INVESTMENT GRADE ENERGY AUDIT

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ABSTRACT
The requirements of an investment grade energy audit for commercial, institutional and industrial facilities are reviewed. The results of review of investment grade audits for ten institutional facilities are briefly presented, and main deficiencies of the audits and their perceived causes are outlined. A checklist for the principal issues to look for in an investment grade audit is developed from the findings.

INTRODUCTION
Energy assessment/audit has become an accepted first step in identification and implementation of various energy efficiency opportunities in residential, commercial, institutional and industrial facilities. The objective of an energy audit is to identify economical energy/cost saving measures that do not adversely affect the quality of work/product and the environmental consequences of the equipment and processes. Energy audit is a needed step in implementation of any detailed and sizable energy efficiency project. Often there will be the need for engineering design before implementation/ construction of the project.

The major impetus behind an energy audit is that the analysis of energy consumption and identification of potential conservation measures in facilities relate to various disciplines of engineering, that are often beyond the expertise of one person or small engineering firms. For example, on the less complex end of energy consumers, in the residential facilities, energy consumption depends on the structure, windows and doors, lighting, HVAC and refrigeration systems as well as cooking equipment. On the other end of the spectrum, in manufacturing facilities, the energy consumption is very process-dependent and greatly varies from facility to facility. Industrial facilities do not often lend themselves to standard prescriptive energy efficiency measures customarily used in residential, commercial and institutional facilities.

There are two basic types of audits, walk-through audit and detailed audit, the latter considered investment grade audit. Investment grade audit is also called feasibility study by CEC (2000). An investment grade audit may be a comprehensive audit that is intended to identify all energy efficiency opportunities in a facility, or a more targeted audit which focuses on a specific piece of equipment or process, e.g. lighting, a boiler, a drying process, compressed air system.

Walk-through audits – Walk-through audits are usually done by utility representatives or equipment vendors. In an ideal case a person or a team knowledgeable in energy efficiency issues walks through the facility along with a facility personnel and identifies simple and standard energy efficiency measures such as lighting replacement, light and occupancy sensors, and high efficiency motors. The measures may be reported to the facility management with little substantiation and back-up information. Milan (2002) has prepared a guidebook for walk-through audits. Although the guide is for industrial facilities, it equally applies to commercial and institutional facilities.

Investment Grade Audits - According to CEC (2000), a detailed or investment grade audit (whether comprehensive or targeted) is a technical and economic analysis of potential energy saving projects in a facility that:

- Provides information on current energy-consuming equipment operations
- Identifies technically and economically feasible energy efficiency improvements for existing equipment, and
- Provides the customer with sufficient information to judge the technical and economic feasibility of the recommended projects.

Detailed or investment grade audits are the basis for further engineering analysis and design, and investment in energy efficiency improvements by facility owners or third parties. They can be also the basis for performance contract agreements. An accurate investment grade audit can result in identification of highly cost effective projects, and result in substantial cost/time savings in realization of the projects, while a low quality audit will result in unrealistic savings analysis, duplicate work in the engineering design process, and potential problems in performance contract agreements. More importantly, because some of these energy audits may become a basis for investment in, and establishment of distributed generation facilities in the present energy market, energy audit work may have significant economic repercussions.

It is the intent of this paper to review the requirements of detailed investment grade audit, including the audit of industrial facilities. A number of detailed audits for some institutional facilities in California are reviewed as cases, and their shortcomings are identified. The perceived causes of the shortcoming will be elaborated. Finally, a checklist for the basic contents of a detailed energy audit will be developed.

SOME ENERGY AUDIT CASES

BASE Energy, Inc. under contract with the State of California has had the opportunity to review some energy audit reports as owner representative for the State. The reports were prepared by energy service companies (ESCos), and in a few cases by energy engineering consultants. The audits and reviews have been performed since July 2001 after the peak of California energy crisis. The results from review of ten comprehensive audit reports are presented in the following table. The ten audits that are presented here were done by seven firms, some of them with national operations. The table has three columns, showing the facility that the audit report was prepared for, the recommended measures and the major issues that were raised by BASE staff after careful review of the audit reports.

It should be noted that despite shortcomings in some of these reports, many of the identified measures were deemed reasonable and were recommended for adoption. An eleventh report prepared by one of the firms was fairly complete and is not included in the table.

As noted in the third column "Issues Raised", there were significant deficiencies in most of these reports that stems from lack of adherence to the procedures outlined in CEC (2000). The important issue was lack of sufficient information in the reports for a design engineer to follow and complete the engineering of most of the projects. Additionally in most cases there was not sufficient information to repeat the analyses.

EXPECTATIONS FROM AN INVESTMENT GRADE AUDIT

CEC (2000) elaborates on the details of an investment grade audit. Although it may sometime be costly to follow the details of the process as outlined by CEC (2000), the final product of an investment grade audit (the audit report) needs to at least address the following issues:

- Clear operating hours per department (and equipment in the case of major energy users)
- Clear inventory of energy consuming equipment including their nominal ratings and capacities
- Energy rate/cost per unit of energy usage and for different types of energy (electricity, natural gas, etc.). In the case of electricity the customer may be paying for electrical demand too. In such a case, the demand cost and its basis should be clearly identified.
- Analysis of at least one year (as the base year) of energy consumption by type of energy/fuel
- Energy balance of the plant per type of fuel and preferably per meter based on rating, operating hour, utility factor and load factor of equipment. Utility factor is the ratio of the operating hours of a piece or group of equipment to the total operating hours of facility or department. Load factor is the ratio of the actual draw of equipment to the nominal rating of equipment, usually determined from measurement.
- Clear identification of major energy consuming processes and equipment in the whole facility
- Analysis of major energy efficiency measures identified in the audit process, which at least includes source of energy saving, amount and type of energy saved, cost savings, implementation cost and a pay-back analysis, as well as any major assumptions made in the analysis. In the case of computer simulation, a clear and succinct input/out put for computer programs needs to be included.
- Clear identification of the retrofit or control scheme/technology, and inclusion of cut sheets of the proposed equipment
- Clear identification of the measures that may have potential in similar facilities that do not exist or are not economical in the audited facility

It is expected that investment grade energy audits include realistic assumptions on the conservative side; be complete, self sufficient, and a clear guide to implementation, and serve as a roadmap to any future energy efficiency retrofit work in the facility. Assuming that an identified measure is chosen, and the detailed design is done, no more detailed energy consumption analysis should be needed to design and construct the measures.

SUMMARY OF ISSUES RELATED TO 10 REVIEWED COMPREHENSIVE ENERGY AUDIT REPORTS

Audit	Measures Recommended	Issues Raised
Office Building Southern California Firm A	Retrofit part of the lighting system HVAC system upgrade	Type of lamps and fixtures not identified, energy savings overestimated by about 40% HVAC system energy savings overestimated by about 50% (methodology problem) Various measures not identified: VFD* for chilled water and condenser pumps VFD for cooling tower fans VFD for return fans Proper control of supply fan VFD Various control issues
Office Building Central Valley, CA Firm B	Installation of a New 400 Ton Variable Speed Chiller Upgrade Existing Partial Thermal Energy Storage System Install VSD* on Pumps and Fans Energy Management Hardware and Software Retrofit Lighting	No energy or demand balance presented Utility rate schedules were not identified DOE-2 simulation had been used but no input/output data were presented No equipment cut sheets presented, so performance data used in DOE-2 not clear It is not clear how cooling tower fans are controlled
Office Building San Francisco Bay Area, CA Firm A	Installation of VFDs on the Supply and return Fans. Installation of CO_2 Controls on the Return Air Fans. Installation of Damper Control.	Measured power of the motors is based on current measurement, lacks power factor measurement Fan curves have been used for VFD justification, not clear if flow and pressure were measured or assumed, fan curves are sensitive to both Numerical errors in power savings calculations resulted in overestimation of savings by 50% It is not clear why installation of CO_2 sensors are recommended and how it will result in any energy savings, maintenance cost savings, etc. Automating the on/off of the HVAC system not identified, while it is done manually now
Office Building Sacramento, CA Firm C	Lighting Retrofit Installation of a 100 kW photo voltaic Solar System	Rate schedules not identified Operating hours of equipment not identified Monthly utility data not included No equipment listing No energy balance has been done Inconsistent demand values has been used to size PVC system DOE-2 simulation done, but no conclusions were drawn
Prison Central Valley, CA Firm D	Lighting Retrofit Energy Management System Variable Air Volume HVAC Boiler Economizers and Fan VSDs Transformer Substation Cogeneration Replacement	Assumed plug load without justification No details of the HVAC system to be controlled by the EMS has been presented Measurement data for boiler not presented, but various measures recommended The basis for choosing the kW rating of the cogen is not clear FERC's criterion for cogen not clarified
Vocational Institution Central Valley, CA Firm D	Lighting Retrofit Thermal Energy Storage Programmable Timeclocks and Thermostats Boiler Economizer and Fan VSDs Dairy Chiller Heat Recovery New Water Booster Pump Cogeneration	Rate schedules not identified Boiler measurements not included Boilers optimization not taken into consideration Cogen calculations do not include actual plant data
Office Building Southern California Firm D	Lighting Retrofit EMS Controls Modifications VSD's for Pumps and Chillers Window Film Thermal Energy Storage	The schedule of operation of HVAC system and building temperature control (chillers included) are not clear. The specs for the HVAC system are not provided. The DOE-2 simulation has not been properly calibrated. There is a discrepancy of upto 50% in demand estimation

*Variable Speed Drive (VSD), the same as Variable Frequency Drive (VFD)

TABLE – CONTINUED

Audit	Measures Recommended	Issues Raised
Office Building Central Valley, CA Firm E	Lighting System Upgrade Power Conditioner (480V) Constant Volume to Variable Air Volume Energy System Management /Controls Cooling Tower Upgrades 120 kW Power Guard Photovoltaic System	Lighting energy savings significantly overestimated Cut sheets not included Energy and cost savings from Power Conditioner unsubstantiated Trace simulation input and output not included VFD is recommended for cooling tower fan, but motor size and info not provided No battery is recommended for the Photovoltaic cell, and it is not clear what will happen to produced energy when there is no need in the building
Office Building Central Valley, CA Firm F	Motors and Variable Speed Drives Air Handler Unit Upgrades Domestic Hot Water Heater Controls	Operating hours not clarified and inconsistent in the report No detailed equipment listing and energy balance presented Not clear how the savings in HVAC have been estimated, no analytical method presented
Office Building Central Valley, CA Firm G	Interior Lighting Retrofit High Energy Motor Replacement Retrofit Centrifugal Chiller with VSD	No energy balance presented Unrealistic cost savings of 43% has been presented for fluorescent lighting retrofit without delamping Effect of lighting retrofit on cooling not considered Overestimation of chiller operating hours by over 25% Overestimation of cost savings from high efficiency motors due to unrealistic unsubstantiated values in motor efficiencies

The following can serve as a checklist for preliminary screening of a detailed/investment grade energy audit:

____ Are the energy rates based on historical (or projected) energy consumption and current (or projected) energy rates?

____ Has energy usage (and demand in the case of large electricity users) been balanced for at least one full year of energy data, separately for different fuels and preferably per meter? The preferred forms of presentation is graphical (e.g. pie chart) or tabular.

____ Are operating hours for different areas in the facility clearly identified and taken into consideration?

____ Are major energy consumers clearly identified, and taken into consideration in the energy balance?

____ Are the bases for implementation costs clearly identified?

____ If a modeling software has been used, are the inputs and outputs clearly identified, so that another expert can repeat the work?

____ For the proposed measures, is it clear why energy will be saved?

____ Is it clear what form of retrofit is proposed and what are the advantages?

____ Is it clear where the retrofit should take place?

____ Have all potential energy efficiency measures been addressed?

MAJOR SHORTCOMINGS IN REVIEWED AUDIT REPORTS

The following have been the major issues with the audit reports we have reviewed:

- Lack of consistency in energy cost, demand cost, operating hours of various area of the facilities; often the basis for the considered demand cost is not clear
- Lack of energy balance, which often results in overestimation of the cost savings
- Lack of a clear description of the energy rate schedules, annual energy analysis, so that the customer is not really provided with a clear picture of how they are charged.
- Lack of equipment inventory and their ratings
- Lack of clear description and identification of retrofit scheme
- Overestimation of savings due to lack of consistency
- Lack of consideration of the latest retrofit technology
- Lack of pointing out the measures that may exist in similar facilities but do not exist in the surveyed facility

Overall, while the comprehensive detailed energy audit reports are supposed to provide a clear picture of the energy supply and consumption in the facility, and act as a roadmap for improvement of the energy utilization and cost reduction, they lacked some key components to serve the ultimate purpose.

PERCEIVED CAUSES

Some of the perceived causes of deficiencies in the audit reports seem to stem from:

- Lack of expertise of people who do the surveys, and more importantly those who prepare the report. Although taking inventory of equipment is fairly

straightforward (filling out a site sheet), it often takes a clear understanding of complicated systems (e.g. a multiple-chiller system) to offer any meaningful energy efficiency improvements.
- Lack of basic knowledge of the fundamental engineering principles. Energy efficiency work is multidisciplinary, which necessitates a strong knowledge of fundamentals of mechanical and electrical engineering. It is always advisable to have a professional engineer oversee comprehensive energy audit projects.
- Lack of training in application of sophisticated simulation software such as DOE-2 and its various derivatives. Very sophisticated computer programs can produce incorrect results if they are not fed with the proper data (e.g. operating hours, load factors, etc.), and properly applied to the specific situation.
- Conflict of interest – Often the firm that conducts the survey and prepares the audit report, is the same or affiliated with the firm that will do the engineering design and implementation (such as full energy service companies). There may be cases that are not directly leading into a profitable project and get omitted, or some required steps and information are overlooked in the interest of "green lighting" a project. An example is when a firm is hired to do a comprehensive energy audit, but fails to take inventory of all equipment and evaluate them, in the interest of an attractive lighting retrofit project. Other examples are consideration of unrealistic operating hours, utility factors, load factors of the equipment. An oversized 50 hp fan motor may operate at 50% of its load, but it will not be known in the plant audit if its power draw is not measured!

MORE COMPLICATED ENERGY AUDIT CASES

Comprehensive energy audit of manufacturing facilities requires significantly higher expertise than commercial and institutional facilities. Energy consuming devices are highly varied and process/product-dependent, and many remote users may dictate the operation of major energy-consuming devices, e.g. boilers and compressors. In such cases understanding the process is as important as understanding the equipment. An auditor of commercial buildings will not necessarily have the expertise of auditing industrial facilities. While there are tens of energy saving opportunities in commercial facilities (refer to CEC 2000), there are hundreds of energy efficiency opportunities in industrial facilities. It is not uncommon to identify 10-30% energy efficiency opportunities with simple paybacks of zero to a few years in industrial facilities. Major guidelines for performing comprehensive energy audit of manufacturing facilities are the same as those for commercial facilities. Some specific issues in audit of manufacturing facilities are:

- A much wider scope of measures and advanced technologies (inclusive of those for commercial facilities) can be identified in industrial facilities.
- While there are significant commonalties between industrial facilities with different processes, most facilities may have their unique energy efficiency measures that can be identified and analyzed based on fundamental engineering principles.
- Load measurements are required for major energy consuming devices. Some equipment may go through significant load variations.
- Energy usage in most industrial facilities are highly product and production dependent, and much less dependent on ambient conditions.
- Taking a detailed inventory (which includes the rating, usage pattern, loading) of energy consuming equipment is an essential component of a comprehensive energy audit of industrial facilities.

CONCLUDING REMARKS

CEC (2000), "Guide to Preparing Feasibility Studies of Energy Efficiency Projects" provides a comprehensive guide for reporting investment grade audits of various types of facilities. Although the guide has been mostly developed with institutional facilities in mind, its general recommended methods apply well to commercial, and for the most part to industrial facilities.

The results from review of investment grade audit of ten institutional facilities performed by seven ESCOs and engineering consulting firms show major deficiencies in their process and reporting, suggesting that closer adherence to the guidelines will significantly improve the works, and result in more realistic evaluation of the economics of the projects. Major deficiencies of the reviewed reports are outlined, and potential causes are briefly discussed. A checklist for initial evaluation of the investment grade audit reports is proposed.

At the end, in addition to the economics of the suggested measures, an investment grade energy audit should clearly define what the change/improvement is, and where it will take place, so that a designer would have specific knowledge for completing the design and specifications.

REFERENCES

1 - CEC (2000), "Guide to Preparing Feasibility Studies of Energy Efficiency Projects," Report P400-00-002, California Energy Commission.
2. – Milan, C. B. (2002), "A Guidebook for Preparing Walk-Through Energy Audits of Industrial Facilities,' Bonneville Power Administration, http://www.bpa.gov/Energy/N/reports/audit/index.shtml.