Online Preparatory Training Course

For

BEE Energy Managers /Energy Auditors

Certification Exam 2020

Paper-1
Session- 4
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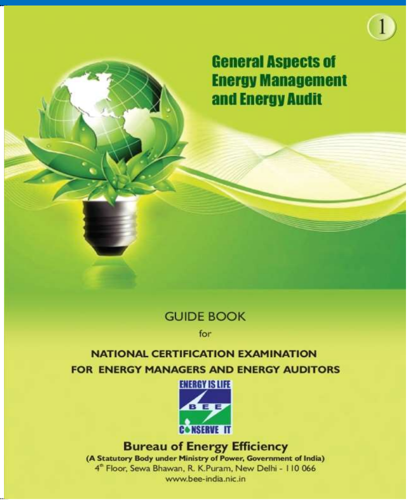
BOOK 1 – GENERAL ASPECTS OF ENERGY MANAGEMENT AND ENERGY AUDIT

Brief Contents



Chapter-9 Energy Monitoring and Targeting

Contents

Introduction

"you can't manage what you don't measure".

- Energy monitoring and targeting (M&T) 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.
- It essentially combines the principles of energy use and statistics.

- By using M&T, 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.**
- Monitoring and Targeting (M&T) programs have been so effective that they show typical reductions in annual energy costs in various industrial sectors between 5 and 15%.

9.2 What is Monitoring & Targeting?

Monitoring is the process of establishing the existing pattern of energy consumption and explaining deviations from existing pattern. Its primary goal is to maintain existing pattern by providing all the necessary data on energy consumption and key related data such as production.

Targeting is the identification of desirable energy consumption level and working towards achieving them. Targets are based on the historical (average or best) data acquired during the monitoring as wel as benchmarking with energy performance of similar organizations.

9.3 Setting up Monitoring & Targeting

The First step to Identify or Establish **Energy Account Centers** (EACs) within an organization before initiating M&T

- Ex Every departments, processes or cost centers.
- Operational managers should be accountable for the energy consumption of the EACs

Typical classifications are

✓ Single site **with central utility metering**
✓ Single site **with sub-metering**

✓ Multi-site **with central utility metering**
✓ Multiple-site **with sub-metering**

9.4 Key Elements of Monitoring & Targeting System

The key elements of M&T system are:

Recording

- Measuring and recording energy consumption of each EAC.
- Set up procedures for regular collection of reliable energy data.

Analysing & Comparing

- Relating energy consumption to a measured output for 12-24 months of historical data for each EAC.
- Standard energy performance is established through regression analysis of past data.
- If these data do not exist, conduct an energy audit to establish standard energy performance.It provides a *base line* for the assessment of future performance.

Setting Targets

- Set energy targets for each EAC.
- Targets can be set based on external benchmarking with other similar organization or historical achievement of least energy consumption in the same organization

Monitoring

- Comparing actual energy consumption to the set target on a regular basis

Reporting

- Reporting the results to management including any variances from the targets which have been set and related performance problems in equipment and systems.
- Generate reports for each EAC on a regular basis. Reports provide improved energy performance any improvements that are achieved.

Controlling

- Implementing management measures to correct any variances

What are the benefits of M&T

- Identify and explain an increase or decrease in energy use
- Draw energy consumption trends (weekly, seasonal, operational)
- Improve energy budgeting corresponding to production plans
- Observe how the organization reacted to changes in the past
- Determine future energy use when planning changes in operations
- Diagnose specific areas of wasted energy
- **Develop** performance targets for energy management programs / **energy action plans**
- Manage energy consumption rather than accept it as a fixed cost that cannot be controlled.

Where do you find Data and Information(Sources)?

Information related to energy use may be obtained

- **Plant level** : information **from financial accounting systems—utilities cost centre**
- **Plant department level** : found in comparative energy consumption data for a group of similar facilities, **service entrance meter readings** etc.
- **System level:** (ex- compressor house) performance data from **sub-metering data**
- **Equipment level** : obtained from **nameplate data, run-time and schedule information**, sub-metered data on specific energy consuming equipment.

Data & Information Analysis

Carry out Analysis of annual energy consumption

- **Convert all the energy** data into standard units
- **Compile the data - A**nnual energy consumption and cost for various fuel and energy types.
- **Compile information** : to produce % breakdown of the total energy consumption and cost of each energy type
- **Produce pie-charts** -graphically the energy and cost contribution
- **Identify trends** for past and current years

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

Standard Energy Conversions

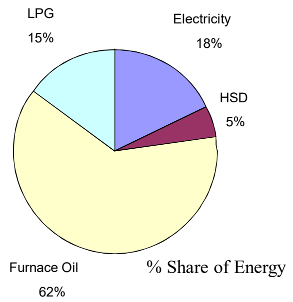
Annual energy cost sheet

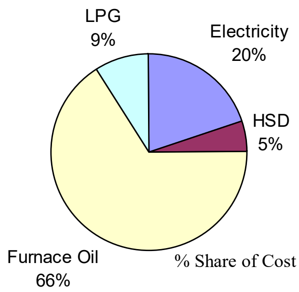
	Thermal Energy Bill				Electricity Bill				Total Energy Bill
Month	Fuel 1	Fuel 2	Fuel 3	Total Rs. Lakhs	Day Kwh	Night Kwh	Maximum Demand	Total Rs.Lakhs	Rs. Lakhs
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
Sub-Totals									
%									

Annual Energy Consumption and Cost for Various Fuels and Energy Types

Example of % Breakdown of Energy Consumption & Costs

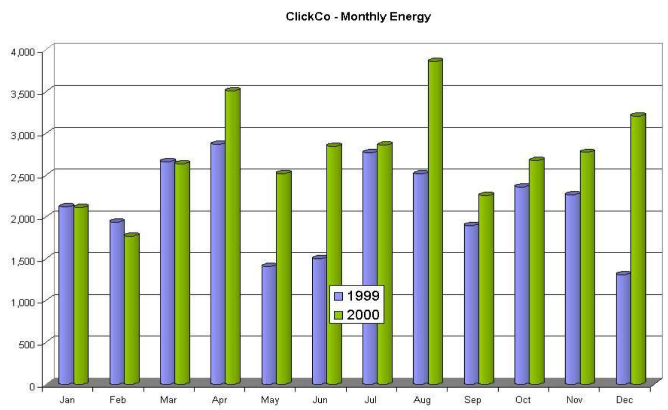
Energy Type	Purchased units	Consumption		Cost	
		kCal	%	Rs.	%
Electricity	1570	1350200	18	6280	20
HSD	36	378000	5	1620	5
Furnace Oil	456	4651200	62	20520	66
	110	1320000	15	2750	9





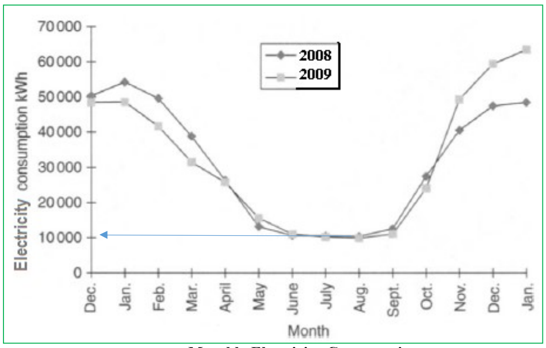
Relating Energy Consumption and Production.

Energy current year Vs Previous Year

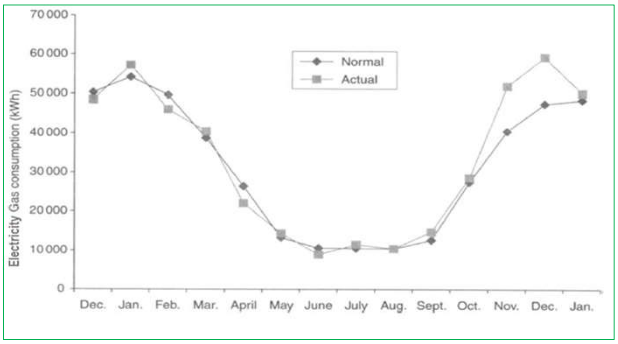


It does not tell full story about what is happening.

Time-dependent Energy Analysis



Monthly Electricity Consumption



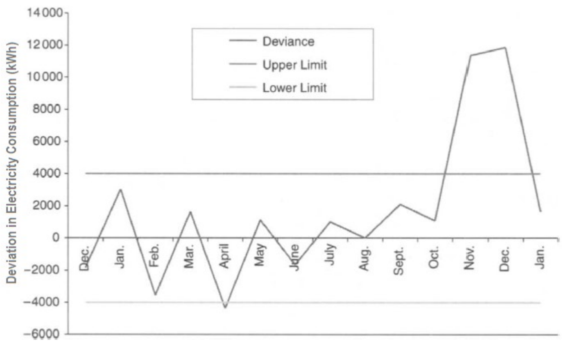
Norms Chart for Gas Consumption

Through this simple **time-dependent analysis**, it is possible to identify general trends **and seasonal patterns in energy consumption.** This enables exception to the norms to be identified immediately

It is a sequential plot of actual energy consumption overlaid on a plot of target consumption. It is easy to understand operational managers .

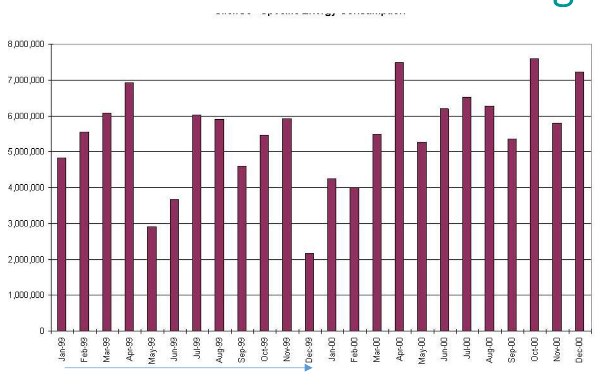
Deviance Chart

- Deviance charts plot the difference between target and actual energy consumption
- If, in any one month, energy consumption is above the target value, then the consumption is plotted as a positive value, by contrast a negative value is returned if actual consumption is lower than predicted.
- It helps to distinguish between normal limits and serious deviations from the norm.
- Deviance charts are good at highlighting problems, so that remedial action can be taken.

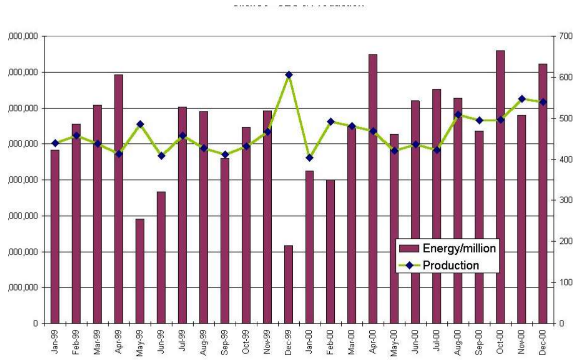


plot the difference between target and actual energy consumption

Relating Annual Energy and Production using Bar Chart



Monthly Specific Energy Consumption

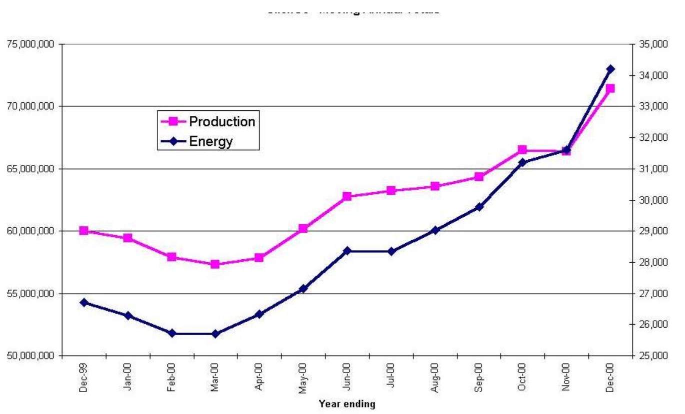


SEC with Production

EC is very low in December 1999 because of record level production This indicates there could be some fixed energy consumption

Moving Annual Total – Energy vs. Production

- *Draw this chart* If 12 months of energy & production data are available.
- Each point represents the sum of previous 12 months of data. It covers full range of the seasons, holidays. It smoothes out errors in the timings of meter readings
- If energy and production are plotted in the same chart and are tracking each other as shown
- Any deviations in energy line has to be watched for **early warning of energy waste** or energy efficiency measures are making a positive impact.



Linear Regression Analysis

- **Regression analysis overcomes the limitation of time-dependent analysis by removing the 'time' element** from the analysis and focusing instead on the variables which influence energy consumption.
- The variables compared are:
  - Furnace Oil consumption versus units of production.
  - Electricity consumption versus units of production.
  - Water consumption versus units of production.
  - Electricity consumed by lighting versus hours of occupancy.
- Regression analysis is very much dependent on the quality of the data used.

Factors which influence Energy Consumption

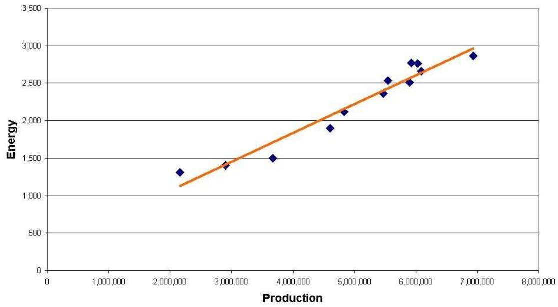
Energy	Purpose	Influencing Factors
Electricity	Air compressors	**Air volume delivered**
Furnace oil	Steam raising in boilers	**Amount of steam generated**
Steam	Production process	**Production volume**

Energy vs. Production

a) Single Independent Variable : XY Scatter Diagram

- XY Scatter Diagram provides more understanding of relationship between energy and production.
- This chart shows a low degree of scatter indicative of a **good fit.**
- **If data fit is poor,** it indicates poor level of control and hence a scope /potential for energy savings.
- A relationship relating production & energy consumption is obtained.

Ex. If energy consumption in toe (i.e. a dependent variable) and production in Metric tonnes (i.e. an independent variable) in a furnace

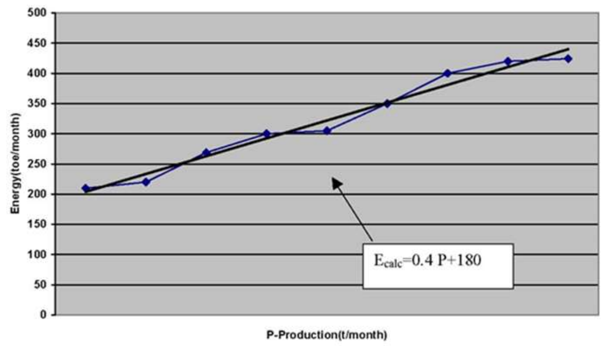


The equation for a straight-line graph

$$y = mx + c$$

y is the dependent variable (e.g. energy consumption),
x is the independent variable (e.g.production),
c is the value at line intersects the 'y' axis, and
m is the gradient of the straight-line curve.

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



Derive equations

$9c + 4100m = 3264$

$4100c + 1994800m = 1537280$

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

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

$1486933 - 1867778m + 1994800m = 1537280$

$127022m = 50347$

$m = 0.4$

and $c = 180$

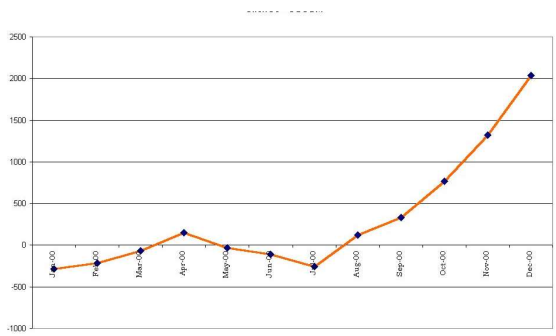
The best fit straight line equation is therefore:

$y = 180 + 0.4\,x$

The same relationship can be obtained by plotting in a graph as shown in Fig.

Cumulative Sum **(CUSUM)** Technique

- Difference between expected or standard consumption with actual consumption data points over baseline period of time.
- Follows a fixed trend unless something (energy saving measure, deterioration in performance..) happens
- Helps calculation of savings/losses till date after changes
- From the chart, it can be seen that starting from year 2000, performance is better than standard. Performance then declined (line going up) until April, and then it started to improve until July.
- However, from July onwards, there is a marked, ongoing decline in performance – line going up



CUSUM chart -Example

CUSUM -Example

Steps for CUSUM analysis

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 E = 0.4 P + 180
4. Calculate the expected energy consumption based on the equation
5. Calculate the difference between calculated and actual energy use
6. Compute CUSUM (refer table in next slide)
7. Plot CUSUM graph
8. Estimate savings accumulated from heat recovery system use

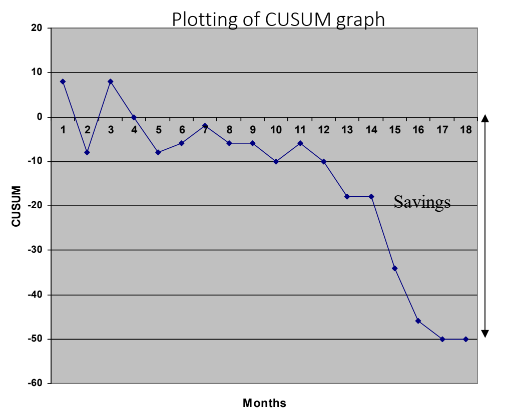
During month 9, heat recovery system was installed

Table: 9.6 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

CUSUM

Month	E_{act}	P	E_{calc}	$E_{act} - E_{calc}$	CUSUM
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



- CUSUM graph oscillates around the zero line for several months and then drops sharply after month 11.
- This suggests that the heat recovery system took almost two months to commission and reach proper operating conditions, after which steady savings have been achieved.
- Savings of 44 toe (50-6) have been accumulated in the last 7 months. This represents savings of almost 2% of energy consumption.

Solved Example:

The Energy- production data (**for Jan-June, 2011**) of an industry follows a relationship:
Calculated energy consumption = **0.5 P +220.**
A Waste heat recovery system was installed at **end of June 2011** and further data was gathered up to December 2011. Using CUSUM technique, calculate energy savings in terms of ton of oil equivalent (**toe**) and the reduction in specific energy consumption achieved with the installation of waste heat recovery system. The plant data is given in the table below.

2011-Month	Actual Energy Consumption, toe/month	Actual production, ton/month
Jan	620	760
Feb	690	960
Mar	635	790
Apr	628	830
May	545	610
Jun	540	670
July	**590**	**760**
Aug	**605**	**820**
Sep	**670**	**940**
Oct	**582**	**750**
Nov	**512**	**610**
Dec	**540**	**670**
		4550

Ans:

The table below gives values of actual energy consumption vs. calculated (predicted) energy consumption from July –Dec. 2011.
Specific energy consumption monitored vs. predicted for each month. The variations are calculated and the Cumulative sum of differences is calculated from Jan-June-2011.
Energy savings achieved = **96 toe**

2011-Month	Eact.	Ecal 0.5P+220	Eact - Ecal	CUSUM
July	**590**	600	-10	-10
Aug	**605**	630	-25	-35
Sept	**670**	690	-20	-55
Oct.	**582**	595	-13	-68
Nov.	**512**	525	-13	-81
Dec.	**540**	555	-15	**-96**

Reduction in specific energy consumption = 96/4550 = 0.021 toe/tonne of production (Production for 6 months = 760+820+940+750+610+670 = **4550 tonnes**).

Objective Type Questions

1.	A chart in Scatter Diagram shows a low degree of scatter. It is indicative of------ a) good fit b) poor fit c) skewed fit d) normal fit
2.	Between variables and enables standard equations to be established for energy consumption. a) linear regression analysis b) time-dependent energy analysis c) moving annual total d) CUSUM
3.	In a cumulative sum (CUSUM) chart, if the graph is going up, then a) nothing can be said b) actual and calculated energy consumption are the same c) energy consumption is reduced d) specific energy consumption is going up
4.	Energy monitoring and targeting is built on the principle of “ _____”. a) “production can be reduced to achieve reduced energy consumption” b) “Consumption of energy is proportional to production rate” c) “You cannot manage what you do not measure” d) None of the above.
5.	Which of the variable does not contribute to energy consumption? a) production b) hours c) climate d) none of the above

1a,2a,3d,4c,5d

Practice Problems

L-1 In a food processing plant the monthly production related (variable) energy consumption was 1.8 times the production and non-production related (fixed) energy consumption was 15,000 kWh per month up to May 2010. In the month of June 2010 a series of energy conservation measures were implemented. Use CUMSUM technique to develop a table and calculate energy savings for the subsequent 6 months period from the data given below

Month	Production (kg)	Actual Energy Consumption (kWh)
Jul’ 10	62000	113600
Aug’ 10	71000	139000
Sep’ 10	75000	158000
Oct’ 10	59000	119300
Nov’ 10	62000	123700
Dec’ 10	73000	143600

L-2 Use CUSUM technique and calculate energy savings for first 6 months of 2011 for those energy saving measures implemented by a plant prior to January,2011.

The average production for the period Jan-Jun 2011 is 1000 MT/Month

The plant data is given in the table below.

2011-Month	Actual Specific Energy Consumption, kWh/MT	Predicted Specific Energy Consumption, kWh/MT
Jan	1203	1121
Feb	1187	1278
Mar	1401	1571
Apr	1450	1550
May	1324	1284
Jun	1233	1233

Thank You

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