacks etc.

11. System type and size.
12. Record Rooms Temperatures and Barometric Pressures. This information is used to calculate air leakages due to missing seals, door openings, etc.
13. Record outside temperature and barometric Pressure
14. Record Diffuser CFM or ft./sec.
15. Record Supply Air temperature coming out of Diffusers

5.4.2.7 Plumbing Systems

1. Determine gallons per flush for all toilets and urinals
2. Determine flow rates for all lavatories and showers
3. Note any leaks, damage or faulty pluming issues
4. Determine insulation condition and adequacy for all hot and coldwater piping
5. Determine condition of all pumps and record service and nameplate data
6. Determine overall piping layout (design) for its intended service
7. Determine pipe size and assure it is adequate for the intended purpose
8. Inspect potable water for backflow preventer
9. Note all “water hammer” arrestors in place
10. Inspect all piping for proper supports

5.4.3 Potential Seeds for ECM’s

1. Capture rainwater for irrigation
2. Low flow plumbing fixtures
3. LED or T-8 lighting
4. Lighting Controls
5. Energy Star Appliances (Typically only if existing equipment is in need of repair or has failed)
6. Occupancy sensors
7. HVAC set back controls
8. Natural lighting
9. Shading windows
10. Window and door seals
11. VFD drives
12. Damage repair
13. Add Insulation (Usually has diminishing returns)
14. Upgrade windows (Frequently too costly).
15. Conjunctive electrical billing (Check available rate structures from the Utility Companies)
16. Minimize equipment left in on condition
17. Boiler controls

18. DOA system settings
19. Waste heat recovery
20. Air to Air exchangers
21. Utility billing analysis
22. Upgraded lighting
23. Alternate heating and cooling systems such as air source heat pumps.

5.4.4 Additional Remarks

These lists should be amended as new information from audits becomes available. All identified issues should be accompanied by photographs to support the findings. It is recommended that an annual team review be conducted to amend this document, including the check lists.

Often, items can fall under more than one category, i.e. a motor driven pump may be mechanical, electrical and tied to the HVAC system. Electrical evaluations could confirm voltage, amps and check for phase balance. On the other hand, Mechanical could assure clear cooling air paths, minimum vibrations, coupling guards, lubrication etc. For issues noted, additional follow up investigation may be necessary in a Level III Audit.

5.5 Phase IV – Preparing the Final Report

5.5.1 Introduction

A standard report format must be adhered to. Appendix I provides the fundamental framework for energy audit reports. This must include standardized ECM labeling and evaluation processes. This will assure consistency in reporting and the methodologies used to validate potential savings.

ECM's identified must be categorized, properly labeled and certain economic indicators calculated. Some issues may be cured at the local level without additional funding, while others may require funding. A group of Appendices are provided to assist in preparing final recommendations and conclusions. Appendix B provides information on evaluating natural gas usage. Appendix C discusses the need to understand electrical billing fundamentals.

Appendix D is provided as a method of estimating an energy quotient for multiple buildings served by a single meter. While the intent is not to provide an exact quotient, it is useful in assessing the potential conservation measures that may be identified.

Appendix F assists in the evaluation of replacing appliances with upgraded models. In general, operating systems will not show a payback if replaced only due to increased efficiency. Appendix G is provided for calculating the reduction in CO2 and water use

based on reduced energy consumption. Essentially, it illustrates the amount of each for each kW generated, by state.

Complex issues, or costly proposals, may fall under the category of "more study required." These items generally require a Level III audit. This would entail more precise data collection and engineering studies to justify savings. These may also require enlistment of outside contractor assistance.

5.5.2 Renewable Energy Sources

Renewable energy projects such as solar PV, solar water heating, wind energy and ground source heat pumps should be listed separately within the report. In general, these ECM's will require further study and are best left to Level III studies. There are some generalized guides as to their potential viability which may assist in drafting recommendations.

5.5.3 Final Analysis

The findings, measurements and count of various data should be analyzed and specific ECM/WMC recommendations postulated. In turn savings and costs should be analyzed to both indicate specific categories as well as determining potential savings and the viability of recommended projects. This should include LCCA of the various options available including the "do nothing option."

Once the ECM/WCM list is generated and they are categorized, they must be detailed as illustrated in the following example. Appendix E is included to provide guidance as to the anticipated useful life of certain products and certain economic indicators.

5.5.3.1 ECM Example

ECM – B101 Replace Main Entrance Door.

5.5.3.2 Category 1 Low Investment Project.

The main entrance exterior door was observed to have missing and damaged seals. In addition, the door appears to be warped and does not close on its own. The door leaves a 1-inch gap when left to close on its own. Closing the door requires considerable effort.

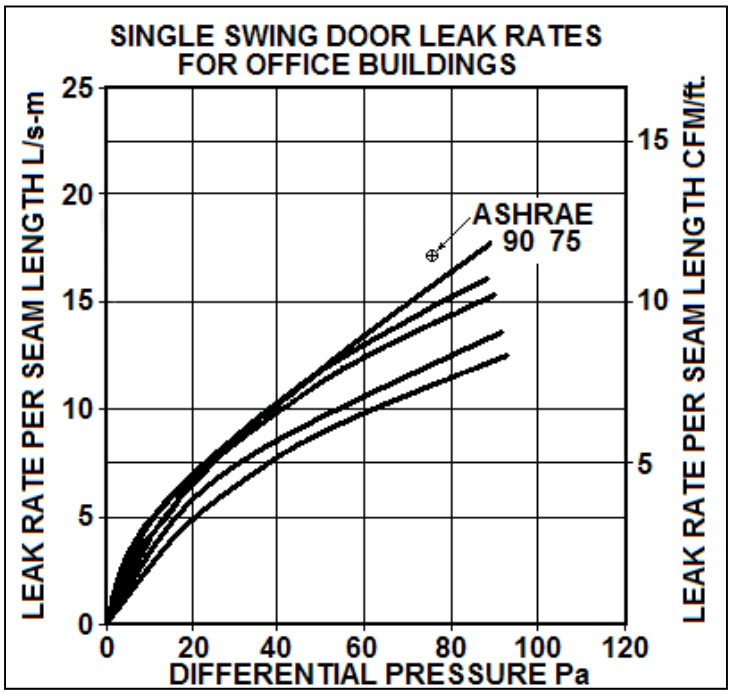
Figure S1 ECM – B101.1 Main Front Door

To provide some insight as to the annual energy loss, the differential pressure was measured to be 0.05 inches of water column or 12.4 Pa. and was used to calculate flows.

Some required conversion factors are:

1 Pa = 0.000145037738 psi
1 psi = 27.67 in. H_2O
1 in. H_2O = 0.031396 psi
1 in. H_2O = 249.174 Pa

The discharge coefficient for the door is set at 0.65, which is considered as an "average" value for this type flow.



Graph 1 ECM –B101.1 ASHRAE Door Leak Graph

Air density is taken as 1.15 kg/m^3 for this specific location.

NOTE: The standard air density at sea level is:

PV = ρRT or ρ =PV/RT

or for air:

ρ = 14.696(144)(1) / 53.53(459.667+59) or 0.076221198 pounds per cubic foot.

A correction for altitude is $\rho_1 = (\rho)e^{(-\text{altitude in feet}/27250)}$

The following equation is used by ASHRAE in determining flows through openings at low pressure.

Note all variables are in metric units!

$$Q = C_d A(2Pa/\rho)^{0.5} \qquad \textbf{(ECM – B101.1)}$$

For the front entrance door:

.25" x 32" or (.25)(32)/(39.3701)^2 = 0.00516 m^2

Q = (.65)(0.0052)[(2)(12.459)/1.15]$^{0.5}$ = 0.0118 m^3/sec. or 27.9 CFM

When cocked open the flow is calculated to be 390.2 CFM. Assume the door isn't completely closed for 5 minutes per day during the week, this is 0.272% of the time so that the flow is (390.2)(.00272) or 1.06 CFM (Average).

$$Q = mC_p\Delta T \qquad \textbf{(ECM – B101.2)}$$

For normal air:

Cp = 0.245 BTU/lbm-°F

ρ **=** 0.074328 lb./ft^3 (measured)

On a relatively hot day with a high of 99°F and the inside temperature being maintained at 74°F, the differential temperature would be 25°F. The anticipated thermal loss for the door above is thus:

(.074328)(28.96)(0.245)(25)(60)/1000 or 0.79 kBTU/hr. or about 0.23 kWh or $0.032 per hour.

Adjusting for heating and cooling degree days:

Summer losses:	$433.46
Winter losses:	$275.45
Total potential savings after repair:	$708.91

20 year Door Replacement Cost Analysis LCCA					
CODE	COST ITEM	BASE DATE COST	YEAR OF OCCURANCE	DISCOUNT FACTOR	PRESENT VALUE
I	Initial cost	-$281.00	1	1.0000	-$281.00
Labor	Install Door	-$421.50	1	1.0000	-$421.50
OM&R	Maintenance	$0.00	Annual	0.0000	$0.00
E	Electricity Offset	$708.91	Annual	14.9376	$10,589.40

Figure 6 ECM - B101.2 LCCA for Entrance Door Replacement

SPB:	1 yr.
NPV:	$9886.90
IRR:	100%
SIR:	15.1

Recommendations

1. Replace door with a pre-hung metal exterior door.
2. Automatic door closing devices should be adjusted for minimum closing time that provides adequate safety and complete closure.
3. Based on the short payback seals should be inspected annually and replaced when signs of wear appear.

5.5.4 Generating the Final Report

The recommended format and specific layout for the final audit report is shown in Appendix I. The report should be succinct with sufficient detail to allow decision

making. This would include what is proposed, estimated savings, how savings were calculated, costs and certain economic indicators. The total potential energy or water conservation potentials should be summarized to indicate the estimated percent reduction. These should be presented by specific category as well as the total.

The ole adage of *"tell them what you're going to tell them. Tell them. Then tell them what you told them,"* fundamentally holds true for the final audit report. The executive summary should detail the findings, savings potentials and a summary of categorized ECM's and WCM's.

The body of the report details the findings while the individual ECM/WCM sections summarize the recommendations and economic indicators for each.

The audit team not only has the opportunity to view a facility through new eyes, but also to display knowledge of energy and water conservation methods which may be incorporated. The final report should consist of a document which fulfils the audit requirements, but further should be tempered with practical knowledge and be a source of information for the local facility. (Refer to the appendix sections for more details.)

6. EISA 2007 SECTION 432 STIPULATIONS

Within a four-year period, agencies must conduct comprehensive energy and water evaluations for all covered facilities, which include energy and water audits and a commissioning assessment for the purpose of identifying ECM opportunities. "Evaluation" means that ". . . energy managers shall complete, for each calendar year, a comprehensive energy and water evaluation for approximately 25 percent of the [covered] facilities of each agency . . . in a manner that ensures that an evaluation of each such facility is completed at least once every 4 years." (42 U.S.C. 8253(f)(3)(A))

Energy and water use audits identify performance deficiencies when compared against similar structures. These deficiencies might lead the facility energy manager to recommend improvements to the building. Recommended improvements might include both no-cost and low-cost improvements and the more capital-intensive replacement of inefficient equipment and systems.

Commissioning is an ongoing process that ensures that building systems are operating to original design specifications. It requires a detailed evaluation of current (including newly installed) building systems and can lead to operating cost savings without having to install expensive new equipment. Aspects of ongoing commissioning processes are often referred to as re-commissioning (the subsequent commissioning of a previously commissioned system) and retro-commissioning (the commissioning of an existing system that was not commissioned within a year of initial installation).

In order to complete comprehensive evaluations, agencies can draw upon government employees with training in managing energy and water use (in-house facility engineering staff. To standardize the energy audit process, the energy manager may choose to utilize the protocols created by ASHRAE. For many facilities, an ASHRAE Level I audit will be adequate to meet the statute. A Level II analysis includes a more

detailed survey and cost-benefit analysis of potential ECMs. The Level II analysis will be adequate for *most* covered facilities. In some cases in which capital intensive modifications are desired, an ASHRAE Level III analysis may be performed. A Level III analysis performs energy modeling to verify potential savings and includes additional systems measurements, schematics and equipment lists.

7. ADDITIONAL REFERENCES

• DOE FEMP's **"Energy Savings Assessment Training Manual"** which provides information leading to self-sufficiency in and the ability to conduct on-site energy audits.

• DOE FEMP's **"Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency, Release 3.0"** which provides updates to areas of O&M technologies, equipment performance, costs, water use and the impacts of recommended O&M practices on water efficiency. This guide is located at:
http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf.

• The **"Life-Cycle Costing Manual for the Federal Energy Management Program" (NIST Handbook 135)**, located at:
http://www.bfrl.nist.gov/oae/publications/handbooks/ 135.pdf
This document explains, in detail, the principles of life-cycle cost analysis and integrates them with FEMP criteria and how agencies shall use life-cycle cost analysis in making decisions about investments in products, services, construction, and other projects to lower the Federal Government's costs and to reduce energy and water consumption. Annual updates to the handbook are posted for Federal agencies to review located at: http://www1.eere.energy.gov/femp/pdfs/ashb10.pdf.
The National Institute of Standards and Technology (NIST)
Developed the Building Life-Cycle Cost (BLCC) software to provide computational support for the analysis of capital investments in buildings located at:
http://www1.eere.energy.gov/femp/information/cfm/register_blcc.cfm.

• **"Federal Water Efficiency Best Management Practices"** located at: http://www1.eere.energy.gov/femp/program/waterefficiency_bmp.html. FEMP originally developed Federal Water Efficiency Best Management Practices (BMPs) in response to Executive Order (E.O.) 13123 requirements. E.O. 13423 superseded E.O. 13123. To account for the superseded requirement changes, water use patterns, and advancing technologies, the Environmental Protection Agency's WaterSense Office updated the original BMPs

APPENDIX A: ABBREVIATIONS & CONVERSIONS

ABBREVATIONS

AHU Air Handling Unit
ASHRAE American Society of Heating, Refrigeration and Air Conditioning Engineers
BAS Building Automation System
BTU British Thermal Unit
C Celsius
DoD Department of Defense
DoE Department of Energy
ECM Energy Conservation Measure
EISA Energy Independence and Security Act
EMCS Energy Management Control Systems
EPACT Energy Policy Act
F Fahrenheit
FC Foot-candle
FW Fort Worth
HHV Higher Heating Value
HID High Intensity Discharge
HVAC Heating, Ventilating, and Air Conditioning
IGP Investment Grade Projects
IR Infrared
IRR Initial Rate of Return
kW Kilowatt
kWh Kilowatt-Hour
LCCA Life Cycle Cost Analysis
LED Light Emitting Diode
MDP Main Distribution Panel
MH Metal Halide
MW Megawatt
NPV Net Present Value
O&M Operations and Maintenance
psia Absolute pressure in pounds per square inch (14.696 @ STP)
PC Personal Computer
PF Power Factor
PPE Personal Protective Equipment
PV Photovoltaic

SCADA Supervisory Control and Data Acquisition
SCF Standard Cubic Foot
SHGC Solar Heat Gain Coefficient
SHWH Supply Hot Water Heating
SIR Savings to Investment Ratio
SPB Simple Pay Back
SRI Solar Reflectance Index
STP Standard temperature pressure. (14.696 psia and 69ºF)
USACE United States Army Corps of Engineers
VFD Variable Frequency Drive
VT Visual Transmittance
WCM Water Conservation Measure

USEFUL EQUIVALENTS

Standard Pressure and Temperature is used as 14.696 psia and 69°F.

Natural Gas is assumed to have a HHV of 1,000 BTU/SCF.(See Apex. B.)

HHV includes the latent heat of vaporization for the water.

One sun is 1,000 watts per square meter.

There are 3,412 BTU per kW.

There are 2,545 BTU per Horsepower-hour.

Water has a mass of 8.334 pounds per gallon.

There are 7.48 gallons per

APPENDIX B: NATURAL GAS BASICS & BILLING NOTES

Natural gas received at any location is a mixture of various hydrocarbon gases as well as certain inert gases. The specific makeup of these constituents changes constantly due to the mixing of numerous individual wells and the various "stripping" processes.

Natural gas is rated both in Higher Heating Value (HHV) and Lower Heating Value (LHV), with the former accounting for the latent heat of evaporation of the produced water. HHV is the higher heating value which includes the latent heat of evaporation of the water vapor, and is often referred to as the gross caloric value of a fuel. The LHV (Lower Heating Value) is the HHV minus the latent heat of the water vapor, and is referred to as the net caloric value. The net difference depends on the number of hydrogen bonds, but for naturals gas a value of about 1.108 may be used. Thus the average HHV of 1,000 is a LHV of about 902.5 BTU/SCF.

Internal Combustion engines are rated for LHV consumption while Combined Heat and Power (CHP) systems are based on the HHV. Water heaters and boilers are typically based on LHV to increase their apparent efficiencies. By using the standard 1,000 BTU/SCF to calculate boiler savings, will lead to as much as a 10%+ error!

It is vital to understand the utility method of selling fuel as well as the equipment's rating of HHV or LHV. Some gas companies use 14.696 psia, some 14.4 psia and some 14.73 psia as their base pressure. Some change the base pressure for pressure drop across the metering system. Still others may correct the volume by a constant factor and sell in Therms (100k BTU). Thus it is imperative to calculate the actual BTU's consumed and not a volume. It is recommended that a sample caloric (constituent) analysis be obtained from the providing utility.

While natural gas is assumed to have a caloric value of 1,000 BTU per SCF (14.696 psia and 59°F), this can vary considerably. According to the Gas Producers Association (GPA) Pipeline Quality natural gas must contain:

Methane (CH_4)	75% Minimum
Ethane (C_2H_6)	10% Maximum
Propane (C_3H_8)	5% Maximum
Butane (C_4H_{10})	2% Maximum
Pentane and greater (C_5H_{12})	.05% Maximum
Nitrogen and other inerts (N_2)	3-4% Maximum
Carbon Dioxide (CO_2)	3-4% Maximum
Hydrogen Sulfide (H_2S)	.25-1.0 grains/100 SCF
Mercaptan Sulfur	.25-1.0 grains/100 SCF
Total Sulfur (S)	5-20 grains/100 SCF

Water Vapor (H_2O)	7 pounds/MMSCF
Oxygen (O_2)	0.2-1.0 ppmv*

Parts per million by volume.

The stated caloric value for pipeline quality gas is 950 - 1,050 BTU/SCF HHV

Note:
A MCF is 1,000 SCF, a MMCF is 1,000,000 SCF.
A Therm is 100,000 BTU and Decatherm is 1,000,000 BTU.
There are 7,000 grains in a pound.

A typical pipeline quality natural gas analysis is:

Component	Symbol	Mole%	BTU/SCF LHV	BTU/SCF HHV
Hydrogen	H2	0.000	274.00	324.32
Carbon Dioxide	CO	0.350	0.00	321
Nitrogen	N2	2.540	0.00	0
Methane	CH4	92.700	909.10	1009.73
Ethane	C2H6	3.490	1617.80	1768.75
Propane	C3H6	0.540	2316.10	2517.37
Normal Butane	C4H10	0.110	3010.40	3261.98
Iso-Butane	C4H10	0.060	3001.10	3252.68
Normal Pentane	C5H12	0.030	3707.50	4009.4
Iso-Pentane	C5H12	0.030	3698.30	4000.2
Normal Hexane	C6H14	0.060	4403.70	4755.91
Normal Heptane	C7H16	0.090	5100.20	5502.73

TABLE B1 Typical Gas Analysis.

For the above analysis, the HHV is 1,027.09 BTU/SCF and the LHV is 926.27 BTU/SCF.

Often, manufacturers use the LHV to bolster their efficiency claim. The use of the standard HHV would lead to significant errors. In the following Figure C.4, a claim based on LHV of 100% is really about 90.2%. It is easy to see that projected savings based on the HHV could be excessive by about 10%

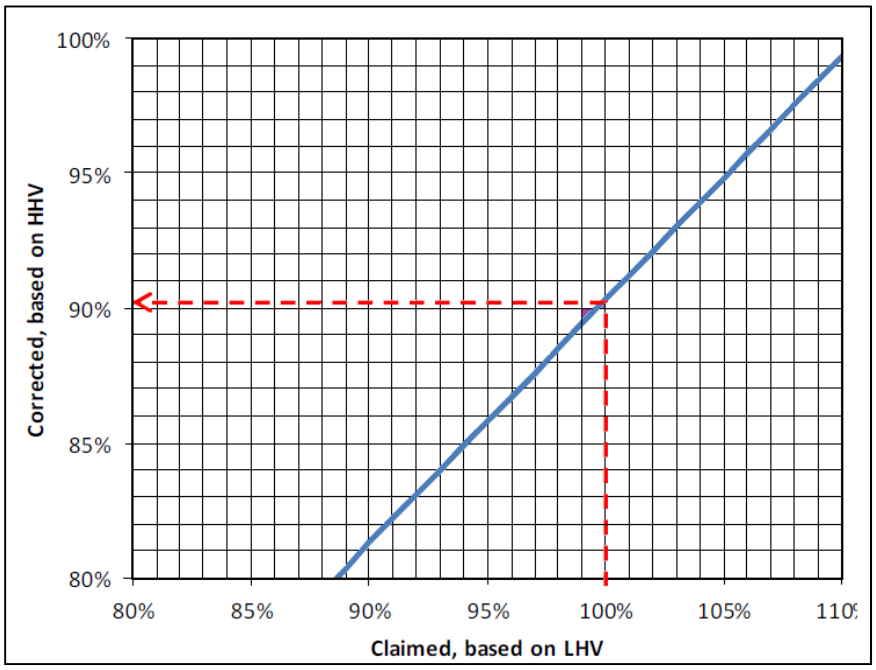


FIGURE B1 Efficiency based on LHV vs. HHV.

Energy consuming devices that use natural gas as a fuel will produce the emissions as indicated in the following tables. The specific reduction in "greenhouse gases" can be calculated from the savings in either kWh or MCF.

Pounds per kWh	
Carbon Dioxide	0.3992040
Carbon Monoxide	0.0001365
Nitrogen Oxides	0.0003139
Sulfur Dioxide	0.0000034
Particulates	0.0000239
Mercury	0.0000000

TABLE B2 Emissions for Natural Gas in Pounds/kWh.

Pounds per MCF	
Carbon Dioxide	120.1683881
Carbon Monoxide	0.0410832
Nitrogen Oxides	0.0944914
Sulfur Dioxide	0.0010271
Particulates	0.0071896
Mercury	0.0000000

TABLE B3 Emissions for Natural Gas in Pounds/MCF.

The analysis in Table B3 would produce 2.0856 pounds of water per pound of fuel. However, the amount of water saved is directly dependent upon the mix of generation

for the specific location. The amount of water saved is shown in the accompanying table as gallons per kWh generated. These data are derived from the mix of various forms of power generation utilized by state, in conjunction with the above table.

APPENDIX C: ELECTRICAL UTILITY BILLING

Electric utility billing consists of numerous facets. Principally, there is a customer service charge to recover costs associated with metering and the billing of customers; a form of fuel cost recovery; energy charges which recovers generation costs; the cost of maintaining poles and wires; a demand charge to recover capital expenses; and a marginal profit.

Electric utility providers must maintain a certain level of “spinning reserves” to assure sudden connection of loads won’t trip off the generators. Like the end user, they also have peak demand periods when added reserves must be operational, usually during the heat of summer days.

Since there are many facets to electrical billing, which can be very convoluted, it is vital that the specific provider, and their specific rate be obtained and modeled to assure proper savings calculations.

Also note that the “monthly” bill rarely is the same as a calendar month. Some could run from the 15th to the next 17th. This becomes important when overlaying weather data on consumptions curves. Remember it is the trend and not the quantitative number that is providing insight to the energy use.

Only through a comprehensive understanding of the rate structure and available riders or options can true savings be postulated. Study the available rates and model the current rate to determine areas for savings.

Check for conjunctive billing (combining the meters into a single account) where more than one meter is used. This can reduce demand charges as well as customer service charges. Sub-metering could be required, but will usually provide cost savings.

APPENDIX D
ASSESSING ENERGY QUOTIENTS FOR MULTIPLE BUILDINGS FEED FROM A SINGLE METER

Many facilities consist of multiple buildings clustered and fed by a single utility meter. This creates a difficult to impossible situation when attempting to determine an energy quotient. The situation is exacerbated when the facilities consists of different building types.

Conventional methods do not account for these differences, nor do they account for an occupancy load factor. This leads to false impressions as to the energy efficiency or a measured energy consumption rate for the facility.

Most facilities to be audited will have an office building, or at minimum dedicated office space. The initial premise will be that an office area has a factor of 1.00. That is its total square footage will be added to the adjusted equivalent square footage.

The average $/ft^2 for various building types as reported by the Department of Energy (DoE) has been used to determine their specific equivalent space factor. This is accomplished by dividing their cost index by that of an office complex.

Various other areas or total buildings will require their floor space adjusted by a factor determined from average Department of Energy total energy consumption per square feet-year, adjusted to make an office area equal 1.00.

Table D1 illustrates the adjusted square foot factor for various building types.

Type	Factor
Office	1.00
Warehouse	0.40
Storage Area	0.40
Vacant	0.17
Barracks	0.86
Dining Facility	2.33
M.P./Fire Stations	1.03
Theaters	0.86
Class Rooms	0.71
Chapel	0.38
Maintenance Facility	0.69
Dispensary	1.37
Hospital	1.37
Commissary	1.11

TABLE B.1 Floor Area Weight Factors.

To determine a factored square footage, simply multiply the actual area by the listed factor. This can be total buildings or in the case of a multiple use building individual measured areas. This sum can be used to determine an equivalent square footage and subsequent adjusted energy quotient when multiple areas/buildings are clustered with single utility metering.

In order to obtain a more meaningful measure, all areas should be adjusted for their occupancy levels and use factors. It can easily be seen that two identical facilities with major differences in occupancy levels will exhibit different consumption profiles. By dividing specific areas by a man-year of occupancy will provide a better "apples-to-apple" comparison of these facilities.

As a simplified example, using only the adjusted square footage, a facility consists of a 2,400 square foot office building, a 3,000 square foot maintenance shop and a 4,000 square foot warehouse.

The overall annual energy use is calculated to be 336,000 kBTU. If only the office were considered, the facility would have a quotient of 140 or an F rating. If the entire square footage were considered, the energy quotient becomes 35.6 or an A rating. Neither quotient represents the performance of the facility.

Modifying the areas becomes 336,000/(2400 + 3000(.69)+4000(.04)) or 72.57 Which is a much more believable B rating.

If it were assumed that the office area has 8 employees and operates 1,930 full time hours per year (accounting for 10 paid holidays and certain vacation time). The shop is occupied by 2 persons 5 days per week or 8*[(5*52)-10-20] = 1,840 hrs or (2*1840) = 3,680 man-years. The warehouse averages 14 man hours per week or 728 man-years. Note that this figure is subtracted from the shop total, since they are the personnel entering the warehouse.

Therefore, the total occupancy:

Office:	(8)(1930/8760) = 1.76
Shop:	[(2)(1840)-728]/8760 = 0.3369
Warehouse:	(728)/8760= 0.0831

Total Facility Occupancy factor = 2.18 man-years

The facility consumes (55.35)/2.18 or 25.4 kBTU per man-year per sq. ft.

This number can be directly compared to other facilities even of different types.

These techniques are to be used for comparison purposes only and are not intended to establish a final energy quotient.

APPENDIX E: LCCA & USEFUL LIVES

Table E1 is a partial list of the useful life expectancy for certain equipment and systems. The Life Cycle Cost Analysis (LCCA) length should not exceed the anticipated life, without repair or replacement costs added to the appropriate year costs added. If a longer LCCA is deemed necessary, a new purchase, installation and removal cost must also be added.

Expected Life	
Equipment	Years
Window A/C unit	10
Packaged unit	15
Water cooled	15
Heat pump air-air	15
Commercial air-air	15
Commercial water-air	19
Roof top Single Zone	15
Roof top multi Zone	15
Hot Water Boiler Electric15	15
Hot Water Boiler Steel Tube	25
Hot Water Boiler Cast Iron	30
Burners	21
Unit heater gas or electric	13
Hot water or steam	20
radiant heater electric	10
Radiant heater hot water or steam	25
Packaged chillers reciprocating	20
Packaged chillers centrifugal	23
Packaged chillers absorption	23
Shell & Tube exchanger	24
Reciprocating compressor	20
Base mount pump	20
Pipe mount pump	10
Air cooledcondenser	20
Evaporative cooled condenser	20
Reciprocating engines	20
Electric motors	18
Steam Turbines	30

Expected Life	
Equipment	Years
Dishwasher	9
Microwave	9
Washing Machine	13
Refrigerator	13
Gas range	16
Electric range	14
Clothes dryer	13
Freezer	15

Expected Life	
Equipment	Years
Wind Turbine generator	20
Solar System Batteries	7
Inverters	10
PV Panels	20

Table E1 Useful life.

The life expectancy was extracted from DoE reports. LCCA discount factors are from NIST Handbook 135, latest edition.

A simplified LCCA consists of the initial project cost, annual maintenance and operational expenses, the postulated savings and the salvage value for each alternative. The project cost is entered as a year one expense.

20 year LCCA Sample					
CODE	COST ITEM	BASE DATE COST	YEAR OF OCCURANCE	DISCOUNT FACTOR	PRESENT VALUE
I	Initial cost	$ (10,000.00)	1	1.0000	$ (10,000.00)

Figure E2 Project Cost.

Next, required overhauls or major repairs are added as expenses.

20 year LCCA Sample					
CODE	COST ITEM	BASE DATE COST	YEAR OF OCCURANCE	DISCOUNT FACTOR	PRESENT VALUE
I	Initial cost	$ (10,000.00)	1	1.0000	$ (10,000.00)
Repl**	Replace wear items	$ (2,500.00)	15	0.6419	$ (1,604.65)

Figure E3 Adding O&M expenses.

The discount factor for the replacement of wear items in year 15 1/(1+.03)^15 = 0.6419

Next the anticipated residual value (salvage value) is input. Its discount factor is: 1/(1+.03)^20 = 0.5537

20 year LCCA Sample					
CODE	COST ITEM	BASE DATE COST	YEAR OF OCCURANCE	DISCOUNT FACTOR	PRESENT VALUE
I	Initial cost	$ (10,000.00)	1	1.0000	$ (10,000.00)
Repl**	Replace wear items	$ (2,500.00)	15	0.6419	$ (1,604.65)
Res	Residual value	$ (1,500.00)	20	0.5537	$ (830.55)

Figure E4 LCCA with residual value added.

20 year LCCA Sample					
CODE	COST ITEM	BASE DATE COST	YEAR OF OCCURANCE	DISCOUNT FACTOR	PRESENT VALUE
I	Initial cost	$ (10,000.00)	1	1.0000	$ (10,000.00)
Repl**	Replace wear items	$ (2,500.00)	15	0.6419	$ (1,604.65)
Res	Residual value	$ 1,500.00	20	0.5537	$ 830.55
OM&R	Maintenance	$ (250.00)	Annual	14.8775	$ (3,719.38)

Figure E5 LCCA with maintenance and repair costs.

Notice that the maintenance and repairs occur annually and thus the discount factor is (((1+.03)^ 20)-1/.03(1+.03)^20) = 14.877475

NOTE: The .03 is the current government discount rate (See the NIST Handbook 135 for potential changes.)

20 year LCCA Sample					
CODE	COST ITEM	BASE DATE COST	YEAR OF OCCURANCE	DISCOUNT FACTOR	PRESENT VALUE
I	Initial cost	$ (10,000.00)	1	1.0000	$ (10,000.00)
Repl**	Replace wear items	$ (2,500.00)	15	0.6419	$ (1,604.65)
Res	Residual value	$ 1,500.00	20	0.5537	$ 830.55
OM&R	Maintenance	$ (250.00)	Annual	14.8775	$ (3,719.38)
E	Electricity Offset	$ 1,908.89	Annual	16.7469	$ 31,967.99

Figure E6 LCCA with electrical savings.

The annual electrical savings are calculated. In this case, there was no gas savings and only the annual electrical savings is added. Since fuels are region sensitive, the discount factor is best looked up in the NIST Handbook 135.

The far right hand column is added to determine the net Present Value (NPV). In this case $17,474.51

The Simple Payback (SPB) is cost / net savings or 10,000/(1908.89-250)) = 6.02 years. The Savings to Investment Ratio (SIR) is the net savings / total cost or (31967.99-3719.38) / (10000+1604.65-830.55) or 2.62. Calculating the Internal Rate of Return is a bit more difficult. It is the interest rate which reduces the net present value to zero.

Calculating the IRR is simply an iterative process, guessing at an interest rate and calculating the NPV. Additional guesses will eventually provide an interest rate that forces the NPV to equal zero. Many computer software spread sheets have this function built-in and are quite easy to use. Here, using the Excel IRR function produces 20.87%

Be sure to account for all costs and savings. While not currently considered, the water and CO_2 savings can be calculated by using the information found in Appendix G. Use the annually reoccurring discount factor.

Savings in terms of fossil fuel is best displayed as tons of CH_4 equivalent.

1 kW = 0.14805 pounds of CH_4

1 MCF of typical natural gas = 2.685 pounds of CH_4

APPENDIX F: APPLIANCE ECONOMICS

Part I - Refrigerators

Quite often energy audits include an energy conservation measure for replacing existing refrigerators with Energy Star models with an attempt to provide some form of economic justification through energy savings alone. Typically, energy savings alone do not provide justification for replacing an operating appliance with a more efficient model.

22cf refrigerator		
Year Made in	kWh per yr.	Maximum Savings
<1976	2,200	1,775
1976-86	1,700	1,275
1987-89	1,150	725
1990-92	1,100	675
1993-00	850	425
2001-2010	600	175
2001-04 Energy Star (10%)	550	125
2004-08 Energy Star (15%)	525	100
2008-10 Energy Star (20%)	500	75
CEE Tier3 (30%)	425	-

Table F1 Energy use vs. refrigerator age.

The current average price for a plain model with an upper freezer compartment is about $1,200.00 (2015). Based on numerous reliable sources, the standard refrigerator as priced above has an expected life span of 14 years. To illustrate the economic impact, a Life Cycle Cost Analysis using 15 years is presented. The escalation factor for electricity is dependent upon the fuel region as shown in Table F2.

15 Years	
Fuel Region	Escalation Factor
1	14.4164
2	14.4726
3	14.6384
4	14.8334

Table F2 Escalation Factors vs. Fuel Region.

Another factor that influences the economics is the cost of electrical energy. It is obvious that the higher the cost, the greater the savings, and the shorter the payback. In 2015, the average cost per kilowatt-hour is 9.8¢ for commercial power. The illustration will use 10¢ for comparison.

The majority of the U.S. Army Garrisons fall into Fuel Region 3, and that escalation factor is used below. Since the anticipated life of a refrigerator is 14 years, it is assumed the unit has not failed and is 13 years old (2002 manufacture).

From Table F.1 above, the annual maximum savings is 175 kilowatt-hours or $17.50 @ 10¢ power.

15 year LCCA for refrigerator replacement fuel region #3.					
CODE	COST ITEM	BASE DATE COST	YEAR OF OCCURANCE	DISCOUNT FACTOR	PRESENT VALUE
I	Initial cost	-$1,200.00	1	1.0000	-$1,200.00
Res	Residual value	$60.00	20	0.6419	$38.51
E	Electrical Savings	$17.50	Annually	14.6384	$256.17
				NPV:	-$905.31
				Simple Payback:	65 yrs.
				IRR:	-12.61%
				SIR:	0.246

Figure F1 Typical Refrigerator 15 year LCCA.

It is easy to see the energy savings alone does not justify the replacement of an operating system even with the most efficient Energy Star model. If the electrical rate doubled and the region 4 escalation factor used, the economics are still not favorable.

Replacing appliances should thus only be done when the existing unit fails, and replacement is required. Repair is an option which should be considered, if the unit has not reached its useful life.

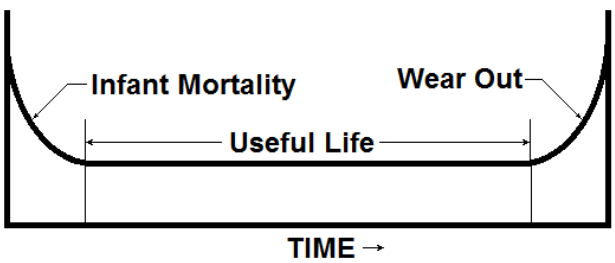


Figure F2 Failure probability.

Often, when equipment is repaired correctly, the useful life expectancy can be “re-set” and the functional life extended.

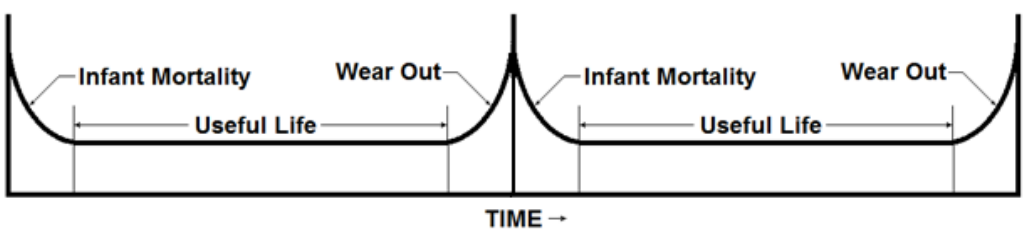


Figure F3 Life Extended with Proper Repairs.

This option must be given equal weight when deciding on unit replacement.

PART II – Clothes Dryers

Electric clothes dryers meeting federal standards [10 CFR Part 430.32(h)] consume 967 kWh per year based on a standard 4.4 cubic foot unit used for 416 cycles per year. Compact models use less energy: 430 kWh for a 240 VAC and 399 kWh for a 120 VAC

model. Gas models consume an average of 1091 kWh (equivalent) per year. About 300 to 5,000 Watts are used for the tumbler motor the remaining is in heat to the drum.

The updated Federal Standards are: 2.4169 kWh per load for a standard electric model; 1.0777 kWh for an electric 120 VAC compact model; 1.2014 for a compact electric 240 VAC; and 2.64 for a standard gas unit.

Clothes dryers have an average expected life of 13 years. For LCCA, be sure to select the proper fuel region and locate the discount factor for electricity.

REGION 1	REGION 2	REGION 3	REGION 4
Connecticut	Illinois	Alabama	Alaska
Maine	Indiana	Arkansas	Arizona
Massachusetts	Iowa	Delaware	California
New Hampshire	Kansas	D.C.	Colorado
New Jersy	Michigan	Florida	Hawaii
New York	Minnesota	Georgia	Idaho
Pennsylvania	Missouri	Kentucky	Montana
Rhode Island	Nebraska	Louisana	Nevada
Vermont	North Dakota	Maryland	New Mexico
	Ohio	Mississippi	Oregon
	South Dakota	North Carolina	Utah
	Wisconsin	Oklahoma	Washington
		South Carolina	Wyoming
		Tennessee	
		Texas	
		Virginia	
		West Virginia	

TABLE F3 Fuel Regions

The discount factors for Clothes Dryers.

Region	Electric	Gas
1	10.0632	11.8477
2	10.1538	12.3106
3	10.2975	12.4278
4	10.6113	12.2648

TABLE F4 Discount Factors based on a 13 Year Life.

Basically, the first assumption required is the time and number of cycles per year anticipated. Second is the name plate rating or the assumed average energy usage of 4,296 watts per hour (older units).

The average drying time is 45 minutes or (45/60)(4296/1000) = 3.22 kWh of electricity. A new Energy Star unit uses approximately 2.42 kWh for the same load. Thus the savings per load is about 0.80 kWh.

With the estimated number of annual uses, the electric rate ($/kWh) and the differential above the annual potential savings can be calculated.

As an example if a dryer in fuel region #3 was used 1,240 times per year and the electric rate was $0.115 per kWh, what are the potential savings if an Energy Star replacement was installed?

The annual savings would be (.81 kWh)(1240 uses)($0.115) or $114.79. The discounted savings would be (12.4278)(114.79) or $1,426.62

With an average price of about $1,000.00 for a quality Energy Star model, the SIR is 1.296. Note that the uses per year are the driving factor that will validate the replacement savings.

PART III Washing Machines.

Washing machines have a life expectancy of about 14 years. A replacement cost for Energy Star is about $1,300.00.

The discount factors for Washing Machines.

Region	Electric
1	14.4164
2	14.4726
3	14.6384
4	14.8334

TABLE F5 Discount Factors for a 14 Year Life.

Standard Clothes Washer Water Temperatures		
Wash	**Rinse**	**kWh**
Hot	Warm	4.5
Warm	Warm	3.5
Hot	Cold	2.8
W	Cold	1.9
Cold	Cold	0.3

TABLE F6 Wash Temperatures vs. Energy Consumed.

APPENDIX G: UTILITY EMISSIONS AND WATER CONSUMPTION

NOTE: The following table values are based on data which was extracted from the Department of Energy report for electrical generation mix, 2013, and subsequent calculations by Robert B. McMillan, PE, CEM.

STATE	CO_2 lbs/kWh	Water Gal./kWh	STATE	CO_2 lbs/kWh	Water Gal./kWh
Alabama	1.3950	2.5000	Montana	1.5630	16.7400
Alaska	1.3212	0.2700	Nebraska	1.3958	0.3000
Arizona	1.0895	7.8500	Nevada	1.1487	7.2500
Arkansas	1.2345	0.2600	New Hampshire	0.7933	0.1000
California	0.6910	4.6400	New Jersy	0.7299	0.0700
Colorado	1.7849	1.2000	New Mexico	1.9500	1.1300
Connecticut	0.7209	0.0700	New York	0.8099	1.6200
D.C.	1.3748	0.0100	North Carolina	1.3505	0.5500
Delaware	2.0300	1.6100	North Dakota	2.2585	5.1300
Florida	1.2913	0.1400	Ohio	1.8473	0.9400
Georgia	1.4853	1.6500	Oklahoma	1.5572	8.3900
Hawaii	1.8261	0.0400	Oregon	0.4607	3.7100
Idaho	0.3981	7.8500	Pennsylvania	1.2723	0.5300
Illinois	1.1182	1.0500	Rhode Island	0.9373	0.0000
Indiana	2.0932	0.4100	South Carolina	0.9486	0.2500
Iowa	1.8321	0.1100	South Dakota	1.1914	72.6400
Kansas	1.7247	0.5800	Tennessee	1.3436	3.6000
Kentucky	2.1237	5.3200	Texas	1.4030	0.4300
Louisana	1.2992	1.4700	Utah	1.9354	3.0500
Maine	1.1752	0.1200	Vermont	0.1990	0.2500
Maryland	1.3748	0.2100	Virginia	1.1848	0.0600
Massachusetts	1.2343	0.0000	Washington	0.2926	2.7000
Michigan	1.4841	0.4800	West Virginia	1.9921	0.5800
Minnesota	1.5194	0.4100	Wisconsin	1.6422	0.4600
Mississippi	1.2913	0.3700	Wyoming	2.1852	4.1500
Missouri	1.8692	0.3000			

Table C4 Emission constants by State.

To determine energy reduction is devices using natural gas as a fuel, the following must be considered.

A. ***Know the caloric value of the gas being purchased, both HHV and LHV.***
B. ***Know how the gas utility bills for the commodity.***
C. ***Know how the efficiency of the gas consuming device is calculated.***
D. ***Calculate a real savings by adjusting for the conditions above.***
E. ***Perform a fundamental LCCA with SIR, IRR, SPB and NPV to determine the validity of the proposed energy savings. This requires the use of proper discount factors based on the proposed life and the specific fuel region.***

NOTE: A kWh is equivalent to 3,412 BTU.

APPENDIX H:
PARTIAL ECM AND WCM LIST

Project Name:				
Checked	ECM	Potential Energy Conservation Opportunities	Does this apply?	Model Run?
	A100 Envelope			
	A101	Door weather-stripping or revolving door		
	A102	Seals and Air Gaps in Doors and Window		
	A103	Roof Insulation or replacement		
	A104	Window film or replacement		
	A105	Damper or Louver Leakage		
	A106	Insulation Issues		
	A107	Apparent Structural Issues		
	A108	Building Penetrations (Required Sealing)		
	A109	Exterior Wall Issues		
	E100 Lighting			
	E101	Interior Obsolete Fixture Removal		
	E102	Interior Lamp Replacement w/ Reduced Wattage		
	E103	Interior Lamp Removal		
	E104	Interior Fixture Replacement		
	E105	Exterior Fixture Replacement		
	E106	Exit Sign Replacement		
	E107	Building Master Lighting Control System Addition		
	E108	Local Manual/Automatic Lighting Control Additions		
	E109	Occupancy Sensor Additions - General		
	E110	Occupancy Sensor Additions - Stairwells		
	E111	Occupancy Sensor Additions - Corridor		
	E112	Occupancy Sensor Time Delay Adjustments		
	E113	Interior Bi-level Control Additions		
	E114	Interior Zoning & Circuiting Revisions		
	E115	Exterior Time clock & Photo Control Addition		
	E116	Daylight Harvesting Controls		
	E117	Interior Fixture & Surface Cleaning		
	E200 Power Distribution			
	E201	Premium-efficiency Motors		
	E202	Energy Efficient Step-down Transformers		
	E203	Energy Star Refrigerators & Appliances		
	E204	Office Equipment Controllers		

Project Name:				
Checked	ECM	Potential Energy Conservation Opportunities	Does this apply?	Model Run?
	E205	Vending Machine Controllers		
	E206	Utility Metering		
	E207	Solar PV System		
	E208	Wind Turbine System		
	E209	Power Factor Correction		
	E210	Elevator Control Modifications		
	M100 HVAC - Mechanical and Related Systems			
	M101	Install Demand Control Ventilation		
	M102	Install Total Energy Wheel in Air Handlers		
	M103	Refine Time of Day Reset		
	M104	Install VFD Drives on Remaining Air Handlers		
	M105	Reject Heat to a Ground loop		
	M106	Install Run-Around Loops for Heat recovery		
	M107	Install Water Side Economizer on Air Cooled Chiller		
	M108	Increase Chilled Water Differential to 15 F		
	M109	Replace Office Air Handlers with VRF Systems		
	M110	Supplement Water Heaters with Solar Hot Water Heater		
	M111	Replace Existing Boilers with High Efficiency Boilers		
	M112	Air Economizer Controls		
	M113	Thermal Ice Storage		
	M114	Condenser Water Filtration		
	M115	Steam Trap Retrofit		
	M116	Infrared Heating		
	M117	Re-Commissioning HVAC Controls		
	M118	Re-air balance the system (detail the systems which may require)		
	M119	Occupied/Unoccupied Temperature reset		
	M120	Insulate piping and valve bodies		
	M121	Variable Speed Drives (VSD) on Pumps		
	M122	Radiant heating and cooling		
	M123	High efficiency chiller and boiler with GSHP		
	P100 PLUMBING (Domestic and Storm)			
	P101	Storm/Roof Drain Water Harvesting		
	P102	Heat Pump Water Heater		
	P103	Cooling Tower Deduct Meter		
	P104	Instantaneous Water Heater		

Checked	WCM	Potential Energy Conservation Opportunities	Does this apply?
	W100 PLUMBING (Domestic and Storm)		
	W101	Low Flow Aerators	
	W102	Low Flow Toilets	
	W103	Low Flow Urinals	

APPENDIX I:
A SAMPLE AUDIT FINAL REPORT

Energy Optimization Assessment for the Tulsa Oklahoma District's Truscott Brine Lake Facilities.

US ARMY Corps
Of Engineers
Tulsa District

22 January, 2013

Level Two Energy Optimization Assessment for Tulsa District, OK. – Truscott Brine Lake Facilities.

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Abstract

An Energy Optimization Assessment (EOA) was conducted at the Tulsa, Oklahoma District's Truscott Brine Lake Facilities as a part of the US Army Corps of Engineers' Energy Engineering Analysis Program (EEAP) initiative, in compliance with OPORD 2010-71. The purpose of the assessment was to identify energy inefficiencies and wastes, and to propose energy related projects with applicable funding and execution methods that could enable the installation to meet the energy reduction requirements mandated by Executive Orders 13423 and 13514 and Energy Policy Act (EPAct) 2005, and EISA 2007.

The audit was designed to satisfy the stipulations of OPORD 2010-71, FRAGO #1 and FRAGO #2, in identifying energy consumption reduction, water consumption and the reduction in greenhouse emissions.

The assessment included an ASHRAE Level II study of energy conservation opportunities, including an analysis of the buildings envelopes, HVAC systems, controls, interior and exterior lighting as well as opportunities to use renewable energy resources.

The majority of the facilities have extremely low utilization factors, which nullify the majority of common ECM applications. As an example, the lighting fixtures in the Bateman pump station could be changed from T-12 to T-8 fixtures, but they only operate about 39 hours per year!

The major opportunity for energy savings will be the addition of VFD's to the 250 horsepower pump motors at the Bateman station. These and other ECM's with actual savings potential are discussed herein.

Executive Summary

General

On behalf of the U.S. Army Corps of Engineers, an energy use optimization audit [ASHRAE Level II] was conducted at the Tulsa Oklahoma District Truscott Brine Lake Facilities. The energy assessment was supplemented by the completion of forms provided by Washington State University and ASHRAE.

The principal goals were to identify energy and water reduction/conservation measures and the associated greenhouse gas reduction. These objectives are in line with OPORD 2010-71, FARGO #1 and FARGO #2 stated goals.

Photograph 1.0 The Truscott Project Office.

The Truscott Brine Lake Facilities are U. S. Army Corps of Engineers installations consisting of ten buildings located at seven installations. Located near Crowell Texas in Knox County, the Truscott Brine Lake is the result of an earthen dam constructed by the U.S. Army Corps of Engineers. It dams the South Fork of the Wichita River, and was completed in 1983. It covers approximately 4.7 square miles of surface area. The dam is 107 feet tall and 16,080 feet in length, with a maximum capacity of 116,000 acre feet and a normal fill of about 107,000 acre feet. It can release 35,400 gallons per second.

The Truscott Brine Lake is on the Bluff Creek and became operational in 1987. Brine is pumped from the Bateman low-flow collection dam on the South Fork of the Wichita River above Lake Kemp and transported via pipeline for storage in the Truscott Reservoir.

Water evaporates from the Truscott impoundment leaving the salt permanently stored. The 143 million cubic meter storage capacity is designed to contain a 100-year accumulation of brine and sediment and a 100-year reoccurrence interval flood. Additional brine collection and transport facilities are planned for the future in the watershed above Lake Kemp. The

Lawrence low-flow dam and pump station have been completed, but construction has not started on the pipeline, pumps and controls necessary to transfer the brines to the Truscott Brine Lake for disposal.

The Assessment

The assessment consisted of on-site facility audits of 9 buildings, conducted on November 5th through the 7th of November, 2012. This was followed by energy and economic analyses of selected Energy Conservation Measures (ECMs) for each facility.

Facility	Building	Sq. Ft.
Bateman Area VIII	Bateman Pump Station	1332
Peak Surge Complex	Peak Surge Building	200
Hunter Mountain Valve Building	Valve Building	798
Outlet Complex	Outlet Building	1164
Project Office Compound	Project Office	4507
	Janitors Building	
Maintenance Compound	Maintenance Building	8040
	Equipment Shed	4320
	Green House	1826

Table 1.0 Buildings of the Truscott Brine Lake Facilities.

The assessment was performed in an effort to identify energy-related upgrades with potential funding and methods of execution enabling the installation to better meet the energy reduction requirements mandated by Executive Orders 13423 and 13514, Energy Policy Act (Epact) 2005, and EISA 2007.

ECM's are organized into seven categories, which are listed below:

1. Low Investment Cost Projects (less than $25k Investment).
2. Moderate Investment Cost Projects ($25k – $150k).
3. Significant Investment Cost Projects ($150k & Above).
4. Renewable Technology Projects.
5. Further Study Required.
6. Savings to Investment Ratio (SIR) less than 1.0.
7. Known Issues, (Under Study).

This facility is somewhat unique in that the Project Office has just been expanded and updated with new low energy lighting, low energy appliances, motion sensors, insulation and low flow water fixtures. The pipeline facilities are occupied less than 40 hours per year and updated

lighting; newer HVAC and infiltration measures simply have no economic payback and would achieve very small energy conservation changes. Traditional ECM's, in general, don't apply to the Truscott facilities.

It should be pointed out that the housekeeping for the entire facility was noted to be far above normal, especially in lieu of the dusty conditions for the remote pipeline locations. The attention paid reflects great credit to the individuals as well as the USACE.

The team thanks Tracy Cartwright for his hospitality and guidance during the assessment process. The team offers a special thanks to Brent Vanderpol who not only guided the pipeline tour, but provided valuable information and answers to our continued questions.

Electrical maintenance items were noted which require the services of contract electricians as well as an effort on the part of the utility companies. These mostly include safety items and corrosion damage and a partial listing and photographs are included to assist in preparation of a scope of work for the repairs and maintenance. Thermal images of the pump motors and other major electrical components indicated no unusual "hot spots" or other indications of problems.

The study identified a total of only 7 potential ECM's.

Of the renewable energy proposals only wind generation shows any promise.

ENERGY CONSERVATION MEASURE SUMMARY

No.	ECM	Category No.
1	Conjunctive Billing	1
2	VFD's on Water Pumps	7
3	Dam @ Bateman	6
4	Pipeline Study	6
5	Solar Water Heating	4
6	Solar PV	4
7	Wind Power	4
8	Rain Water Collection	2
9	Pipeline Energy Recovery	2

Table 2.0 ECM list.

Category 1 ECM's

Only a single ECM was identified in Category 1, that being conjunctively billing the five tri-county electrical services at the Project Office Area. This should be a no cost project requiring only negotiations with the electric utility. It has a minimum savings potential of $720.00 per year. In the event the electrical charges require further break out, sub metering with USACE owned meters should provide a low cost option with a relatively short payback.

Category 2 ECM's

Again, only a single ECM was identified. Capture and use of rain water from the major buildings of the Project Office Area could potentially save close to one thousand dollars annually. The actual rain fall will of course dictate the actual savings.

Category 3 ECM's

No ECM's were identified that fall under this category.

Category 4 ECM's

Three renewable energy options were investigated, with only a slight favor for potential wind power generation. Here, the utility is typically only obligated to pay their avoided cost for any excess power generated and exported onto their system. This is usually in the range of 1.5 to 2¢ per kilowatt-hour. This reduces the potential savings, in that non-occupied periods have very little electrical consumption, and equal probability for strong winds.

Although wind energy shows potential, it would be wise to proceed involving the utility in hopes of their contribution to the project. They are also task to develop renewable energy sources.

Category 5 ECM's

There was no Category 5 ECM identified.

Category 6 ECM's

There were three potential ECM's identified under category 6. These include extracting power from the pipeline energy; replacing or repairing the Bateman Dam; and studying and modifying the pipeline operation. Although it is not possible to assign exact dollar savings to each of these potential projects, each is discussed in detail to provide guidelines for future study.

Category 7 ECM's

There is one known ECM under consideration at this juncture, that being the addition of VFD's on the three 250 horsepower electric motor pump drives at the Bateman Pump Station. The VFD installation will allow better operation of the pipeline, but caution should be taken when considering reducing the voltage from 2,300 to 480 VAC. First, the transformer(s) will need to be replaced. Larger conductors will be required since the amperage will increase due to the reduced voltage. Additional conduits will be required. The existing motors, which still operate fine, will require replacement. These factors add up to considerable cost in both materials as well as labor.

Medium voltage (2,300 VAC) VFD's can be purchased and installed eliminating the above mentioned expenses. This option should be presented in a LCCA and compared to other options.

THE TRUSCOTT PROJECT OVERVIEW

Brackish water from the South Fork of the Wichita River is pooled via an inflatable dam near the Bateman Pump Station. As the level rises, the pumps at the Bateman Pump Station are activated to lower the level in the collection basin, pumping the brine water to the Truscott Brine Lake for containment.

Picture 2.0 South Fork of the Wichita River at the Bateman Pump Station.

Picture 3.0 The inflatable dam at the Bateman Pump Station.

The Bateman Pump Station is at an elevation of 1,622.5 feet above sea level, while the sump maintains the reservoir from approximately 1,597.58 feet (Pool depth at 2.33 ft.) to about 1,600.39 feet (Pool depth at 5.12 ft. and overflowing dam). The sump level within the pump station controls the operation of the pumps to maintain a regulated level.

Picture 4.0 Dam on the South Fork of the Wichita River and the Bateman Pump Station.

Picture 5.0Sump at Bateman Pump Station.

The brine water is pumped from the sump within the building to the peak surge building, 38,375 feet away at an elevation of 1,774 feet. This is the highest point on the pipeline. This is a static head of approximately 171.5 feet including the lift from the sump.

Based on the pump name plate and pump curves, it provides a flow of 2,250 GPM @ 1,770 RPM FL, with a 305 foot total head.

Picture 6.0 Pipeline Road from the Bateman Pump Station.

Picture 7.0 Peak Surge Building.

From this point, the water flows 37,460 feet to the Hunter mountain valve building which has an elevation of 1,707.5 feet. This drop of 66.5 feet results in an effective slope of 0.001775.

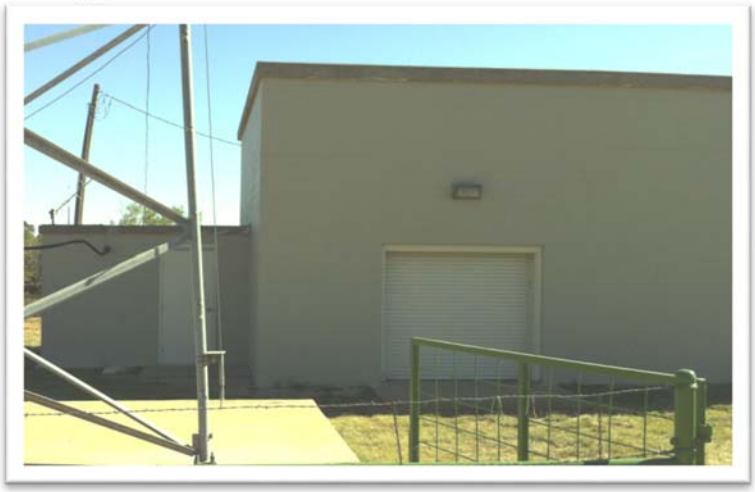
The effective slopes of the pipeline segments alter the flow rates, causing the water to be "pulled away" from the previous segments. This creates a vacuum at the individual high points which results in the apparent cavitations. Partially filled pipe flow calculations are provided at the end of this segment which indicates the variations in flow rates.

Picture 8.0 Pipeline Road to the Hunter Mountain Building.

Picture 9.0 Hunter Mountain Valve Building.

From Hunter Mountain to the discharge building is 39,165 feet and the elevation drops 147.5 feet to 1,560 feet above sea level. This is an equivalent slope of 0.003766.

From the Discharge Building to the outlet nozzles is 1,282 feet with a 50 foot drop for an equivalent slope of 0.039001.



Photograph 10.0 Peak Discharge Building.

Photograph 11.0 Slope from Discharge Building to the spray field.

Photograph 12.0 Spray field and excess flow discharge.

Photograph 13.0 Bluff Creek segment.

The brine water now naturally flows into the Truscott Brine Lake via Bluff Creek.

Photograph 14.0 Truscott Brine Lake.

Photograph 15.0 The earthen dam at Truscott Brine Lake.

BACKGROUND INFORMATION

The Tulsa Oklahoma District's Tuscott Brine Lake Project Office is located at an approximate longitude of 99°'43'35" West and an approximate latitude of 33°59'32" North at about 1,476 feet above sea level. Knox County Texas is in ASHRAE climate zone 3B and in fuel zone 3.

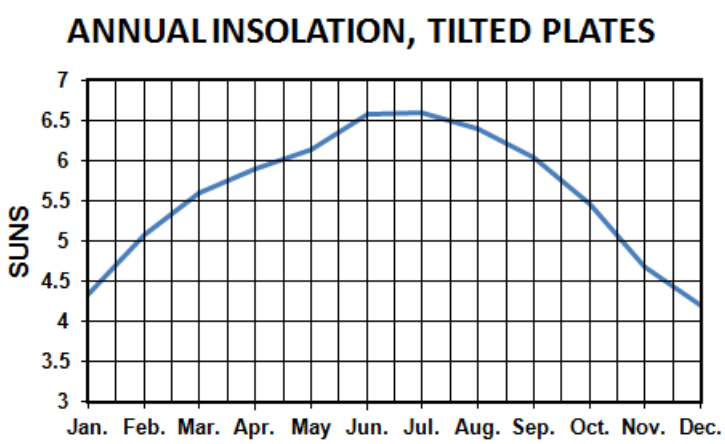
The pipeline consists of the Bateman Pump station, The Peak Surge Building, Hunter Mountain Valve Building and the Outlet Building. The main area consists of the Project Office, the Maintenance Building, the Warehouse/Equipment Shed and a Greenhouse.

Facility	Building	Sq. ft.
Bateman Area VIII	Bateman Pump Station	1332
Peak Surge Complex	Peak Surge Building	200
Hunter Mountain Valve Building	Valve Building	798
Outlet Complex	Outlet Building	1164
Project Office Compound	Project Office	4507
	Janitors Building	
Maintenance Compound	Maintenance Building	8040
	Equipment Shed	4320
	Green House	1826

Table 2.0 Building square footage.

The area enjoyes an average temperature of 61.5°F with 2,959 heating degree days (HDD) and 2,159 cooling degree days (CDD). The local weather provides 157 days of sunny skies, 88 days of partly cloudy skies and 120 cloudy days. These conditions reduce the available clear sky insolation levels to about 77.6% of the available irradiation.

The tilted insolation average is 5.58 suns per year, the cost of solar projects exceed the life expectancy of the installed equipment, rendering solar not practical for the area.



Graph 1.0 Available Solar Energy.

These area conditions are summarized in the provided graphs and tables.

AVERAGE TEMPERATURES				AVERAGE SUNS			
Jan.	36.7	Jul.	79.8	Jan.	4.35	Jul.	6.59
Feb.	41.6	Aug.	84.0	Feb.	5.09	Aug.	6.40
Mar.	58.7	Sep.	77.7	Mar.	5.61	Sep.	6.03
Apr.	57.3	Oct.	66.6	Apr.	5.90	Oct.	5.46
May	68.9	Nov.	52.9	May	6.14	Nov.	4.67
Jun.	75.7	Dec.	38.3	Jun.	6.58	Dec.	4.19
ANNUAL AVERAGE:			61.5	ANNUAL AVERAGE:			5.58

Table 3.0 Average Temperatures and Solar Insolation for the Crowell, TX area.

The area has above average wind speeds which make wind power generation possible. Current estimated costs for large scale wind power is approximately 1.33 million dollars per megawatt. Although the average wind speeds indicate good potential, it must be recalled that wind is not a primary utility source and thus requires equal backup generation, or adequate storage for periods when the wind speed is below the "break away" speed of the rotor.

Once again, the excessive cost associated with the generation equipment forces the LCCA to become negative. In many instances the payback exceeds the usefull life of the equipment.

Wind Speed @ 10m			
Jan.	11.4	Jul.	11.2
Feb.	12.1	Aug.	10.4
Mar.	13.1	Sep.	10.4
Apr.	13.3	Oct.	10.8
May	12.5	Nov.	11.4
Jun.	12.1	Dec.	11.3
Average 11.7 MPH			

Table 4.0 Average Monthly Wind Speed for the Crowell, TX area.

ELECTRICAL BILLING

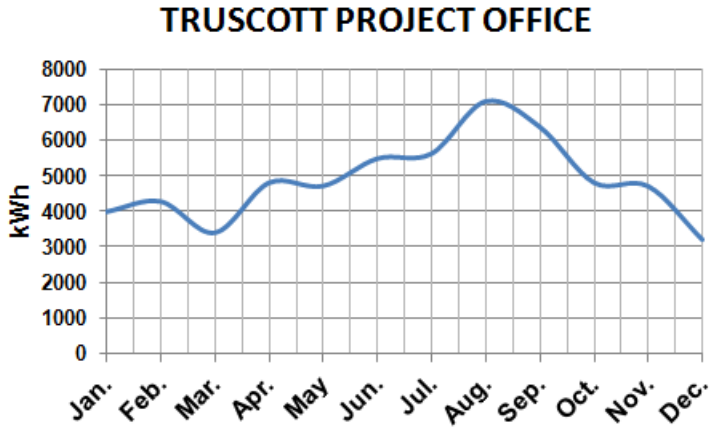
The electrical energy consumption is easily visualized in the following graphs. Billing for a calendar year is presented in the following tables and graphs. The annual average total energy cost is $0.08441 per kilowatt. The annual billing is about $16,120.00 for the five meters near the project office. They are listed below:

TRUSCOTT PROJECT OFFICE

Meter # 177459
Account# 800688479

Month	Billed Days	kWh	Customer Charge	Energy Charge	PCRF Rate	PCRF Charge	Total Bill	Unit Cost
Jan.	34	3977	$15.00	$267.25	0.0150	$59.66	$341.91	$0.0860
Feb.	33	4264	$15.00	$286.54	0.0100	$42.64	$344.18	$0.0807
Mar.	29	3388	$15.00	$227.67	0.0100	$33.88	$276.55	$0.0816
Apr.	34	4789	$15.00	$321.82	0.0150	$71.84	$408.66	$0.0853
May	28	4699	$15.00	$315.77	0.0150	$70.49	$401.26	$0.0854
Jun.	31	5469	$15.00	$367.52	0.0100	$54.69	$437.21	$0.0799
Jul.	27	5605	$15.00	$376.66	0.0075	$42.04	$433.69	$0.0774
Aug.	32	7075	$15.00	$475.44	0.0075	$53.06	$543.50	$0.0768
Sep.	32	6356	$15.00	$427.12	0.0075	$47.67	$489.79	$0.0771
Oct.	29	4793	$15.00	$322.09	0.0150	$71.90	$408.98	$0.0853
Nov.	32	4693	$15.00	$315.37	0.0150	$70.40	$400.76	$0.0854
Dec.	25	3193	$15.00	$214.57	0.0150	$47.90	$277.46	$0.0869

Table 5.0 Project Office Electrical Billing.



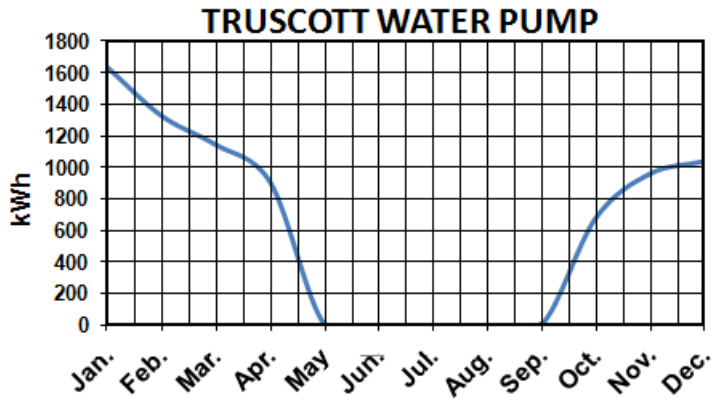
Graph 2.0 Truscott Project Office Energy Use.

Meter # 150055

WATER PUMP Account# 121404104

Month	Billed Days	kWh	Customer Charge	Energy Charge	PCRF Rate	PCRF Charge	Total Bill	Unit Cost
Jan.	35	1628	$15.00	$109.40	0.0150	$24.42	$148.82	$0.0914
Feb.	32	1321	$15.00	$88.77	0.0100	$13.21	$116.98	$0.0886
Mar.	30	1139	$15.00	$76.54	0.0100	$11.39	$102.93	$0.0904
Apr.	33	900	$15.00	$60.48	0.0150	$13.50	$88.98	$0.0989
May	28	0	$15.00	$0.00	0.0150	$0.00	$15.00	N/A
Jun.	31	0	$15.00	$0.00	0.0100	$0.00	$15.00	N/A
Jul.	27	0	$15.00	$0.00	0.0075	$0.00	$15.00	N/A
Aug.	32	0	$15.00	$0.00	0.0075	$0.00	$15.00	N/A
Sep.	35	0	$15.00	$0.00	0.0075	$0.00	$15.00	N/A
Oct.	29	675	$15.00	$45.36	0.0150	$10.13	$70.49	$0.1044
Nov.	32	956	$15.00	$64.24	0.0150	$14.34	$93.58	$0.0979
Dec.	25	1035	$15.00	$69.55	0.0150	$15.53	$100.08	$0.0967

Table 6.0 Office Area Water Pump.



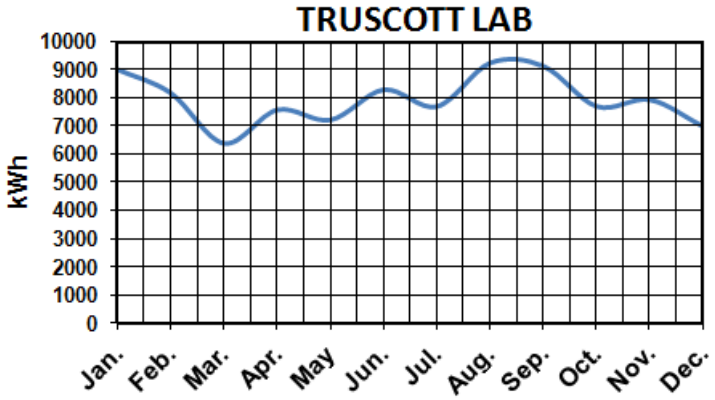
Graph 3.0 Office Area Water Pump Energy Use.

Meter # 174177

LAB Account# 121404103

Month	Billed Days	kWh	Customer Charge	Energy Charge	PCRF Rate	PCRF Charge	Total Bill	Unit Cost
Jan.	34	9000	$15.00	$604.80	0.0150	$135.00	$754.80	$0.0839
Feb.	34	8160	$15.00	$548.35	0.0100	$81.60	$644.95	$0.0790
Mar.	28	6360	$15.00	$427.39	0.0100	$63.60	$505.99	$0.0796
Apr.	34	7560	$15.00	$508.03	0.0150	$113.40	$636.43	$0.0842
May	28	7200	$15.00	$483.84	0.0150	$108.00	$606.84	$0.0843
Jun.	31	8280	$15.00	$556.42	0.0100	$82.80	$654.22	$0.0790
Jul.	27	7680	$15.00	$516.10	0.0075	$57.60	$588.70	$0.0767
Aug.	32	9240	$15.00	$620.93	0.0075	$69.30	$705.23	$0.0763
Sep.	35	9120	$15.00	$612.86	0.0075	$68.40	$696.26	$0.0763
Oct.	29	7680	$15.00	$516.10	0.0150	$115.20	$646.30	$0.0842
Nov.	32	7920	$15.00	$532.22	0.0150	$118.80	$666.02	$0.0841
Dec.	25	6960	$15.00	$467.71	0.0150	$104.40	$587.11	$0.0844

Table 7.0 Lab Energy Use.



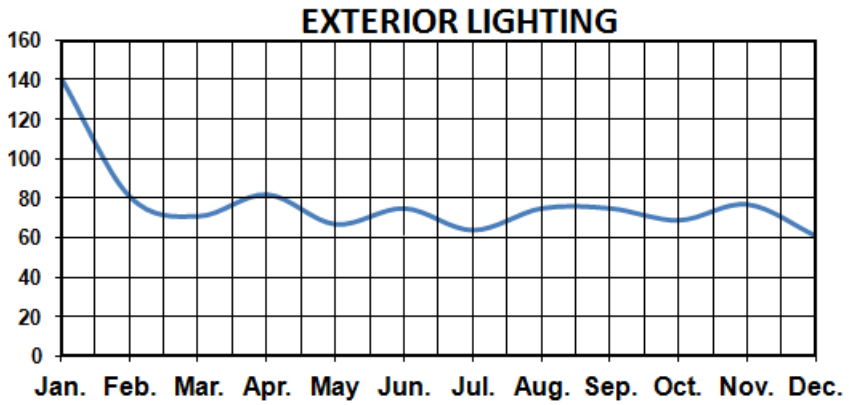
Graph 4.0 Lab Energy Consumption.

OUTSIDE LIGHTS

Meter # 149997
Account# 121404102

Month	Billed Days	kWh	Customer Charge	Energy Charge	PCRF Rate	PCRF Charge	Total Bill	Unit Cost
Jan.	34	141	$15.00	$9.48	0.0150	$2.12	$26.59	$0.1886
Feb.	33	81	$15.00	$5.44	0.0100	$0.81	$21.25	$0.2624
Mar.	29	71	$15.00	$4.77	0.0100	$0.71	$20.48	$0.2885
Apr.	34	82	$15.00	$5.51	0.0150	$1.23	$21.74	$0.2651
May	28	67	$15.00	$4.50	0.0150	$1.01	$20.51	$0.3061
Jun.	31	75	$15.00	$5.04	0.0100	$0.75	$20.79	$0.2772
Jul.	27	64	$15.00	$4.30	0.0075	$0.48	$19.78	$0.3091
Aug.	32	75	$15.00	$5.04	0.0075	$0.56	$20.60	$0.2747
Sep.	32	75	$15.00	$5.04	0.0075	$0.56	$20.60	$0.2747
Oct.	29	69	$15.00	$4.64	0.0150	$1.04	$20.67	$0.2996
Nov.	32	77	$15.00	$5.17	0.0150	$1.16	$21.33	$0.2770
Dec.	25	61	$15.00	$4.10	0.0150	$0.92	$20.01	$0.3281

Table 8.0 Outside Lighting.



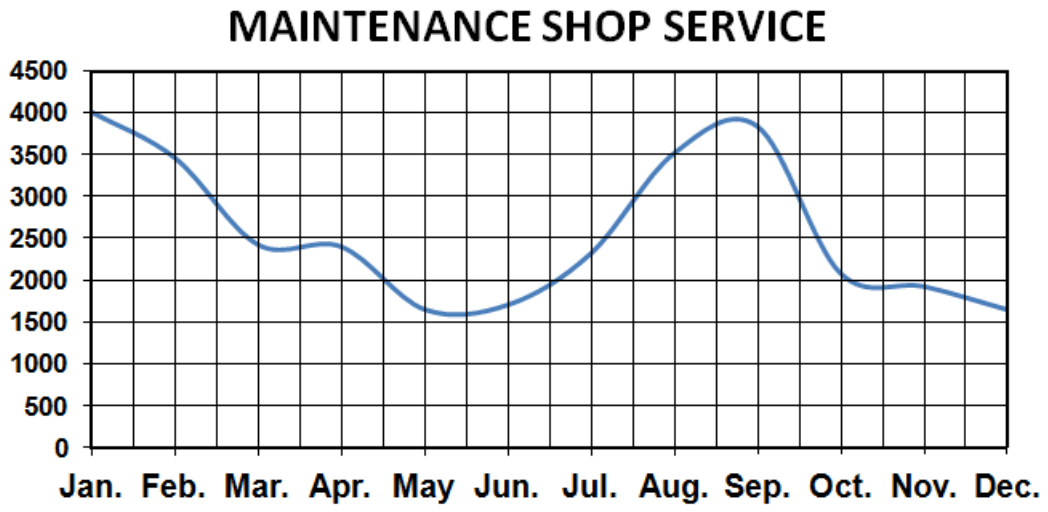
Graph 5.0 Exterior Lighting Energy use.

MAINTENANCE SHOP

Meter # 177472
Account# 121404101

Month	Billed Days	kWh	Customer Charge	Energy Charge	PCRF Rate	PCRF Charge	Total Bill	Unit Cost
Jan.	34	3996	$15.00	$268.53	0.0150	$59.94	$343.47	$0.0860
Feb.	33	3451	$15.00	$231.91	0.0100	$34.51	$281.42	$0.0815
Mar.	29	2419	$15.00	$162.56	0.0100	$24.19	$201.75	$0.0834
Apr.	34	2397	$15.00	$161.08	0.0150	$35.96	$212.03	$0.0885
May	28	1651	$15.00	$110.95	0.0150	$24.77	$150.71	$0.0913
Jun.	31	1705	$15.00	$114.58	0.0100	$17.05	$146.63	$0.0860
Jul.	27	2318	$15.00	$155.77	0.0075	$17.39	$188.15	$0.0812
Aug.	32	3508	$15.00	$235.74	0.0075	$26.31	$277.05	$0.0790
Sep.	32	3830	$15.00	$257.38	0.0075	$28.73	$301.10	$0.0786
Oct.	29	2082	$15.00	$139.91	0.0150	$31.23	$186.14	$0.0894
Nov.	32	1925	$15.00	$129.36	0.0150	$28.88	$173.24	$0.0900
Dec.	25	1650	$15.00	$110.88	0.0150	$24.75	$150.63	$0.0913

Table 9.0 Maintenance shop Billing.

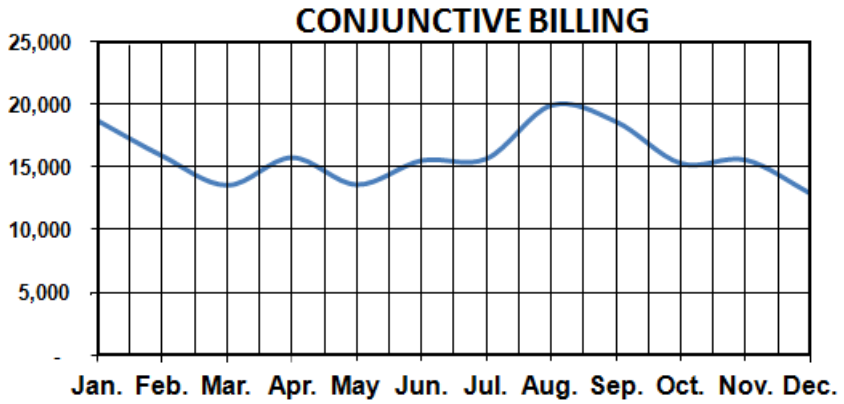


Graph 6.0 Maintenance Shop Energy Use.

CONJUNCTIVELY BILLED

Month	Billed Days	kWh	Customer Charge	Energy Charge	PCRF Rate	PCRF Charge	Total Bill	Unit Cost
Jan.	34	18,695	$15.00	$1,256.34	0.0150	$280.43	$1,551.77	$0.0830
Feb.	33	15,882	$15.00	$1,067.29	0.0100	$158.82	$1,241.11	$0.0781
Mar.	29	13,566	$15.00	$911.65	0.0100	$135.66	$1,062.31	$0.0783
Apr.	34	15,755	$15.00	$1,058.75	0.0150	$236.33	$1,310.08	$0.0832
May	28	13,617	$15.00	$915.06	0.0150	$204.26	$1,134.32	$0.0833
Jun.	31	15,529	$15.00	$1,043.55	0.0100	$155.29	$1,213.84	$0.0782
Jul.	27	15,667	$15.00	$1,052.82	0.0075	$117.50	$1,185.32	$0.0757
Aug.	32	19,898	$15.00	$1,337.15	0.0075	$149.24	$1,501.38	$0.0755
Sep.	32	18,599	$15.00	$1,249.87	0.0075	$139.49	$1,404.37	$0.0755
Oct.	29	15,299	$15.00	$1,028.09	0.0150	$229.49	$1,272.58	$0.0832
Nov.	32	15,571	$15.00	$1,046.37	0.0150	$233.57	$1,294.94	$0.0832
Dec.	25	12,899	$15.00	$866.81	0.0150	$193.49	$1,075.30	$0.0834

Table 10.0 Billing for Conjunctively Billed Meters.

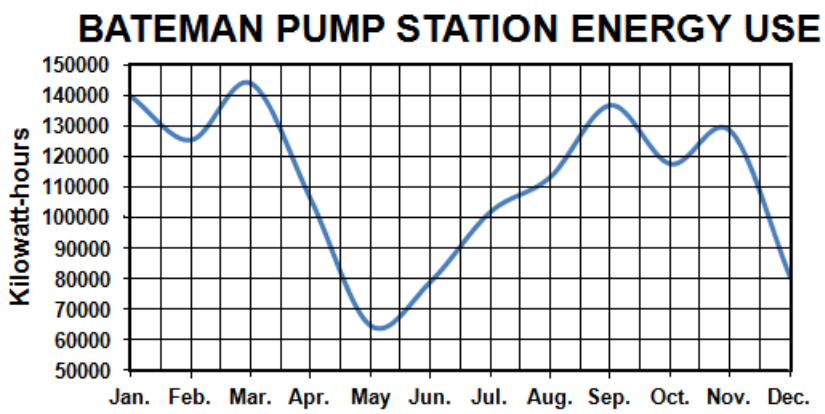


Graph 7.0 Energy Consumption for Conjunctive Billing.

The Bateman Pump Station electrical consumption is shown below:

BATEMAN PUMP STATION								
Month	Days	kW	kWh	Energy	Demand	PCRF	PUC	Total
Jan.	30	216	139800	$9,998.06	$1,728.00	-$2,097.00	$16.05	$9,645.11
Feb.	28	222	125400	$9,073.27	$1,776.00	-$1,881.00	$14.95	$8,983.22
Mar.	34	222	144000	$10,294.92	$1,776.00	-$2,160.00	$16.52	$9,927.44
Apr.	28	222	106200	$7,812.22	$1,776.00	-$1,593.00	$13.33	$8,008.55
May	29	222	64800	$5,093.00	$1,776.00	-$972.00	$9.83	$5,906.83
Jun.	33	222	79200	$6,038.86	$1,776.00	-$1,188.00	$11.05	$6,637.91
Jul.	29	216	102000	$7,515.36	$1,728.00	-$1,530.00	$12.86	$7,726.22
Aug.	33	210	113400	$8,243.11	$1,680.00	-$1,701.00	$13.71	$8,235.82
Sep.	31	210	136800	$9,780.02	$1,680.00	-$2,052.00	$15.68	$9,423.70
Oct.	25	216	117600	$8,539.97	$1,728.00	-$1,764.00	$14.18	$8,518.15
Nov.	31	222	128400	$9,270.31	$1,776.00	-$1,926.00	$15.20	$9,135.51
Dec.	32	234	80400	$6,159.67	$1,872.00	-$1,206.00	$11.38	$6,837.05

Table 11.0 Bateman Pump Station Billing.



Graph 8.0 Bateman Pump Station Energy Use.

Based on the heating degree days (HDD) and cooling degree days (CDD) only, there appears to be little to no correlation of ambient temperature to individual energy use.

Month	HDD	CDD	Month	HDD	CDD
JAN	316.00	18.00	JUL	0.00	596.00
FEB	220.00	23.00	AUG	0.00	601.00
MAR	94.00	65.00	SEP	0.00	482.00
APR	15.00	163.00	OCT	6.00	286.00
MAY	0.00	367.00	NOV	113.00	122.00
JUN	0.00	575.00	DEC	245.00	30.00

Table 12 Heating and Cooling Degree Days (Base 65°F)

Since the summer of 2011 provided record high temperatures and a record draught, the water consumption totals maybe some what higher than normal. Thus, 2011 may not be a good year for consumption measures A rain water recovery tank system should provide adequate water volumes for irrigation during normal rain fall years.

AUDIT FINDINGS

General

The outward appearance of the Truscott Project buildings and grounds show a well maintained facility with above normal attention to the grounds, parking facilities and the overall appearance of the structures. The building interior conditions reflect credit upon the facility manager and his staff, as evidenced in the accompanying photographs.

Although there are some electrical safety and maintenance concerns, they are issues which require qualified electricians, and/or the local utility to correct. These were pointed out in an effort to assist in preparation of a scope of work to be contracted for the required repairs.

Quantification of economic parameters influencing the life cycle cost of a project has developed to a point of high confidence. Obtaining believable quotes and projected time value of money are common practice. Environmental impact of projects has developed over the past decade to a point that quantification of specific emissions and their associated dollar impact are easily obtained. It is the social impact that is difficult if not impossible to quantify.

In this report, emphasis is placed on the economic impact of recommendations and a specific LCCA is formulated. The environmental impact may be expressed in terms of Carbon Dioxide [CO_2] and Water [H_2O], with defined associated costs displayed. However, these figures are not used in any LCCA.

With respect to the social impact, the intrinsic occupant reactions are expressed without attempting to assign a dollar value. It is hoped that the recommended ECM's will stand on their economic evaluations alone.

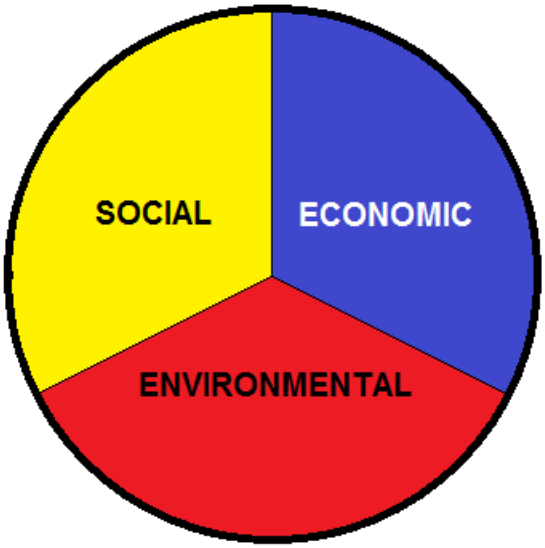


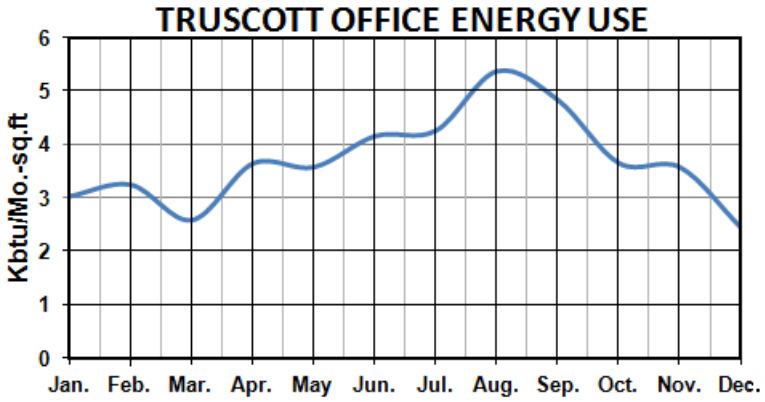
Figure 1.0 The triple bottom line evaluation.

Energy Utilization

The average annual cost for the main electrical service is $0.08171 per kWh or a total of approximately $4.763.97. This represents 58,301 kWh for an annual cost of $1.06/square foot. The Energy Use Index is the kBTU/square foot and is thus 44.1 kBTU/sq.ft.-yr.

Other buildings

Maintenance Shop 13.12 kBTU/yr. or A rating.



Graph 9.0 Office Energy Rating.

Scale Range	Rating	Description
≤0	A+	Net Zero Energy
1-25	A	High Performance
26-50	A-	Very Good
51-75	B	Good
76-100	C	Fair
101-125	D	Poor
>125	F	Unsatisfactory

Table 13 ASHRAE building rating scale.

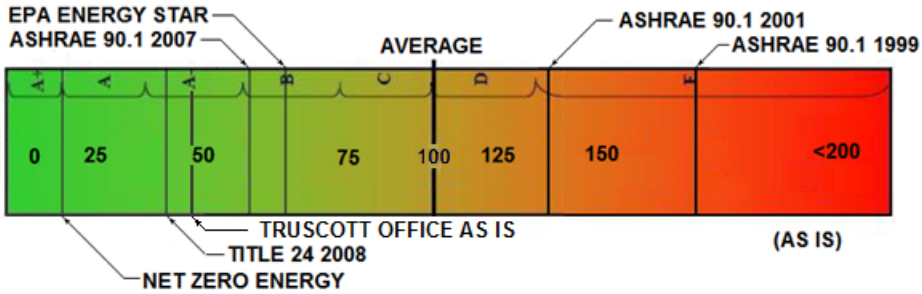


Figure 2.0 Current Truscott Office Building rating.

The Truscott Project Office Building currently has a EUI of 44.1, resulting in a grade of A-, as shown above. No ECM'S were identified for this building, and thus the A- rating will still apply.

RECOMMENDED ENERGY CONSERVATION MEASURES

In this section, the identified ECM's are listed along with some of the reasoning and calculations as to their viability and value, or lack thereof, in terms of both dollars and energy savings potential. The major ECM's are complete with LCCA, NPV, SPB, IRR, SIR and the reduction in energy expressed as kWh/year and as a percent of the overall energy.

Again, it must be pointed out that the office complex has recently been renovated and has taken advantage of insulation, lighting motion detectors energy star appliances and water conserving fixtures. The other areas of the project are limited in occupancy and thus energy use.

NOTE: Emission values shown on LCCAs are for reference only and not accounted for in the LCCA!

ECM 1 CONJUNCTIVELY BILL ELECTRIC UTILITY.

Category 1 Low investment project.

The Project Office area is billed on 5 separate meters, causing added customer service charges for each individual meter. Although this is only $60.00 per month, it also eliminates the meter reader from multiple trips (as evidenced in the varying billing days) to read individual meters. The billed rates are the same, Rate Structure 50. (See Appendix A.) This rate structure has a customer charge of $15.00 per month for single phase service and an energy rate of $0.0672 per kilowatt-hour. There is also a Power Cost Recovery Factor (PCRF) charge, which varies based on the cost of fossil fuels. Typically, this is between $0.0075 and $0.0150 per kilowatt-hour consumed. There is no tax associated with this rate for the Truscott facilities.

RECOMMENDATION

Four of these can be eliminated by conjunctively billing these services. A single main meter would be installed in lieu of the current sub meters.

Photographs 16 a, b & c Typical Tri-County Electric Meters.

ECM 2 INSTALL VFD's ON BATEMAN PUMP MOTORS.

Category 7 project under study.

This ECM falls under category 7, in that it is in the process of being pursued. The use of VFD's on the main water pump electric motors will offer several benefits. However, there are other considerations which must be weighed.

First, converting the existing three 250 horsepower motors from 2,300 volts to 480 volts will obviously increase the amperage draw. In turn, this will require a considerable increase in the conductor size and the number of required conduits. In addition, the existing transformers will require replacement of the 15KV transformer to a 480V, 3 phase transformer.

Medium voltage (2,300) VFD's are currently available, and the cost of both options should be carefully considered.

There other benefits which should also be included in this and the recommended pipeline study (ECM # 2). These would include elimination the air operated valves and replacing them with mechanically operated check valves. With the addition of a VFD and its' "soft" start capability, the need for the air operated valves is eliminated. In turn, the VFD's will off load the air compressor usage.

ECM 3 REPLACE OR REPAIR DAM

Category 6 requires further study.

The inflatable dam at the Bateman Pump Station has considerable air leakage. This requires a high cycling rate for the air compressor to maintain the dam in an inflated state. Considerable energy can be conserved by replacing the inflatable dam with a solid structure.

If it is necessary to lower the pool by deflating the existing dam, the same could be achieved with a simple flood gate. However, at minimum, the leak(s) should be repaired to reduce the air requirements.

The air compressors (3 each 5 horsepower units) consume considerable energy. The ratio of specific heats for air is approximately 1.4 and the approximate horsepower required per CFM is:

$$\mathbf{Hp = 0.015 \times P \times (R^{(k-1)/k} - 1)} \qquad \mathbf{(1.0)}$$

Where:
P = is atmospheric pressure [$14.696 \times e^{(-altitude/27,250)}$]
R = ratio of compression.

For the Bateman compressor P =$14.696 \times e^{(-1622/27250)}$ = 13.85 psia
R = 250/13.85 or 18.05
Hp = $0.015 \times 13.85 \times (18.05^{0.2557} - 1)$ = 0.227 or 0.169 kW

@ an average cost of $0.07938 per kWh, each CFM costs (60)(.07938)(.169) or about $0.39 per hour.
The compressor was noted to be cycling about every 5 minutes!

ECM 4 INVESTIGATE PIPELINE OPERATION

Category 6 requires further study.

This potential ECM involves a re-investigation of the pipeline operation. With the addition of VFD's on pump motors, more control is available, however the apparent issue is that each progressive segment has a higher flow potential than its predecessor. In turn this causes partial pipe flow and creates a vacuum at the high points in the line. The addition of a check valve and a vacuum breaker should correct the issue and allow turning off expensive air compressor use for air operated valves.

Another potential solution may be the addition of properly sized orifices to limit downstream flows to that of the pump outputs.

The fundamental objective is to balance the flows in each segment and reduce the need for surge tanks, air compressors and air operated valves. This is a category 7 ECM.

The manning flow equation for partially filled pipes is

$$Q = (148.6/n)AR^{2/3}S^{1/2} \qquad (2.0)$$

Where:

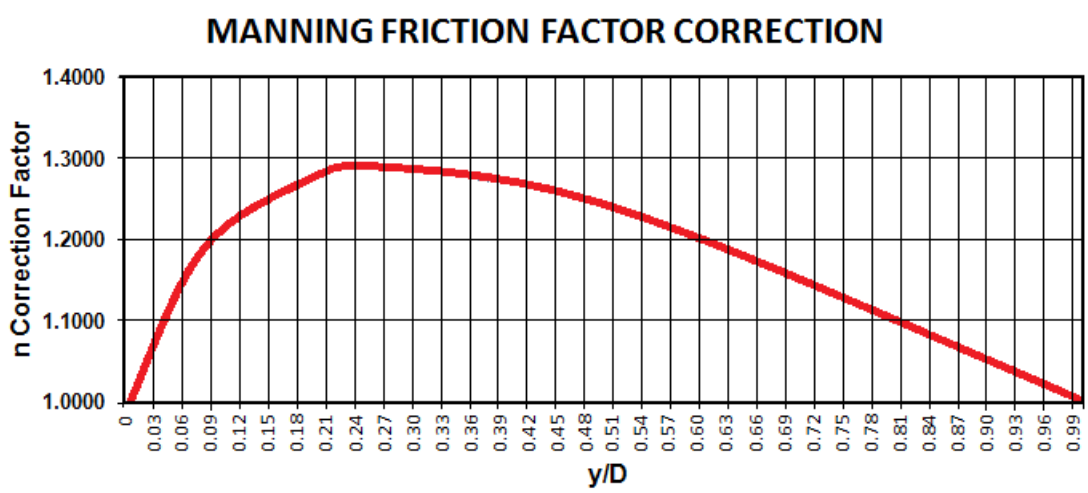
n = the Manning roughness factor (0.009 for the fiber glass pipe)

A = the flow area in ft^2.

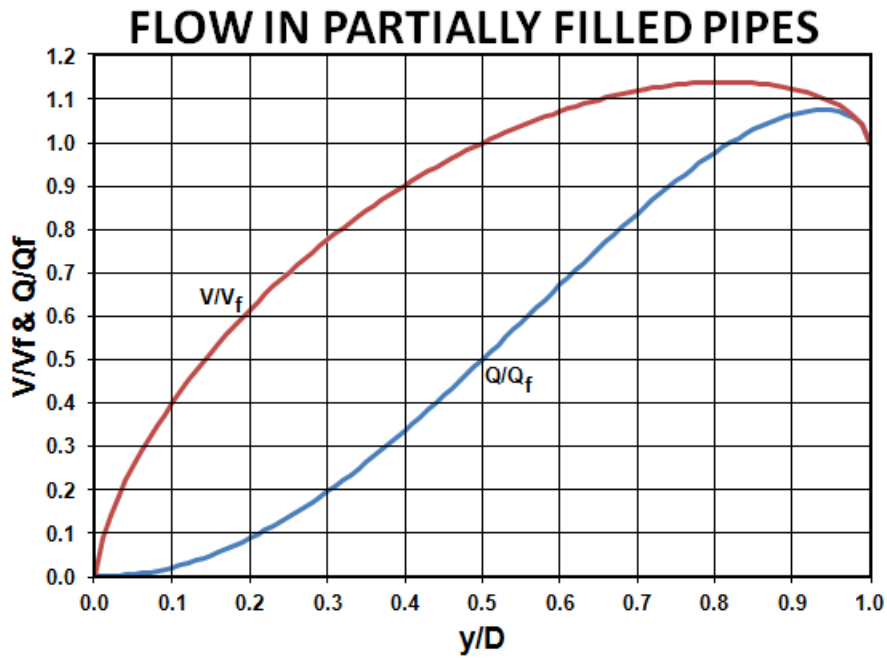
R = the hydraulic radius.

S = the slope.

NOTE: n is modified based on the depth of the flow within the pipe.



Graph ECM 3.1 Corrections to the Manning roughness factor.



Graph ECM 3.2 Partial flow and velocity profiles for partially filled pipes.

The pumps at Bateman are rated for a flow of 2,250 GPM with a single pump in operation. Since the pump(s) are pumping the brine up hill, the pipeline is 100% full.

This would be the anticipated volume that arrives at the Peak Surge Building. The second pipeline segment gravity flows from the Peak Surge Building to the Hunter Valve Building.

The second segment can flow 2,303.98 GPM when the pipe is completely full. To accommodate the 2,250 flow rate, the pipe is only filled to a y/D of 0.86, and thus the pipe flows more than the pump can output, creating a vacuum at the highest point (Surge Building.)

Figure 3.0 Flow profile for the pipeline from the Peak Surge Building to the Hunter Mountain Valve Building.

The third segment runs from the Hunter Mountain Valve Building to the Outlet Building. It can flow 3,355,82 GPM when completely full. At a flow rate of 2,250 GPM the pipe has a y/D ratio of about 0.625, and once again flows faster than the previous segment and also creates a vacuum at the high point.

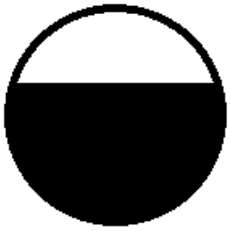


Figure 4.0 Flow profile for the pipeline from Hunter Mountain Valve Building to the Outlet Building.

The final segment from the Outlet Building to the spray nozzles can flow 10,799.22 GPM and only has a y/D of .37 at the 2,250 GPM flow rate. The restriction of the nozzles could back the flow up to fill this segment, but it appears to be relieved with a supplemental discharge pipe limiting the back pressure. The 50 feet of heat a a fluid with a specific gravity of 1.03 would produce a pressure of about 22.31 psi at the nozzles.

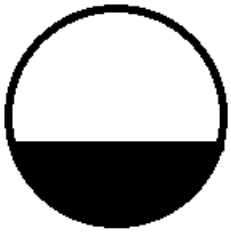


Figure 5.0 Flow profile for the discharge segment of the pipeline.

It is apparent that the partially filled pipe segments could create low pressure segments, in part due to “valleys” or low segments being completely filled trapping the previous segment and producing partial vacuum. This would be very similar to the normal “P” traps found in drains.

When the pump(s) are off, the first segment would tend to flow back to the pump station except where any part of the pipe would be lower than about 34 feet (almost a perfect vacuum. It would be less due to the higher sp. gr. of the brine). Other segments would tend to flow until a vacuum is formed and the low portions would remain full of brine.

RECOMMENDATION

A study be conducted to properly size pipe flows to balance the system, and a focus be given to eliminating surge tanks, air operated valves and air compressors. This should be a parallel study to the installation of VFD's on the pump motors.

ECM – 5 SOLAR WATER HEATING.

Category 4 Potential renewable energy.

The Truscott area has an annual average of 5.58 suns for collectors tilted to the latitude +/- 15 degrees. In conjunction with the small domestic hot water use, any form of solar water heating is far too expensive, and simply not viable.

The current electric hot water heater is a small residential type, and without a source of natural gas or propane, it provides adequate hot water at minimal energy consumption. Other options simply cannot be justified for this application.

AVERAGE SUNS			
Jan.	4.35	Jul.	6.59
Feb.	5.09	Aug.	6.40
Mar.	5.61	Sep.	6.03
Apr.	5.90	Oct.	5.46
May	6.14	Nov.	4.67
Jun.	6.58	Dec.	4.19
ANNUAL AVERAGE:			5.58

Table 14.0 Solar irradiation.

The Truscott area has a favorable latitude for solar energy, but the weather patterns significantly reduce the amount of solar insolation available. With only 107 days per year of sunny skies, the tilted plate annual average is only 4.4 suns or 4.4 kWh/day per square meter. Using the data from the top rated flat plat collector, this provides an average annual output of 948.07 BTU/ft^2-day.

With a ground water temperature of approximately 64 °F, it requires about 633.4 BTU/gal. to heat the water. The typical panels' rated output for the area is approximately 0.885 square feet per gallon. The average panel has a net area of 37.47 square feet and thus could heat approximately 42.3 gallons per day.

RECOMMENDATION

Due to the relatively small hot water use, installing a solar water heater would not be a viable options and is thus not recommended.

ECM - 6 PHOTOVOLTAIC POWER GENERATION

Category 4 Potential renewable energy.

There are several major issues associated with solar energy recovery. First, the sun only shines 12 hours per day average at any spot on the earth. This automatically reduces the efficiency by half. Secondly, the latitude of the specific site plays a role in the amount of actual insolation that reaches the earth's surface, in part due to the mean air mass (the path through the atmosphere). Altitude plays a small role, while the number of cloud cover days is perhaps the most significant.

Again, the Truscott area is not conducive to solar energy collection. A sample 20 kW system was evaluated, with the results as shown in the LCCA below.

Truscott, Texas 20 year LCCA for Solar PV; 20 kW					
CODE	COST ITEM	BASE DATE COST	YEAR OF OCCURANCE	DISCOUNT FACTOR	PRESENT VALUE
I	Initial cost	-$27,567.60	1	1.0000	-$27,567.60
Repl**	Replace System	$0.00	20	0.0000	$0.00
Res	Residual value	$1,378.38	20	0.5537	$763.18
OM&R	Maintenance	-$75.71	Annual	14.8775	-$1,126.38
Energy	Electric offset	$639.07	Annual	13.0617	$8,347.41
Energy	Water savings	$5.96	Annual	14.8775	$88.71
Energy	Carbon Savings	$145.23	Annual	14.8775	$2,160.72

Table 5.0 LCCA for Photovoltaic Power Generation.

Cost:	$27,567.60
Savings:	$639.07/yr.
SPB:	43.1 yrs.
IRR:	-7.336%
NPV:	$-19,583.40
SIR:	0.2964
Energy:	7571 kW
Energy percent:	0.60%

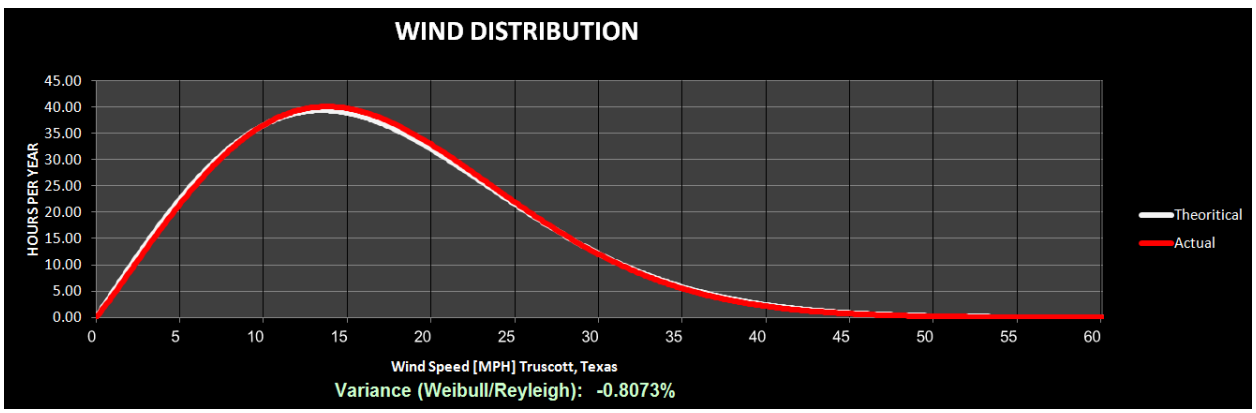
RECOMMENDATION

Based on the poor performance parameters this project is not recommended.

ECM –7 WIND POWER GENERATION.

Category 4 Potential renewable energy.

The location of the Truscott Project Office building lends its self to a good source of wind energy and has a favorable wind shear coefficient of 2.03. This presents an opportunity to generate power with a wind turbine. It must be noted like many other alternative energy sources, the wind does not blow 24/7, nor does it have a constant speed.



Graph 10.0 Weibull and Rayleigh Wind Speed Distributions.

Truscott, Texas 40 year LCCA for WIND GENERATION (31 ft. dia.)					
CODE	COST ITEM	BASE DATE COST	YEAR OF OCCURANCE	DISCOUNT FACTOR	PRESENT VALUE
Project Cost	Initial cost	-$68,103.37	1	1.0000	-$68,103.37
Replacements	Replace Components	-$51,077.53	Every 25 years	0.4776	-$24,394.91
Residual	Residual value	$32,008.58	40	0.3066	$9,812.45
Maintenance	Maintenance	-$749.14	Annually	23.1148	-$17,316.26
Energy	Avoided Electric	$4,215.67	Annually	21.5219	$90,729.14
Energy	Avoided Water	$28.71	Annually	23.1148	$663.64
Energy	Avoided CO_2	$958.04	Annually	23.1148	$22,144.95

Table 15.0 LCCA for Wind Power Generation.

Cost:	$68,103.37
Savings:	$4,639.86/yr.
SPB:	14.7 yrs.
IRR:	4.72%
NPV:	$6,245.65
SIR:	1.08
Energy:	54,968 kW
Energy percent:	4.39%
CO_2 reduction:	42.52 Tons per year

From this data, a 20 kW rated wind turbine actual output was used to predict the available electrical output and the economics. An LCCA is provided as well.

A Jacobs J31-20, 31 foot diameter, 20 kW wind turbine performance curve was used to develop the actual anticipated output. This model was selected based on its low cut-in of 6.7 MPH and a high cut-out speed of 40 MPH. It has its 100% rating at 26 MPH.

RECOMMENDATION

Wind power has potential in the area due to the above average annual winds. Due to large periods on non-occupancy and the fact that the wind can blow at any hour, it is recommended that the local utility company be consulted for a potential partner in any wind power project.

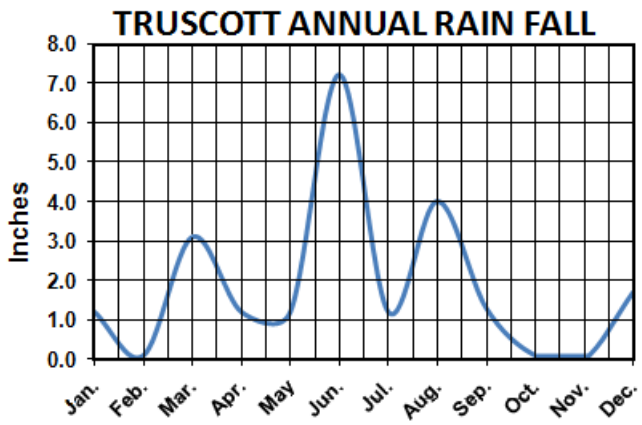
ECM- 8 RAIN WATER STORAGE SYSTEM.

Category 2 Moderate Investment.

The reported winter low billing was approximately $200.00 which translates into an approximate water use of (200-110)/4.25 = 21,176 gallons. The summer high bill was approximately $1,200.00 or (1200-110) $1090 for water only. The charge for the first 50,000 gallons would be 4.25 x 50 or $212.50 and the remaining $877.5 would be charged at $6.20 or approximately 141,532 gallons. Therefore the summer high billing

represents a use of about 191,532 gallons. Assuming a 31 day billing cycle, this is a use of 8,237 gallons per day or over 1,387 gallons per person.

The Truscott area receives an annual average rain fall of about 22.3 inches. The roof surface of the Office, maintenance shop and equipment shed cover approximately 16,867 square feet. Thus the rain runoff from the buildings is approximately 234,457 gallons annually.



Graph 11.0 Annual Rain fall.

Based on the current water rates and using the lower tier, this amounts to $996.44 annually.

AVERAGE RAIN			
Jan.	1.2	Jul.	1.2
Feb.	0.1	Aug.	4.0
Mar.	3.1	Sep.	1.3
Apr.	1.2	Oct.	0.1
May	1.2	Nov.	0.0
Jun.	7.2	Dec.	1.7
ANNUAL AVERAGE:			22.3

Table 16.0 Rain Fall by Month.

Storage tank should be adequate for the maximum month rain fall plus an additional 50%

RECOMMENDATION

It is recommended that a type of rain water recovery system be investigated, for the capture and storage of rain water for irrigation.

ADDITIONAL NOTES

This segment will be completed once specific domestic water consumption is fully understood. With a summer month's bill equivalent to four 16 foot diameter tanks 31.5 feet tall, there is a huge water consumption (191,532 gallons).
This is placed in perspective when considering the average family of four consumes on average 12,000 gallons of water per month. Thus this consumption amounts to about 16 homes of families of 4 or about the average use of 64 people.

ECM 9 ENERGY RECOVERY FROM PIPELINE

Category 6 SIR below 1 – not recommended.

Since the discharge stream from the brine pumps still has considerable energy at the nozzle area, it was decided to determine the viability of capturing this energy for power generation. The flow volume is about 300.8 cubic feet per minute from the Discharge Building. Using the MTL system (Mass, Time, Length) it is easily shown that work is pressure times volume. Pressure (M/L^2) x Volume (L^3) = Work (LM) or in this case ft-lbs. By definition, power is work per unit time and a horsepower is defined as 33,000 ft-lbs/min.

The 50 foot head in terms of pressure is (50 feet)(62.4 pounds/ft^3)(1.03 sp.gr.)/(144 sq. in/ft^2) = 22.31 lbf/in^2. Therefore, the work is 300.8 ft^3/min x 22.31lbf/$\cancel{in^2}$ x 144$\cancel{in^2}$/$\cancel{ft^2}$ or 966,362 ft-lbs/min. In terms of horsepower 966362/33000 = 29.28 and in kW 29.28 x 0.746 = 21.85. Now adjusting for an overall efficiency of 60% yields a potential output of approximately 13.1 kW.

With the electrical cost at about $0.08441 per kWh, the system output would be about $1.11 per operating hour.

The overall utilization was approximately 70% over the past year or about 6,132 hours. The value of the generated electricity would be about $6,806.52 per annum. However, the full output may not be required during certain operating hours, an utility companies typically only pay avoided cost or about 1.5 to 2 cents per kWh. The "manned" ratio, assuming 9.5 hour days M-F would be (52)(9.5)(5)/8760 or 28.19%. Thus the more realistic anticipated value of generated electricity would be about $2007.26 per annum.

This small amount may pay the anticipated high maintenance due to the corrosive atmosphere and the remote location. Capital costs would render this project to negative savings.

RECOMMENDATION

It is recommended that recuperation of the energy stream is not viable and should not be considered.

APPENDIX A

UTILITY SUPPLIERS AND RATES

Electricity:

TRI-COUNTY Electric Cooperative,	Section III	Sheet No. 8
	Revision	Page:
SECTION TITLE: RATE SCHEDULES APPLICABLE TO ALL AREAS	Effective Date July 15, 2002	

202.2 General Service. Rate Code 50 Single Phase, 51 Three Phase

A. Application.

Applicable to all individually metered commercial and industrial, rectifiers, and cathodic protection Customers, as well as three phase residential, noncommercial farm operations and public buildings, measured through one meter whose connected transformer capacity is less than 50 KVA. Service for Irrigation and Oil Field is not available under this rate schedule but is available through other rate schedules. Service will be furnished under this rate schedule subject to the established rules and regulations of the Cooperative covering this type of service, including all applicable billing adjustments.

B. Type of Service.

Single Phase or Three Phase Service at the Cooperative's standard distribution voltages, where available. Where service of the type desired by the customer is not already available at the point of delivery, additional charges under the Cooperative's line extension policy and contract arrangements may be required prior to service being furnished.

C. Monthly Rate.

Each billing period the customer shall be obligated to pay the

following charges: (1) Customer Charge: $15.00 single

phase service

$25 three phase service
This is an availability charge for providing electric distribution service; and

(2) Energy Charge: $0.0672 per kWh

D. Minimum Charge

Each billing period the Customer shall be obligated to pay the following charges as a minimum, whether or not any energy is actually used.

(1) The Customer Charge

(2) Any amount authorized under the Cooperative's line extension policy for amortization of line extension costs

E. Billing Adjustments

This rate is subject to all applicable billing adjustments.

F. Agreement

An agreement for electric service with a fixed term may be required by the Cooperative for customers who require line extension to establish electric service. This rate schedule may be changed by the Cooperative's board of directors and service hereunder is subject to the Cooperative's tariff for electric service.

Payment:

Bills are past due if not paid within 16 days of issuance. However, if the due date falls on a holiday or weekend, the due date for payment purposes shall be the next work day after the due date.

South Plains Electric Cooperative
Tariff for Electric Service
Applicable to all areas effective June 2010

Section 20

RATE SCHEDULE	38	Large Power – Tax Exempt	SHEET 22

Availability:
Available for tax exempt general, and industrial service to Customers, having KW demand in excess of 50 KW;
for all uses including lighting, heating and power and municipal water pumping, subject to the established rules and regulations; not available for cotton gins, oil well, or irrigation pumping. This rate is for existing customers only and no new customers will be added to it. Existing customers will be moved to rate 8 when appropriate.

Type of Service:
Single phase and three phase at available primary or secondary voltages. Frequency and voltage shall be subject to reasonable variation.

Rate:

Customer Charge: $60.00 per month

Demand Charge: $8.00 per kW
applied to the maximum kilowatt demand for any period of fifteen minutes of maximum use during the billing period, but in no event is billing demand less than 75% of the highest adjusted kW demand established in the billing period or eleven (11) months preceding the billing period.

Energy Charge:
$0.085679 per kWh for the first 175 kWh per KW of billing demand.
$0.065679 per kWh for all remaining kWh.

Power Factor Adjustments:
The Customer agrees to maintain unity power factor as nearly as practicable. The kW demand will be adjusted for Customers to correct for average power factors lower than ninety-five percent (95%), if and when the Cooperative deems necessary. Such adjustments will be made by increasing the measured demand one percent (1%), for each one percent (1%) by which the average power factor is less than ninety-five percent (95%) lagging.

Minimum Monthly Charge:

The minimum monthly charge shall be the highest one of the following charges as determined for the Customer in question, but not including any applicable billing adjustments provided for under Tariff Section 20.01.

1. The minimum monthly charge specified in the contract for service.
2. A charge of $1.00 per KVA of installed transformer capacity.
3. The Customer Charge stated above.

WATER

Red River Water Authority
$55.00 per meter base charge
$4.25 per 1,000 Gallons 1 to 50 k
Over 50k $6.20 per 1,000 gallons.

PROPANE

Adkins Oil Crowell Tx.
$2.35 per Gallon.

APPENDIX B

Abbreviations and Acronyms use in this report.

ACF	Actual Cubic Feet
AHU	Air Handling Unit.
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
CCF	100 Cubic Feet
CDD	Cooling Degree Day
ECM	Energy Conservation Measure
EPAC	Energy Policy Act
GHG	Greenhouse Gas as Carbon Dioxide (CO_2)
HDD	Heating Degree Day
HHV	Higher Heating Value
HVAC	Heating, Ventilating and Air Conditioning
IRR	Internal Rate of return
kW	kilowatt
kWh	kilowatt-hour
LCCA	Life Cycle Cost Analysis
LED	Light emitting diode
MCF	1000 Cubic Feet
MDP	Main Distribution Panel
MW	Megawatt
psia	Absolute pressure in pounds per square inch
PV	Photovoltaic
SCF	Standard Cubic Foot
SIR	Savings to Investment Ratio
SPB	Simple Payback
TAB	Total Air Balance
THD	Total Harmonic Distortion
VFD	Variable frequency drive

NOTE: Specific terms in equations are defined at their use.

APPENDIX C

Useful Definitions

Standard Pressure and Temperature is used as 14.696 psia and 69°F.
Natural Gas is assumed to have a HHV of 1000 BTU/SCF
HHV includes the latent heat of vaporization for the water.
One sun is 1,000 watts per square meter
There are 10.7639 square feet per square meter
There are 3,412 BTU per kW
There are 2,545 BTU per Horsepower-hour
Water has a mass of 8.334 pounds per gallon.
There are 7.48 gallons per cubic foot.

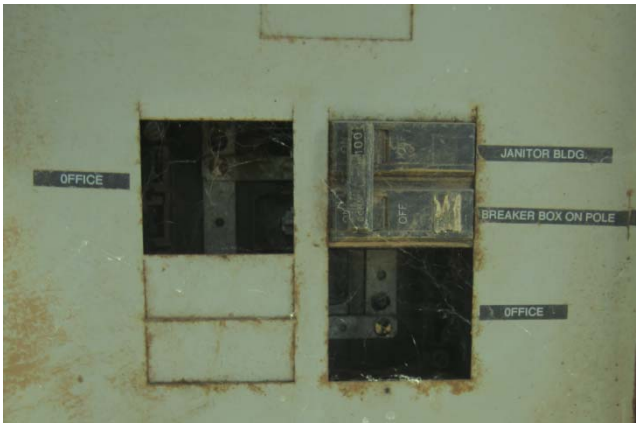
APPENDIX D

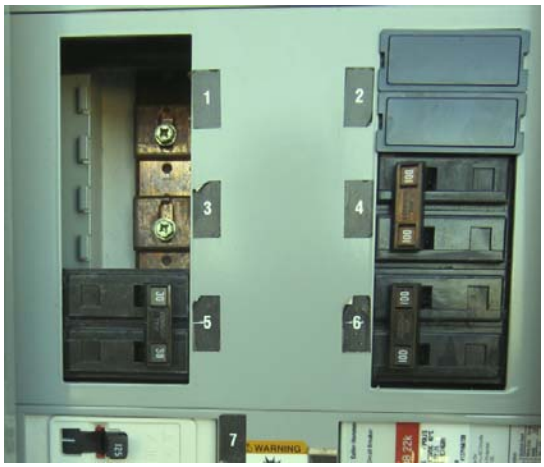
WIND MPH	FORCE psf	FORCE psi	FORCE in H2O
1	0.0051	0.00004	0.001
2	0.0205	0.00014	0.0039
3	0.0461	0.00032	0.0089
4	0.0819	0.00057	0.0157
5	0.1280	0.00089	0.0246
6	0.1843	0.00128	0.0354
7	0.2509	0.00174	0.0482
8	0.3277	0.00228	0.063
9	0.4147	0.00288	0.0797
10	0.5120	0.00356	0.0984
11	0.6195	0.00430	0.1191
12	0.7373	0.00512	0.1417
13	0.8653	0.00601	0.1663
14	1.0035	0.00697	0.1929
15	1.1520	0.00800	0.2214
16	1.3107	0.00910	0.2519
17	1.4797	0.01028	0.2844
18	1.6589	0.01152	0.3189
19	1.8483	0.01284	0.3553
20	2.0480	0.01422	0.3937

ADDITIONAL RECOMMENDATIONS

General electrical maintenance as evidenced in the following photographs requires scheduling an electrician and/or contacting the utility companies. These are all basic safety concerns and not related to conserving energy. A complete survey of corroded, broken and missing components should be made so that a comprehensive repair list and associated costs can be generated.

The following pictures are meant only as an indicator of the types of issues that require repair.


OFFICE
JANITOR BLDG.
BREAKER BOX ON POLE
OFFICE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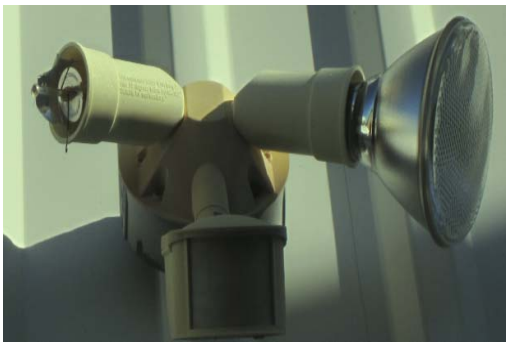

Although not in strict violation with any code, battery systems should be vented to the atmosphere to prevent and potential of hydrogen gas build up.