Building Energy Auditing

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DME-Danida Capacity Building in Energy Efficiency & Renewable Energy

Energy Assessment and Savings Opportunity Identification

Module 1: A Context for Building Energy Audits

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Energy Efficiency in South African Buildings

Module 2: Basic Principles of Energy

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Understanding how energy works in buildings

Learning objectives

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- Define energy in its various forms and energy related properties;
- Use the correct units for energy and power, and convert from one unit to another as needed;
- Determine the properties of steam and moist air;
- Describe the mechanisms by which heat is transferred;
- Explain the effect of insulation on heat transfer, and the means by which radiative heat transfer is controlled.

Energy in its various forms

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- Chemical – in fuels
- Thermal – sensible and latent
- Mechanical
- Electrical

Energy Equivalents	
1000 joules (J)	1 kilojoule (kJ)
1 kilowatt-hour (kWh)	3,600,000 J or 3.6 MJ

Basic electricity

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- Voltage

  This is what pushes electricity through a circuit - the "driving force"

  Units are Volts (V)

- Current

  This is what is pushed through by the voltage - the "flow"

  Units are Amperes (A) ("Amps", for short)

Electrical power

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When voltage and current work together to do something useful - such as turn a motor or light a lamp

- Units are Watts
- 1000 Watts = 1 kilowatt (kW)
- 1 horsepower (HP) = 746 Watts

AC/DC

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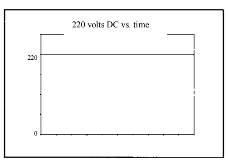

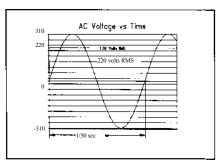

Calculating power

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- Watts = Volts x Amps x Power Factor
  - VA = Volts x Amps
- Power factor (PF) indicates how well the current and voltage are working together

Incandescent Lamps	100%
Large Motors	80-90%
Small Motors	60-75%

Power Factor - lagging current

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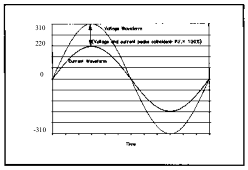

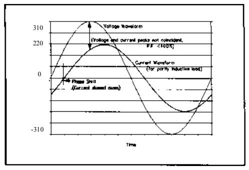

Why should I care about power factor?

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- Utilities may bill for Volts x Amps (kVA) or apply a surcharge for PF below a set value
  - Note that kVA is always greater than or equal to kW
- Increased line currents
- Low PF may suggest lightly loaded motors
- Facilitates interpretation of electrical profiles

Power factor correction

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- Add capacitance
  - At service entrance
  - In distribution system
  - At point of use – e.g. on motors

Power and energy

- Power = How Fast
  (Demand)
- Energy = How Much
  (Consumption)
- Energy = Power x Time
  Units are kilowatt-hours (kWh)

What is efficiency?

$$\textbf{Efficiency} = \frac{\textbf{Output}}{\textbf{Input}} \times 100\%$$

Device	Efficiency	Input - Output
Electric Heat	100%	Elec - Heat
Incandescent Lamp	10-20%	Elec - Light
Motors	50-95%	Elec - Power
Pumps/Fan	20-60%	Elec - Flow
Air Compressor	5-15%	Elec - Air

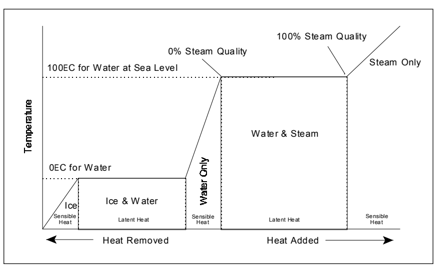
Thermal energy units

- Unit of thermal energy is a Joule (J)
  - Typically use MJ or GJ.
- 1 Joule per second = 1 Watt
- 1 kWh = 3.6 MJ (0.0036 GJ)
- 1 boiler HP = 9,810 Watts

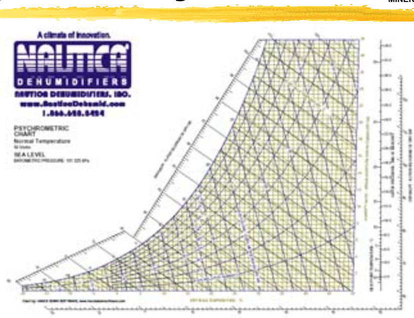
Other useful units

- 1 kWh = 3413 BTU
- 1 Ton of refrigeration
  - = 12,000 BTU/Hr
  - = 3.6 kW

Sensible and latent heat



Humid air - psychrometry



“Quality” of heat - a question of usefulness

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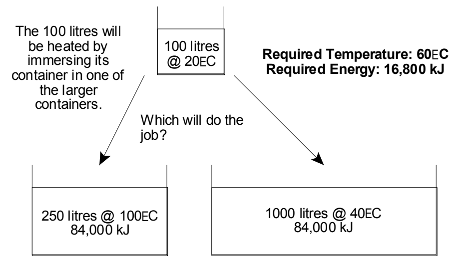

Heat transfer mechanisms

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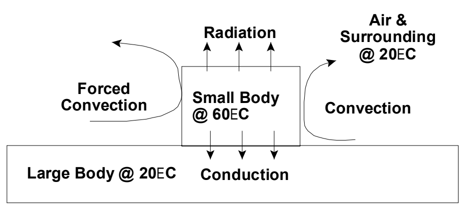

Thermal resistance of insulation

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$$Q = \frac{\Delta T \times A}{(R + R_s)}$$

R = thickness/thermal conductivity

Controlling heat loss - insulation

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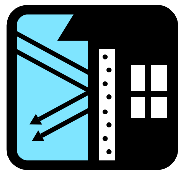
- Types:
  - Fibrous
  - Cellular
  - Granular
- Forms:
  - Rigid board
  - Flexible sheet
  - Flexible blankets
  - Cement



Protective coverings

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- Weather barrier
- Vapour retarder
- Mechanical protection
- Fire and corrosion resistance
- Appearance coverings and finishes
- Hygienic coverings

Radiation heat loss

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$$q = \varepsilon \sigma \ (T_h^4 - T_c^4) \ A$$

- Radiation from a hot body to a cold body
- Depends on
  - ε, the emissivity of the surface
  - The temperature difference
  - The radiating area
- Controlled by selecting low-emissivity materials

Heat flow calculations

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- Conduction:
  - $Q = U \times A \times (T_2 - T_1)$
- Air flow:
  - $Q = V \times (T_2 - T_1) \times 1.232$
- Humid air:
  - $Q = V \times (H_2 - H_1) \times 3.012$
- In liquids:
  - $Q = M \times (T_2 - T_1) \times C \times 1000$
- Pipe heat loss:
  - $Q = F \times L$
- Refrigeration:
  - Q = COP x Power to Compressor (kW)
- Steam leaks:
  - $Q = M \times h / 3600$

Module 3: Overview of Building Energy Audits

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A Systematic Approach to Energy Auditing

Learning objectives

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- Describe the theoretical framework for a building audit;
- Identify the information that should be collected and analysed before the site visit;
- Develop a building audit plan and schedule;
- Identify the steps involved in conducting a building audit.

What is energy auditing?

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> *"An energy audit is <u>developing an understanding</u> of the specific energy using patterns of a particular facility."*
>
> Carl E. Salas, P.E.

How is energy management done?

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- Purchase energy supplies at the lowest possible price.
- Manage energy use at peak efficiency.
- Utilize the most appropriate technology.

Managing Technology

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- No cost - housekeeping measures
- Low cost - some technology, lots of people input
- High cost - capital investment

Energy consuming systems in buildings

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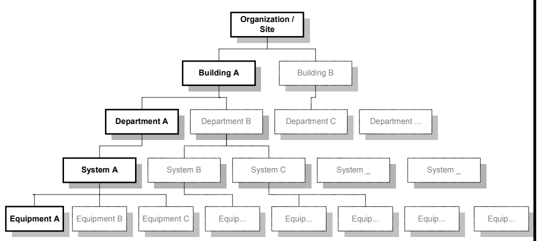

A basis for the energy audit . . . what comes in, goes out

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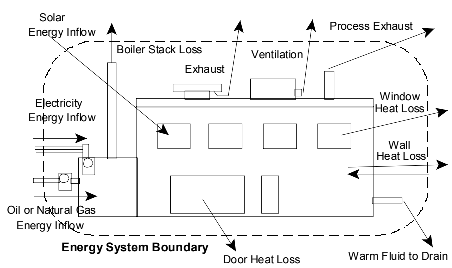

Two levels of audit

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- Preliminary Audit
  - High level assessment
  - Assesses merits of doing detailed audit
  - Identifies areas of focus for detailed audit
  - Includes walk-through and preliminary data analysis
- Detailed Audit
  - Greater detail in assessment of specific areas
  - Identifies specific EMOs

DME's Audit Process

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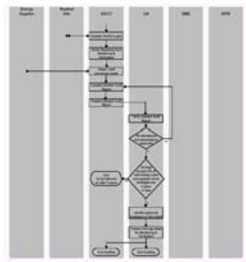

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Pre-site inspection data requirements

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- Historical energy and water consumption and billings data for at least 12 months, preferably multi-year;
- Basic building configuration information, including at least conditioned floor area;
- Building schedule and occupancy data;
- Breakdown of building uses by area (i.e. general office, computer facilities, library, cafeteria, etc.);
- Any other energy assessment data that may be available, including demand profiles, equipment inventories, etc.
- Degree-day information applicable to the building location.

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Preliminary data analysis

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- Organise historical data
- What are the patterns and trends?
- Calculate the Energy/Demand Intensity
- Correlate consumption with weather/occupancy

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Preliminary Audit

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- Purpose
  - the need for or merits of a detailed audit, based on performance indices:
    - consumption index

      $MJ/m^2/year$

    - demand index

      $VA_{average}/m^2/month$

- Steps
  - historical analysis
  - collect building data
  - demand profile
  - walk-through
  - tariff analysis

Preliminary audit findings

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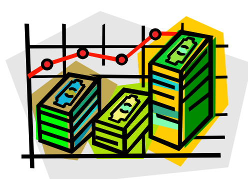
- Building performance indices
- Demand profile analysis
- Potential savings opportunities
- Confirmation of tariff



Detailed audit

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- Purpose
  - identify specific measures to reduce consumption, demand, cost
- Steps
  - examine site drawings
  - prepare load inventory
  - assess demand profile
  - assess all energy load areas
  - provide baseline criterion
  - assess tariff change opportunity

Auditing – the "big picture"

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- How and where energy enters the facility, department, system or piece of equipment;
- Where it goes and how it is used;
- Any variances between inputs and uses;
- How it can be used more effectively or efficiently.

Ten Steps

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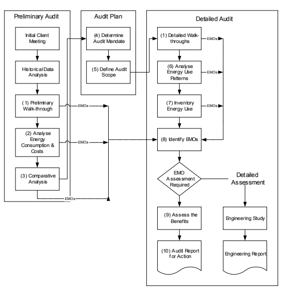
Preliminary Client Meeting and Historical Data Analysis

1. Conduct a Walk-through Inspection
2. Analyze Energy Consumption and Costs
3. Compare Energy Performance
4. Establish the Audit Mandate
5. Establish the Audit Scope
6. Profile Energy Use Patterns
7. Inventory Energy Use
8. Identify Energy Management Opportunities
9. Assess the Benefits
10. Report for Action



Planning for the audit

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- Audit mandate and scope
- Dates and places where the audit is to be conducted
- Details of the organizational and functional units to be audited and contacts
- Identification of the energy audit elements that are of high priority
- Expected time and duration for major audit activities
- Identification of audit team members
- Audit report content and format, expected date of issue and distribution.

Coordination with O&M personnel and building occupants

- Review the purposes, scope and plan of the audit – change as needed
- Describe audit methodologies
- Define communication links
- Confirm availability of resources and facilities
- Confirm schedule of meetings with management group
- Inform about site health, safety and emergency procedures
- Answer questions - create comfort level with the audit purposes and outcomes.

Step 1: the walk-through

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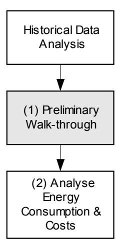
- Where energy is being wasted;
- Where repair or maintenance work is needed;
- Where capital investment may be needed to improve energy efficiency.



Step 2: Analyse energy consumption and costs

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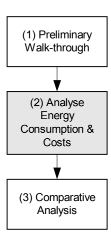
- Understand the tariffs
- Assess the trends
- Correlate to independent variables (e.g. weather, occupancy, schedule)
- Unit energy cost
- Incremental energy cost – what does the next unit consumed, or the first unit saved cost



Step 3: Comparative analysis

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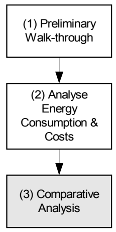
- Two kinds of comparison:
  - Internal - period to period, site to site;
  - External - to standards of performance established in the buildings sector.



Data analysis

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- Energy density:
  - $MJ/m^2/year$
- Demand density:
  - $VA_{average}/m^2/month$
- Correlation with weather - HDD and CDD

Performance indices

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- Consumption

  $MJ/m^2/year$

- Demand

  $VA_{average}/m^2/month$

Energy use drivers

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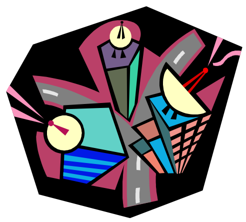
- Climate
- Facility size & Age
- Schedules
- Equipment type
- Building design
- Processes
- Organisational culture
- Behaviour



Types of comparisons

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- External benchmarks
- Internal benchmarks
  - multiple facilities
  - Historical consumption
  - Trends and patterns

Benchmarking is…

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- A methodology to improve energy performance
- Comparison of energy performance to a "standard"
- Investigation of the differences between existing and "standard" practices
- Driving action to improve practices

Selected benchmarks

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- Demand intensity
  - VA/m²
  - relates to size/number of electricity consumers
- Electric energy intensity
  - kWhE/m²
  - relates to size/number/duration of electricity use
- Cooling or heating energy intensity
  - kWhC/m² or kWhH/m²
- Total energy intensity
  - kWhT/m² = kWh(C or H)/m² + kWhE/m²

Best practices

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- Proven solutions for improving performance
- External sources:
  - Industry / sector case studies
  - Survey / study groups
- Internal sources:
  - Individuals/groups
  - Best historical performance

"This facility is different from those benchmarks!"

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- Investigate the differences
- The opportunities lie in the differences

Step 4: Define the audit mandate

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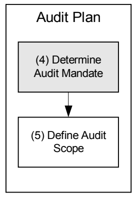
- Clarification of the goals and objectives of the audit, and the key constraints that will apply to actions on its recommendations



Step 5: Define the audit scope

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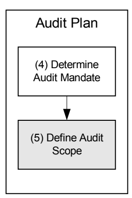
- Specification of
  - The physical extent of the audit
  - The energy inputs and outputs
  - The sub-systems to be assessed



Step 6: Profile energy consumption

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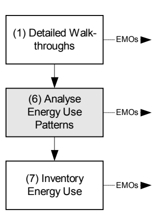
- Electrical demand profile:
  - Time pattern of consumption
  - System sizing
  - Demand reduction opportunities
  - Power factor correction?
  - Loads on when they don't need to be?



Step 7: Inventory energy loads

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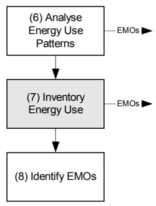
- Electrical load inventory:
  - How much and how fast?
  - Where?
- Thermal load inventory:
  - An energy flow diagram



Step 8: Identify EMOs

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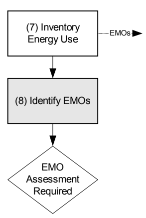
- STEP 1 - Match usage to requirement
- STEP 2 - Maximise system efficiencies
- STEP 3 - Optimise the energy supply

Begin the search for opportunities where the energy is the most expensive – at the point of end use!



Step 9: Assess the costs and benefits

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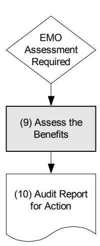
- What benefits should be taken into account
- What costs should be included in the analysis
- What economic indicators should be used



Costs and benefits

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- Benefits
  - direct energy savings
  - indirect energy savings
  - comfort/productivity increases
  - operating and maintenance cost reductions
  - environmental impact reduction
- Costs
  - direct implementation costs
  - direct energy costs
  - indirect energy costs
  - O&M cost increase

Step 10: Report for implementation

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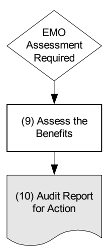
- Provide a clear account of the facts upon which your recommendations are made
- Interest those who read the report in acting upon those recommendations



Module 4: Historical Energy Assessment

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Understanding the patterns of energy use

Learning objectives

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- Identify data sources for the assessment of the building's energy performance
- Describe the instrumentation used for energy audits
- Analyse the energy tariffs that apply to the building
- Correlate energy consumption to building operational parameters and weather

Analyzing performance requires energy data

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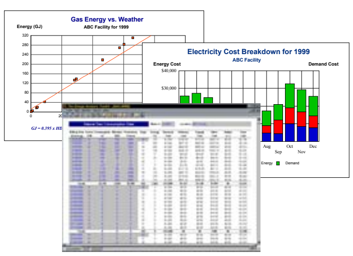

Data requirements

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- Historical energy consumption data
- Metered energy consumption
- Building configuration
- Weather data
- Energy system nameplate data
- mechanical, electrical, architectural plans and specifications
- building automation system (BAS) documentation
- maintenance logs
- key plans (floor plans)
- contact information for building operational personnel or service contractors

Instrumentation for auditing

- Electric Power Meter
- Combustion Analyzer
- Digital Thermometer
- Infrared Thermometer
- Psychrometer (Humidity Measurement)
- Air Flow Measurement Devices
- Tachometer
- Ultrasonic Leak Detector
- Other useful items:
  - A camera
  - Binoculars and a small flashlight
  - Duct tape & Tie Wraps
  - Multi- screw driver, adjustable wrench and pliers
  - Tape measure
  - Bucket and stopwatch
  - Safety Glasses, Gloves & Ear Plugs
  - Caution tape

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Hand-held wattmeter

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Single-phase connections

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3-phase digital power meter

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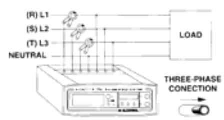

Combustion analysis

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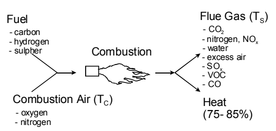

Light level measurement

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Table 5.14
RECOMMENDED ILLUMINANCE LEVELS, POWER DENSITIES AND SURFACE REFLECTANCES

Area and Task	Illuminance	Power Density	Reflectances %		
		W/m^2	Ceiling	Walls	Floor
Offices - accounting - drafting - general	750 - 950 750 - 950 540 - 700	25 25 18	70 - 80	40 - 60	20 - 40
Corridors	210	5.5			
Lobbies	320	9			
Cafeterias and Kitchens	320 - 500	14	70 - 80	40 - 80	20 - 40
Lecture Rooms	540 - 700	18	70 - 80	40 - 60	20 - 40
Toilet Areas	320	9			
Laboratories	750 - 950	25	70 - 80	40 - 80	20 - 40
Production - general	750 - 950	25			
Warehouses	320	9			
Roadways	50	2			
Parking	50	2			

Temperature measurement

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Humidity measurement

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Static pressure

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Leak detection - ventilation and compressed air

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Check your speed - digital tachometer

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An electricity tariff

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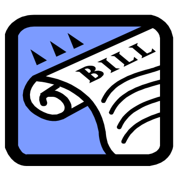
- Administrative charge
- Demand charge per kVA
  - May be time of use – on-peak/off-peak
- Energy charge per kWh



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Analysing the electricity billings

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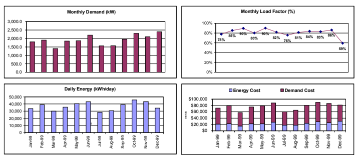
Electricity Consumption Data Location: ABC Facility

[C:\Project Files\Audit Manual\Spreadsheets\[Electricity Cost.xls]Electicity Consumption Data]

Billing Date	Metered kVA	Metered kW	Power Factor	Billed kW	Energy kWh	Days	Daily kWh	Load Factor	Demand Cost	Energy Cost	Adjust (+/-)	Sub Total	Total Cost
01/01/99		1,800.0		1,800.0	1,006,703	30	33,557	78%	$21,250	$50,365	($11,147)	$71,615	$64,701
02/01/99		1,900.0		1,900.0	1,206,383	31	38,916	85%	$22,750	$56,441	($13,204)	$79,191	$70,607
03/01/99		1,400.0		1,400.0	842,286	28	30,082	90%	$15,250	$42,144	($9,263)	$57,394	$51,501
04/01/99		1,850.0		1,850.0	1,102,176	31	35,554	80%	$22,000	$53,315	($12,132)	$75,315	$67,606
05/01/99		1,870.0		1,870.0	1,213,021	30	40,434	90%	$22,300	$56,641	($13,252)	$78,941	$70,287
06/01/99		2,200.0		2,200.0	1,339,599	31	43,213	82%	$27,250	$60,438	($14,716)	$87,688	$78,080
07/01/99		1,560.0		1,560.0	850,195	30	28,340	76%	$17,650	$42,540	($9,438)	$60,190	$54,304
08/01/99		1,570.0		1,570.0	948,747	31	30,605	81%	$17,800	$47,467	($10,429)	$65,267	$58,677
09/01/99		1,950.0		1,950.0	1,213,798	31	39,155	84%	$23,500	$56,664	($13,308)	$80,164	$71,536
10/01/99		2,300.0		2,300.0	1,373,054	30	45,768	83%	$28,750	$61,442	($15,111)	$90,192	$80,337
11/01/99		2,100.0		2,100.0	1,347,059	31	43,454	86%	$25,750	$60,662	($14,731)	$86,412	$76,699
12/01/99		2,400.0		2,400.0	1,024,475	30	34,149	59%	$30,250	$50,984	($11,685)	$81,234	$74,418
Totals/Max		2,400.0		2,400.0	13,467,496	364			$274,500	$639,104	($148,415)	$913,604	$818,752



Load factor

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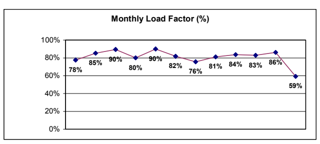
$$Load\ Factor\ (\%) = \frac{kWh\ used\ in\ period}{Peak\ kW\ x\ 24\ hr\ per\ day\ x\ \#\ days\ in\ period}\ x\ 100$$

Low load factors mean excessive demand for a short duration - and higher than necessary cost.



Graphical analysis of historical energy use

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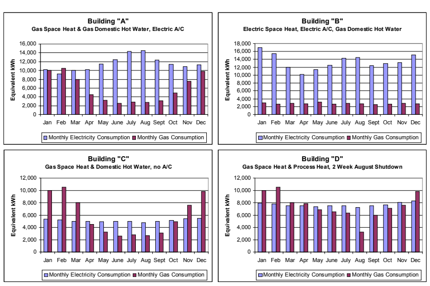

Calculating degree-days

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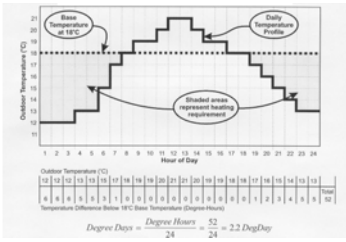

Table 5.16: Degree-Day Calculations for Cape Town

Month	Days	Tavg.	HDD18	CDD20
J	31	20.9	0.0	27.9
F	28	21.0	0.0	28.0
M	31	19.8	0.0	0.0
A	30	17.5	15.0	0.0
M	31	14.8	99.2	0.0
J	30	13.0	150.0	0.0
J	31	12.2	179.8	0.0
A	31	12.7	164.3	0.0
S	30	14.0	120.0	0.0
O	31	16.0	0.0	0.0
N	30	18.4	0.0	0.0
D	31	19.9	0.0	0.0
Yearly			728.3	55.9

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Correlation of energy consumption to degree-days

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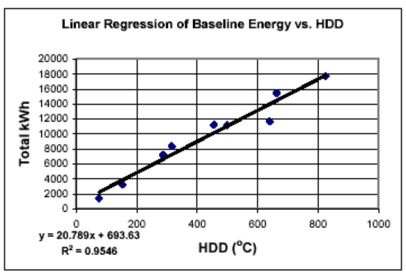

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Module 5: Energy Assessment - Demand Analysis

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DME-Danida Capacity Building in Energy Efficiency & Renewable Energy

Understanding the time patterns of energy use

Learning objectives

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- Obtain an electrical demand profile, interpret it, and identify possible EMOs;
- Identify opportunities for power factor correction.

Hourly Demand Profile

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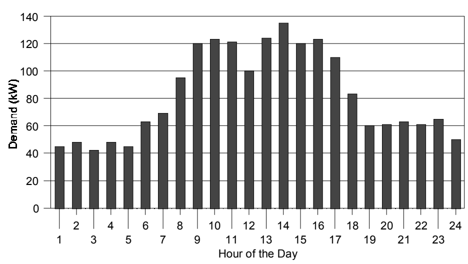

An Electrical Fingerprint

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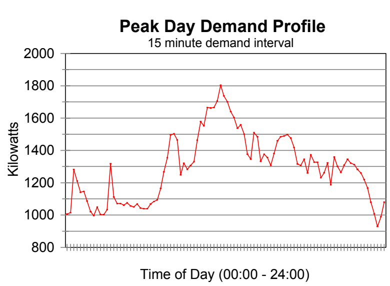

Patterns Revealed

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- Peak Demand
- Night Load
- Start-Up
- Shut-Down
- Weather Effects
- Loads that Cycle
- Interactions
- Occupancy Effects
- Production Effects
- Problem Areas

Analyzing the Profile

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- Requires facility operational knowledge
- Mark scheduled events on the profile
- Correlate events with:
  - Demand increase, decrease, cycling, peaks
- Reconcile with demand on utility bills
- Investigate unknown patterns

"There's always a savings opportunity in a new demand profile"

Obtaining a Demand Profile

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- Periodic utility meter readings
- Recording clip-on ammeter measurements
- Basic recording power meter
- Multi-channel recording power meters
- A Facility energy management or SCADA system
- A dedicated monitoring system

Obtaining a demand profile

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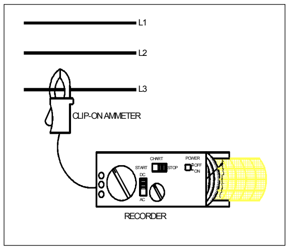

3 phase power from single phase measurement:

kVA = Amps x Volts x 1.73 ÷ 1000

3 phase measurement

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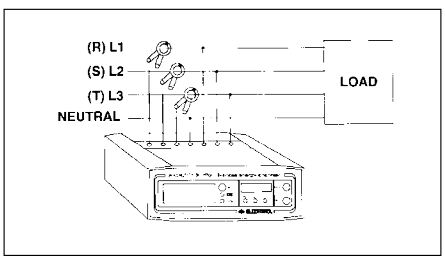

Daily or monthly

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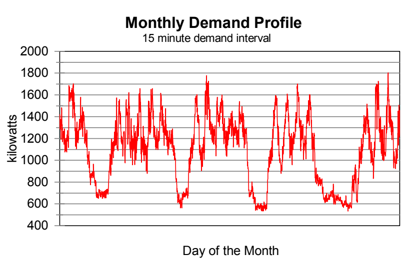

Meter response

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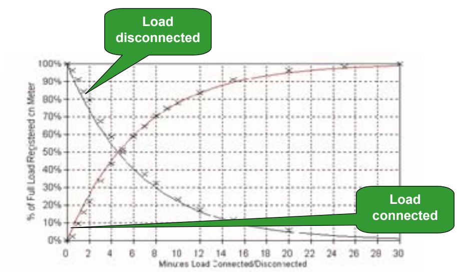

What the demand meter sees

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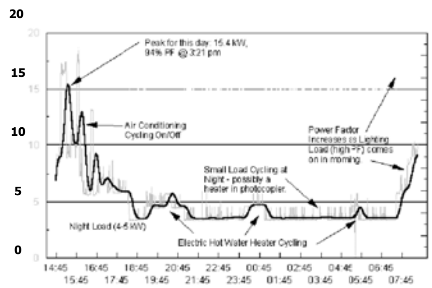

Savings opportunities

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- Scheduling – reduce startup peaks
- Infrequent demand peaks – avoidable
- Shift on-peak to off-peak usage pattern
- Equipment loading – consider sequencing

Peak demand control

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- Eliminate accidental peaks
- Shift activity "off-peak"
- Peak demand warning for staff
- Interlock equipment
- Load shedding system
- Use generator to "clip" the peak

Power factor correction

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- Correct power factor – on peak
  - at service entrance
  - in the distribution system
  - at the point of use power factor

Analyse this!

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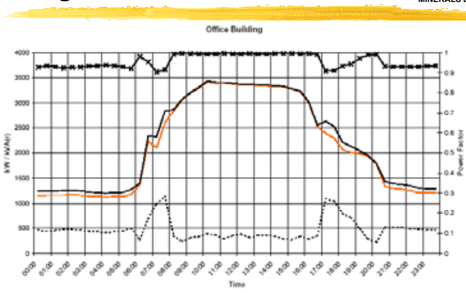

Module 6: Energy Assessment - Load Inventory

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DME-Danida Capacity Building in Energy Efficiency & Renewable Energy

Understanding where energy is used

Learning objectives

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- Create an energy load inventory, and reconcile it to consumption data

Analyse the load inventory

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- Where is electricity used?
- How much - i.e. consumption
- How fast - i.e. demand

Why inventory?

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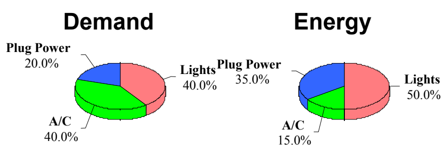
- Focus your efforts
- Establish a basis for savings calculations



Inventory calculations

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Item	Units	Formula
Quantity	(a number)	
Unit Load	kW	
Total kW	kW	Quantity. x Unit Load.
Hrs/Period	hours	
kWh/Period	kWh	Total kW x Hrs/Period
Diversity Factor (Div'ty Factor)	0 - 100%	
Peak kW	kW	kW x Diversity Factor

Demand breakdown

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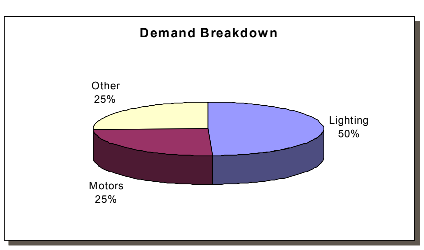

Peak demand breakdown

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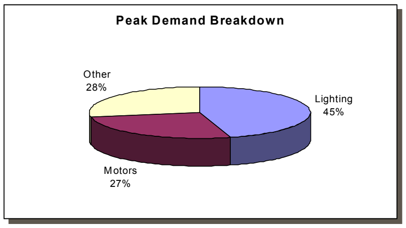

Energy breakdown

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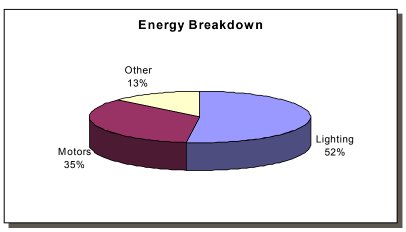

Sample inventory

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Loads	Qty	Unit KW	Total KW	Diversity Factor	Peak KW	Hours	KWH
Fluorescent F96	4	0.165	0.66	1	0.7	300	198
Incandescent 100 w	24	0.1	2.4	0.9	2.2	100	240
400w MH Lights	21	0.465	9.765	1	9.8	420	4,101
Compressor.(60HP)	1	50	50	1	50.0	400	20,000
Pump (20 HP)	1	16	16	0.75	12.0	400	6,400
Micro-Wave	1	0.75	0.75	0.1	0.1	2	2
Coffee Machine	2	1.5	3	1	3.0	200	600
Total			**83**		**77.7**		**31,541**

Energy flow diagram

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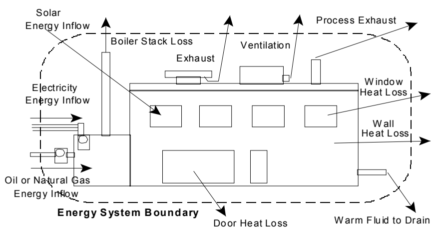

Thermal energy inventory

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Energy Flow Type	Example	Equipment/Functions
Conduction	Wall, windows	Building structure.
Air Flow - Sensible	General exhaust	Exhaust and makeup air systems, combustion air intake.
Air Flow - Latent	Dryer exhaust	Laundry exhaust, pool ventilation, process drying equipment exhaust.
Hot or Cold Fluid	Warm water to drain.	Domestic hot water, process hot water, process cooling water, water cooled air compressors.
Pipe Heat Loss	Steam pipeline.	Steam pipes, hot water pipes, any hot pipe.
Tank Heat Loss	Hot fluid tank.	Storage and holding tanks.
Refrigeration system output heat	Cold storage.	Coolers, freezers, process cooling, air conditioning.
Steam Leaks and Vents	Steam vent	Boiler plant, distribution system, steam appliance.

Module 7: Energy Assessment - EMOs

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DME-Danida Capacity Building in Energy Efficiency & Renewable Energy

Finding energy management opportunities

Learning objectives

- Systematically identify EMOs;
- Describe the factors that need to be considered in assessing costs and benefits.

Finding opportunities: Start at the end-use

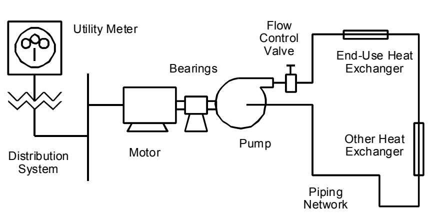
Meter

1st Analyze Present Usage

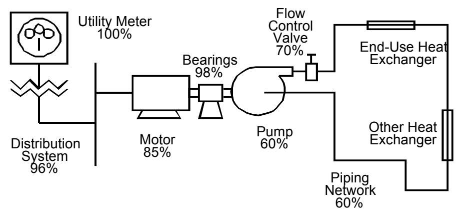
End-Use

2nd Identify and Quantify the Savings Opportunities

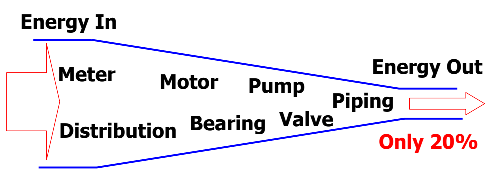
Start at point of end-use



Component efficiencies



System efficiency



Component and system efficiencies

Component	Typical Efficiency
Meter	100%
Distribution	96%
Motor	85%
Bearing	98%
Pump	60%
Valve	70%
Piping	60%
Overall	20%

Three simple steps

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- Start with a valid need
- Waste-loss analysis
  - i.e. match and maximize
- Optimize the supply

Why this order?

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- End-use actions influence all other parts of the system – do this first
- Lower cost actions are operational – at end-use
- Higher cost actions are technological – higher efficiency components
- End-use determines supply requirement

Match the requirement

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- Setback temperatures
- Turn-off lights in unoccupied areas
- Provide task—rather than general — lighting
- Avoid dampers / throttling – match flows by:
  - Resizing the fan/pump
  - Installing a variable speed drive on fan/pump motor
- Provide ventilation on demand

Maximise efficiencies

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- Reduce ventilation duct flow restrictions
- Clean air filters regularly
- Keep heat exchange surfaces clean
- Use a higher efficacy light source
- Install a high efficiency motor

Assessing the costs and benefits

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- Benefits:
  - direct energy savings
  - indirect energy savings
  - comfort/productivity increases
  - operating and maintenance cost reductions
  - environmental impact reduction
  - O&M savings
- Costs:
  - direct implementation costs
  - direct energy costs
  - indirect energy costs
  - O&M cost increase

More about savings

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- Energy Savings: energy saved x incremental energy rate
- Demand Savings: kVA saved x incremental demand rate
- Thermal Fuel Savings: Fuel Energy Saved = Point of Use Energy Saved ÷ Heating Plant Efficiency
  - Fuel Cost Saved = Fuel Energy Saved x Incremental Cost of Fuel ÷ Energy Content of Fuel
- Indirect electrical savings
  - e.g. reduced A/C loads due to more efficient lighting:
    - A/C kWh Saved = Lighting kWh saved ÷ COP
- Less re-lamping labour and lamp cost from switching to a longer-life lamp type
- Increase in employee productivity from converting to a higher quality, higher efficiency fixture type.

More about costs

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- Initial cost of implementing the retrofit
- Decrease in lamp life - increased re-lamping costs
  - Decrease in lamp life due to increase in switching
- Any increase in maintenance costs such as higher cost lamps and ballasts
- Higher cost of repairs or lower life of any replacement energy-efficient equipment
- Indirect energy costs:
  - Increase in heating costs due to more efficient or switched lighting

$$Heating\ Increase\ (kWh) = \frac{Lighting\ kWh\ Saved}{Heating\ System\ Efficiency}$$

Module 8: Energy Efficiency in Building Electrical Systems

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DME-Danida Capacity Building in Energy Efficiency & Renewable Energy

Electrical energy management opportunities

Learning objectives

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- Describe building performance standards
- Identify and assess energy efficiency opportunities for lighting systems; miscellaneous plug loads; motors, drives, fans and pumps.

Building performance standards - SAEDES®

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- Intended to:
  - Minimise ODS use
  - Minimise GHG emission
  - Conserve non-renewable energy resources
  - Optimise building performance to achieve the economic benefits
- Provisions:
  - Minimum demand and energy efficiency of new buildings
  - Building performance parameters
  - Climate data
  - Application of other standards
  - Detailed technical criteria

SAEDES performance standards

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Area	Lux	W/m^2
General Office Space	400	17
Computer Rooms & Drafting Areas	600	26
Public Areas (Foyer & Corridors)	200 - 400	7 - 17
Stairs	50 - 100	3 - 5
Kitchen	200-300	10 - 16
Toilets	100	5
Car Park	50 - 100	3 - 5
Plant Rooms	100 - 200	5 - 10
Retail	400 - 800	8 - 25

. . . And climate data

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City	Latitude	Longitude	SI Units (EC)					
			Elev (m)	HDD	CDD	Win. Des. 99%	Summer DB 2,5%	WB 2,5%
CapeTown/ D F Malan	33,97S	18,60E	46	936	2474	22	72	53
Johannesburg	26,13S	28,23E	1694	1066	2362	13	65	51
Pretoria	25,73S	28,18E	1330	639	3,238	14	69	51

SABS 0400-1990 – ventilation rates

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Occupancy	Minimum Air Requirement, l/s (per person except where noted)	
	Smoking	Non-smoking
Educational Buildings		
Classrooms	-	7,5
Laboratories	-	7,5
Libraries	-	6,5
Shops		
Malls, arcades, warehouses	7,5	7,5
Sales floors, showrooms, dressing rooms	7,5	7,5
Garages	per m^2 floor area	per m^2 floor area
Parking garages	7,5	7,5
Ticket kiosks	5,0	5,0
Libraries		
General	-	6,5
Bookstock	-	3,5
Offices		
General	7,5	5,0
Meeting and waiting spaces	7,5	5,0
Conference and board rooms	10,0	5,0
Cleaner's rooms	1,0	1,0

The building as an energy system

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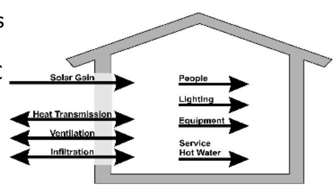
- What are the interactions?
  - Heat from lights
  - Humidity reduction by AC
  - Increased fresh air requirement from reduction of infiltration
  - Others?



Other impacts of energy reduction

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- Power quality – introduction of harmonics?
- Indoor air quality – changes with ventilation/infiltration rates
- Greenhouse gas emissions – CO_2 emission reduction has monetary value

Lighting system

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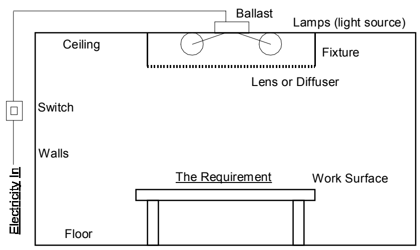

Lighting considerations

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- Minimise operating time
- Ensure appropriate levels and quality
- Maximise efficiency of delivery
- Maximise the source efficiency
  - Lamp efficiency = efficacy

Lighting quality

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- Illumination level
- Uniformity
- Absence of glare
- Colour temperature
- Colour rendition index (CRI)

Colour rendering index (CRI)

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Light Source	CRI	Rendering
Incandescent lamps	97	Excellent
FL, full spectrum 7500	94	Excellent
FL, cool white deluxe	87	Excellent
Compact Fluorescent	82	Excellent
FL, Warm White deluxe	73	Good
MH (400 W clear)	65	Good
HPS (250 W deluxe)	65	Good
Fl, Cool White	62	Good
FL, Warm White	52	Fair
MV (phosphor-coated)	43	Poor
HPS (400 W diffuse coated)	32	Poor
MV (clear)	22	Poor
Low Pressure Sodium	---	Impossible

Light source efficacy

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Lamp Type	Lumens/Watt
Incandescent	10 - 18
Mercury Vapour	20 - 50
Fluorescent	40 - 100
Metal Halide	60 - 100
High Pressure Sodium	60 - 120
Low Pressure Sodium	90 - 200

Some questions

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- Are lights on when the space is unoccupied?
- Are lights on in an area served by daylight?
- Is lighting switched from breakers?
- Is there sufficient and convenient switching available?
- Is the level of light appropriate for the task at hand?
- Is regular maintenance performed?

Summary of lighting opportunities

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- Lower Cost – match the requirement
  - Better switching - more switches & levels
  - Occupancy sensors & timers
  - Reduce overall level & use task lights
- Higher Cost – improve the efficiency
  - Upgrade to a more efficient fixture
  - Use a more effective fixture layout
  - Use a more efficient light source

EMOs for lighting

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- Switch off unnecessary lights
- Remove redundant fixtures
- Delamping
- Relamping
- Modifications or replacement
  - Remove or replace fixture lenses
  - Retrofit the existing lighting system with a more efficient system
  - Replace inefficient ballasts
- Clean light fixtures, lamp reflectors and room surfaces

Plug loads

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- Plug loads add up
- Turn them off
- Select high efficiency models

Electric motors

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- First, reduce unnecessary use
- Ensure proper operating conditions
- Provide good maintenance
- Consider an energy efficient motor

The motor is not the end-use; consider what is being driven.

Imbalance = Inefficiency!

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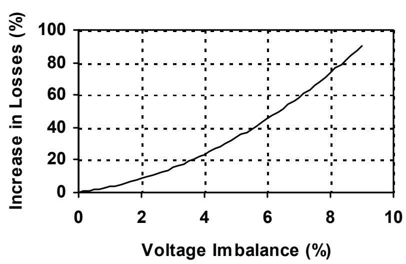

Match the motor to the load

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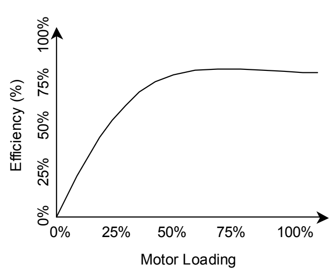

Operating conditions

- Leading cause of motor failure is heat
- 10% temperature increase = ½ life
- Clean air vents
- Balance voltages
- Avoid too many starts

Motor rewinding

- Could reduce efficiency by 5%
- Depends upon rewind shop
- Specify motor iron core test after rewind
- It is realistic to expect minimal reduction in efficiency after a rewind

Energy efficient motors

Loading (%)		100% Load		75% Load		50% Load	
HP	Type	Eff'y	P.F.	Eff'y	P.F.	Eff'y	P.F.
1	EE	84.0	80.5	84.0	74.0	81.5	62.0
1	Std	72.0	78.0	72.0	70.0	68.0	58.0
10	EE	90.2	88.0	90.2	85.0	90.2	77.0
10	Std	84.0	85.5	84.0	80.5	81.5	75.0
50	EE	92.8	84.5	93.0	81.0	91.7	73.0
50	Std	91.7	84.0	91.7	81.	90.2	71.5
100	EE	93.5	91.5	94.0	91.0	93.8	87.0
100	Std	91.7	83.5	91.7	80.5	90.2	73.0
200	EE	94.8	90.5	95.0	88.5	94.6	83.0
200	Std	93.0	88.5	93.0	86.5	91.7	80.0

Watch your speed!

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- Energy efficient motors tend to have higher rated/operating speeds.
  - 1-3% higher rated speeds.
- When driving a centrifugal load:
  - A 1% speed increase = 3.5% power increase.

Fans & pumps

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- Comprise significant load in buildings
- Typically oversized
- Misapplication is common
- Proper flow control can yield large savings

Assessing fans & pumps

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- **Match the need** - make sure the fan/pump size matches the need for flow
- Ensure that the pump or fan is operating at close to optimal conditions - if not reconsider the pump/fan selection
- Reduce resistance to flow in the distribution systems - flow resistance, fittings, pipe/duct sizing

Powerful laws

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$$\frac{Q_2}{Q_1} = \frac{N_2}{N_1} \qquad \frac{P_2}{P_1} = \left(\frac{N_2}{N_1}\right)^2 \qquad \frac{kW_2}{kW_1} = \left(\frac{N_2}{N_1}\right)^3$$

Affinity laws for centrifugal fans and pumps.

N = speed, Q = flow, P = pressure, kW = power

Efficiency optimisation

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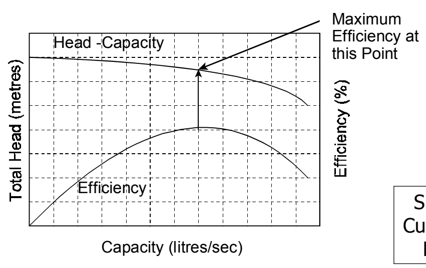

Similar Curve for Fans

Fan/Pump savings strategy

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	Operational	Technological
Match the Requirement	**1** Turn it off or reduce volume.	**3** Apply a variable speed drive
Maximize Efficiency	**2** Maintain & operate at best point.	**4** Replace pump or motor.

Assessment questions

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- Is the fan/pump being throttled at the discharge?
- Is the fan/pump doing a meaningful job?
- Is the fan/pump correctly sized?
- Check fan/pump curves; is fan/pump operating efficiently?
- Does the requirement for air/liquid vary?

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More fan/pump questions

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- Can the fan/pump be slowed down?
- Can the system head be reduced, ducts/pipes cleaned?
- Is the fan/pump excessively noisy, hot or vibrating?
- Are there leaks in the air distribution system?
- Is the fan being throttled at the inlet?

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Fan/pump EMOs

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- Clean and balance air distribution systems
- Check overall fan/pump sizing and efficiency
- Eliminate air flow reduction with dampers, fluid flow control with valves
- Use a booster fan/pump
- Reduce fan/pump speed

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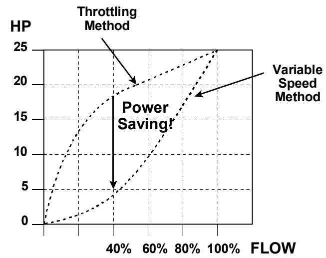
The advantage of variable speed



Module 9: Energy Efficiency in Building Thermal Systems

DEPARTMENT OF MINERALS AND ENERGY
DME-Danida Capacity Building in Energy Efficiency & Renewable Energy

Thermal energy management opportunities

Learning objectives

- Assess the heating and cooling load of a building;
- Identify and assess energy efficiency opportunities for building envelope; HVAC systems including boilers, steam and hot water distribution systems, air distribution systems; and the application of building control systems.

Heating/cooling loads and the "comfort zone"

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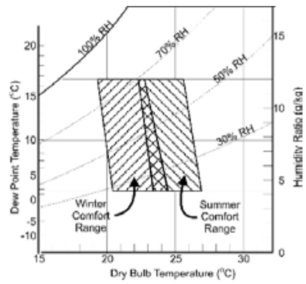

Heat loss and gain – basic relationship

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$$Q = U \times A \times (T_2 - T_1)$$

Q = Heat loss rate (W)
U = 1 / R-value = Heat transfer coefficient ($W/m^2.^oC$)
A = Surface area (m^2)
T2 = Indoor Temperature (°C)
T1 = Outdoor Temperature (°C)

Insulation EMOs – reduce heat loss/gain

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- Maintenance:
  - Repair damaged insulation
  - Repair damaged coverings and finishes
  - Maintain safety requirements
- Low-cost:
  - Insulate non-insulated pipes & fittings
  - Insulate non-insulated vessels
  - Add insulation to reach the recommended level

Insulation EMOs

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- Retrofit:
  - Upgrade existing insulation levels
  - Review economic thickness requirement
  - Limited budget upgrade
- New construction:
  - High R materials
  - Building orientation
  - High efficiency glazing
  - Window shades
  - Floor plans

Infiltration/Exfiltration EMOs

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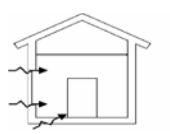
- Caulk all cracks
- Caulk around all pipes, louvers, or other openings that penetrate the building skin
- Repair windows
- Weatherstrip exterior doors and windows
- Cover window air conditioners during off seasons
- Install revolving doors, vestibule and automatic door closers

$$Q = 1.232 \times F_A \times (T_2 - T_1)$$



Solar gain – radiation heat load

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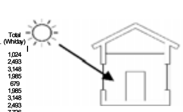
30° South Latitude

	Time of Day	6	7	8	9	10	11	12	13	14	15	16	17	18	Total (Wh/day)
	S	131	115	71	56	56	56	56	56	56	56	71	115	131	1,024
	SE	417	552	516	385	218	75	56	56	56	56	48	40	20	2,493
	E	429	619	639	568	389	175	56	56	56	56	48	40	20	3,148
	NE	167	298	357	357	290	175	67	56	56	56	48	40	20	1,985
Dec	N	20	40	48	56	60	75	83	75	60	56	48	40	20	679
	NW	20	40	48	56	56	56	67	175	290	357	357	298	167	1,985
	W	20	40	48	56	56	56	56	175	389	568	639	619	429	3,148
	SW	20	40	48	56	56	56	56	75	218	385	516	552	417	2,493
	Hor	75	242	520	715	861	953	993	953	861	715	520	242	75	7,726
	S	87	79	56	52	56	56	56	56	56	52	56	79	87	826
	SE	369	520	488	353	183	64	56	56	56	52	48	36	16	2,295
	E	397	615	651	576	393	175	56	56	56	52	48	36	16	3,124
Jan	NE	167	326	397	397	330	210	87	56	56	52	48	36	16	2,176
&	N	16	36	48	56	79	107	119	107	79	56	48	36	16	802
Nov	NW	16	36	48	52	56	56	56	210	330	397	397	326	167	2,144
	W	16	36	48	52	56	56	56	175	393	576	651	615	397	3,124
	SW	16	36	48	52	56	56	56	64	183	353	488	520	369	2,295
	Hor	60	262	488	699	850	937	977	937	850	699	488	262	60	7,567
	S	22	30	41	48	48	52	52	52	48	48	41	30	22	534
	SE	204	401	371	245	100	52	52	52	48	48	41	30	7	1,651
	E	245	545	612	549	378	171	52	52	48	48	41	30	7	2,779
Feb	NE	137	364	471	479	416	304	145	56	48	48	41	30	7	2,545
&	N	7	30	48	100	174	215	234	215	174	100	48	30	7	1,384
Oct	NW	7	30	41	48	48	56	145	304	416	479	471	364	137	2,545
	W	7	30	41	48	48	52	52	171	378	549	612	545	245	2,779
	SW	7	30	41	48	48	52	52	52	100	245	371	401	204	1,651
	Hor	22	174	397	597	742	835	872	835	742	597	397	174	22	6,408
	S	0	19	37	45	48	52	52	52	48	45	37	19	0	453
	SE	0	275	334	148	56	52	52	52	48	45	37	19	0	1,117
	E	0	460	586	534	382	178	52	52	48	45	37	19	0	2,393
Mar	NE	0	364	486	564	523	419	249	93	48	45	37	19	0	2,846



Reduce solar gain . . .

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- In new construction:
  - Glass area and type
  - Building orientation in new construction
  - Overhangs and shading
- In existing buildings:
  - Exterior shading (awnings)
  - Interior shading and blinds
  - Re-glazing (maybe)

Summary of heat load EMOs

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- Reduce heat loss/gain by:
  - Conduction - add insulation
  - Convection - minimize air infiltration
  - and radiation - replace or improve windows, use shading
- Strategy:
  - eliminate waste - ensure building need is exactly met by the energy system;
  - maximize efficiency – select best technology, improve operational and maintenance practices;
  - optimize energy supply - select most economical energy source, utilise waste heat

Reduce heating energy

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- Maintain the indoor temperature as low as possible
- Use most economical level of insulation
- Ensure vapour barrier is installed and in good repair
- Use double or triple glazing for windows
- Reorganise activities inside the building - separate the building into zones based on specific heating and cooling requirements
- Don’t heat unoccupied areas

Reduce cooling energy

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- Maintain the indoor temperature as high as possible
- Use insulation to reduce heat gain in summer
- Use double or triple glazing or low-E glass for windows
- Reorganize activities inside the building - the desired configuration is opposite that required for reducing heat loss
- Don't cool unoccupied areas

Energy efficient HVAC

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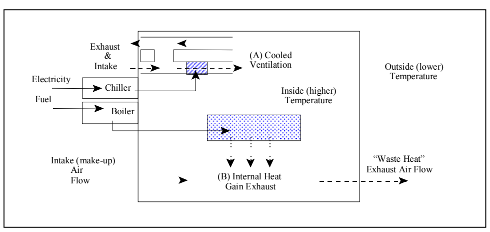

Causes of inefficiency

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- Over/under heating/cooling - set-point or temperature control
- Over ventilation
- Simultaneous heating/cooling
- Inadequate controls for range of conditions
- Increased heating or cooling due to infiltration
- Stratification
- Poor equipment maintenance
- Incorrect system type or sizing
- Lack of coordination in central control

Finding HVAC EMOs - some questions

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- Temperature and ventilation requirements of the conditioned space - match of system capacity to these needs
- Containment of contaminants from other building areas
- What is the accuracy of temperature and humidity control - more accurate controls?
- Does the HVAC load vary daily and seasonally - does the system have capacity control to accommodate these swings?

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. . . more questions

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- Is there a preventative maintenance program for the HVAC systems?
- Are controls calibrated regularly?
- Was the existing system designed for the present purpose or conditions?
- Are there more efficient systems for our application?

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EMOs checklist - ventilation

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- Shut down ventilation/exhaust systems when not required
- Maintain dampers to reduce outside air leakage when not required
- Use correct ventilation/exhaust rates for application & occupancy
- Utilise systems to destratify ceiling air
- Minimise the Use of local exhaust

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EMOs checklist - space conditioning

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- Control temperature and humidity according to comfort zone
- Minimize solar gains
- Raise thermostats during unoccupied hours during the cooling season, lower during heating season
- Adjust space temperatures in unoccupied or storage areas
- Ensure automatic controls are operating correctly and are calibrated regularly
- Use enthalpy control on HVAC systems
- Use filters to remove odours

Boiler plant systems

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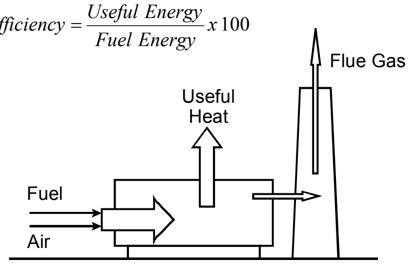
$$\textit{Boiler Efficiency} = \frac{\textit{Useful Energy}}{\textit{Fuel Energy}} \; x\,100$$



Hot water boiler plant

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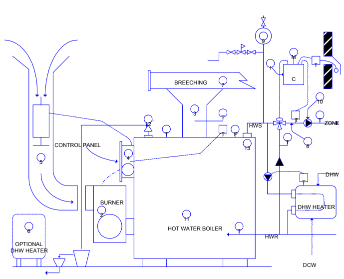

Fuel combustion

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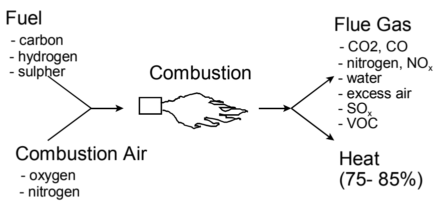

Losses from boiler systems

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- *Combustion by-products* – depends on the air-fuel mixture
- *Heat in the flue gas* – depends on the amount of excess combustion air and effectiveness of heat exchange
- *Blow-down* – hot water removed from the boiler to control accumulation of solids
- *Skin Loss* – heat escaping from the boiler enclosure

Combustion efficiency measurement

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- Flue gas & combustion air temperature
- Flue gas constituents
  - O_2 (indicates CO_2 and excess air)
  - CO
  - NO_x, SO_x, etc
- Draft and differential pressure
- Efficiency is calculated from flue heat loss

Measuring combustion efficiency

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- Equipment required:
  - Combustion analyzer
  - Or, minimally O_2, temperature sensor and efficiency tables
- Access required:
  - ¼" to 3/8" hole in flue close to last heat exchange

Boiler plant EMOs

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- Adjust fuel/air ratio
- Ensure boiler temperature set point is OK
- Clean heat transfer surfaces
- Staging/control of multiple units
- Off cycle heat loss reduction
- Burner alignment/adjustment
- Boiler/pipe insulation

More boiler plant EMOs

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- Relocate combustion air intake to use waste heat
- Replace inefficient units
- Right-size boilers
- Smaller boiler for summer loads
- Heat recovery on larger boilers
  - Reduction of loss is first consideration

. . . And more EMOs

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- Reduce blowdown rate, by managing water treatment.
  - Reduction from 10% to 5% saves about 1% of fuel
- Reduce steam pressure
  - Lower flue, radiation, and leak losses
- Reduce venting/leaks if possible

Heat recovery opportunities

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- Use economizer to heat make-up water
- Combustion air pre-heater
- Flue gas condenser
- Blow down heat recovery
- Recover de-aerator steam

Savings example

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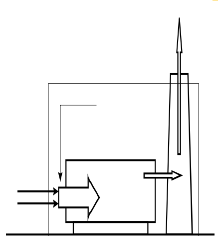
- Preheat combustion air with heat from power house ceiling
- Combustion air $20^{o}C$ to $40^{o}C$
- Boiler efficiency improvement of 1.1%



Assessment of boiler plant

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Steam distribution

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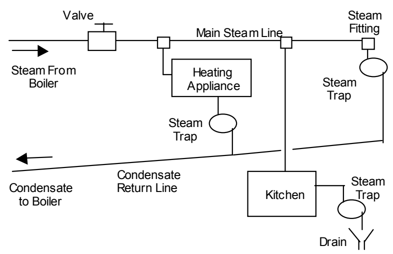

Assessment of steam distribution

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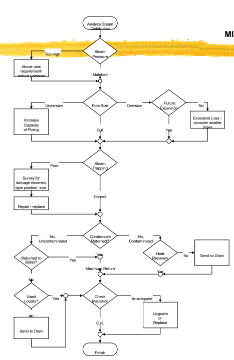

Losses in distribution systems

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- Steam leaks
- Excessive pressure drop in steam lines in undersized lines
- Excessive standby losses due to oversized lines
- Steam lost due to failure of steam traps
- Condensate sent to drain rather than returned
- Heat loss from un-insulated pipes valves and fittings

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Losses in domestic hot water

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- Leaking faucets/valves
- Appropriate temperatures
- Shut down recirculation during unoccupied periods
- Flow restricting devices
- Insulation of equipment
  - Tanks
  - Recirculation lines

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Insulation opportunities

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- Repair damaged insulation
- Insulate non-insulated pipes and vessels
- Insulate valves and flanges
- Paint/wrap tank/pipe surfaces with low-E/aluminum paint/foil
- Add/Upgrade insulation up to the economical thickness

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Cooling plant

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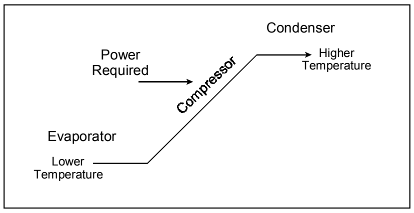

Refrigeration EMOs - some questions

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- Are the condensing devices clean and well maintained?
- Are the evaporator devices clean and well maintained?
- How is defrosting accomplished on freezer units?
- Are inlet refrigerant lines insulated properly?
- Are controls operating properly (small and large units)?
- Is there a regular maintenance program for the refrigeration systems?
- Do condensers and cooling towers have adequate cool air?
- Does simultaneous heating and cooling occur?
- Can evaporator temperature be increased?
- Can condenser temperature be reduced?
- Are the compressor crankcase heaters off during the warmer months of the year?

Refrigeration EMOs - more questions for the experts

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- Is the refrigeration unit appropriate to the load?
- How do the refrigeration systems handle part load conditions?
- Has the heat load within refrigerated spaces been minimised?
- Can thermal storage avoid peak demand caused by refrigeration systems?

Minimize temperature lift

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- **Match the requirement**
  - Setup space temperatures
- Clean heat exchange surfaces
- Reduce condenser temperature
  - Look at cool air supply
- Increase evaporator temperature
  - Chilled water reset

Reduce the cooling load

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- Building insulation
- Window solar radiation control
- Reduce infiltration
  - especially warm moist air
- Refrigerant line insulation

Maintenance & monitoring

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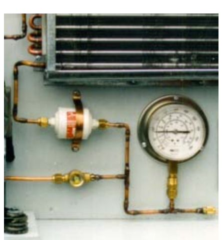
- Use the sight glass to check condition of refrigerant
- Lubrication
  - leading cause of failure
- Log operating conditions



Higher cost opportunities

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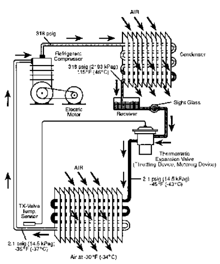
- Avoid head pressure control
  - Save 20-40%
- Avoid hot gas bypass
  - 35-40% power in bypass
- Compressor upgrade
  - Higher efficiency or variable speed



Match the requirement

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- What are the requirements?
  - Temperature, RH, illumination, ventilation
- What energy is being consumed?
- What energy should be consumed?
- Why is there a difference?
  - Eliminate waste

Maximize efficiency

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- How do operation and maintenance practices impact energy use?
  - Schedules
  - Temperatures
  - Damper condition
  - Heat exchanger fouling
- Is more efficient technology available?
  - Lighting
  - Boilers & chillers
  - Controls

Chiller efficiency

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Electric Chiller		New Chiller kW/ton	Existing kW/ton
Reciprocating		.78 to .85	.90-1.2 or higher
Screw		.62 to .75	.75-.85 or higher
Centrifugal	High	.50 to .62	NA
	Moderate	.63 to .70	.70-.80 or higher

Note: ton of refrigeration = 12 000 Btu/hr

Efficiency in air distribution systems

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- **Match the need** - ensure that neither too little nor too much air is supplied to a given area
- **Eliminate waste** - clean filters to prevent high back pressures
- Clean ventilation ducts to eliminate the additional flow resistance caused by dirt deposits
- **Optimise efficiency** by using fan speed control to regulate air flow rather than dampers

Waste heat recovery

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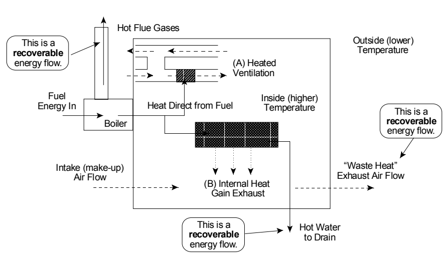

Match the source to use

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- What waste heat sources are available?
  - What quantity of heat is available?
  - At what temperature is the heat available?
- Where can the heat be used?
  - How much energy is required and at what temperature?
  - What is the time coincidence between waste and use?
  - At what location is the heat required?
- What is the practical recovery rate - what portion of the waste heat may be used?

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Simple heat exchange

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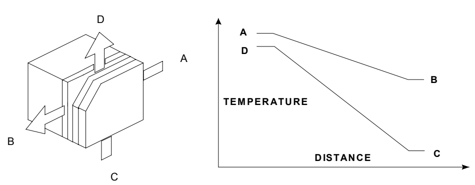

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Heat recovery methods

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- Direct
  - From one outflow to another inflow
  - From higher to lower temperature
  - Rate depends upon approach temperature
- Indirect
  - From one energy form to another
  - Typically requires outside energy input

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Direct heat recovery

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Regime	Exchanger	Typical Use
Gas - Gas	Cross Flow	Commercial Air Exchange
	Rotary	Flue Gas Heat Recovery
	Regenerative	High Temp. / Low Volume Exhaust
Liquid - Liquid	Shell & Tube	Process Water, Oil Coolers
	Spiral	High Pressure Cooling
	Plate & Frame	Dairy, Process Water
	Heliflow	Oil Coolers
Gas - Liquid	Recovery Boiler	Furnace , Engine Exhaust
	Evaporative	Water Cooling, Humidification, Exhaust Gas Scrubber
	Air Cooling	Oil Cooler, Space Heating

Gas to gas

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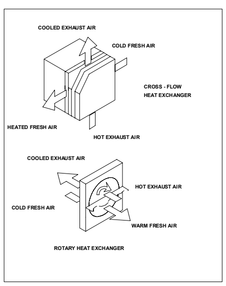

Liquid to liquid

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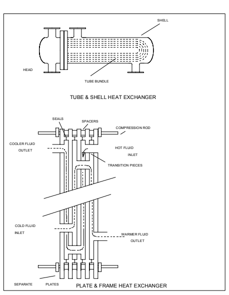

Gas to liquid

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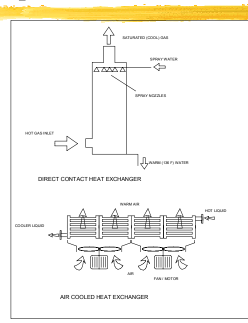

Indirect heat recovery

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Regime	Exchanger	Typical Use
Thermal - Thermal	Heat Pump	Space Heating, Hot Water Production
	Absorption Chiller	Water Chilling, Space Heating
	Flash Tank	Boiler Blow down
	Mechanical Vapour Recompression	Brewing, Sugar Processing
	Combustion of Waste Gases	Sewage Treatment, Foundries
Thermal - Mechanical / Electrical	Expansion Turbine	Chemical Plants
	Rankine Cycle	High Temperature Waste Gas

Heat pump

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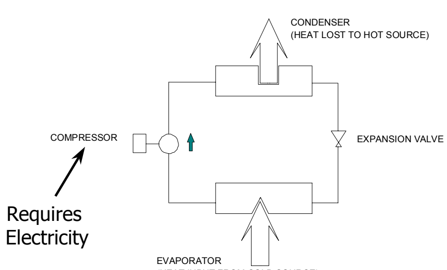

Flash tank

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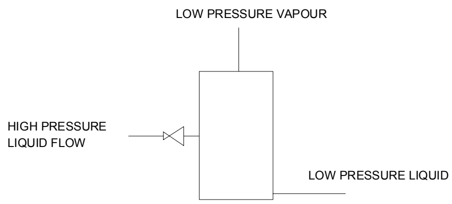

Creates steam from a hot high pressure liquid.

Compressed air systems

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Compressed air is expensive - typical efficiency is 5% to 20%

Hole Diameter	Air Leakage @ 600 kPa (87 psi) (Gauge)
1 mm	1 l/s
3 mm	10 l/s
5 mm	26.7 l/s
10 mm	105.7 l/s

Compressed air EMOs - some questions

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- Are you supplying leaks in distribution system/end use?
- Is the supply pressure higher than required to overcome pipe loss?
- Can you reduce the requirement for air?
- Can compressor inlet pressure be raised?
- Can compressor inlet temperature be dropped?
- Is compressor drive system efficient?
- Do screw compressors have proper capacity control?
- Is storage capacity large enough?

Compressed air EMOs

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- Reduce leaks in air distribution system and at point of use
- Reduce compressed air system pressure
- Reduce compressed air requirements
- Ensure low inlet restrictions (clean air filter)
- Reduce inlet air temperature (relocate the intake)
- Provide sequencing control of air compressors
- Use screw compressors with capacity control
- Consider two stage compression with cooling

Building control systems

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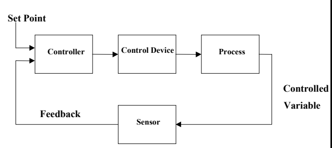
- Three components
  - sensors
  - controllers
  - control devices



HVAC control loop

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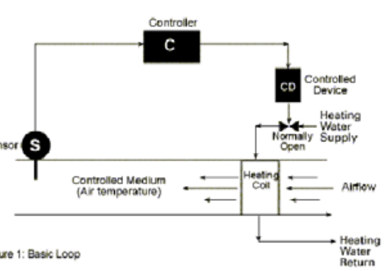

Figure 1: Basic Loop

Efficiency through control - 4 principles

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- Run equipment only when needed
- Sequence Heating and Cooling
- Provide only the heating or cooling required
- Supply heating and cooling from the most efficient source

Control applications

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- Programmed Start/Stop
- Optimised Start/Stop
- Duty cycling
- Demand control
- Temperature setback/setup
- Alarms/monitoring
- Energy monitoring
- Optimised ventilation
- Optimisation of supply air temperature
- Supply water optimisation
- Chiller/boiler optimisation
- Other control options
  - Interior and exterior lighting
  - Domestic hot water temperature
  - Cistern flow optimisation

Module 10: Assessing the Business Case

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DME-Danida Capacity Building in Energy Efficiency & Renewable Energy

Analysing the costs and benefits

Learning objectives

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- Do preliminary assessment of proposed energy management investments

Objectives of investment appraisal

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- Which investments make the best use of available money?
- Ensure optimum benefits from investment
- Minimise the risk
- A basis for subsequent performance analysis

Investment Criteria

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- Simple Payback

$$SPP\,(years) = \frac{Capital\ Cost}{Annual\ Savings}$$

- Return on Investment (ROI) and Internal Rate of Return (IRR)

$$ROI = \frac{Total\ Energy\ Savings\ (For\ Life\ of\ Project) - Estimated\ Project\ Cost}{Estimated\ Project\ Cost} \times \frac{100}{Project\ Life}$$

- Net Present Value (NPV) and Cash Flow

$$FV = PV \times (1+i)^n \quad \text{or} \quad PV = \frac{FV}{(1+i)^n}$$

Simple payback period

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- Quick and easy way of assessing financial merits of measures
- Does not account for:
  - cost of money
  - anything after payback period

$$SPP(years) = \frac{Capital\ Cost}{Annual\ Savings}$$

Cash flow analysis

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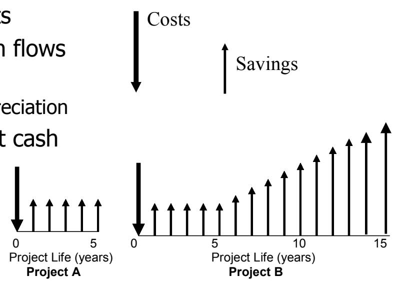
- Capital costs
- Annual cash flows
  - Taxes
  - Asset depreciation
- Intermittent cash flows



Cash flow table

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Table 7.1: Cash Flow Table for Purchase of new Boiler						
Capital Expenditure R100,000 Expected Savings R48,000			90% on delivery/commissioning, and 10% performance guarantee due at one year. Half in first year, full amount in all remaining years.			
(Values in R'000)						
Year	**0**	**1**	**2**	**3**	**4**	**5**
Costs	(90.0)	(10.0)	0	0	0	0
Savings	0	24.0	48.0	48.0	48.0	48.0
Net cash flow	(90.0)	14.0	48.0	48.0	48.0	48.0
Net Project Value	(90.0)	(76.0)	(28.0)	20.0	68.0	116.0

$ROI = Total\ Energy\ Savings\ (For\ Life\ of\ Project) - Estimated\ Project\ Cost \quad x \quad 100$

5 year average ROI = 116 / 100 x 100/5 = 23.2%

Time value of money - discount factors

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$$PV = \frac{FV}{(1+i)^n}$$

Discount Factors 1/(1 + i)ⁿ						
Year (n)	0	1	2	3	4	5
Discount Factor						
6%	1	0.942	0.888	0.840	0.792	0.747
10%	1	0.909	0.826	0.751	0.683	0.620
20%	1	0.833	0.694	0.579	0.482	0.402
30%	1	0.769	0.591	0.456	0.350	0.270
40%	1	0.714	0.510	0.364	0.260	0.186
45%	1	0.690	0.476	0.328	0.226	0.156
50%	1	0.666	0.444	0.297	0.198	0.132

Net present value

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Table 7.3: NPV Calculation						
Year	0	1	2	3	4	5
Net cash flow (R000s)	(90.0)	14.0	48.0	48.0	48.0	48.0
The discounted cash flow at 10% can be found as follows:						
Year 0	1 x (90.0) = (90.0)					
Year 1	0.909 x 14.0 = 12.73					
Year 2	0.826 x 48.0 = 39.65					
Year 3	0.751 x 48.0 = 36.05					
Year 4	0.683 x 48.0 = 32.78					
Year 5	0.620 x 48.0 = 29.76					
NPV = the sum of all these values = 60.97 (compare to net project value = 116.0)						

Internal Rate of Return

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year	net cash flow	Discount	NPV	IRR
0	-90000	10%	R61,048.67	30.37%
1	14000	20%	R25,216.05	
2	48000	25%	R11,885.44	
3	48000	30%	R753.50	
4	48000	31%	-R1,250.47	
5	48000	35%	-R8,627.04	

Excel Spreadsheet

Payback and IRR

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Project Life (years)

Simple Payback (years)	1	2	3	4	5	10	15
1	0%	62%	84%	93%	97%	100%	100%
2		0%	23%	35%	41%	49%	50%
3			0%	13%	20%	31%	33%
4				0%	8%	21%	24%
5					0%	15%	18%
6						11%	15%
7						7%	12%
8						4%	9%
9						2%	7%
10						0%	6%

Risk and sensitivity analysis scenarios

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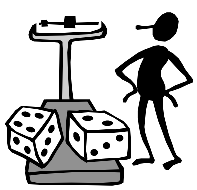
- Pessimistic
  - e.g. much higher interest rates
- Realistic
  - Best guess
- Optimistic
  - e.g. much higher energy costs



Module 11: Reporting for Implementation

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Getting action on the audit recommendations

Learning objectives

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- Prepare complete and effective energy audit reports

Writing good audit reports

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- Know your reader
- Use simple, direct language
  - Use an action-oriented style in the active (rather than passive) voice
  - Avoid technical jargon
- Ensure that your report is grammatically correct
- Present information graphically
- Make your recommendations clear
- Explain your assumptions
- Be accurate and consistent

A report template

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- Executive Summary
  - Summary information on key audit findings
  - The recommended EMOs
  - The implementation cost, savings, and payback
  - Any special information related to implementation
- Technical Section
  - details of your audit findings
  - Audit mandate, scope, and methodology
  - Facility description and observations
  - Assumptions and calculations
  - Audit recommendations
  - Appendices