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MENG449 INTRODUCTION TO ENERGY MANAGEMENT

Chapter 4 – Energy Audit

Coverage:

- What is energy audit?
- Types of audit
- Audit process and stages
- Writing the energy audit report

Company-level energy management cycle

What is Energy Audit?

- The **energy audit** is one of the first tasks to be performed in accomplishing an **effective energy management** program designed to **improve the energy efficiency** and reduce **the energy operating costs** of a facility.
- An energy audit consists of a
  - **detailed examination of how a facility uses energy**,
  - **what the facility pays for that energy**, and finally,
  - **a recommended program for changes in operating practices or energy consuming equipment that will cost effectively save dollars on energy bills**.

Types of Energy Audits

Type 1	• Walk through the facility • Make a check list of equipment
Type 2	• Mini audit • Perform economic calculations
Type 3	• Maxi audit • Computer modelling
Investment grade audit	• Includes risk analysis • Useful for getting funding to projects
Master audit	• Includes code compliance • Maintenance schedule development

Type 1 audit

- This audit consists of a walk-through inspection of a facility
  - to identify maintenance, operational, or deficient equipment issues and
  - to also identify areas which need further evaluation.
- Name plates of equipment are photographed
- Lists of equipment are made with their numbers

Type 2 audit

- This audit includes
  - monitoring/metering/testing of equipment to identify actual energy consumption and losses
  - conducting economic calculations
  - Proposing energy efficiency measures

Type 3 audit

- This audit additionally includes the performance of computer modeling to determine the actual year round energy consumption.

Investment grade audit

- This audit includes weighing risk into the economic calculations of a type II or III energy audit. This audit can be utilized to obtain funding for the projects identified.

Accurate evaluation of major energy uses

Detailed plan with new energy solutions

Preparation of procurement for implementation

Master audit

- This energy audit also contains information such as
  - code compliance,
  - maintenance schedule development,
  - equipment inventories, etc.

How do you know which type of audit is required?

- Depends on the funding available for the audit, the cost and potential of the Energy Management Opportunity, and the required accuracy for the audit information.
- Depends on the type of facility, function of the facility, and processes within a facility.

Energy audit process

Pre-site work

- Collect data about facility energy use and utility bills
- Understand the plant process
- Develop a site sketch
- Identify the equipment to be used during the audit

Site visit

- Talk to plant manager and/or operators
- Take notes and make inspections
- If necessary conduct measurements
- Take photos and record videos

Post-site work

- Review the collected information
- If necessary ask for additional data
- Make assessments and determine energy efficiency measures
- Prepare the audit report

Stages in conducting an energy audit

- The audit process begins with collection of information about:
  - a **facility's operation** and
  - its **past record of utility bills**.
- This data is then analyzed
  - to understand how the facility uses – and possibly wastes – energy
  - to help the auditor learn what areas to examine to reduce energy costs.

Stages in conducting an energy audit

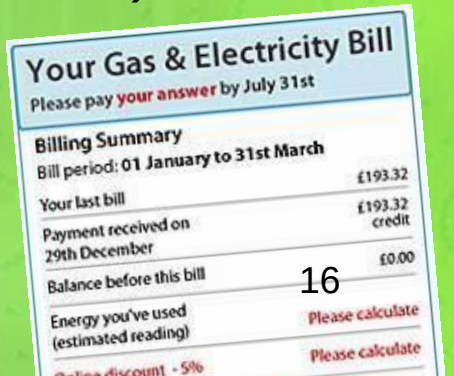
- Specific modifications in energy use – called Energy Conservation Measures (ECM's) – are identified of which **economic and environmental benefits** are estimated.
- Finally, an Energy Action Plan is created where certain ECM's are selected for **implementation**
- The action plan is reported to the management of the facility
- If the management is convinced for implementation **the actual process of saving energy and money** begins.

Pre-site work

- Why we need to do pre-site work?
  - Get to know the facility
  - Reduce time spent while on-site
  - Determine the most relevant on-site work
- Pre-site tasks:
  - Utility data analysis
  - Review plans & drawings
  - Develop facility description
  - Prepare preliminary list of measures

Utility data analysis

- Establish energy use index
  (indicator of building performance)
- Analyze historical energy use
  (consumption profiles)
- Identify areas with savings potential
  (energy use by system)
- Detect increased consumption
  (equipment, area, operations)



Review plans and drawings

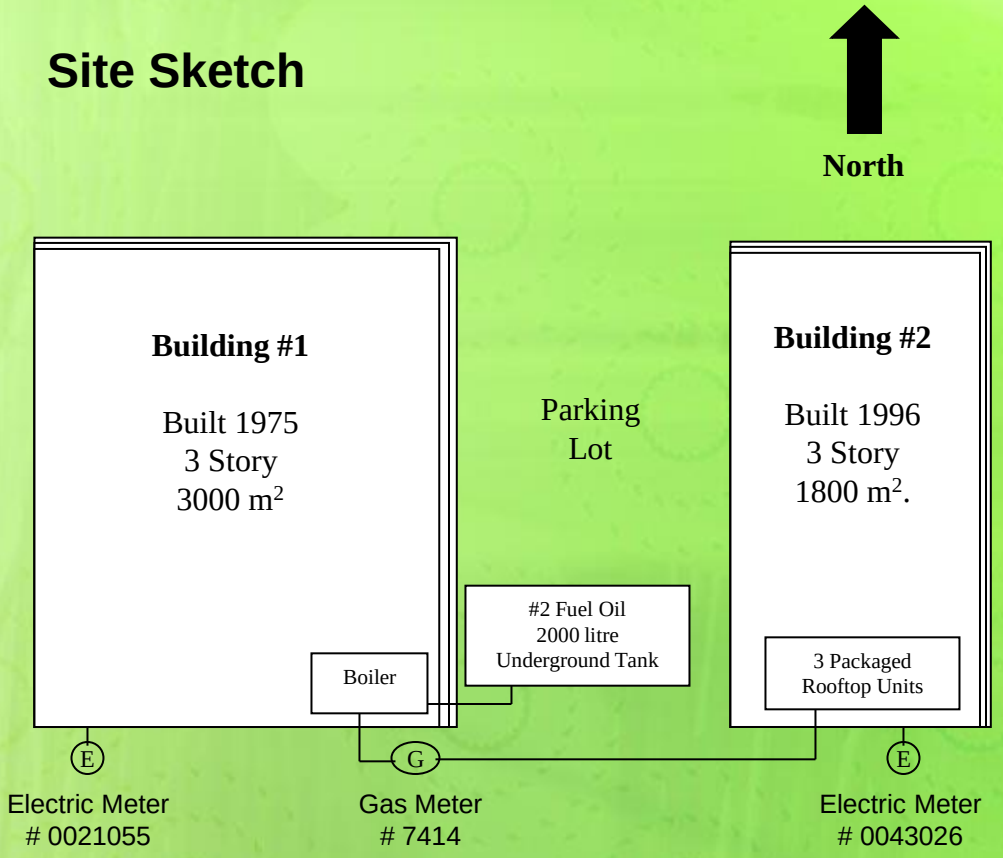
- Architectural & mechanical-systems plans
- Electrical/lighting plans and layout
- Specifications
- O&M manuals
- Old studies and audits (if any)
- Additions & remodeling

Prepare a sketch of the site if necessary

Show the following information

- Relative location of each building
- Building number and name
- Construction year
- Floor area
- Utility meters and their location
- Heating and cooling plans
- Orientation of building

Site Sketch



Source: Albert Thumann, W. J. Younger, Handbook of Energy Audits 6th ed. The Fairmonth Press, 2003

Develop facility description

- Overall description and age
- Occupancy schedules & patterns
- Envelope components and condition
- Mechanical/HVAC systems
- Lighting and electrical systems
- Ancillary systems
- Operation & maintenance considerations

Prepare preliminary list of measures

- Estimate where the major savings can be and prepare energy conservation measures (ECMs)
- Operation and maintenance (O&M) measures
- Energy use analysis
- Building and systems review

The site visit

- Meet with building personnel
  - Occupancy, operation
  - Maintenance practices & staff
  - Past/future facility changes
  - Budget for O&Ms and ECMs
- On-Site Tasks
  - Physical inspection of facility and systems
  - Answer specific questions
  - Testing and measurement

On-site tasks

- Confirm floor plans.
- Locate and inspect equipment.
- Testing and measurement of systems.
- Complete audit data forms.
- Review/modify ECM and O&M lists.
- Take photos.

On-site measurements

- Temperature
- Humidity
- Pressure
- Fluid velocity or flow rate
- Electrical power

Electric resistance thermometer

Wet and dry bulb hygrometer

Bourdon pressure gauge

Power logger

Hand held anemometer

Audit tools

Basic audit tools

- Flashlight
- Pocket thermometer
- Calculator
- Tape measure
- Camera
- Smoke generator
- Pocket knife
- Hand-held tape recorder
- Screwdrivers

Technical tools

- Light meter
- Infrared thermometer
- Data loggers
- Psychrometer
- Tachometer
- Multi-meter
- Power factor meter
- Combustion analyzer
- Anemometer
- Ultrasonic leak detector

Light level meter / Lux meter

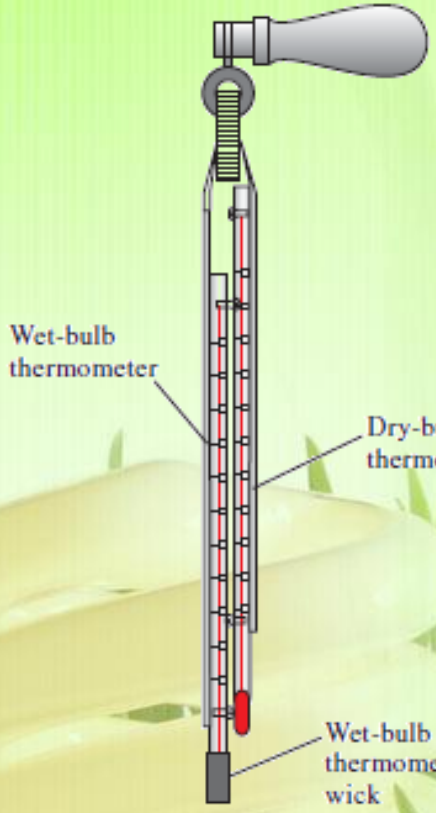
- Measures the amount of light in lux or foot candles
- Allows a direct comparison with recommended levels
- Many spaces are over-lighted, meaning that there is potential for energy saving
- Measures may include
  - ✓ lamp removals
  - ✓ task lighting with lamps with less illumination
  - ✓ Substituting with efficient lamps with slightly less illumination

Temperature measurement

- Temperature measurement is useful in identifying efficiencies of processes, over-heated areas and sources of waste heat
- Many types of thermometers, such as:
  - ✓ Liquid in glass
  - ✓ Thermocouples
  - ✓ Liquid in steel
  - ✓ Infrared thermometer
- Which one to use depends on the cost, durability and application.

Humidity measurement

- Relative humidity is an indicator of thermal comfort and performance of ac systems
- Can be measured with:
  - ✓ wet and dry bulb hygrometer (sling psychrometer)
  - ✓ Electronic portable hygrometers



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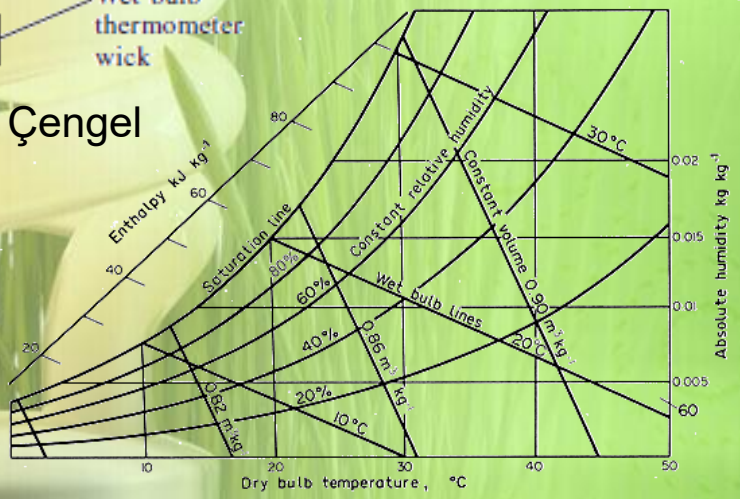
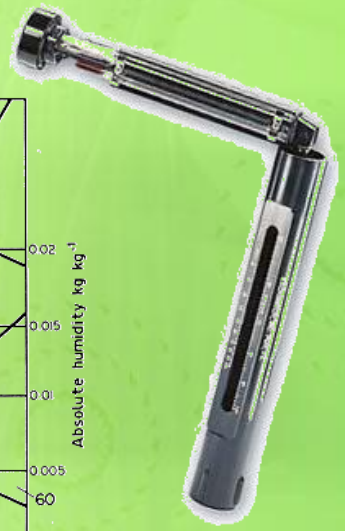




Conversion of temperature readings to relative humidity with sling psychrometer

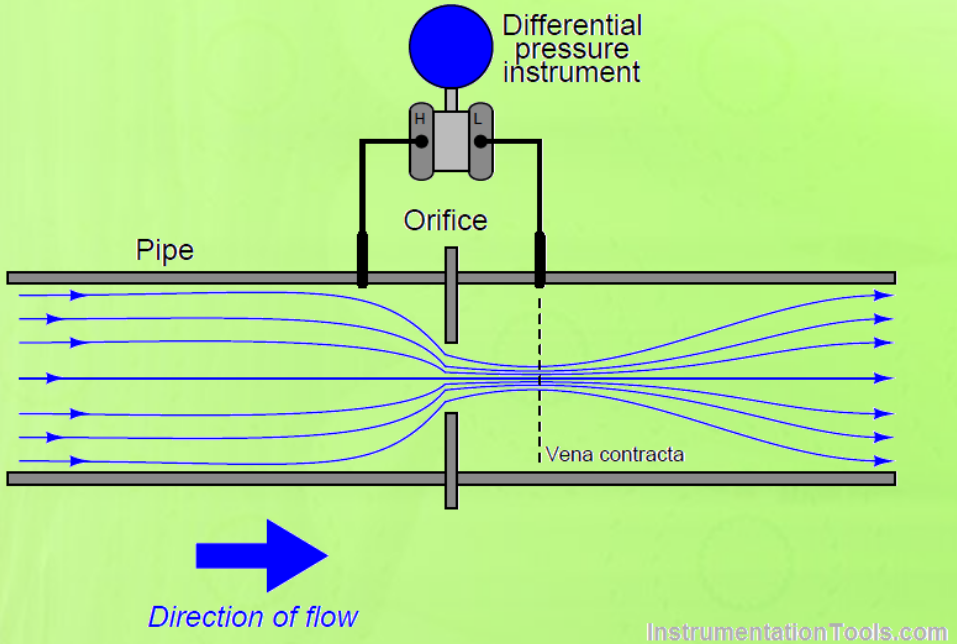
RELATIVE HUMIDITY CONVERSION TABLE

Dry-bulb temperature	Dry-bulb temperature minus wet-bulb temperature, °C									
	1	2	3	4	5	6	7	8	9	10
10°C	88	77	66	55	44	34	24	15	6	
11°C	89	78	67	56	46	36	27	18	9	
12°C	89	78	68	58	48	39	29	21	12	
13°C	89	79	69	59	50	41	32	22	15	7
14°C	90	79	70	60	51	42	34	26	18	10
15°C	90	80	71	61	53	44	36	27	20	13
16°C	90	81	71	63	54	46	38	30	23	15
17°C	90	81	72	64	55	47	40	32	25	18
18°C	91	82	73	65	57	49	41	34	27	20
19°C	91	82	74	65	58	40	43	36	29	22
20°C	91	83	74	66	59	51	44	37	31	24
21°C	91	83	75	67	60	53	46	39	32	26
22°C	92	83	76	68	61	54	47	40	34	28
23°C	92	84	76	69	62	55	48	42	36	30
24°C	92	84	77	69	62	56	49	43	37	31
25°C	92	84	77	70	63	57	50	44	39	33
26°C	92	85	78	71	64	58	51	46	40	34
27°C	92	85	78	71	65	58	52	47	41	36
28°C	93	85	78	72	65	59	53	48	42	37
29°C	93	86	79	72	66	60	54	49	43	38
30°C	93	86	79	73	67	61	55	50	44	39

Pressure measurement

- Pressure measurement is required in fluid flow applications in buildings and industry
- Measurement methods are:
  - ✓ Manometers
  - ✓ Barometers
  - ✓ Bourdon pressure gauge

Flow measurement in a pipe with orifice meter



Bulk velocity through orifice can be estimated from:

$$v_{orifice} = C_d \times \sqrt{\frac{1}{1-\beta^4}} \times \sqrt{2\Delta P/\rho}$$

where $\beta = \frac{Orifice\ diameter}{Pipe\ diameter}$ and C_d= discharge coefficient

Note that C_d = 0.6 for the orifice if manufactured by the British Standards

Simple measurement of flow rate from a tap (open system)

- Use a scale and a stop watch
- Collect the water in a bucket
- Find the net weight and calculate the volume
- Mass flow rate is: $\frac{mass\ of\ the\ water\ collected}{time\ measured}$
- Volume flow rate is: $\frac{Mass\ flow\ rate}{density\ of\ water}$

Velocity and flow measurement with anemometers

- Used to measure air velocity and flow
- Following instruments are used:
  - ✓ Cup-type: air velocity is found by measuring revolutions over a period of time
  - ✓ Vane anemometer: revolutions of vanes are electronically measured and displayed
  - ✓ Hot-wire anemometer: the cooling of hot wire due to air flow can allow air velocity measurement

Electrical measurements

- Electrical energy consumption by motors, lights, heating elements etc in kWh
- Measuremets can be made
  - ✓ Directly or
  - ✓ Indirectly by measuring voltage, current and phase angle for A/C circuits
- Ohm's law: $V = I \times R$
- Electric Power: $\dot{W}_{el} = V \times I = \frac{V^2}{R} = I^2 \times R$
- A volt-ohm-ammeter with a clamp on probe for measuring currents, which is called a multi-meter, can be quite useful.

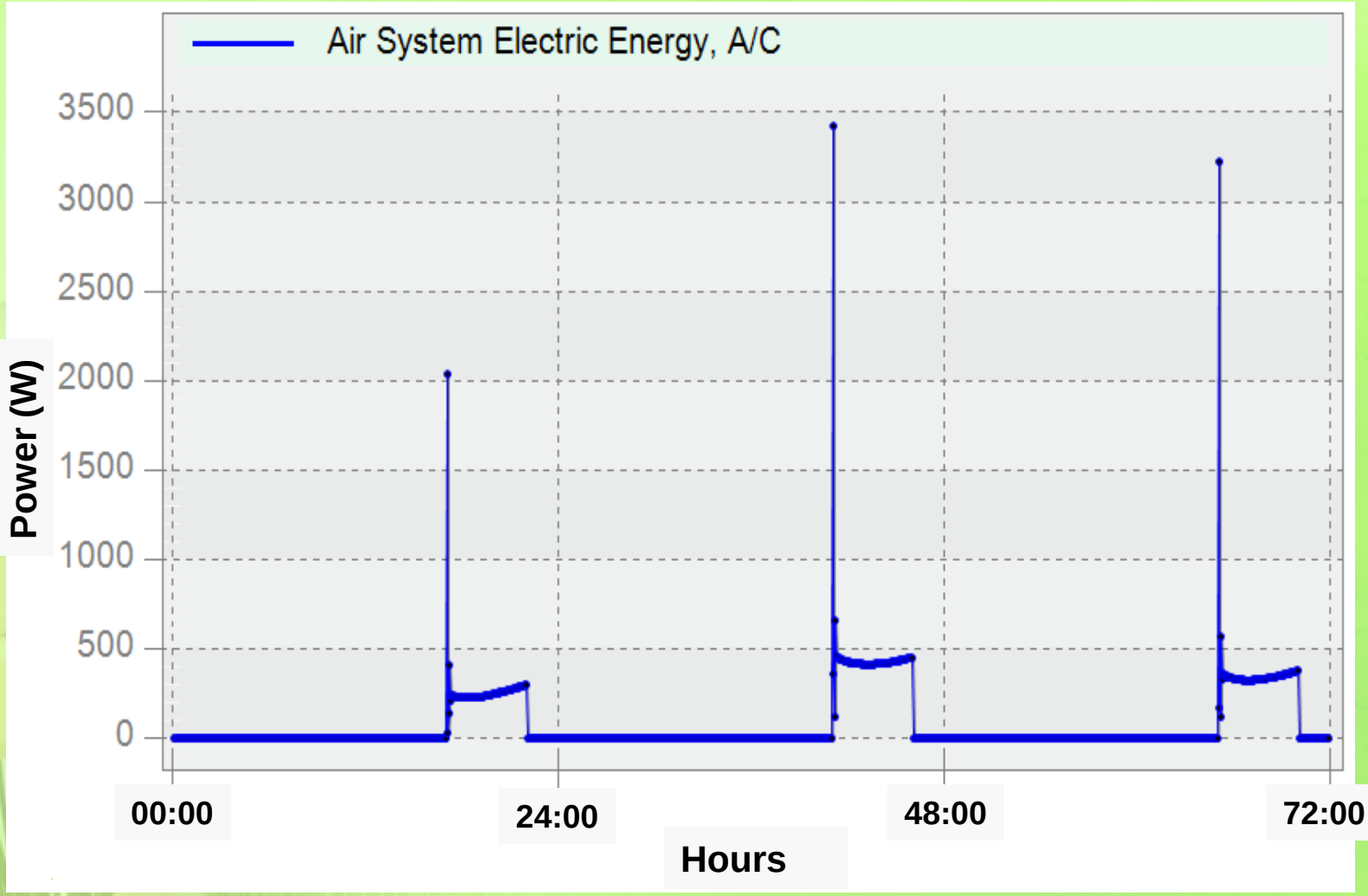
Data loggers

- Lighting
- Motors
- Temperature
- Relative humidity
- CO_2
- Voltage
- Amperage
- Events

On/off status data loggers

AC current sensor that works with a data logger

Typical evening use of an on/off split-unit heat pump: *Power consumed vs time*

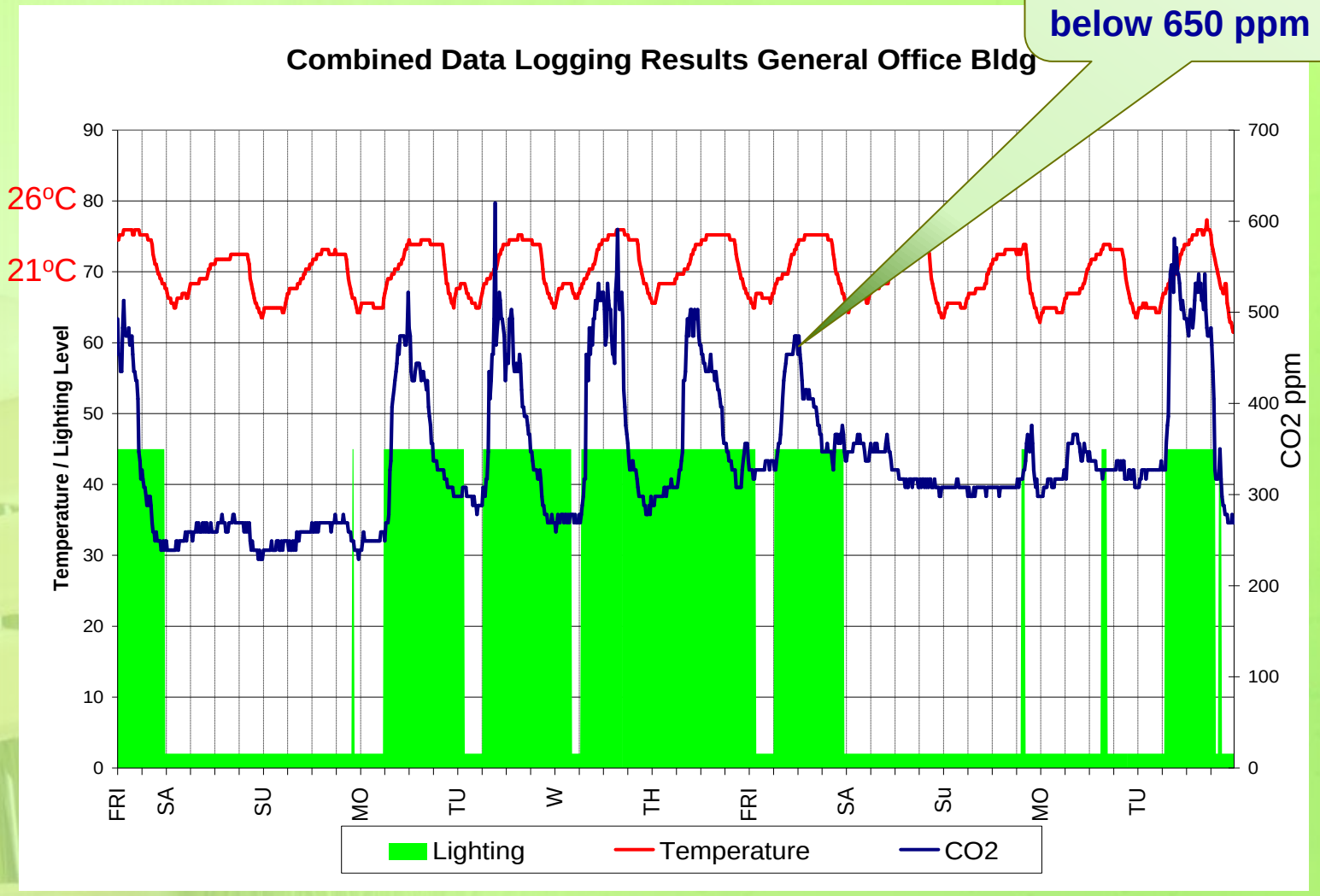


Power Loggers can measure the following

- **Power**
- **Energy**
- **Voltage**
- **Current**
- **Power factor**
- **Phase angle**

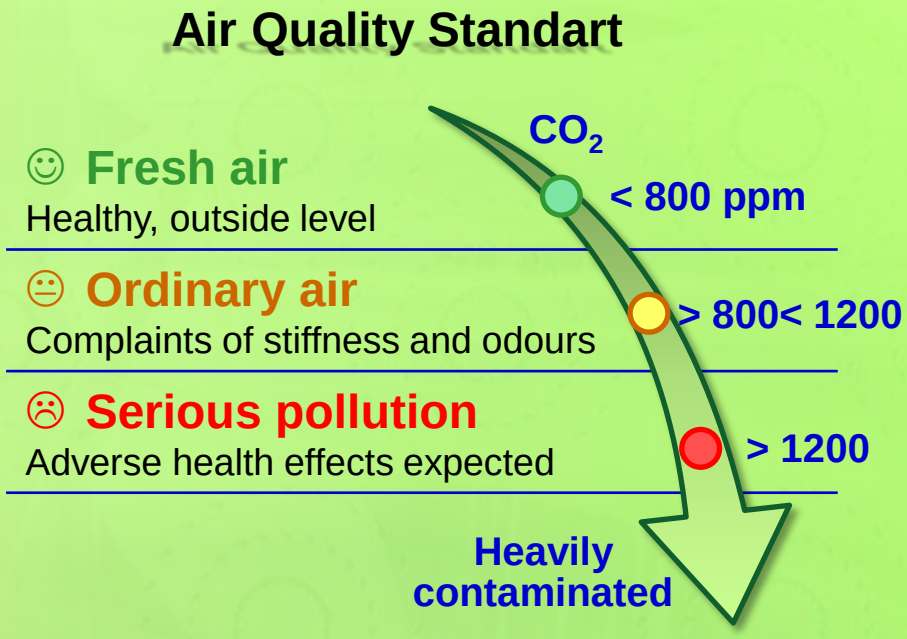
- Power loggers can be used for a more accurate analysis
- They can measure and record data unattended for a long period of time
- They are interfaced with a personal computer or laptop to analyze the data (with the help of a software supplied with the power logger)

Office building case study



Data logger observations

- Is there excessive amount of outside air?
  - CO_2 can be 800 ppm maximum for healthy environment
- Limited night set-back
  - 19°C (66°F) minimum
  - No weekend/holiday schedule
- Manual lighting control
  - Switched at breaker box



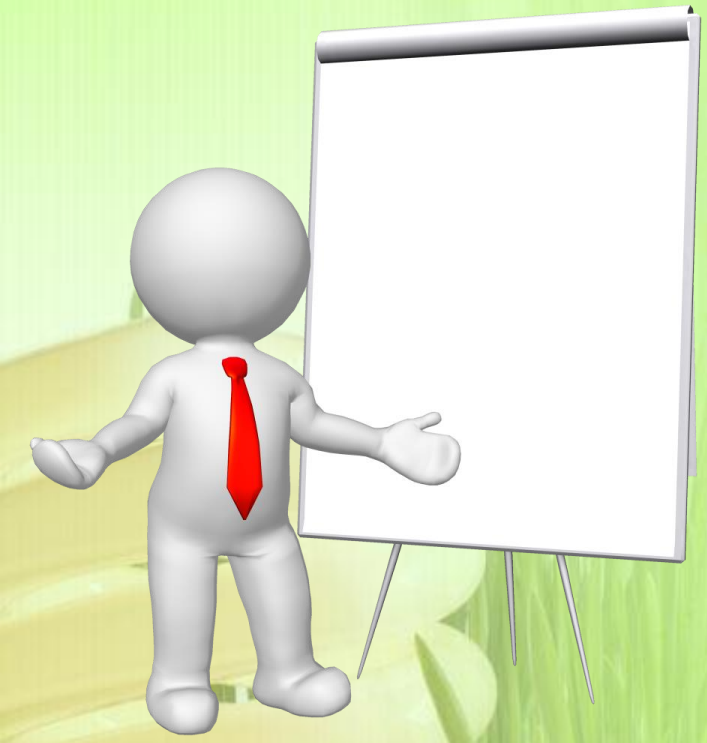
Post-site work

- Clean up site notes
  - Review and complete data forms and notes
- Review/revise O&M/ECM list
  - Develop energy conservation measures
  - List areas for engineering follow-up
- Review pictures
  - Organize and label photos
- Complete audit report
  - Prepare executive summary
  - Organize audit report

Energy audit report

- The energy audit report details the final results of the energy analyses and provides energy cost saving recommendations.
- The length and detail of this report will vary depending on the type of facility audited.
- A residential audit may result in a computer printout from the utility.
- An industrial audit should have a detailed explanation of the ECMs and benefit-cost analyses.

Audit report delivery



Oral presentation is the best

- Remember that businesses usually do not have time
- Keep it short and interesting

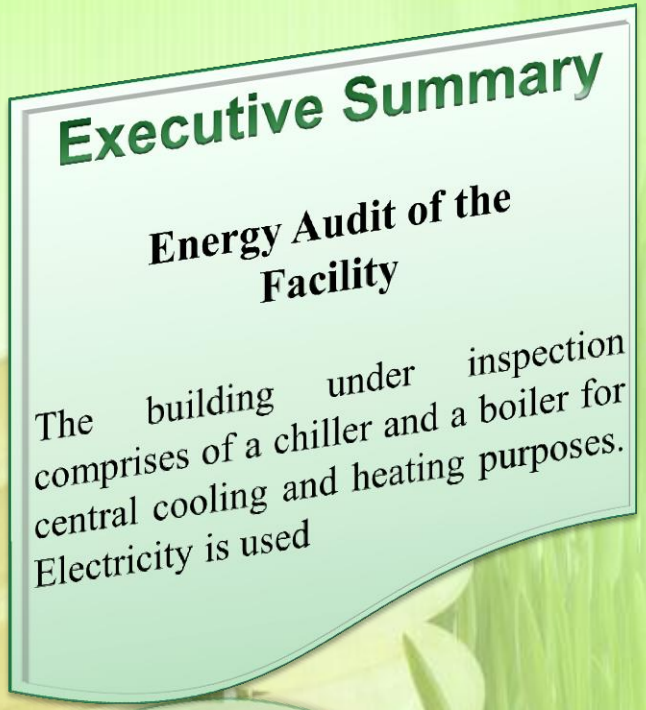
Typical audiences for audit reports:

- Chief executive officer (CEO), administrator, or superintendent
- Facilities and plant managers
- Controller or finance director
- Plant engineer
- Operations and maintenance staff

Report format

- Executive Summary
- Building Information
- Utility Summary
- Energy Conservation Measures (ECMs)
- Operation and Maintenance Measures (O&Ms)
- Appendices

Executive summary



- This is the **most important section** of the report *as it might be read by the CEOs etc.*
- It should be **simple**, **straightforward**, **to the point**. Should answer the question:

  "What do you want me to do?"
- Should cover:
  - Introduction to the facility
  - Purpose of the audit
  - Overall conclusions

Sample executive summary

Executive Summary, Group 3, Project 10
Fuel Switching at the Artmed Medical center

Larry Good, 2 Sep 05

The medical rehabilitation Center Artmed in Yerevan currently heats its domestic hot water (DHW) and cooks with electricity. This project will replace the electric appliances with gas appliances to save money, reduce demand on the electric grid and reduce emissions at the power plant. Predicted project cost is $26.9 k, and annual savings are $9.7 k, for a simple payback of 2.7 years. USAID's cost in this project will be $21.5 k, or 80%.

Summary Table

Measure	Annual Net Savings			Installed Cost (USD)	Life Cycle Cost Indicators			Emissions Reductions		
	Site Energy (MWh)	Source Energy (MWh)	Money (USD)		NPV (USD)	SIR	IRR	CO_2 (T/yr)	NO_x (kg/yr)	SO_x (kg/yr)
Gas appliances	-28	440	9.7 k	24.9 k	27.0 k	2.1	36%	88	60	0.4
Service, M&V				2.0 k						
Total	-28	440	9.7 k	26.9 k	27.0 K	2.1	36%	88	60	0.4

Life Cycle Indicators: NPV = Net Present Value; SIR = Savings Investments Ratio; IRR = Internal Rate of Return

Sample executive summary (cont.)

Proposed Measure

The Medical Center Artmed currently has 35 kW of electric DHW heaters and 20 kW of electric stoves. As a result of the following measures, this project will use equivalent gas appliances for the same amount of cooking and hot water for showers.

- Stove replacement (total capacity 33.5 kW)
- Water heater replacement (total capacity 21 kW)
- Gas pipe: 300 m main, 200 m internal distribution
- Gas meter
- Ventilation system

Because Artmed is a humanitarian institution, its cost share is 20% of the initial investment instead of the usual 50% for Group 3.

Sample executive summary (cont.)

Discussion

Performance- This project will stop the use of 234 MWh/yr of electricity and instead start using 25,000 m^3/yr of gas for DHW and cooking. As with all fuel switching from electric to gas heating, site savings are negative, but source savings at the power plant and cost savings to the customer are positive.

Economics- The cost reduction for heating water and cooking will be almost $10 k/yr. All economic indicators are positive. The life-cycle savings-to-investment ratio (SIR) is 2.1 meaning the project saves more than twice what it costs in a 10 year analysis.

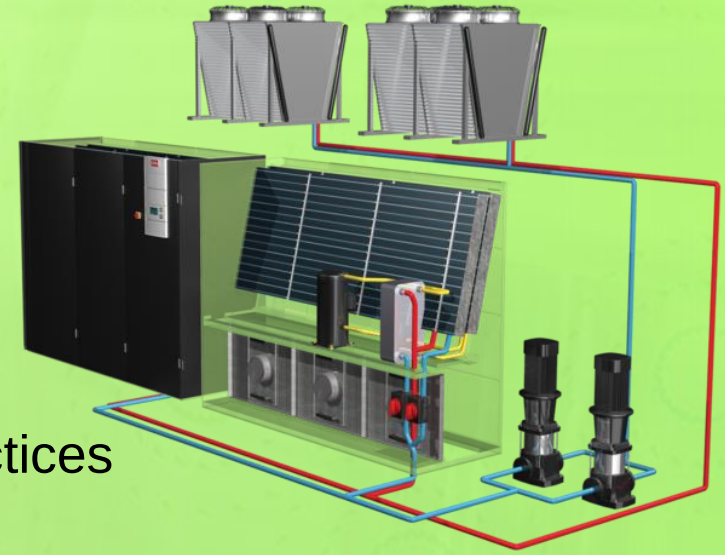
Environment- This project offers large reductions in emissions (see Summary Table) of CO_2 (global warming) and NOx (smog). Fuel switching projects eliminate marginal demand from the grid and cause high fuel savings at the thermal power plants.

Service- The contractor will provide quarterly preventive maintenance and monitoring until 31 Dec 06 as part of the fixed-price contract.

Replicability- This project can be applied throughout Armenia. Most similar institutions use electric appliances that could be switched to gas in the same manner. This is considered to be a humanitarian project, therefore requires less cost share from the recipient.

«Building information» required in the report

- General Background of the Facility,
- Mechanical Systems, and
- Operation of the facility
- The contents can be arranged as follows:
  - Envelope description
  - Floor plans
  - Operating schedule
  - Occupancy patterns
  - Energy use in the plant
  - Mechanical systems
  - Operation and maintenance practices



Utility summary

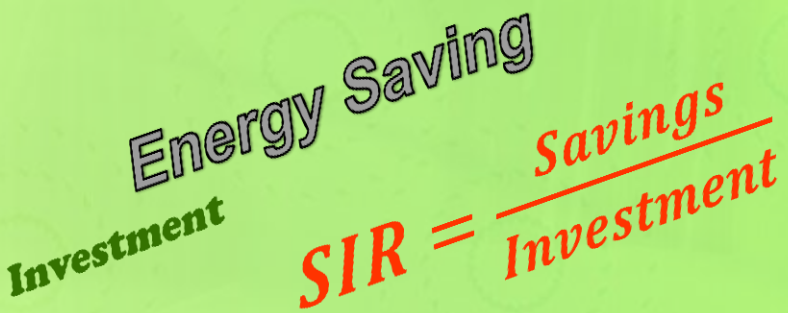
The report should comprise of

- Energy accounting data and
- the grapics for the last two years
- Energy use index (EUI)
- Monthly consumption profiles
- Demand profile
- Energy use history
- Rate schedules/rate alternatives

Energy conservation measures (ECMs)

The report should have detailed information on the following items:

- List of ECMs that meet financial criteria
- Descriptions
- Energy calculations
- Economic feasibility (NPV, SIR, IRR)
- Emissions reductions
- ECMs considered but not recommended



Operation and maintenance measures

- Potential operational changes
- Maintenance issues affecting energy use
- Energy and equipment savings estimates
- Costs to implement measures
- No cost, low cost measures

Appendices

- Floor plans, site notes, photos
- Audit data forms
- Computer simulation runs
- Motor and lighting inventory
- Energy program information and applications

Final step

- Meet with client.
- Discuss report.
- Discuss next steps.
- Instill a sense of importance and urgency

"If you don't get started,

you can't get finished."