ENERGY EFFICIENCY GUIDELINES

2. Recommendations for conducting energy audits in buildings

ENI CBCMED
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ABBREVIATIONS

AC	Alternate current
ASHREA	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BPIE	Buildings Performance Institute Europe
DC	Direct current
DOE	US Department of Energy
EEM	Energy efficiencymeasures
EPA	Environmental Protection Agency
ESCO	Energy services company
EU	EuropeanUnion
EUI	Energy Utilization Index
IEA	International Energy Agency
IEC	International Electrochemical Commission
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
KPI	Key performance indicator
kW	Kilowatt
kWh	Kilowatt-hour
NZEB	Nearly zero-energy buildings
O&M	Operation and maintenance
ROI	Return on investment
SLD	Single line diagram
SPP	Simple payback period
TTA	Trama Tecnoambiental

1 INTRODUCTION TO AN ENERGY AUDIT

An energy audit is an inspection, survey and analysis of energy flows in a building, process or system. The objective of an energy audit is to understand the energy dynamics of the system and identify the possibilities for improvements in the operation processes and equipment of a building, but also to develop a set of Energy Efficiency Measures (EEMs) in order to reduce energy costs, save energy and increase performance.

The goals of the energy audit are:

- To clearly identify the types and costs of energy use.
- To understand how the energy is being used – and possibly wasted.
- To identify and analyse various EEM alternatives such as improved operationaltechniques and/or new equipment that could substantially reduce energy costs.
- To perform an economic analysis on those alternatives and determine which ones are cost effective for the business or industry involved.

Typically, an energy audit ranges from a simple walkthrough of the facility to identify major problem areas to a more sophisticated and comprehensive analysis of implications of energy efficiency measures.Simple energy audits result to low- or on-cost general guidelines and recommendations, which are easy to implement and produce immediate, evident results. Such recommendations might be changes in personnel behaviour, like turning off the lights and AC units when leaving a room. More complex audits result to more complex energy efficiency measures that require structural changes and a long-term, larger investment.

Moreover, energy audits may follow a holistic approach and target the whole building or only specific systems, such as lighting or heating and cooling.

2 THE PROCESS OF ANENERGY AUDIT

The energy audit is carried out following the below set of tasks which are divided into four phases. The first phase is an initial desk study, followed by a field survey and visit to the building or complex of buildings, data assessment, modelling and simulations, and concluding with the proposal of EEMs and reporting (according to DOE's Guide to Energy Audits). The report should include three main chapters:

1. Detailed analysis of the present facility's energy status including utilities analysis, energy balance, detailed systems description…
2. EEMs: Technical analysis, savings development, financial analysis.
3. Appendixes: Full load inventory list and any supporting technical documentation.

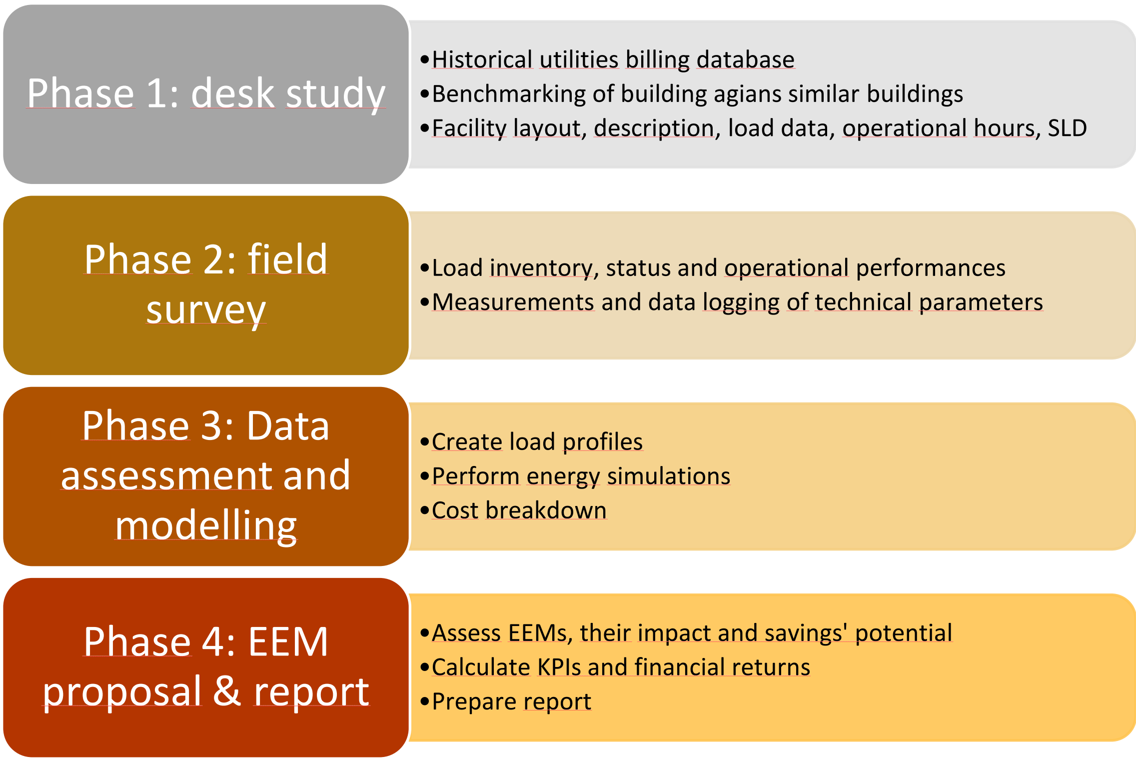


FIGURE 1: PHASES OF AN ENERGY AUDIT

2.1 Phase 1: Desk Study

The energy auditor first performs a preliminary energy use evaluation by examining utility data, building or system diagrams, equipment lists, and other facility information. In general, the energy auditor should collect and review at least two years of utility data during the energy use analysis to account for seasonal variations and patterns of energy use. Monthly utility bill data is most commonly used; however, hourly, or more frequent interval meter data is becoming more widely available from utilities. All forms of energy (electricity, gas, oil, water) should be included in this analysis.

From this evaluation, the energy auditor will calculate your facility's Energy Utilization Index (EUI) value (annual energy use/square footage) and energy end uses (energy used by each building system). The EUI and base energy load enable the energy auditor to benchmark this data against energy use of similar buildings and systems to illustrate the potential magnitude of energy efficiency opportunities and provide an early estimate of potential savings. The energy auditor also looks for any changes in energy use over time and potential causes for those changes.

The energy auditor will provide a preliminary report which includes a summary of data and graphs and other visuals to allow for easy interpretation. Results from this analysis can be helpful in determining which level of audit to perform; results also inform recommendations in the final audit report.

2.2 Phase 2: Field Survey

After the preliminary review, the energy auditor will conduct a physical assessment of your facility and its operations. During the site assessment the energy auditor will meet with key operations and maintenance staff to learn how your building operates and discuss any current concerns or issues with the facility.

The energy auditor will also conduct a visual inspection and inventory of the building's key elements, including:

- Construction details of the building envelope (e.g. walls, roof, windows, doors and related insulation values)
- An inventory of the heating and cooling systems (HVAC) capacities and rated efficiency
- Manual, timeclock, or automated HVAC control methods
- Interior and exterior lighting systems and related controls
- Service hot water systems

Level 1, Level 2 and Level 3 site assessments each include some degree of investigation into operations and maintenance procedures, schedules, and typical building occupancy. The duration of the onsite assessment varies depending on the level of audit you choose, and time commitments required from the staff may increase as one moves from Level 1 audits (which could take as little as four to eight hours) to Level 2 and Level 3 audits. Level 3 audits in particular may require the auditor to conduct multiple site visits and meter equipment to capture usage data. In this phase the data will be collected and logged.

2.3 Phase 3: Data assessment and modelling

After the energy auditor has collected the necessary data for the building, the energy and cost analysis begin. Baseline energy use, data collected through the onsite assessment and financial impacts of energy efficiency installations are considered during the analysis. Before beginning the analysis, the energy auditor should have a good understanding of the economic methodology and business criteria to ensure that the analysis is compared with other non-energy related investment opportunities and that cash flows match expectations.

Energy analysis methodologies vary widely, as seen in the following chapters. The project goals should inform the analysis methodology selected to avoid results that yield too much or too little detail. Typical analysis methodologies include spreadsheet analysis based on engineering formulas that account for variations in time of day and season, and whole-building hourly energy use analysis for larger buildings or buildings with complex mechanical systems. More complex methods used in Level 2 and Level 3 audits enable more accurate calculations of potential energy savings but are also more costly.

The cost analysis considers current energy costs, implementation costs of interventions and potential savings over time. This analysis aims to determine practicality and priority of EEM recommendations. Examples of financial methods that the energy auditor will use to determine the order of EEM implementation include simple payback period, life cycle cost, internal rate of return and discounted payback.

Accurate cost data is crucial to the financial analysisin order to avoid inadequate budgeting for the energy efficiency improvements. Overestimation may cause delays for approval or rejection of the energy efficiency measures proposed.

2.4 Phase 4: EEM proposal &audit report

In the last phase, the energy auditor develops a list of recommended EEMs with the associated savings estimates.It is important to note that, some EEMSs such as premium efficiency motors and motor controls, produce total savings greater than the sum of the individual savings.Documentation of analysis methodology, assumptions, and supporting calculations should all be included with the savings estimates.

Aspects that should be considered when analysing potential EEMs include:

- Operations and maintenance (O&M): Does the facility have the staff to ensure savings from the energy efficiency retrofit persist over time, and will the measure have a positive or negative effect on the O&M costs?
- Comfort: Will the measure result in increased human comfort (and potentially lead to fewer maintenance calls)?
- Improved system reliability: Will the measure lead to lower contractor costs?
- Feasibility of system replacement: Are parts easily replaced, will installed technology be outdated in the near future?
- Ease of implementation: How will installation of the measure affect daily business operations? Are power outages required? Can the facility stay open during installation?
- Risk of failure: What are the operational, financial and safety impacts if the system fails?

The energy auditor's main deliverable for the energy audit is the final report. Any audit report should provide enough information to allow the client to make informed decisions about next steps to meet the financial goals. Audit reports include an inventory of existing equipment, a summary of the building's current conditions and energy use, and a list of recommended no-cost, low-cost, and longer-term EEM recommendations based on analysis of historical energy use and the onsite assessment.

3 ENERGY AUDIT LEVELS

According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), there are three levels of audits, each with an additional level of complexity and, thus, more energy savings, as seen in the following figure.

Level I preliminary audits offer general recommendations for improvements of a building's energy performance through a general inspection of the building and electricity bills. Those audits are preferred for small facilities with limited budget availability for energy efficiency improvements. Level II audits are done with a more thorough site survey and more detailed analysis of energy usage and costs than level I audits. Finally, the level III audits consist of on-site monitoring and measurements of technical indicators, a thorough list of recommendation and a cost-benefit analysis. Level II and III audits incur a higher cost than level I one and are recommended for buildings with specific energy efficiency objectives (voluntary or mandatory) and plans for renovation of the equipment of building envelope.

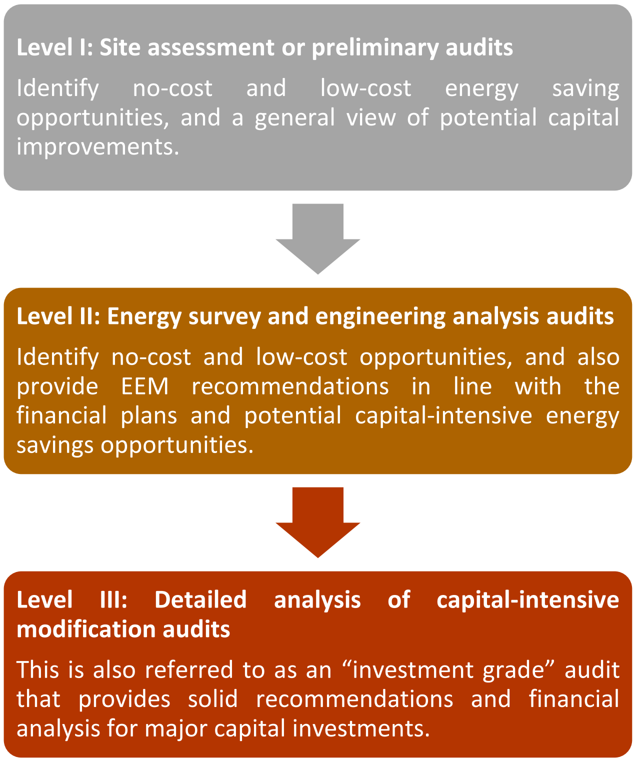


FIGURE 2: ENERGY AUDIT LEVELS ACCORDING TO ASHREA (SOURCE: DOE)

3.1 Level 1: Site assessment or preliminary audits

The *preliminary audit* (alternatively called a simple audit, screening audit or walk-through audit) is the simplest and quickest type of audit. It involves minimal interviews with site-operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency.

Typically, only very problematic areas will be covered during this type of audit. Corrective measures are briefly described, and quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided. This level of detail, while not sufficient for reaching a final decision on implementing a proposed measure, is adequate to prioritize energy-efficiency projects and to determine the need for a more detailed audit.

During the preliminary audit, the following information should be collected[1]:

- Power of existing equipment: The power of all major equipment in the building should be collected. The information about current energy demand of the equipment can usually be gathered from the building managers or users, either as a list of equipment or as verbal information during the visit. Some information could be also gathered from nameplates.
- Current energy usage: The percentage loading of equipment and hours of operation can be also obtained from the plant managers or operators. Some of this information can sometimes be retrieved simply by reading the amperes on the meter of the distribution panel or other existing sources of information or metering devices. The

[1]A detailed list of information to be collected is available in the annex 1

current load factor and hours of operation will be important data to estimate the current energy usage of each category of equipment.

- Current efficiency of equipment: One of the objectives of the preliminary audit is to assess the potential for energy improvement in a facility. The auditor should be looking for system characteristics that provide information about the current efficiency level of the existing equipment. By comparing these efficiencies with modern equipment, the potential of savings can be estimated.
- Improvement in systems controls: A large quantity of energy can be saved in facilities using simple measures that allow to achieve a better control of equipment. The auditor will be looking for information that can point to potential reduction of operation time or better control of the equipment that can be automatically turned on and off with sensors, for example.

BOX 1: Example of a typical survey for the lighting system of a building.

Step 1: Existing system survey

A standard office occupies a space of 3m x 4m and comprises typically 4 fixtures with T12 fluorescent tubes. Each fixture uses 2 x 40 W tubes and a 16 W electromagnetic ballast. So, a total of 384 W is needed for a standard office of 12 m^2, the typical lighting energy density is thus 32 W/m^2.

Step 2: Existing system potential for reduction

The replacement of existing fixtures by 32 W nominal power fluorescent tubes could be a first step to realize savings. Moreover, using *electronic ballast* will allow to further reduce the input power of a fixture to 58 W with the same lumen output as the existing system. This would result in a reduction of 38 W per fixture or savings reaching 39%.

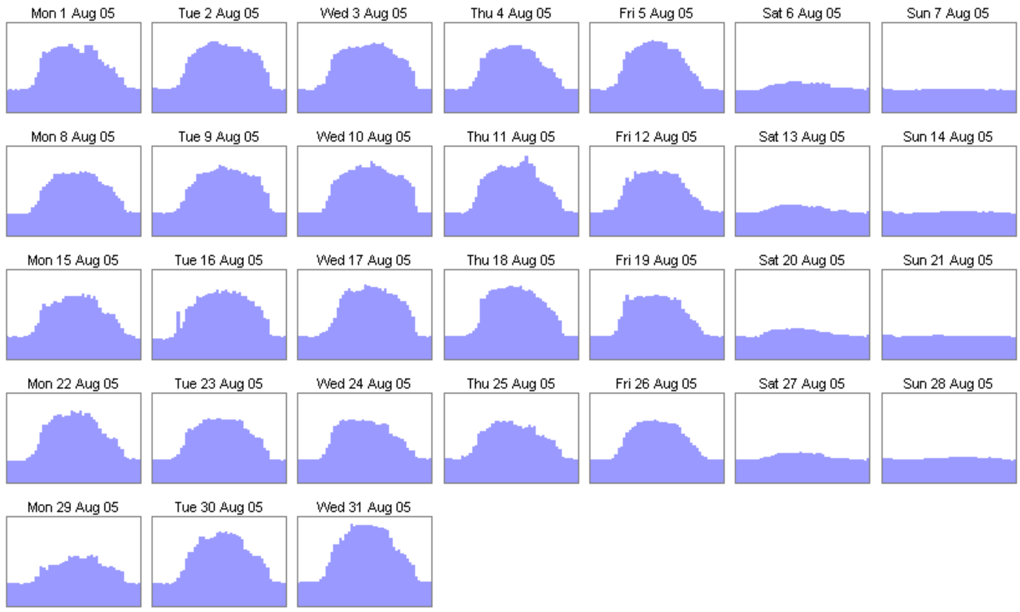
Step 3: Facility wide extrapolation

The 39% reduction represents 32 W/m^2 x 39% or 12.5 W/m^2 of potential reduction. Assuming the total facility lighted area of 15 000 m^2, a potential for reduction by 187 kW is achievable. This saving will be effective 12 hours a day and 5 days a week and will result in a saving of 583.4 MWh per year or USD 58 340, assuming an electricity tariff of 0.10 USD/kWh.

3.2 Level 2: Energy survey and engineering analysis audits

The energy survey audit (alternatively called a general audit, mini-audit, site energy audit or complete site energy audit) expands on the preliminary audit described above by collecting more detailed information about the facility operation and by performing a more detailed evaluation of energy conservation measures. This type of audit will be able to identify all energy-conservation measures appropriate for the facility. A detailed financial analysis is performed for each measure based on detailed implementation cost estimates, site-specific operating cost savings, and the customer's investment criteria. Sufficient detail is provided to justify project implementation.

Utility bills are collected usually for a 12 to 36 months period to allow the auditor to evaluate the facility's energydemand rate structures and energy usage profiles. If interval meter data is available, it will be analysed as discussed in the first chapter to identify the signs of energy waste. A daily energy profile of a typical administrative building for one-month period is shown in Figure 3. It can be noted that the facility is working from Monday to Friday from the morning to the evening hours. During the night times and weekends, there is some baseload consumption, typically due to cold loads (fridges, freezers), servers, stand-by power of electronics etc.



All chart scales run from 0 to 1191.3 kW. Use the "Single Day" feature of the Energy Lens to look at individual days in more detail.

FIGURE 3: ENERGY PROFILE OF A TYPICAL ADMINISTRATIVE BUILDING FOR ONE-MONTH PERIOD

Additional metering of specific energy-consuming systems is often performed to supplement data collected by the utility. In-depth interviews with facility operating personnel are conducted to provide a better understanding of major energy consuming systems and to gain insight into short- and longer-term energy consumption patterns.

Level 2 audits should consider the level 1 findings and additionally perform the steps depicted below (according to the ASHRAE Standard 211P).

Steps	Description
Step 1. **Do a breakdown of the annual total energy cost by energy source**	Estimate the annual cost and share of different sources of energy like electricity and natural gas. This will be derived by analysing the utilities' bills.
Step 2. **Perform a facility site survey**	Determine key operating parameters and operations setpoints for the following: - Space temperature - Space humidity - Space lighting levels - Hot water supply setpoint controls - Chilled water supply setpoint controls

Steps	Description
	- Supply air temperature setpoint controls - DHW storage and delivery temperatures - Fan system flow controls - Economizer controls - Minimum outdoor airflow rates - Carbon dioxide levels
Step 3. **Determine operating schedules**	- Occupied or unoccupied hours in controlled zones - Space temperature setpoint schedules - Lighting occupancy schedules and controls - Warm-up and cool-down periods
Step 4. **Equipment efficiencies considering part-load functioning and seasonality**	- Combustion efficiency - Cooling equipment efficiency - Energy recovery efficiency - Pump efficiency - Fan efficiency
Step 5. **Do a breakdown of the energy consumption per appliance**	Based on data from meters/dataloggers, equipment efficiencies and a building energy model, estimate the share of energy consumption per appliance (e.g. lighting, space heating, space cooling, pumps, fans, miscellaneous, etc).
Step 6. **List energy efficiency measures per group of appliances, processes or systems**	<u>Envelope:</u> - Opaque elements insulation, roof painting - Windows replacement, glazing replacement <u>Lighting:</u> - Replace fixtures, replace lamps - Daylighting utilization - Occupancy sensors <u>HVAC systems:</u> - Reduce distribution losses (Insulation, VSD, Economizers) - Replace HVAC <u>DHW waterheating</u> - Low Water Use Devices - Solar Systems
Step 7. **Estimate EEM costs**	The cost calculations should include: - Material costs

Steps	Description
	- Labor costs - Design fees - Construction management - Site-specific installation factors - Permits - Temporary services - Test and Balancing - Commissioning
Step 8. **Calculate savings**	Savings on energy demand should consider the following: - Analysis of measures and/or measure groups shall include interactions - Weather data shall be long-term average data. - Equipment performance shall take into account part-load or seasonal efficiencies where applicable
Step 9. **Conduct economic analysis**	Estimate the following key economic indicators: $Simple\ payback\ (SPP) = \frac{Investment}{Annual\ savings}$ $Return\ on\ investment\ (ROI) = \frac{Annual\ savings}{Investment}$
Step 10. **Quality assurance review**	- Evaluate the feasibility and appropriateness of identified measures, as well as the reasonableness of energy savings projections, implementation cost estimates, and all observations and findings of the energy audit report. - Compare the energy savings, cost savings, costs, and ROIs for each measure to expected ranges for the type of measure specified to verify reasonableness. - Validate savings by calculating the percent savings of each measure in relation to total energy use of the relevant end-use category.
Step 11. **Review EEMs with owner or representative**	- Provide to the owner or their appropriate representative a list of identified measures, their brief descriptions, energy, energy cost, and non-energy cost savings, available incentives, simple ROI, and simple paybacks. - Obtain from the owner or owner's representative their comments about which measures are preferred for implementation or further study. - After the review with the owner or owner's representative, the audit shall be revised to show the recommended measures, measure groups, and measures identified but not recommended.

3.3 Level 3: Detailed capital intensive "Investment Grade" audit

The investment-grade audit (alternatively called a comprehensive audit, detailed audit, maxi audit or technical analysis audit) expands on the general audit described above by providing a dynamic model of energyuse characteristics of both the existing facility and all energy conservation measures identified. The building model is calibrated against actual utility data to provide a realistic baseline against which to compute operating savings for proposed measures. Extensive attention is given to understanding not only the operating characteristics of all energy consuming systems, but also situations that cause load profile variations on short and longer-term bases (e.g. daily, weekly, monthly, annual). Existing utility data is supplemented with metering of major energy consuming systems and monitoring of system operating characteristics.

The level 3 audit requires a annual building energy modelling, using a simulation software that meets the requirements of ASHRAE Standard 140 (e.g. OS, eQuest, EnergyPlus, ies, DesignBuilder, DOE-2).

In most corporate settings, upgrades to a facility's energy infrastructure must compete for capital funding with non-energy-related investments. Both energy and non-energy investments are rated on a single set of financial criteria that generally stress the expected return on investment (ROI). The projected operating savings from the implementation of energy projects must be developed in such a way that they provide a high level of confidence. In fact, investors often demand guaranteed savings.

4 REFERENCES

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ANNEX1 – GENERAL LIST OF INFORMATION TO GATHER FORPUBLIC AND INSTITUTIONAL BUILDINGS

Client Name:

Address:

Contact:

GENERAL INFORMATION

1. Gross and net area of the facility (excluding car park or other non-energy or low energy usage areas)
2. Number of stories (including basement)
3. Occupancy level for the past three years
4. Operating hours for shops / office / hotel / restaurant / etc.
5. Electrical tariff used (unit price of kW for ON/OFF peak hours, unit price of kWhr with respect to different consumption segments, power factor penalties, subscribed power contract and credits for voltage transforming).
6. Fuel (gas, oil, propane, etc.) tariff used and tariff structure (unit price of m3 with respect to different consumption segments, subscribed volume contract)
7. Electricity bills for the past 3 years (Subscribed demand, kW, kVA, kWhr and power factor). Note: If bills are not available, a summary of the history of consumption could be used at the preliminary audit stage.
8. Fuel (gas, oil, propane, etc.) bills for the past 3 years. Note: If bills are not available, a summary of the history of consumption could be used at the preliminary audit stage.
9. Single line electrical diagram

Lighting

1. Type of fixtures
2. Type of lamps in fixtures (technology and power)
3. Type of ballasts for driving lamps (power consumption)
4. Operating hours
5. Lux level requirement (if any)
6. Type of activity in the various areas of the facility (to check the lux level requirement)

As much as possible, the auditor will try to gather this information for each specific group of fixtures or areas in the facility with similar energy usage pattern and equipment. For instance, in an office building, the auditor may look at the main lobby, car park, toilets, auditorium, conference room, etc.

Air-Conditioning System

1. Information about the central chillers system if applicable:
    - Chillers
    - Brand and Model
    - Quantity
    - Tonnage, KW/AMP, BTU
    - Operating hours
    - Season of operation
    - Chillers log in different seasons (if available)

2. Chilled Water Pumps
    - Brand and Model
    - Quantity
    - HP, KW/AMP

3. Condenser Water Pumps
    - Brand and Model
    - Quantity
    - HP, KW/AMP

4. Cooling Towers
    - Brand and Model
    - Quantity
    - Capacity, motor: KW/AMP/HP
    - Operating hours

5. Air-Handling Units (Inclusive of primary air-intake)
    - Brand and Model
    - Quantity
    - Breakdown the AHUs into the location it serves, KW/AMP, tonnage and operating hours

6. Air-Cooled Package Unit
    - Brand and Model
    - Quantity
    - Breakdown the AHUs into the location it serves, KW/AMP, tonnage, and operating hours

Exhaust Fans

1. Information about fan supplying mechanical and electrical rooms, toilets, central plant:
    - Brand and model
    - Flow rate
    - Power
    - Operating hours

Pumps

1. Information about other pumps in the plant. This could include hot water pumps, sump pumps, building water supply pumps, domestic hot water recirculation pumps, etc.
    - Brand and Model
    - Flow rate
    - Power
    - Operating hours

Vertical transportation (lifts and escalators)

1. Information about lifts and escalators:
    - Brand and Model
    - Quantity
    - KW/AMP
    - Breakdown the lifts into the location served and their operating hours

Steam Boiler

1. Information about boilers:
    - Brand and Model
    - Type (Oil / Gas / Elect.)
    - Quantity
    - Capacity (kw or kg/hr)
    - Operating hours
    - Seasonal load profile
    - Current efficiency if tested recently
    - Stack temperature

Other Equipment

1. Please specify equipment, quantity, capacity & operating hours