Energy Auditing of Buildings

University of Hong Kong
Ir K. K. Lam

Energy Consumption Pattern of Commercial Premises

- Average consumption:
  - -Office 305 kWH/m^2/year
  - -Hospital 200 kWH/m^2/year
  - -Post office 170 kWH/m^2/year
- Energy consumption pattern:
  - -AC 48%
  - -Office equipment 22%
  - -Lighting 19%
  - -Lift and Other 11%

Building Energy Efficiency Ordinance

- Effective from 21 February 2011
- 18 months' grace period
- Energy Audit is part of the requirement for existing buildings
- Also covers replacement works for total floor area of not less than 500 sq. metre, 400A or above, 350 kW AC or above and lifts
- Registration of Registered Energy Assessor will likely to commence in 2nd quarter of 2011

Energy Audit Requirement

- The first energy audit for a building with a certificate of compliance registration must be carried out within10 years.
- For other buildings, the following table shall apply:

Date of Issue of Occupation Permit	First Energy Audit must be carried out
On or after 1.1.1988	12 months from commencement of ordinance
After 31.12.1977 but before 1.1.1988	24 months from commencement of ordinance
After 31.12.1969 but before 1.1.1978	36 months from commencement of ordinance
On or before 31.12.1969	48 months from commencement of ordinance

What is Energy Audit

- Energy Audit is a periodic examination of an energy system to ensure that energy is being used as efficiently as possible.
- Energy audit is a top-down initiative
- Its result depends on the resources being allocated by top management.
- In many ways, an energy audit is similar to financial accounting and auditing.

Advantages of Energy Audit

Through energy audit, you can:

- Promote awareness in energy efficiency
- Identify the cost of energy you use
- Identify and minimize wastage
- Making changes to procedure, equipment and system to save energy
- Retrofit energy efficiency technologies
- Conserve non-renewable energy resources
- Protect the environment by reducing power generation
- Reduce running costs

Procedure of Energy Audit

- **Pre-audit stage**
  1. Defining scope of energy audit
  2. Forming an energy audit team
  3. Estimating time frame and budget
  4. Collecting building information
- **Energy audit stage**
  1. Conducting site inspection and measurement
  2. Analyzing data collected
  3. Preparing energy audit report
- **Post-audit stage**
  1. Implementation of energy management opportunities
  2. Monitoring and review

Scope of Energy Audit

- Importance of involvement of senior management, facilities operator and staff in determining the scopes of works and the available resources for conducting the energy audit
- The scopes of work include the areas to be audited, the level of sophistication of the audit, the savings anticipated, the needs for improvements on O&M and the needs for training
- The available resources mean staff, time and budget

Energy Audit Team

- A team of auditors form the audit team. The number of auditors depend on the scope and objectives of the energy audit. The duties of the members of the audit team should be defined
- Auditors are competent person having adequate knowledge on BS installations.
- Involving the facilities operators to provide input
- If in-house expertise is not adequate, energy audit consultants (including University staff) should be employed

Time Frame and Budget

- Based on available resources, the time frame and the budget can be established.
- The budget is mainly built-up on cost of auditor-hours.
- The number of auditor-hours is dependent of the degree of sophistication required by the scope of audit. A detailed audit can have auditor-hours that are about 5 to 10 times that required by a walk-through audit.
- The audit team should check if adequate testing instruments are available and cost of purchasing additional instruments should be added.
- In addition, the cost of employing BS Consultants should be included, if so required.

Required Testing Instruments (1)

- Electrical

Voltmeter	Voltage
Ammeter	Current
Ohmmeter	Resistance
Multi-meter	V, I & R
Wattmeter	Active power
Power factor meter	Power factor/apparent power
Light meter	Lighting level
Power quality analyzer	Harmonic contents
Thermographic scanner	Conductors temperature

Required Testing Instruments (2)

- Temperature and Humidity

Thermometer	Dry bulb temp.
Sling psychrometer	Dry & wet bulb temp.
Infrared remote temp. sensing gun	Sense energy losses due to improper insulation
Digital thermometer with temp. probe	Temp. inside air duct (thermocouple probe for high T)
Hair hygrometer	Humidity/wet bulb temp.
Digital thermometer	Humidity/dry & wet bulb temp.

Required Testing Instruments (3)

- Pressure & Velocity

Pitotstatic tube manometer	Air flow velocity & pressure
Digital anemometer with probe	Air flow velocity & pressure
Vane type anemometer	Air velocity through a coil, air intake & exhaust, etc.
Hood type anemometer	Air flow rate of grille
Pressure gauge	Liquid Pressure
Ultrasonic flow meter with pipe clamps	Liquid flow & velocity

Required Testing Instruments (4)

- Miscellaneous

Exhaust gas analyzer with probe	T, O_2, CO, CO_2 and NO_x
Refrigerant gas leakage tester	Detect refrigerant leakage
Ultrasonic leak detector	Detect compressed air leakage
Steam leak detector	Detect steam leakage (usually for steam trap)
Tachometer	Rotating speed

Collecting Building Information (1)

- General building characteristics such as floor plans, number of occupants, hour of occupation, details of building elements, orientation, etc.
- Technical details of energy consuming equipment/systems
- BS design reports with system schematic diagrams, layout drawings, etc.
- Equipment/system operation records, including data log sheets
- Record of EMO already implemented
- O&M manuals and T&C reports
- Energy bills (electricity, town gas, LPG, diesel, etc.) for the past 3 years

Collecting Building Information (2)

- The audit team should determine the appropriate parties to be approached for information collection.
- The needs to discuss with these parties for familiarization of the building and the equipment/systems
- The audit team should consider issuing questionnaires to end-users to collect information on thermal comfort, lighting comfort, operational hours of the offices, etc.

Collecting Building Information (3)

As this stage, the audit team should be able to tell the characteristics of the energy consuming equipment/systems such as:

1. Type of chillers, their capacities & characteristics
2. Type of HVAC systems, their components and characteristics
3. Occupancies or usage for various systems
4. Control devices for various equipment/systems
5. Type of luminaires, their characteristics and control mechanisms
6. Power distribution system characteristics
7. Operational characteristics of lift & escalator system
8. Characteristics of the building

Site Inspection & Measurement (1)

- Plan the site inspection for the areas and the equipment/systems to be investigated
- Allocate the work among the auditors
- Develop energy audit forms to record the findings
- Plan ahead on the site measurements to supplement or verify the information collected. The measurements should focus on equipment/systems that inadequate information is available

Site Inspection & Measurement (2)

- Inspection of building and plants to identify obvious areas of wastage and EMO. Typical areas include:
  - Running hours of AC system
  - Running hours of other system/equipment
  - Length of AC pre-cool period
  - Control set point of above system/equipment
  - Internal comfort conditions, e.g. T, RH, air flow rates, lighting level, water temperature, etc.
  - Doors not properly closed
  - Curtains or blinds not provided in AC areas
  - Locations where AC and lighting are unnecessarily provided
  - The use of energy inefficient lighting
  - Improper positioning of thermostats and switches
  - Abnormal water consumption
  - Adequacy of insulation of building fabrics
  - Amount of waste heat discharged from equipment that could be recovered
  - Areas of high energy consumption and the opportunities for improvement

Site Inspection & Measurement (3)

- During measurement, the sensors should be located at points that can best reflect the need or function of the controlled parameters.
- If provisions for measurement are absent, the auditor may have to install test holes & plugs or to use ultrasonic type meters.
- If measurements are not practical for some systems, the auditor may have to refer to the characteristics curves/graphs from the O&M manuals.

Analyzing Data Collected (1)

- Based on the information collected, the audit team should screen and spot the parameters with values and trends that deviate from what would be anticipated. These are potential energy management opportunities (EMOs).
- EMOs are improvement works that save energy and the investments can be repaid by the savings in reasonable time.
- However, they should take into account the analysis of the irregularities caused by changes in occupancy, weather or other activities.
- To identify the potential EMOs, calculations should be performed qualifying energy savings.

Analyzing Data Collected (2)

- To evaluate the effectiveness of an EMO, the auditor has to calculate the payback period, net present day value or rate of return. Sometimes a life cycle cost assessment may have to be performed.
- An EMO should normally not downgrade the quality of service to that below common design standards.
- It is important to maintain good thermal comfort, lighting comfort and adequate supply of fresh air.
- It is always possible to improve energy efficiency and at the same time maintain or even improve indoor air quality.

Analyzing Data Collected (3)

- When determining EMO, it is necessary to take into account the already scheduled major maintenance works. This reduces the cost accountable to the implementation of the EMOs.
- The auditors should produce the following for use in the audit report:
  1. graphs of various energy consumption against months
  2. Charts of different proportion of energy consumption of a building
  3. Energy utilization index (e.g. energy/m^2)

Analyzing Data Collected (4)

Data collected may have different units and it is useful to use the following conversion table to facilitate comparison.

Energy form	Unit	Conversion factor (MJ)
•Electricity	kWh	3.6
•Town gas	Unit	48
•LPG	kg	46.3
•Diesel fuel	kg	42.5
	litre	37
•Petrol	litre	32.5
•Kerosene	litre	35
•Fuel oil	litre	39.7
	kg	41.8

Energy Management Opportunities

- Cat. 1 EMOs are EMOs with no cost implication
- Cat. 2 EMOs are EMOs with little cost implication
- Cat. 3 EMOs are EMOs with significant investment

Cat.1 EMOs (1)

- Correcting air/water flow rate
- Switching off fittings in vacant areas
- Delamping
- Closing of doors, windows
- Checking fresh air dampers
- Switch off lifts and escalators during off peak period
- Adopt natural or mechanical ventilation as far as possible

Cat. 1 EMOs (2)

- Housekeeping measures, e.g. notices, promotional activities, turn on equipment & systems based on operational hours
- Adopting good operation & maintenance procedure
- Check water leakage and air leakage
- Cleaning of luminaries/heat exchanger/filter
- Setting of thermostat
- Top up refrigerant, compressor oil, etc.
- Lower lighting level for areas that is too bright

Cat. 2 EMOs (1)

- Blinds & curtains
- Tree planting near curtain wall
- Air curtain for automatic door
- Self luminous exit sign
- Additional switches and controllers
- Sealing of building leakages
- Replace incandescent lamps with compact fluorescent lamps
- Replace electro-magnetic ballasts with electronic ballasts

Cat. 2 EMOs (2)

- Energy efficient office equipment
- Replacing damaged insulation
- Occupancy sensor
- Time switch
- Re-programming of CCMS
- Day light sensor
- Setback control
- CO_2 sensor
- Harmonic filter
- Power factor correction device

Cat. 3 EMOs (1)

- Installing T5, T8 with electronic ballasts
- BMS and software enhancement
- New chillers with high COP
- Water-cooled system with cooling tower
- High efficiency motors
- VSD
- Water saving taps
- Low volume water closet

Cat. 3 EMOs (2)

- Recover waste heat/cool air e.g. thermal wheel,
- Heat pump
- Automatic condenser cleaning
- Modernization of old lifts
- Green Initiatives that enhance corporate image, e.g. renewable energy, replacement of ozone depleting refrigerant

Energy Audit Report (1)

- Executive summary
  1. Provides the building management a quick overview of the scope of audit, EMOs identified, recommended actions justified by savings and implementation plan
- Introduction
  1. The building being audited with characteristics of the building, schematics, layouts as appendix
  2. Objectives
  3. Scope of audit
  4. Audit team

Energy Audit Report (2)

- Description of equipment/systems
  1. Zoning of systems according to building height or usage
  2. HVAC installation for different areas
  3. Lighting installation
  4. Electrical installation
  5. Lift & escalator installation
  6. Plumbing & drainage system
  7. Hot water system
  8. Other energy consuming equipment/systems

Energy Audit Report (3)

- Findings -This part aims to focus on description of the results of the site inspection
  1. Findings in a systematic format such as in order of systems or order of floors or in order of usage
  2. Description of areas with special requirements e.g. 24-hour operation, low temperature, etc.
  3. Calculation on cooling load, lighting load, electrical load and annual energy consumption with detailed calculation in appendix
  4. Findings on O&M procedures and practices
  5. Preliminary identification of EMOs

Energy Audit Report (4)

- **Analysis and identification of EMOs**
  1. Comparison on actual performance of equipment/systems against original design and identify causes of any discrepancy
  2. Possible EMOs and substantiations (detailed calculations in appendix)
  3. Implementation costs for EMOs (detailed calculations in appendix)
  4. Comparison of different solutions to the same EMOs
  5. Classification of the EMOs into categories
  6. Listing of all EMOs in a systematic format such as in order of system e.g. HVAC, lighting, etc.
  7. Investments and payback of each EMO
  8. Difficulties that may encounter in implementation.
  9. Programme for implementation of EMOs
  10. Areas for further study, if any

Energy Audit Report (5)

- **Recommendations**
  1. Recommendations should be made in a systematic order
  2. Grouping items of similar nature/location/usage together
  3. Grouping according to their categories (i.e. Cat. 1, Cat. 2 and Cat. 3)
  4. The initial investment and payback should be highlighted here again

Implementation of EMO

- Self funding – this will harvest the biggest benefits but the organization must have initial funding
- Energy services company – can be employed to carry out the implementation of EMOs
- Energy performance contracting

- using the saved energy cost to finance the energy efficiency improvement works

- Needs for fair contract and protocol for verification of energy savings

- Successful cases in hospital and university

Common Findings of Energy Audit

HVAC –EMO Cat. 1

AC remained “on” outside office area	The last man out to turn off AC or install time switch	Unnecessary consumption of energy
AC remained “on” for unoccupied areas or redundant areas	The last man out to turn off AC or install occupancy sensors	Unnecessary consumption of energy
Door or window left open when AC is “on”	Close door or window	5 to 20% savings
Too cold in summer e.g. room at 21^0C	Set thermostat to 24^0C	10 to 30% savings
Excessive pressure drop across filters	Clean filters	5 to 20% savings in fan power
Chilled water at 6^0C outside summer	Re-set temperature to 8^0C	3 to 6% savings of chiller power
Automatic control overrides by manual control	Disable manual control	10 to 15% savings
Excessive ventilation	Adjust fresh air dampers	5 to 30% savings

Common Findings of Energy Audit

HVAC –EMO Cat. 2

No blinds or blinds not closed for windows	Install or close blinds	5 to 30% savings to offset solar heat gain
Access door of AHU or ductwork has leakage of say 3%	Rectify leakages	3% of fan power
Excessive water leaving pump gland	Replace stuffing box with mechanical seal	A flow of 1 lit/min flow means 1000 kWh per year
Overcooled spots due to improper air balancing	Add dampers if required and balance the system	15 to 25% savings
Overcooled spots due to improper water balancing	Add valves if required and balance the system	15 to 25% savings
Lack of individual control	Add controller	10 to 15% savings
Building leakage	Rectify leakage	5 to 10% savings
Poorly maintained systems	Improve maintenance procedures	10 to 30% savings

Common Findings of Energy Audit

HVAC –EMO Cat. 3

Equipments operating beyond their economic life expectancy	Replace with energy efficient equipment	10 to 30% savings
Inefficient air cooled chillers	Replace with cooling tower with water cooled chillers	20 to 30% savings
Outdated control system	Install BMS/CCMS	10 to 25% savings
Air flow controlled by inlet guide vanes	Install VSD	10 to 30% savings in fan power
Chilled water pump driven by constant speed motor	Install VSD	10 to 30% savings in pump power

Common Findings of Energy Audit

Lighting Installation –EMO Cat. 1

Lighting level too high	Disconnect power supply to some fittings	15 to 30% savings
Lighting along window areas turned “on” at day time	Turn off perimeter lightings	20 to 30% savings
Lighting remained “on” outside office area	The last man out to turn off lighting or install time switch	Unnecessary consumption of energy
Lighting remained “on” for unoccupied areas	The last man out to turn off lighting or install occupancy sensors	Unnecessary consumption of energy
Lighting remained “on” for redundant function	Remove the unnecessary lighting	Unnecessary consumption of energy

Common Findings of Energy Audit

Lighting Installation –EMO Cat. 2

T12/T10 fittings used in lighting	Replace with T5 fittings	30 to 40% savings
T8 fittings used in lighting	Replace with T5 fittings	20 to 30% savings
Manual control for lighting	Install occupancy sensor	>20% savings
Incandescent lamp being used	Replace with compact fluorescent lamp	80% savings
Not enough lighting control switches	Install more switches (about one per 10 m^2)	10 to 20% savings

Common Findings of Energy Audit

Electrical Installation –EMO Cat. 2 & 3

Over sizing of motor by 30%	Replace with smaller motor of proper size Add VSD	5% savings 50% savings
Overall power factor of 0.8	Improve to min. of 0.85	Minimize losses through network
30% total harmonics distortion	Add harmonic filter to reduce THD	Minimize losses through network
Power supply tariff is not favourable	Conduct tariff review and apply to supply company for a special charge rate other than general tariff	Savings in electricity bills

Monitoring & Review

- Subsequent to the implementation of the EMOs, the audit team should monitor the energy consumption for at least one year to verify the predicted savings
- Any discrepancies should be analyzed and corrective actions taken
- Success stories should be recorded and used to justify future energy audit recommendations
- Follow up energy audit should be carried out about 5 years after the first audit