Master Plan and Energy Audits at a Large Texas Medical Campus

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ABSTRACT

Energy Engineering Associates, Inc. was engaged by the Facilities Resource Management Department at a large medical center in Houston, TX to assist with the development of an Energy Management Master Plan and subsequent individual Detailed Building Energy Audits. The Master Plan summarized our methodology for disaggregation of historical energy use by building and end use. We also defined our proposed system for prioritizing buildings for the individual Detailed Building Energy Audits. We proposed a 5-year plan of action to complete detailed audits of existing building inventory and complete energy efficiency retrofit projects to achieve 32 percent reduction in total energy use.

The Master Plan called for maximizing incentive payments from the local electric service provider, and for targeting the maximum available funds over the 5-year period.

To maximize the return on investment in energy efficiency, the manpower and financial resources were targeted toward the best projects. EEA developed a strategy to assess the current performance of the buildings by evaluating historical utility consumption and building infrastructure data. The energy efficiency targets or benchmarks were established for each building based upon relevant variables. Finally, an analysis of the current performance versus targeted performance was made to define the gap between current usage and targeted efficiency level.

Baseline energy consumption models were developed for most of the buildings based upon the HVAC system type installed in the facility. The “Bin Temperature” model calculated the cooling and heating requirements for the buildings based upon local Houston weather data and operating schedule assumptions for lighting and internal loads. The assumptions for internal loads and lighting were calibrated with short term building sub-meter data. Daily and weekly schedule assumptions were verified and total internal loads defined by the meter information.

The types of energy savings projects were categorized into the following six groups:

1. Hot Deck Fans
2. Heat Recovery
3. Variable Ventilation
4. Central Plant Projects
5. Commissioning and Controls
6. Lighting Projects

INTRODUCTION

Annually, buildings consume more than 30 percent of the total energy and more than 60 percent of the electricity used in the United States. As a result, energy conservation within existing buildings is extremely important.

From 2003 through 2006, EEA Consulting Engineers completed an Energy Conservation and Management Plan (Phase I) and subsequent Detailed Energy Audits (Phase II) for a medical center campus and its various sites throughout Texas, with an emphasis on the main Houston, TX campus. This master plan and preliminary audit included numerous buildings with a combined 4.4 million square feet of building area. The subsequent detailed audits included only 2.1 million square feet.

In this report, we define our Phase I Preliminary Energy Audit process, our Phase II Detailed Energy Audit process, Creating a 5-year Plan of Action, and Conclusion. This process and methodology can be extended to any type of campus setting or individual building.

PRELIMINARY (PHASE I) ENERGY AUDIT

The purpose of conducting a preliminary energy audit for a campus is to determine which buildings have the greatest opportunity for improvement and what type of energy conservation projects exist. To maximize the return on investment in energy efficiency, the manpower and financial resources must be targeted toward the best projects. EEA developed a strategy to assess the current performance of the buildings by evaluating historical utility consumption and building infrastructure data. The following sections outline our approach to gathering data, creating baseline models of energy using systems, identifying conservation opportunities, and prioritizing the buildings for future Phase II Detailed Energy Audits.

Data Gathering

Acquiring all relevant energy information for a campus is the first step of performing a preliminary energy audit. The most obvious pieces of information are the campus utility bills and the utility rate structures for each type of utility service, including electricity, water, steam, and gas. Any utility sub-metering data for the individual buildings can be especially helpful in isolating the energy usage of a particular building.

Obtaining the existing floor plans, lighting plans, lighting fixture data and a list of the mechanical equipment within each building is necessary for performing the Phase I baseline energy calculations; typically, this can be done with minimal field work. Conducting an initial field survey of the building and interviewing the operations staff can provide invaluable insight into the current operation of the campus and buildings.

Determining the building type is also essential since different types of buildings (office, laboratory, warehouse, hospital, etc.) can result in drastically different energy usages and offer varying types of energy conservation opportunities. For example, an office building or warehouse will typically have less energy usage per square foot than a laboratory building, hospital or manufacturing facility. These higher energy use type buildings will typically offer the greatest opportunity for improvement.

Baseline Energy Calculations

A rough baseline energy calculation should be done for each building within the campus. The purpose of this baseline calculation is to disaggregate the total energy usage into each system (cooling, heating, lighting, fans, user power, etc.).

Heating, cooling, and fan energies can be estimated by using simplified temperature bin calculations. Lighting energy can be approximated by knowing the quantity of fixtures and fixture types, and applying a schedule to their operation. User power can be determined by assuming a relevant usage per square foot depending upon the space usage. Knowing how much energy is being spent in each of the different systems is essential to making decisions on where energy can be saved.

For many audits, especially on older buildings, detailed information, including drawings, lighting fixture layouts, etc. are not available. Energy use for some buildings must be developed based on square footage by comparing similar buildings with similar usage on the same campus. This method should only be used if no other data is available.

Disaggregation of total energy use is accomplished based upon a series of calculations and assumptions using the collected data. Verification and fine tuning of the baseline data occurs during the Phase II Detailed Energy Audit of each building.

Identify Conservation Opportunities

For the purpose of this study, EEA utilized the Energy Star "Track" system for establishing target energy goals for buildings in the following categories: Medical Office, Hospital, Clinic, and Office. Assumptions for each building were made based upon the Energy Star methodology and the building's physical characteristics. For the Research Laboratory building use, EEA developed a "target" based upon reasonable assumptions using professional judgment and prior experience.

Once it is estimated where and how the total energy of a building is being used, a decision can be made as to where the greatest opportunity of energy savings exists. These conservation opportunities can be very general during this phase and apply to many of the buildings within a campus where there is similar occupancy and building type. All conservation opportunities should be divided into Energy Conservation Measures (ECMs) and Maintenance and Operations Measures (M&Os). ECMs typically require some capital investment on the part of the owner and M&Os may not require any capital investment.

For this project, the types of energy savings projects were categorized into the following six groups: Hot Deck Fans, Heat Recovery, Variable Ventilation, Central Plant Projects, Commissioning and Controls, and Lighting Projects.

The first three categories above represented the greatest opportunity for savings for this audit. These projects target reduction of parasitic energy associated with the dehumidification process. Many of the buildings are "ventilation driven" facilities such as laboratories and patient care facilities, where the outside air and exhaust requirements are very high. To complicate matters, the humid Houston climate requires dehumidification 73% of the time. To maintain comfort, the air is cooled to between 52ºF and 55ºF to remove the moisture and then reheated to maintain a space temperature of 72ºF to 75ºF. A variety of technologies are available to reduce the amount of energy use. An expanded description of each of the project types noted above follows:

Hot Deck Fans

Many of the buildings utilize double duct air handling systems with dedicated outside air pre-treat units. The double duct units generally have a single supply fan as opposed to separate hot and cold deck fans. The result of this single fan arrangement is that the pre-cooled outside air imposes a parasitic heating penalty on the hot deck system. By segregating the hot and cold deck systems, the pre-cooled outside air can be delivered to the cold deck side of the system. This hot deck arrangement eliminates the hot deck penalty and provides full utilization of the pre-cooled outside air to reduce the cold deck system loads. Furthermore, this arrangement provides free wintertime cooling on the cold deck system when the outside air temperatures are lower than 55ºF.

Heat Recovery

In many of the laboratory buildings, the addition of heat pipes for heat recovery purposes was suggested. Heat pipes exchange heat from one airstream to another through a closed refrigeration circuit. Heat pipes can be used in a variety of roles to achieve heat recovery savings.

When heat pipes are installed in exhaust air streams, they are used to recover heat from the exhaust stream for use in pre-treating the incoming make-up air. In the summertime, the cool conditioned exhaust is used to pre-cool the make-up air. In the wintertime, the conditioned exhaust is used to pre-heat the make-up air.

Heat pipes can also be used in a single air stream, wrap-around arrangement. In 100% outside air handling unit systems, the entire airstream is cooled to around 52ºF and then reheated to avoid overcooling the space. Based on preliminary calculations, most of the buildings are reheating to an average supply temperature of 65ºF. A wrap-around heat pipe can be installed around the cooling coil to exchange heat between the air entering the cooling coil and the air exiting the cooling coil. Heat from the warm outside air is taken out of the incoming airstream and rejected to the air leaving the cooling coil. The result is free pre-cooling of the outside air and a corresponding free reheat of the supply air. This approach is limited by the maximum amount of reheat that can be tolerated without compromising space-cooling capacity. As a result, the heat recovery effectiveness must be designed to keep from overheating the supply air.

Variable Ventilation

Variable ventilation is available in various forms for different building applications. In laboratories, the existing buildings typically have about 12 air changes per hour (ACH) of outside air. We believed that that the ventilation rates could safely be reduced to 8 ACH or lower in the unoccupied periods. Controls can be added to monitor occupancy based upon a combination of time of day, lighting and occupancy sensors. Variable ventilation energy savings for laboratories were calculated using a bin temperature energy model assuming one-third reduction of ventilation during unoccupied hours. Other variable ventilation strategies include variable air volume (VAV) exhaust for fume and kitchen hoods and CO_2 controls on outside air for office and assembly areas.

Central Plant Projects

Central Plant projects include major equipment replacement, such as chillers, cooling towers and boilers. While equipment replacement projects typically have longer paybacks, upgrading equipment to the best efficiency level makes sense when equipment needs replacing due to age or technology obsolescence. Other central plant projects include: replacement of air-cooled equipment with water cooled equipment; variable flow pumping; primary/secondary pumping conversions; chilled water thermal energy storage; heat pump chillers, variable speed cooling tower fans; cooling tower evaporation rebates; compressed air demand control and air compressor sequencing; and steam pressure reductions.

Commissioning and Controls Projects

Commissioning and Controls opportunities generally represent low-cost or no-cost projects. In our preliminary walk through of the buildings, a number of obvious commissioning opportunities stood out, including pre-heat coils operating when outside air was over 60ºF, cold deck supply air temperatures below 50ºF and hot deck supply air temperatures over 90ºF. Casual conversations with operating staff indicated brute force solutions to comfort problems. VFDs appear to be installed in systems that are constant volume, and excessive static pressure set points were common.

A comprehensive review of systems and operations will most likely yield many opportunities for improvement by repair, recalibration, and adjustment to meet proper operating requirements. Many additional opportunities can be identified in the areas of optimized sequence of operation for temperature, pressure and flow. In some cases, mechanical systems upgrades will be required to accomplish the desired functionality.

Lighting Projects

There are two primary methods for reducing lighting energy consumption in existing buildings. The first method is replacement of existing, inefficient light fixtures and ballasts with new, more efficient fixtures. Many existing facilities utilize outdated fluorescent lighting equipment that can consume up to 50% more energy per fixture than modern fluorescent light fixtures. Direct replacement of these fixtures is attractive because the cost of replacement is relatively low, while the reduction in energy consumed is relatively high. Light fixture replacement projects typically have the lowest payback period of any proposed energy conservation measure, excluding M&O modifications, due to the low retrofit/installation cost and the indirect reduction of cooling capacity.

The second opportunity for lighting energy reduction is by implementing controls projects. Savings can be achieved based on reducing the lighting power requirements during the unoccupied periods through the use of timed lighting controls and occupancy sensors.

On this project, no cooling energy savings associated with the lighting projects was assumed. Although some may occur, most of the buildings have peak cooling requirements based upon ventilation and not internal loads. It should be noted that reducing the energy consumption of the lights will increase the heating energy consumed.

Summary of Project Types Expected from Phase I Investigation

1. Double Duct Hot Deck Fans
2. Heat Recovery
3. Variable Ventilation
4. Central Plant Projects
5. Commissioning and Controls Projects
6. Lighting Projects

Prioritize Buildings

After all of these steps for all buildings within a campus have been completed, the next step is to identify and prioritize buildings for further study and investigation. A variety of metrics can be utilized to do this task. Some common metrics include energy cost per square foot, energy usage per square foot, savings potential, and Energy Star scores. Owner input into this process is encouraged since the results from this process will guide the Phase II Detailed Energy Audits.

It is generally best to prioritize buildings and projects that have the shortest payback period and greatest return on investment to maximize the effect of any expended capital funds. For example, commissioning and control projects will be high on the list because they typically require no new equipment be installed, only that the operating parameters for existing equipment and systems be modified to perform in a more efficient manner. Other variables that will guide the prioritization process are the availability of utility provider rebates for certain types of projects, and the relative life expectancy of the buildings being considered.

Building Prioritization for this Project

1. Central Hospital Building
2. Clinical Research Laboratory
3. General Medical Research Building
4. General Laboratory and Office
5. Ancillary Hospital Building
6. Remote Research Campus
7. General Medical Research Building
8. Ancillary Hospital Buildings (numerous)

After all steps of the Phase I Audit were completed, the estimated implementation cost, project savings, and payback were calculated. The results are included in the following table. This data only reflects the 2.1 million square feet of building space eventually included in the Phase II Audits.

Table 1. Phase I Savings Estimates

Estimated Project Implementation Cost	$15,000,000
Estimated Project Savings (Annual)	$6,000,000
Overall Project Payback (Years)	2.5

DETAILED (PHASE II) ENERGY AUDIT

Following the prioritization of each building within the campus, the next step is to select which of the highest priority buildings will receive a detailed energy audit to better define project costs and expected savings. The detailed energy audit process is broken down into four basic steps: detailed review of existing plans and documents, field investigations, base case energy distribution analysis, and project analysis. This process is similar to the process described in Phase I, but takes much more time to complete.

Detailed Review of Plans and Documents

At the beginning of the detailed audit process, any available plans and equipment submittals are gathered from the Owner. These plans include the original construction drawings and specifications, as well as any retrofit or remodel plans that may be available. The audit team reviews these plans and submittals to gain a basic understanding of the building, including the architectural, mechanical, electrical, and plumbing system infrastructure. Based on this document review, the audit team can develop a preliminary ECM and M&O project list, a basic strategy, and a plan for field investigation activities.

Field Investigations

Once the document review is complete, an extensive field investigation process is undertaken to clearly establish the current operating conditions of the building and associated mechanical and electrical systems. The field investigation process typically involves numerous tasks.

Interview operations staff

One of the first steps in the field investigation process is to interview the buildings operations staff for that particular building. The purpose of these interviews is to determine the history of the building, current operating schedules, the intended sequence of operations for various systems, and identify current operational and equipment problems or issues. Utilizing the history and experience of the building operations staff is generally helpful and necessary in guiding the other field investigation activities.

Inventory building mechanical equipment

All of the major energy using mechanical and plumbing equipment is inventoried during the field investigation phase. The nameplate data and system configuration is recorded. When possible, the operating schedule for equipment is determined. From this data, energy consumption will be estimated for each piece of equipment and summarized as part of the base case energy distribution analysis.

Perform HVAC system measurements

Detailed measurements are collected on each of the major HVAC systems. The purpose of this data collection is to develop a thorough understanding of the current operating conditions of each system and to identify operational problems, which potentially represent energy conservation opportunities. The data collected on these systems provides the basis for the assumptions that will be made when modeling the building energy consumption. Table 2 lists a sample of the type of mechanical system data collected.

Table 2. Sample of Mechanical System Data Collection

Mechanical System	Measurement Type
Air Handling System	Unit and ductwork configuration
	Damper positions
	Air temperatures and pressures at each AHU component
	Supply and return air pressures
	Airflow measurements and duct velocities
	Fan speed
	Fan electrical data
Exhaust System	Unit and ductwork configuration
	Damper positions
	Distribution ductwork pressures and fan pressures
	Airflow measurement and duct velocities
	Fan speed
	Fan electrical data
Hydronic Cooling and Heating System	System configuration and pipe routing
	Valve positions
	Pump speed
	Pump electrical data
	Pump head
	Chiller data
	Cooling tower data
	Supply and return temperatures
	Distribution piping pressures
	Control valve pressure drops
	Coil entering and leaving water temperaturers

Inventory lighting systems

In addition to the above mechanical system information, a review of the lighting system is performed. If lighting plans are available, then lighting take-offs are done from plans and spot-checked in the field. Furthermore, lighting levels are checked in a representative sampling of rooms to determine if there is adequate lighting available. Measuring the lighting levels within the building can indicate if lighting conservation opportunities exist via de-lamping or day lighting, even if the existing lights are efficient. It is also important to field verify the type of lighting controls that are present in certain areas and if those lighting controls are being utilized. Energy savings can be realized through the use of time-of-day scheduling controls and occupancy sensor installations.

Record trend measurements

Using portable trend recorders and existing building automation systems to measure and evaluate a variety of variables that define the operating profiles of the building is necessary for a detailed energy audit. Some examples of these trend measurements include:

1. Recording the lighting power (by panel amperage readings) provides insight into the building occupancy schedule and indicates if and when lighting systems are turned off during unoccupied periods. This data can also be used in conjunction with lighting plans to determine lighting diversities (actual vs. connected load).

2. Recording the building electrical feed indicates day to night power use, which provides insight into building occupancy schedules. This data can also be analyzed and extrapolated to estimate annual electrical usage when historical data is not available.

3. Recording air handling unit supply and return air temperatures provides an indication of space load and can identify potential controls problems.

4. In variable volume systems, recording fan or pump speed will determine the operating range of the system and potentially identify opportunities for optimization of the controls.

Review building arrangement

The arrangement of the building and associated infrastructure is reviewed while collecting data. Available space and arrangement of the equipment in the mechanical and electrical rooms is evaluated with respect to implementation of potential projects. Alternative equipment areas, such as the roof and site are also checked with respect to suitability for new equipment.

Base Case Energy Distribution Analysis

Once the field data collection is complete, the data is compiled into a base case energy distribution model. This model is the foundation of the detailed audit and provides the basis for all energy conservation calculations. The process of developing this base case model is described below.

Evaluate and compile field data

The field data is reviewed and evaluated to identify potential project opportunities and anomalies in the data. These analyses activities may include the following:

1. Air and water temperatures are reviewed to identify potential controls adjustment opportunities or to identify potential problems with coils and heat exchangers.

2. Airflow measurements are crosschecked to verify accuracy and to gain insight into the air balance of the overall building or of a given air system. System airflows are also checked against design values and ratios of supply airflow to floor area (CFM/sqft) are spot-checked.

3. Fan and pump data are used in conjunction with equipment performance curves to review the current operating conditions (flow, power, and efficiency) and to identify opportunities for more efficient operation.

4. Air and water pressure measurements are evaluated with respect to pressure drop to identify potential problems such as obstructions, poor fittings, high flows, and throttled valves or dampers.

5. Air and water flow rates along with temperature data is used to calculate thermal loads. In many cases, the airside loads are crosschecked with the waterside loads to verify accuracy or identify anomalies.

6. Mechanical data is compared to input made by the building operations staff and differences are noted.

7. Installed lighting watts/sqft are calculated and compared to lighting levels measurements. Lighting trend data is compared to installed lighting power to determine lighting diversities.

8. Trend data is charted to reveal operating profiles.

In many cases, follow-up field measurements are required to resolve questions or to investigate anomalies that were revealed during the data analysis.

Develop base case energy model

Once the field data has been collected and analyzed, the audit team will have a good understanding of the building systems and operating conditions. This understanding is built into a base case energy model which consists of the following components:

1. Equipment Distribution: The equipment distribution is a summary of all of the mechanical equipment in the building with estimates of power, operating schedule, and energy consumption. Typical systems included on the energy distribution include, fans, pumps, chillers, cooling towers, compressors, vacuum pumps, refrigeration equipment, and other major appliances.

2. Lighting Distribution: The lighting distribution is a summary of all of the building's lighting systems with estimates of connected power, diversities, operating schedule, and energy consumption. The lighting is typically grouped by areas corresponding with the major HVAC systems so that lighting loads can then feed directly into the HVAC bin models.

3. HVAC Bin Models: A bin model is a method used to calculate energy use by segregating the total energy usage into temperature bins. Temperature bins are based upon 5 degree increments of the outside air temperature. The major air handling units in the building are grouped by system arrangement or operating/load profile. For each group of air handling units, a bin spreadsheet model is created to estimate the cooling, heating and fan energy consumption. The field data and plan review data are compiled into the basic input assumptions of these bin models in an effort to accurately reflect current operating conditions. Table 3 is a sample bin model.

Table 3. Sample Bin Model

BIN CALCULATIONS									
Step	***BIN DATA***	***ZONE LOADS***	***DRY BULB CONDITIONS***	***SUPPLY TEMP***	***AIR FLOWS***	***HUMIDITY RATIOS***	***COIL LOADS***	***POWER***	***ENERGY CONSUMPTION***
Variable Description	Dry Bulb Temperature Bin								
Units	°F								
	102								
O	97								
C	92								
C	87								
U	82								
P	77								
I	72								
E	67								
D	62								
	57								
H	52								
O	47								
U	42								
R	37								
S	32								
	27								
	22								
	17								
	12								

4. Domestic Hot Water: Domestic hot water consumption is estimated based upon facility size and usage. In buildings with large domestic water consumption, additional field data may be available and collected to better define actual consumption.

5. Process Systems: Some examples of process systems include process heating or cooling applications, DI water systems, kitchen equipment, and incinerators. Energy consumption for these systems is estimated on a case-by-case basis with supporting input from field investigations.

<u>Evaluate historical utility data</u>

There are potentially multiple sources of energy use in a given building including electricity, natural gas, and purchased thermal utilities such as chilled water, heating water, and steam. In many cases the building's annual consumption for each of these energy sources is available in the form of billing statements. In these cases, this data is summarized into annual totals. In other cases, the data is incomplete, unavailable or is aggregate data, which applies to multiple buildings. In these cases, an analysis will be required to estimate annual energy consumption from partial data or to disaggregate the utility data for a given building. Existing sub-meter data may be used in this analysis or additional metering/sub-metering may be required.

<u>Benchmark/calibrate base case energy model</u>

Once the historical utility data is evaluated, the base case energy distribution is then calibrated to closely match the historical data. This is a critical step in the audit process, which ensures reasonable accuracy of the energy distribution and subsequent project savings analysis. In most cases, this calibration process simply involves a minor adjustment of the base case assumptions. When large discrepancies exist between the initial base case model and the utility data, additional field investigations may be required.

The benchmarking process is not complete until the baseline energy model, produced with actual field measurements, matches the disaggregated utility bills within an acceptable tolerance. This tolerance is heavily dependent upon actual data that is available and field measurements that can be taken. For this project all energy models were calibrated within ten percent of utility bills. The following table is an example of a benchmarking/calibration spreadsheet.

Table 4. Sample Benchmarking/Calibration Spreadsheet

MODELED ENERGY USAGE														
MODELED USAGE BASELINE														
SYSTEM	ELECTRIC DEMAND			ELECTRIC ENERGY		PURCHASED THERMAL					EST. USAGE SOURCE		OPERATING COST	
						CHW		STEAM						
	(KW)	W/sqft	% OF TOTAL	(KWH)	% OF TOTAL	TON-HRS	% OF TOTAL	TON-HRS	MLBS	% OF TOTAL	KBTU/GSF-Yr	% OF TOTAL	$	%
AHUS														
FANS														
PUMPS														
MISCELLANEOUS EQUIPMENT														
LIGHTING														
USER-POWER														
DOMESTIC HOT WATER														
PROCESS COOLING WATER														
MODEL SUBTOTALS														
UTILITY DATA														
METERED AND ESTIMATED TOTALS DIFFERENCE														

Project Analysis

The project analysis phase begins with a list of potential project opportunities and ends with estimates of savings, cost, payback, and return on investment for each project.

Identification of potential project opportunities

The audit team keeps a running list of energy conservation project opportunities throughout the course of the audit process. When the project analysis phase begins the project list is first divided into maintenance and operations projects (M&Os) and energy conservation measures (ECMs). M&Os are low cost/no cost measures involving simple set point adjustments or repairs while ECMs are more capital-intensive measures. The ECMs are ordered so as to properly and fairly account for dependencies between projects. For example, a lighting retrofit will impact the cooling and heating loads on the HVAC system, which may in turn affect the savings of a variable air volume (VAV) conversion to that HVAC system. Thus, the VAV project has a dependency with the lighting project.

Project Evaluation Dependency Order

1. Effects on Building Load
2. Distribution System Modifications
3. Primary Equipment Modifications
4. Energy Management Modifications

Perform savings calculations

For each M&O and ECM, modifications are made to the building energy distribution model. The resulting change in energy consumption is then compared to the prior consumption to estimate savings. Project energy savings calculations are performed in order, and the resulting energy consumption prior to each project is always used as the new baseline so that project dependencies are properly accounted for.

Schematic design and cost estimate

For each project, a simple schematic design is sufficiently developed to allow development of a reasonable cost estimate. Based on this schematic design, a cost estimate can be developed using a combination of vendor pricing, RS Means Cost Estimating Guides®, and contractor input.

The cost estimate can also be reduced by taking into account any potential utility rebates that may be available. Sufficient time should be spent to investigate all potential rebates, as this can reduce the payback of a particular project.

Simple Payback

Based on the estimated savings and cost for the project, a simple payback is calculated. This payback is used as a first indicator of project viability. In cases of more complicated or capital-intensive ECMs, additional analysis such as "return on investment" and "life cycle" cost calculations may be justified.

CREATING AN ACTION PLAN FOR POST M&O AND ECM INSTALLATION

After completing the Phase I and II audits, it is important to create a campus action plan to guide future energy conservation strategies in existing and new buildings.

The Action Plan is a living document which needs to be updated over time as projects are completed and experience calibrates operation, design and management regarding how to best leverage available resources to improve energy efficiency. The Action Plan calls out specific buildings and projects for completion within certain time frames. Priorities may change based upon new information or economic factors. Annual updates of the Action Plan are needed to ensure continued success and to document "Institutional Wisdom" based on experience. The specific elements of the Action Plan are described below.

Adopt Clear Energy Efficiency Targets for New Construction

It is very important that some time and effort is devoted to design guidelines for new buildings. Because the nature of an expansive energy conservation and retrofit project necessarily takes place over several years, multi-building campuses will likely be proceeding with construction of new facilities concurrent with the energy conservation efforts in their existing facilities. New buildings should not become energy efficiency retrofit targets upon completion.

During new construction design periods, energy efficiency competes with other "needs" or "wants" of the users for capital. Generic design of building systems due to unknown future requirements tends to push energy efficiency off the table. State of Texas requirements for buildings to meet ASHRAE Standard 90 has made only modest impacts on building designs; designers are not being required to substantially document their compliance with Standard 90. We recommend that energy efficiency targets be set at the preliminary design document stage and that designers document their strategies for minimizing energy use and complete documents to clearly demonstrate compliance with Standard 90. Specifically, compliance calculations for the envelope, lighting, fan power, cooling tower power, HVAC controls, lighting controls, chiller efficiency, boiler efficiency, hot water efficiency, and transformers. An annual energy use estimate needs to be prepared with clearly stated assumptions regarding user power and scheduling of building functions. This design phase analysis will allow a fair comparison in the future when actual energy use is metered.

We recommend that owners set a goal of exceeding Standard 90 requirements by a minimum of 15%. Some areas may be easier or more cost effective to achieve or exceed. Engaging a separate energy efficiency consultant may be merited for some buildings to help steer the design process into using new procedures and techniques.

Define Priorities for Energy Efficiency Retrofits

As described above, the high priority buildings have the greatest potential for energy savings. Most of the efforts in the Action Plan will focus on the existing buildings prioritized during the Phase I audit. The preliminary goals established in this report will be refined during detailed audits. Proposed strategies discussed above for new buildings to exceed minimum efficiency are valid for existing building during major renovations. Preparing a written document to record specific strategies and noting areas where investment is being made to exceed minimum requirements will help in preparing compliance documents for ASHRAE Standard 90 and making estimates of future total building energy use. Overlaying of "factors of safety" and excessive design assumptions tend to be exposed when reconciliation of design assumptions and energy consumption projections are laid out side by side. Comparing proposed systems and operation to actual existing building performance offers the potential for significant first cost reductions that may help pay for energy efficiency upgrades.

Commit Financial Resources to Projects

To effectively implement a substantive number of projects, it is helpful to begin preliminary design of prototype projects directly after completion of the Phase I audit to facilitate good cost estimates and accelerate the schedule for bidding and construction. Additional funds need to be committed to complete detailed audits to clarify the scope for first priority buildings and confirm expected energy savings.

Complete Detailed Audits of Target Buildings

Finishing detailed audits is important for timely implementation of energy efficiency projects. The measurement of actual operating performance will help define low cost / no cost projects that can be accomplished by the owner's maintenance staff. The building specific data will allow more refined and accurate modeling of system performance to improve accuracy of savings calculations.

Complete Retrofit Projects

The first buildings retrofitted will serve as pilot projects. The successful implementation and expected savings will confirm the proposed strategies and expected costs. These projects also have the potential to favorably impact design of new buildings. Detailed investigations and engineering reports are valuable tools. However, the projects must be implemented to accomplish the goal of reducing significant energy. Preliminary design efforts will help to better define expected cost and accelerate completion of plans for the construction project once the detailed audit is completed. After successful completion of the pilot projects, an owner may consider the merits of completing some projects based upon preliminary analysis to expedite project implementation.

Track Energy Consumption and Project Success

We expect that some projects will require detailed Measurement and Verification (M&V) plans and documentation to track actual energy conservation performance. Tracking energy use of all the buildings offers multiple benefits including identification of problems or malfunction, and identification of good practice and improved performance for recognition and replication. Automation of data acquisition and standard report generation is needed, however thoughtful review and comment on trends and deviations is also needed on a monthly basis. Graphics programs are available to report data in 3-D format for easy viewing. We recommend that a monthly progress report be written to track the implementation of energy efficiency projects, design guidelines, detailed audits and metered savings. Reports should include the following:

Summarize Trends

The trends for building energy usage needs to be summarized individually and collectively. Forecast savings should be plotted along with actual results to give a visual indication of success.

Measure Results (Savings and Costs)

Results of the Plan of Action need to be measured and reported. Measurement should be made in the following areas:

1. Cost of retrofits
2. Design standards
3. New building performance
4. Training
5. Utility cost

These measurements need to be standardized or normalized into cost by unit, i.e., cost per cfm, per square foot, per fixture. The cost effectiveness needs to be measured by payback in years or incremental payback for upgrade. The measurement might be percentage complete or dollars ($) per square foot or BTU per square foot. Multiple measures offer the owner the ability to identify clear winners or applications that have universal application or narrow application.

Update the Plan of Action

Annual updates to the Plan of Action are needed to keep a focus on spending available resources on the best projects. New data and information will continue to accumulate. Analysis of the data and progress will drive the updated Plan of Action. We recommend that a formal Plan of Action be produced every year that defines a plan for the next three years and reports on the success to date.

CONCLUSION:

The following list includes the types of M&O and ECM projects were discovered during our Phase II Detailed Audits.

Project Types Discovered During Phase II

1. Double Duct Hot Deck Fans
2. Lighting Controls
3. Controls Commissioning
4. Heat Pipes on Outside Air Pretreat Units
5. Variable Ventilation -Lower Lab Air Change Rates
6. Pumping Projects
7. Steam Leaks
8. Fan Resheaves
9. Duct Fitting Improvements
10. Motor Replacements
11. Heat Pump Chiller Installations

After all steps of the Phase II Audit were completed, the estimated implementation cost, project savings, and payback were calculated. The results are included in the following table.

Table 5. Phase II Savings Estimates

Estimated Project Implementation Cost	$12,700,000
Estimated Project Savings (Annual)	$5,800,000
Overall Project Payback (Years)	2.2

As of the date of this report, only the “Lower Lab Air Change Rates” project has been implemented. The success of the project has been so significant that the facilities department has expanded the concept to many buildings that weren’t initially included in the Phase II reports. The success of this project will determine the viability of any future projects.