Energy Audit

Definition of Energy Audit

- **As per Indian Energy Conservation Act 2001, Energy Audit is defined as:**

"the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption "

Why the Need for Energy Audit

- The three top operating expenses are energy (both electrical and thermal), labour and materials.
- Energy would emerge as a top ranker for cost reduction
- primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs
- Energy Audit provides a " bench-mark" (Reference point) for managing energy in the organization

Types of Energy Audits

1. Preliminary Energy Audit
2. Targeted Energy Audit
3. Detailed Energy Audit

Preliminary Energy Audit

- Preliminary energy audit uses existing or easily obtained data
- Find out the energy consumption area in the organization
- Estimates the scope for saving
- Identifies the most likely areas for attention
- Identifies immediate(no cost or low cost) improvements
- Sets a ‘reference point’
- Identifies areas for more detailed study/measurement

Targeted Energy Audits

- Targeted energy audits are mostly based upon the outcome of the preliminary audit results.
- They provide data and detailed analysis on specified target projects.
- As an example, an organization may target its lighting system or boiler system or compressed air system with a view to bring about energy savings.
- Targeted audits therefore involve detailed surveys of the target subjects/areas with analysis of the energy flows and costs associated with those targets.

Detailed Energy Audit

Detailed Energy Audit evaluates all systems and equipment which consume energy and the audit comprises a detailed study on energy savings and costs.

Detailed Energy Audit is carried out in 3 phases

- The Pre-audit Phase
- The Audit Phase
- The Post-Audit Phase

The Ten Steps for Detailed Audit

Step No	PLAN OF ACTION	PURPOSE / RESULTS
	<u>Phase I –Pre Audit Phase</u>	
Step 1	• Plan and organise • Walk through Audit • Informal Interview with Energy Manager, Production / Plant Manager	• Resource planning, Establish/organize a Energy audit team • Organize Instruments & time frame • Macro Data collection (suitable to type of industry.) • Familiarization of process/plant activities • First hand observation & Assessment of current level operation and practices
Step 2	• Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.)	• Building up cooperation • Issue questionnaire for each department • Orientation, awareness creation

	<u>Phase II –Audit Phase</u>	
Step 3	• Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	• Historic data analysis, Baseline data collection • Prepare process flow charts • All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution. • Design, operating data and schedule of operation • Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step 4	• Conduct survey and monitoring	• Measurements : Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.

Step 5	• Conduct of detailed trials /experiments for selected energy guzzlers	• Trials/Experiments: - 24 hours power monitoring (MD, PF, kWh etc.). - Load variations trends in pumps, fan compressors etc. - Boiler/Efficiency trials for (4 – 8 hours) - Furnace Efficiency trials Equipments Performance experiments etc
Step6	• Analysis of energy use	• Energy and Material balance & energy loss/waste analysis
Step 7	• Identification and development of Energy Conservation (ENCON) opportunities	• Identification & Consolidation ENCON measures ▪ Conceive, develop, and refine ideas ▪ Review the previous ideas suggested by unit personal ▪ Review the previous ideas suggested by energy audit if any ▪ Use brainstorming and value analysis techniques ▪ Contact vendors for new/efficient technology
Step 8	• Cost benefit analysis	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • Select the most promising projects • Prioritise by low, medium, long term measures
Step9	• Reporting & Presentation to the Top Management	Documentation, Report Presentation to the top Management.

Step10	<u>Phase III –Post Audit phase</u>	
	• Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance ▪ Action plan, Schedule for implementation ▪ Follow-up and periodic review

Questions which an Energy Auditor should ask

- What function does this system serve?
- How does this system serve its function?
- What is the energy consumption of this system?
- What are the indications that this system is working properly ?
- If this system is not working, how can it be restored to good working conditions/
- How can the energy cost of this system be reduced?

DETAILED ENERGY AUDIT
A TYPICAL INDUSTRIAL FORMAT OF REPORT

Energy Audit Team
Executive Summary –Scope & Purpose

Energy Audit Options & Recommendations

1.0 Introduction about the plant
- 1.1 General Plant details and descriptions
- 1.2 Component of production cost (Raw materials, energy, chemicals, manpower, overhead, others)
- 1.3 Major Energy use and Areas

2.0 Production Process Description
- 2.1 Brief description of manufacturing process
- 2.2 Process flow diagram and Major Unit operations
- 2.3 Major Raw material Inputs, Quantity and Costs

3.0 Energy and Utility System Description
- 3.1 List of Utilities
- 3.2 Brief Description of each utility
  - 3.2.1 Electricity
  - 3.2.2 Steam
  - 3.2.3 Water
  - 3.2.4 Compressed air
  - 3.2.5 Chilled water
  - 3.2.6 Cooling water

4.0 Detailed Process flow diagram and Energy& Material balance

4.1 Flow chart showing flow rate, temperature, pressures of all input-
Output streams

4Water balance for entire industry

5.0 Energy efficiency in utility and process systems

5.1 Specific Energy consumption

5.2 Boiler efficiency assessment

5.3 Thermic Fluid Heater performance assessments

5.4 Furnace efficiency Analysis

5.5 Cooling water system performance assessment

5.6 DG set performance assessment

5.7 Refrigeration system performance

5.8 Compressed air system performance

5.9 Electric motor load analysis

5.10 Lighting system

6.0 Energy Conservation Options & Recommendations

6.1 List of options in terms of no cost, low cost, medium cost and high cost, annual energy savings and payback

6.2 Implementation plan for energy saving measures/Projects

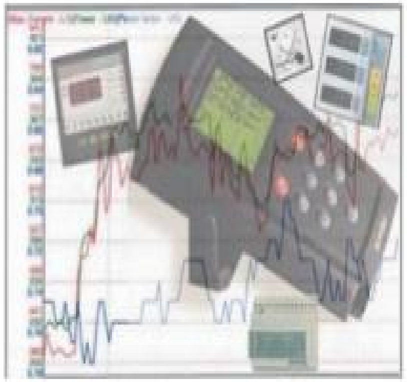
ANNEXURE

Al. List of instruments

A2. List of Vendors and Other Technical details

Energy Audit Instruments

POWER ANALYSERS



Electrical Measuring Instruments:

These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kvar, Amps and Volts. In addition some of these instruments also measure harmonics.

These instruments are applied on-line i.e on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.

FLUE GAS ANALYSERS

Combustion analyzer:

This instrument has in-built chemical cells which measure various gases such as CO_2, CO, NO_X, SO_X etc

Fuel Efficiency Monitor:

This measures Oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.

Fyrite:

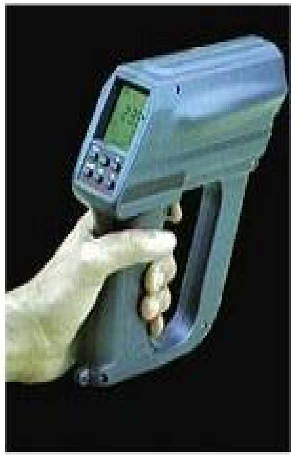
A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. Percentage Oxygen or CO_2 can be read from the scale.

TEMPERATURE MEASURMENTS

Contact thermometer:

These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream.

For surface temperature a leaf type probe is used with the same instrument.



Infrared Pyrometer:

This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. Can be useful for measuring hot jobs in furnaces, surface temperatures etc.

FLOW MEASURMENTS – AIR ,WATER

	**Pitot Tube and manometer:** Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.
	**Ultrasonic flow meter:** This a non contact flow measuring device using Doppler effect principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.

 Tachometer	 Stroboscope	**Speed Measurements:** In any audit exercise speed measurements are critical as thay may change with frequency, belt slip and loading. A simple tachometer is a contact type instrument which can be used where direct access is possible. More sophisticated and safer ones are non contact instruments such as stroboscopes.
		**Lux meters:** Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.

Identification of Energy Conservation Factors & Areas

Steps for conserving energy can be taken if we know the correct factors and areas to be studied and also details of fuels used.

These can be:

- Energy generation
- Energy distribution
- Energy usage by processes
- Fuel substitution

Technical and Economic feasibility-Factors

Technology availability, space, skilled manpower, reliability, service,Impact of measure on safety, quality, production or process.Maintenance requirements and spares availability

Sample Worksheet for Economic Feasibility

Name of Energy Efficiency Measure

i. Investment

a. Equipments
b. Civil works
c. Instrumentation
d. Auxiliaries

2. Annual operating costs

- Cost of capital
- Maintenance
- Manpower
- Energy
- Depreciation

3. Annual savings

- Thermal Energy
- Electrical Energy
- Raw material
- Waste disposal

Net Savings /Year (Rs./year)
= (Annual savings-annual operating costs)

Payback period in months
= (Investment/net savings/year) x 12

Energy Costs in Indian Scenario ?

Common Fuels

- Fuel oil,• Low Sulphur Heavy Stock (LSHS),• Light Diesel Oil (LDO),• Liquefied Petroleum Gas (LPG)
  • Coal,• Lignite,• Wood

Fuels Cost Inputs & Factors

- Price at source, transport charge, type of transport,
- Quality of fuel
- Contaminations, Moisture, Energy content (GCV)

Power Costs

In India Electricity costs vary substantially not only from State to State, but also from city to city and also within consumer to consumer – though power does the same work everywhere.

Reason:

•Tariff Structure

Energy conservation measures

The potential energy saving measures (ENCON) may be classified into three categories:

(a) Low cost – high return

(b) Medium cost – medium return

(c) High cost – high return

Table 4.1 Project Priority Guideline

Priority	Economical Feasibility	Technical Feasibility	Risk / Feasibility
A- good	Well defined and attractive	Existing technology adequate	No Risk/ Highly feasible
B-May be	Well defined and only marginally acceptable	Existing technology may be updated, lack of confirmation	Minor operating risk/May be feasible
C-Held	Poorly defined and marginally unacceptable	Existing technology is inadequate	Doubtful
D-No	Clearly not attractive	Need major breakthrough	Not feasible

Understanding energy costs

An industrial energy bill summary

ENERGY BILL EXAMPLE			
Type of energy	Original units	Unit Cost	Monthly Bill (Rs)
Electricity	5,00,000 kWh	Rs.4.00/kWh	20,00,000
Fuel oil	200,kL	Rs.11,000 KL	22,00,000
Coal	1000 tons	Rs.2,200/ton	22,00,000
Total			64,00,000

Conversion to common unit of energy

Electricity	(1 kWh)	= 860 kcal/kWh	(0.0036 GJ)
Heavy fuel oil	(calorific value, GCV)	=10.000 kcal/litre	(0.0411 GJ/litre)
Coal	(calorific value, GCV)	=4000 kcal/kg	(28 GJ/ton)

Benchmarking

- Benchmarking can be a useful tool for understanding energy consumption patterns in the industrial sector and also to take requisite measures for improving energy efficiency.

- FACTORS INVOLVED:
  - Scale of operation
  - use of technology
  - Raw material specifications and quality
  - Product specifications and quality

Benchmarking for Energy Performance

- Internal Benchmarking
  - Historical and trend analysis
- External Benchmarking
  - Across similar industries

    Scale of operation, use of technology, raw material specification and quality and product specification and quality

Bench Marking Energy Performance

- Quantification of fixed and variable energy consumption trends vis-à-vis production levels
- Comparison of the industry energy performance w.r.t. various production levels (capacity utilization)
- Identification of best practices (based on the external benchmarking data)
- Scope and margin available for energy consumption and cost reduction
- Basis for monitoring and target setting exercises

Benchmarking parameters

Production or Equipment Related

- **Gross production related**

e.g. kWh/MT clinker or cement produced (Cement plant)
e.g. kWh/MT, kCal/kg, paper produced (Paper plant)

- **Equipment / utility related**

e.g. kWh/ton of refrigeration (on Air conditioning plant)
e.g. kWh /litre in a diesel power generation plant.

Measuring Energy Performance

Production Factor = $\frac{\text{Current year's production}}{\text{Reference year's production}}$

- **Reference Year Equivalent Energy Use**
- The *reference year's equivalent energy use (or reference year equivalent)* is the energy that would have been used to produce the current year's production output.
- The reference year equivalent is obtained by multiplying the reference year energy use by the production factor (obtained above)
- **Reference year equivalent = Reference year energy use x Production factor**
- Plant Energy Performance is the improvement or deterioration from the reference year. It is a measure of plant's energy progress.

- **Plant energy performance = $\frac{\text{Reference year equivalent} - \text{Current year's energy}}{\text{Reference year equivalent}} \times 100$**

Maximizing System Efficiencies - Some Measures

- Replace pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy conservation equipment, wherever significant energy efficiency margins exist
- Eliminate steam leakages by trap improvements
- Maximize condensate recovery
- Adopt combustion controls for maximizing combustion efficiency

Matching Energy Usage to Requirement

- The mismatch between equipment capacity and user requirement often leads to inefficiencies due to part load operations, wastages etc. It is thus essential that proper energy matching studies are carried out & actions implemented.

Examples :

Eliminate throttling

Eliminate damper operations

Fan resizing for better efficiency.

Moderation of chilled water temperature for process chilling needs

Optimising Energy Input Requirement

- **In order to ensure that the energy given to the system is being put to optimal use, site specific measures and checks should be carried out regularly.**

- EXAMPLES:

- Shuffling of compressors to match needs.

- Periodic review of insulation thickness

- Identify potential for heat exchanger networking and process integration.

Identification of energy conservation opportunities

Fuel substitution

- Replacement of coal by coconut shells, rice husk etc
- Replacement of LDO by LSHS

Energy substitution

- Replacement of electric heaters by steam heaters
- Replacement of steam based hot water by solar systems

Energy Generation

- Captive power plant
- Steam generation

Energy usage by processes

- Analyze which process gets high energy consumption

Energy monitoring & targeting Importance

An effective monitoring & implementing system with adequate technical ability for analyzing energy saving options is key to ENERGY MANAGEMENT

Energy monitoring and targeting is primarily a management technique that uses energy information as a basis to eliminate waste, reduce and control current level of energy use and improve the existing operating procedures.

These techniques covers all plant and building utilities such as fuel, steam, refrigeration, compressed air, water, effluent, and electricity are managed as controllable resources in the same way that raw materials, finished product inventory, building occupancy, personnel and capital are managed.----It Becomes the "**Energy Cost Centers.**"

Elements of Monitoring & Targeting System

- **Recording** - Measuring and recording energy consumption
- • **Analyzing** - Correlating energy consumption to a measured output, such as production quantity
- • **Comparing** -Comparing energy consumption to an appropriate standard benchmark
- • **Setting Targets** -Setting targets to reduce or control energy consumption
- • **Monitoring** - Comparing energy consumption to the set target on a regular basis
- • **Reporting** -Reporting the results including any variances from the targets which have been set
- • **Controlling** - Implementing management measures to correct any variances, which may have been occurred.
- **Particularly M&T system will involve the following:**
- **Checking** the accuracy of energy invoices
- **Allocating** energy costs to specific departments (Energy Accounting Centres)
- **Determining** energy performance/efficiency
- **Recording** energy use, so that projects intended to improve energy efficiency can bechecked
- **Highlighting** performance problems in equipment or systems

Data and Information Analysis

- Plant level information can be derived from financial accounting systems-utilities cost centre
- Plant department level information can be found in comparative energy consumption data for a group of similar facilities, service entrance meter readings etc.
- System level (for example, boiler plant) performance data can be determined from sub metering data
- Equipment level information can be obtained from nameplate data, run-time and schedule information, sub-metered data on specific energy consuming equipment

TABLE 8.2 FUEL CONVERSION DATA

Energy source	Supply unit	Conversion Factor to Kcal
Electricity	kWh	860
HSD	kg	10,500
Furnace Oil	kg	10,200
LPG	kg	12,000

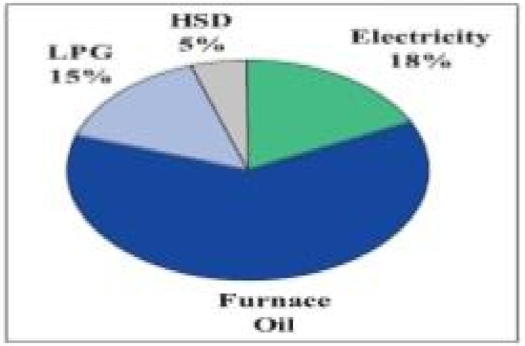


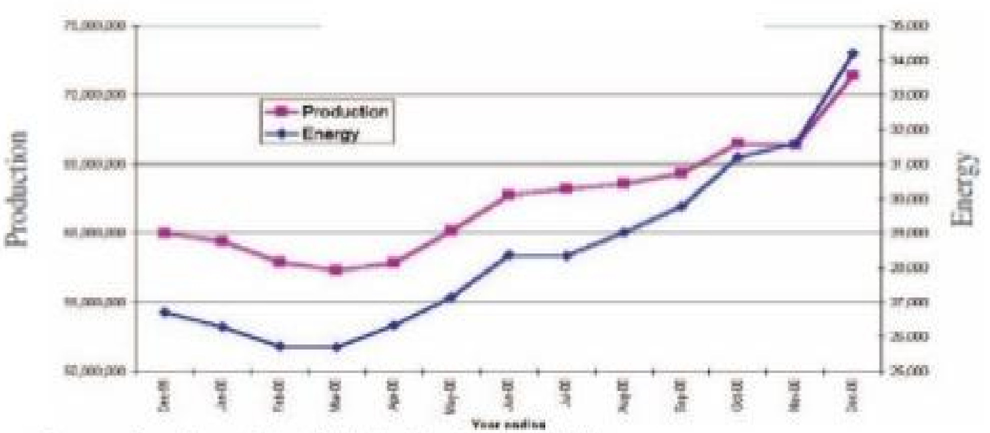
TABLE 8.1 ANNUAL ENERGY COST SHEET

	Thermal Energy Bill				Electricity Bill				Total Energy Bill
Month	Fuel 1	Fuel 2	Fuel 3	Total Rs. Lakh	Day kWh	Night kWh	Maximum Demand	Total Rs. Lakh	Rs.Lakh
1									
2									
3									
4									
b-Total									
%									

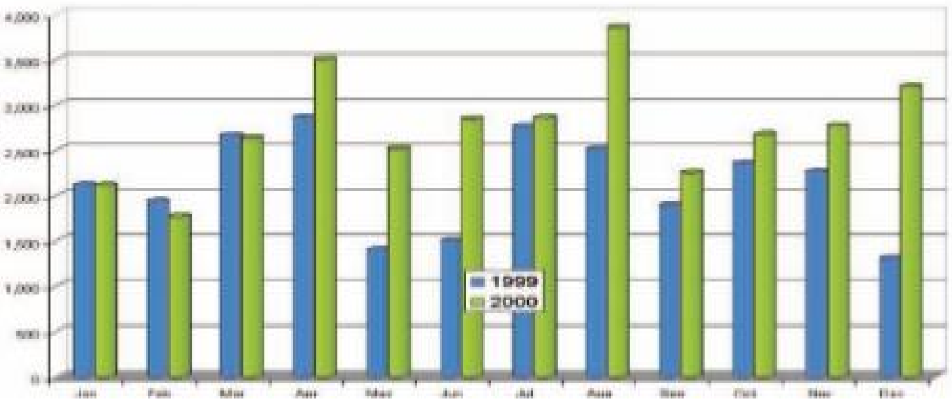
Relating Energy Consumption and Production

- After collection of energy consumption, energy cost and production data, the next stage of the monitoring process is to study and analyze the data and represent it for day to day controls—so represent it graphically

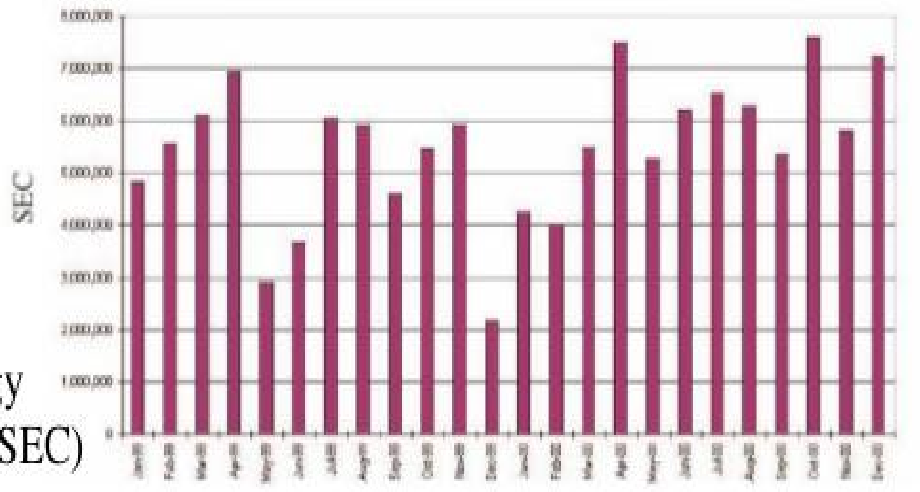
Moving Annual Total - Energy and Production



Energy Consumption :Current Year(2000) Vs. Previous year(1999)

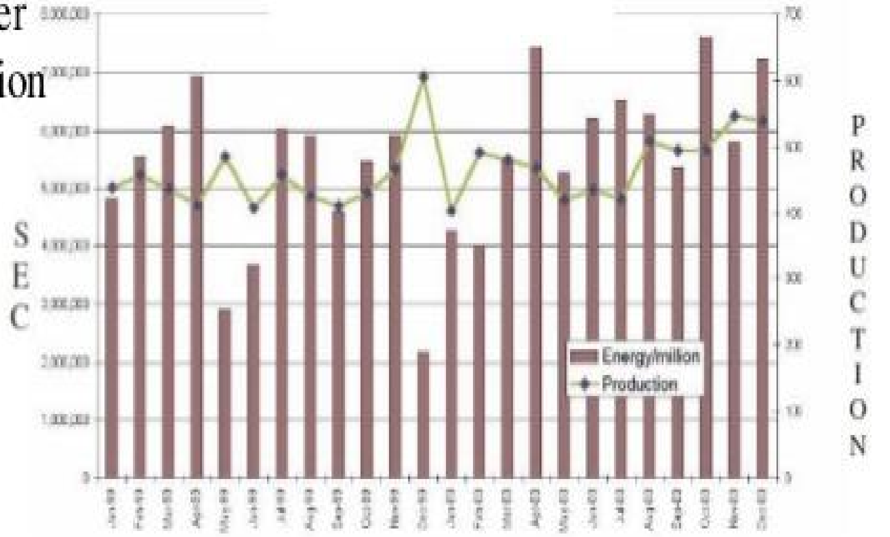


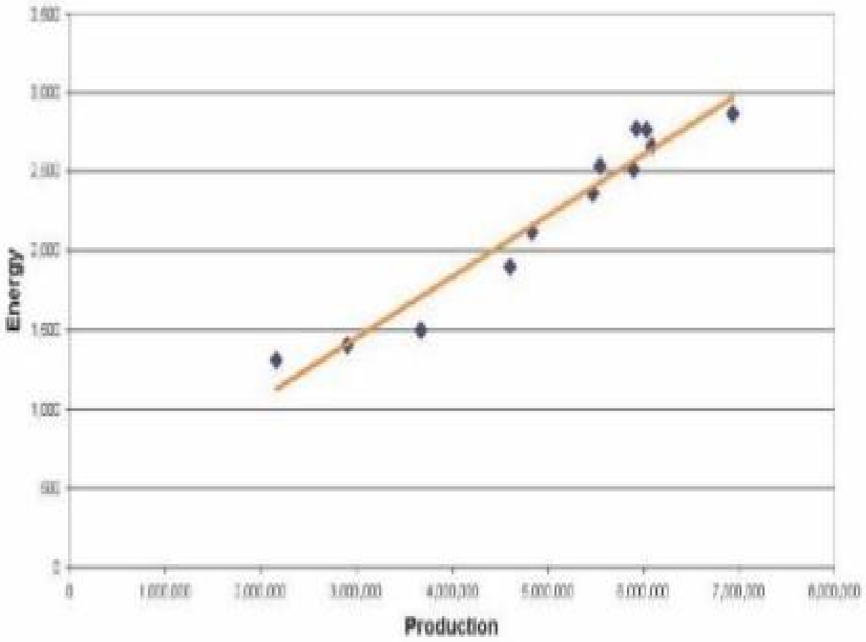
Monthly Specific Energy Consumption



Specific Energy Consumption(SEC) is energy consumption per unit of production

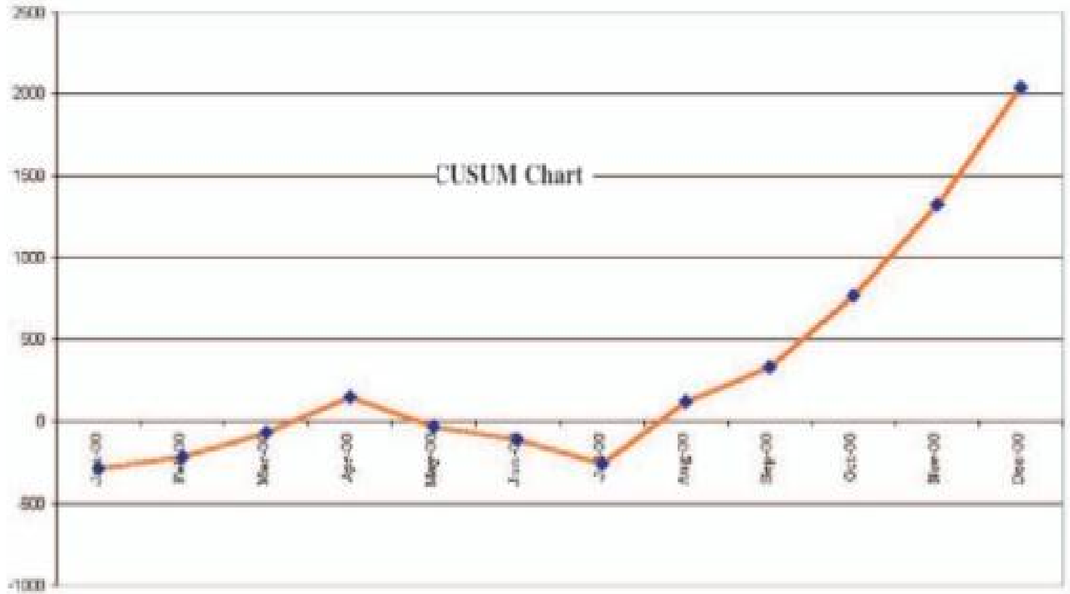
SEC With Production




Energy
Production
0
500
1,000
1,500
2,000
2,500
3,000
3,500
1,000,000
2,000,000
3,000,000
4,000,000
5,000,000
6,000,000
7,000,000
8,000,000

CUSUM -Cumulative Sum

- Cumulative Sum (CUSUM) represents the difference between the base line and the actual consumption points over the base line period of time.
- This useful technique not only provides a trend line, it also calculates savings/losses to date and shows when the performance changes.



CUSUM Technique

CUSUM analysis

4-Analysis-TABLE

1 Plot the Energy - Production graph for the first 9 months
2. Draw the best fit straight line
3. Derive the equation of the line, y=mx+c
4. Calculate the expected energy consumption based on the equation
5. Calculate the difference between actual and calculated energy use
6. Compute CUSUM
7. Plot the CUSUM graph
8. Estimate the savings accumulated from use of the heat recovery system

Month	E_{act} - Monthly Energy Use (toe * / month)	P - Monthly Production (tonnes / month)
1	340	380
2	340	440
3	380	460
4	380	520
5	300	320
6	400	520
7	280	240
8	424	620
9	420	600
10	400	560
11	360	440
12	320	360
13	340	420
14	372	480
15	380	540
16	280	280
17	280	260
18	360	500

* toe = tonnes of oil equivalent.

1-Given

2-plot graph

3-fit equation

$$E = 0.4\,P + 180$$

Case Study
The CUSUM Technique

Energy consumption and production data were collected for a plant over a period of 18 months.
During month 9, a heat recovery system was installed. Using the plant monthly data, estimate
the savings made with the heat recovery system. The plant data is given in Table 8.3:

TABLE 8.3 MONTH WISE PRODUCTION WITH ENERGY CONSUMPTION

Month	E_{act} - Monthly Energy Use (toe * / month)	P - Monthly Production (tonnes / month)
1	340	380
2	340	440
3	380	460
4	380	520
5	300	320
6	400	520
7	280	240
8	424	620
9	420	600
10	400	560
11	360	440
12	320	360
13	340	420
14	372	480
15	380	540
16	280	280
17	280	260
18	380	500

*** toe = tonnes of oil equivalent.**

TABLE 8.4 CUSUM

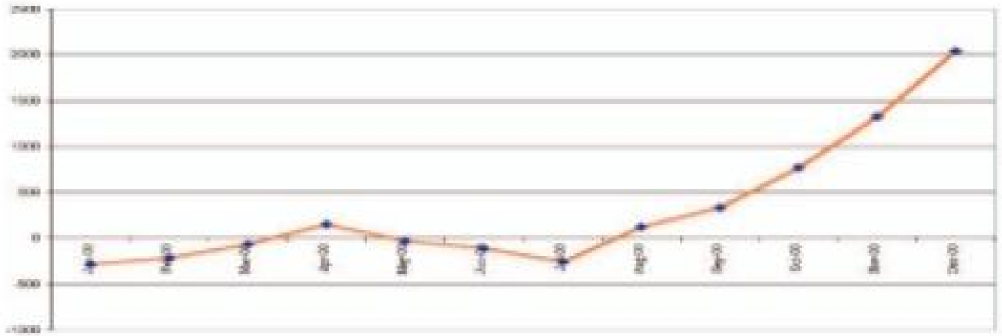
Month	E_{act}	P	E_{calc} (0.4 P + 180)	$E_{act} - E_{calc}$	CUSUM (Cumulative Sum)
1	340	380	332	+8	+8
2	340	440	356	-16	-8
3	380	460	364	+16	+8
4	380	520	388	-8	0
5	300	320	308	-8	-8
6	400	520	388	+2	-6
7	280	240	276	+4	-2
8	424	620	428	-4	-6
9	420	600	420	0	-6
10	400	560	404	4	-10
11	360	440	356	+4	-6
12	320	360	324	-4	-10
13	340	420	348	-8	-18
14	372	480	372	0	-18
15	380	540	396	-16	-34
16	280	280	292	-12	-46
17	280	260	284	-4	-50
18	380	500	380	0	-50

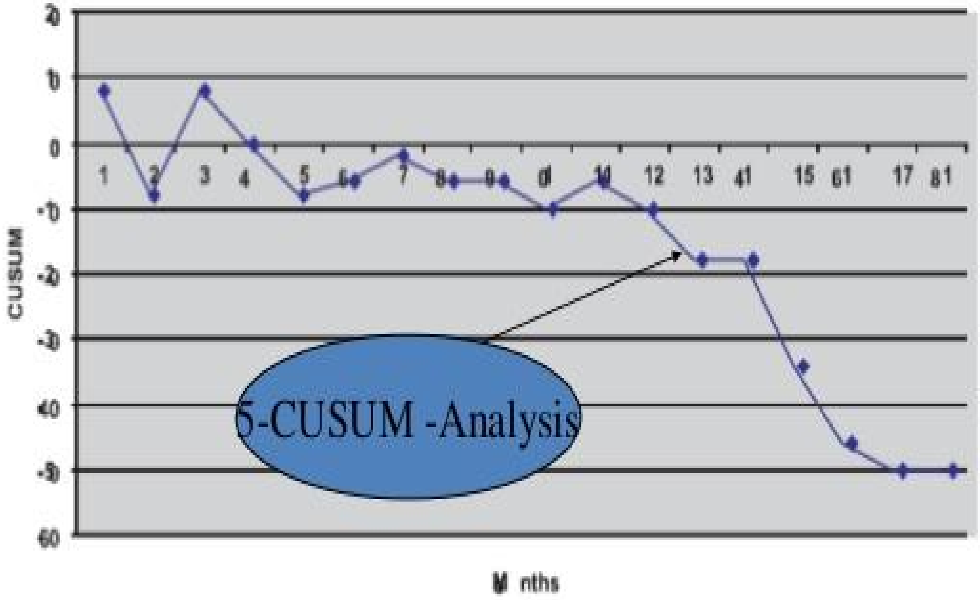
E_{act} - Actual Energy consumption E_{calc} - Calculated energy consumption

Based on the graph 8.10 (see Table 8.4), savings of 44 toe (50-6) have been accumulated in the last 7 months. This represents savings of almost 2% of energy consumption.

$$\frac{44}{2352^{\#}} \cdot 100 = 1.8\%$$

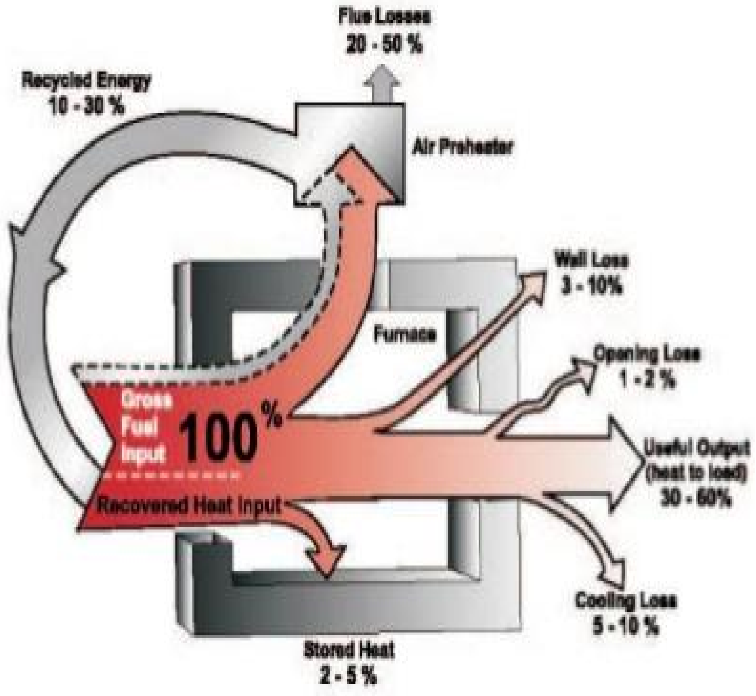
The CUSUM technique is a simple but remarkably powerful statistical method, which highlights small differences in energy efficiency performances. Regular use of the procedure allows the Energy Manager to follow plant performance and spot any trends early.





The Sankey Diagram and its Use The Sankey diagram is very useful tool to represent an entire input and output energy flow in any energy equipment or system such as boiler, fired heaters, furnaces after carrying out energy balance calculation. This diagram represents visually various outputs and losses so that energy managers can focus on finding improvements in a prioritized manner.

Example: The Figure 4.2 shows a Sankey diagram for a reheating furnace. From the Figure 4.2, it is clear that exhaust flue gas losses are a key area for priority attention.



Least Square Method

- We know, equation of slope,

Y=mx+c

Where,

"y" is dependent variable(i.e energy consumption)

"x" is independent variable(i.e production)

"c" is the value at which the straight line curve intersect the "y" axis.

"m" is the gradient of straight line curve.

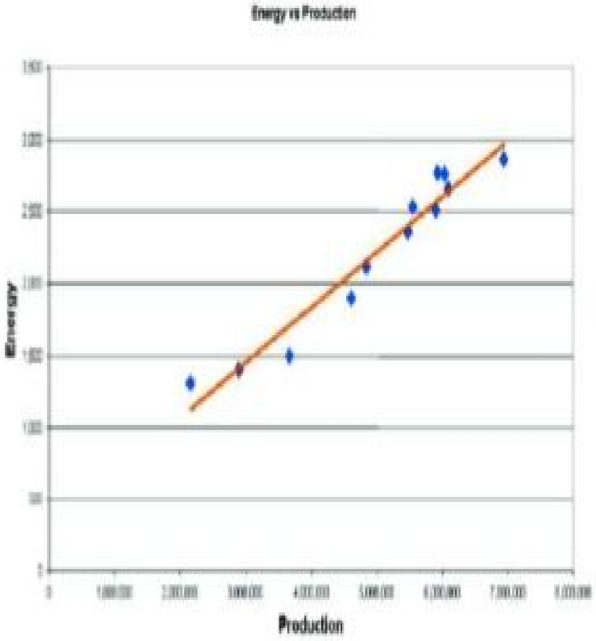


Figure 9.10 XY Chart for Energy-Production Relationship

Therefore,

Energy consumed for the period=C+m*production for the same period.

- Consider the sample points,

$(X_{1,}y_1).(x_{2,}y_2)......(x_{n,}y_n)$

Therefore,

Equation of straight lines are,

1. $cn+m\sum x=\sum y$
2. $c\sum x+m\sum X^2 = \sum xy$....(on the basis of production i.e independent variable)

n= no. of data points

These equations are known as normal equations of the problems and they can be used to establish the value of “c” and “m”.

Example

Consider a foundry which during a monitoring programme produces the following sample data:

Month	1	2	3	4	5	6	7	8	9
Production, Tonnes/month, x	380	440	460	520	320	520	240	620	600
Energy use, Toe/month, y	340	340	380	380	300	400	280	424	420

Answer

n	x	y	x^2	xy
1	380	340	144400	129200
2	440	340	193600	149600
3	460	380	211600	174800
4	520	380	270400	197600
5	320	300	102400	96000
6	520	400	270400	208000
7	240	280	57600	67200
8	620	424	384400	262880
9	600	420	360000	252000
	4100	**3264**	**1994800**	**1537280**

Therefore, the normal equations become,

$$9c + 4100m = 3264$$

$$4100c + 1994800m = 1537280$$

Therefore,

$$c = \frac{3264 - 4100m}{9}$$

Therefore,

$$4100\,(3264\text{-}4100m)/9 + 1994800m = 1537280$$

$$1486933 - 1867778m + 1994800m = 1537280$$

$$127022m = 50347$$

$$m = 0.4$$

and $$c = 180$$

The best fit straight line equation is therefore:

$$y = 180 + 0.4\,x$$

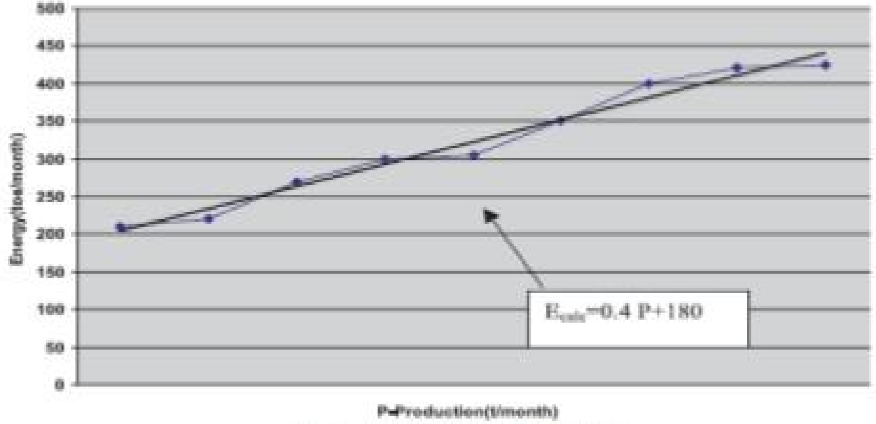


Figure 8.9 Energy Production Graph

Case studies

paper industry.pdf

cement industry.pdf

sugar industries.pdf

- THANK YOU