Energy Conservation Opportunities & GHG Reductions in Textile Cluster

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Abstract- In this study Energy Audits have been done for a cluster of Textile Industries and its outcomes are discussed. The adopted approach & methodology for this study is based on the guidelines of BEE and also scientific approach related to technological, environmental and pollution related aspects. It has been found that energy audit is an important management tool provided Auditor & industry actively & positively participate in Audit exercise. It will not only improve energy performance of industry but also leads to cost as well as GHG reductions. In the study efficiencies of Boiler were evaluated and set of recommendations were suggested to improve the existing Boiler Efficiency. The implementations of suggestions would result in improvement of efficiency in the range of 10 to 17% with monetary benefits in the range of 15 to 42 Lakh per Annum with payback period of less than one year.

Index Terms- Boiler Efficiency, Energy Conservation, GHG Emissions,Heat Losses

I. INTRODUCTION

Ahmedabad is a well known Textile hub since ancient time. In one of the textile cluster of Ahmedabad, on request of the association, Energy Audit was carried out to find out the energy conservation opportunities and energy savings potentials. All the industries in the cluster are of small and medium scale textile industries. These industries are engaged in dyeing, processing, printing of textiles. These textile industries process about 10 million meters of fabric every year.

The process adopted by the units can be divided in to three major classes:

a. Fabric Pretreatment
b. Dyeing and Printing
c. Finishing

The Textile industries require a large amount of energy both in the form of electrical and thermal energy for processing. The cost of energy (electrical and thermal) varies between 15 to 20% of total manufacturing cost. Industries rely on boiler technologies for thermal energy. However, most of the units being in unorganized sector, are operating with limited resources in terms of technical manpower and technology. Hence, there exist potential of savings of about 20-30% fuel in application and increase the Boilers efficiencies.

This paper presents details of the study conducted on existing Boilers for efficiency analysis, possible energy savings opportunities and monetary benefits arising from the same, retrofication /up gradation in available technology/design and estimated GHG reduction.

To evaluate boiler efficiency, indirect method as "input-output method" was used, where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel. Monitoring at site was carried out to measure flue gas temperature, percent Oxygen, CO & CO_2 levels to evaluate efficiency of boilers.

II. STUDY DETAILS

Boiler is used for steam generation in Textile units. Processes requiring steam in a textile process house are jigger Dyeing, Jet Dyeing, Scouring, Mercerizing, Bleaching, Reduction and Clearance, Washing and shrinkage/Sanforizing. Typically, a boiler produce steam in the range of 6 kg/cm^2 to 10 kg/cm^2.

The said study was carried out in 5 of the selected units from cluster. Three of the units were using Coal (Lignite) as a fuel and two of the units were using wood chips as fuel. The Boiler capacity was ranging from 1 to 4 t/hr. All the boilers were packaged boilers. The details pertaining to boilers, fuel and their APCM for the study units are presented at Table No.1

Table No.1:
DETAILS OF BOILERS

Name of Industry	Boiler Capacity (t/h)	Type	Type of Fuel	Air Pollution Control Measures
Unit-1	1500	3-Pass, Wet Back,	Brown-coal(Lignite)	Multi cyclone followed by Water Scrubber

Unit-2	3000	Horizontal Fire Tube, Package Boiler	Brown-coal(Lignite)	Multi cyclone followed by Water Scrubber
Unit-3	4000		Brown-coal(Lignite)	Multi cyclone followed by Bag Filter
Unit-4	1000		Wood Chips	Multi cyclone followed by Water Scrubber
Unit-5	1000		Wood Chips	Cyclone followed by Bag Filter

III. FLUE GAS STACK MONITORING AND ANALYSIS

The flue gas stack Temperature, Percent Oxygen, Percent Carbon Dioxide and Percent Carbon Monoxide levels are primary indicator of combustion efficiency of boilers. The monitoring of the above parameters was carried out in the study units.

Stationary source sampling was conducted to evaluate gas stream emissions to the atmosphere from stacks/ducts. A pollutant's concentration is measured by extracting a known volume from the gas stream and determining the average stack gas flow rate over the sampling period.

The flue gas parameter are measured by following IS method and reported in **Table No. 2.**

Parameter	Monitoring & Analysis Method
CO_2,	IS 13270 : 1992 Reaf. :(2008)
O_2	IS 13270 : 1992 Reaf. :(2008)
CO	IS 5182 (Part-10) : 1999 Reaf. :(2009)

The results of monitoring are presented at **Table No.2.** The standard relation between Percent Oxygen, Percent Excess Air Supplied and Equivalent % CO_2 is presented at **Table No. 3.**

Table No.3
% O_2, % CO_2 and Excess Air Relation in Flue Gases

Percentage of O_2	Percentage of Excess Air Supplied	Equivalent Percentage of CO_2
1	5	17.1
2	11	16.3
3	17	15.4
4	24	14.6
5	31	13.7
6	40	12.8
7	50	12.0
8	62	11.1
9	75	10.3
10	91	9.4
11	110	8.6
12	133	7.7

Source: "Boilers" BEE Report.

IV. STEAM BOILER EFFICIENCY

Operating the boiler with at an optimum air to fuel ratio minimizes heat loss and improves combustion efficiency. Combustion efficiency is a measure of how effectively the heat content of a fuel is transferred into usable heat.

The Indirect method as "input-output method" is used, where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.

The indirect method is also called the heat loss method. The efficiency can be calculated by subtracting the heat loss fractions from 100 as follows:

Efficiency of boiler (n) = 100 - (i + ii + iii + iv + v + vi + vii+viii)

Whereby the principle losses that occur in a boiler are loss of heat due to:

H1	:	Dry flue gas
H2	:	Evaporation of water formed due to H2 in fuel
H3	:	Evaporation of moisture in fuel
H4	:	Moisture present in combustion air
H5	:	Radiation and other unaccounted losses
H6	:	Due to partial conversion of 'C' to 'CO'
H7	:	Unburnt fuel in fly ash
H8	:	Unburnt fuel in bottom ash

Boiler efficiency of all the five units understudy were evaluated and reported at **Table No. 2.** The table reveals that Boiler efficiency in the study units ranges from 57% to 65 %. The major efficiency losses are due to H1-Heat loss due to Dry Flue gas, H6- Partial conversion of 'C' to 'CO, H8- Heat loss due un burnt in bottom ash. The Heat losses due H2, H3 and H4 are related to poor fuel quality and ambient atmospheric conditions and could not be averted.

TABLE NO. 2
EXISTING BOILER EFFICIENCY

Sr. No.	Particulars	Unit -I	Unit-II	Unit-III	Unit-IV	Unit-V
1	Type of Boiler	3-Pass, Wet Back, Horizontal Fire Tube, Package Boiler				
2	Type of Fuel	Coal (Lignite)			Wood Chips	
3	Fuel Feeding System	Manually				
4	Calorific Value of Fuel (kCal/kg)	4000	4000	4000	4200	4200
5	Boiler Capacity(kg/hr)	1500	3000	4000	1000	1000
5	Fuel Consumption (kg/hr)	361	746	964	220	259
6	**Fuel Characteristics**					
	Ultimate Analysis					
	Carbon Content(%)	45.88	45.88	45.88	48.55	48.55
	Sulphur Content(%)	2.50	2.50	2.50	0.10	0.10
	Hydrogen Content(%)	3.78	3.78	3.78	6.99	6.99
	Oxygen Content(%)	9.89	9.89	9.89	41.93	41.93
	Nitrogen Content (%)	0.50	0.50	0.50	0.80	0.80
	Proximate Analysis					
	Moisture(%)	30.00	30.00	30.00	12.00	12.00
	Ash (%)	20.05	20.05	20.05	4.00	4.00
7	Percentage of Oxygen in Flue Gas	9.00	10.00	10.00	9.00	11.00
8	Percentage of CO_2 in flue Gas	10.00	9.00	9.00	8.00	6.00
9	Percentage of CO in flue Gas	1.00	1.00	1.00	1.00	1.00
10	Percent of Excess Air	75.00	90.91	90.91	75.00	110.00
11	Actual Mass of Air Supplied (kg/kg of fuel)	11.05	12.06	12.06	10.93	13.11
12	Flue Gas Temperature	220.00	220.00	200.00	200.00	220.00
13	Ambient Temperature	30.00	30.00	30.00	30.00	30.00
14	**HEAT LOSSES**					

H1	Heat loss due to Dry flue gas loss	14.87	16.32	14.59	13.02	17.78
H2	Heat loss due to evaporation of water formed due to H_2 in fuel	5.69	5.69	5.62	9.89	10.03
H3	Heat loss due to moisture present in the fuel	5.02	5.02	4.95	1.89	1.91
H4	Heat loss due to moisture present in the air	0.43	0.46	0.42	0.36	0.48
H5	Heat loss due to radiation and other unaccounted losses	2.00	2.00	2.00	2.00	2.00
H6	Heat loss due to partial conversion of C to CO	5.99	6.59	6.59	7.38	9.49
H7	Heat loss due unburnt in flyash	0.21	0.21	0.21	0.04	0.04
H8	Heat loss due unburnt in bottom ash	3.61	3.61	3.61	0.69	0.69
BOILER EFFICIENCY		**62.18**	**60.09**	**62.01**	**64.74**	**57.59**

V. ENERGY CONSERVATION OPPORTUNITIES & MEASURES TO IMPROVE BOILER EFFICIENCY

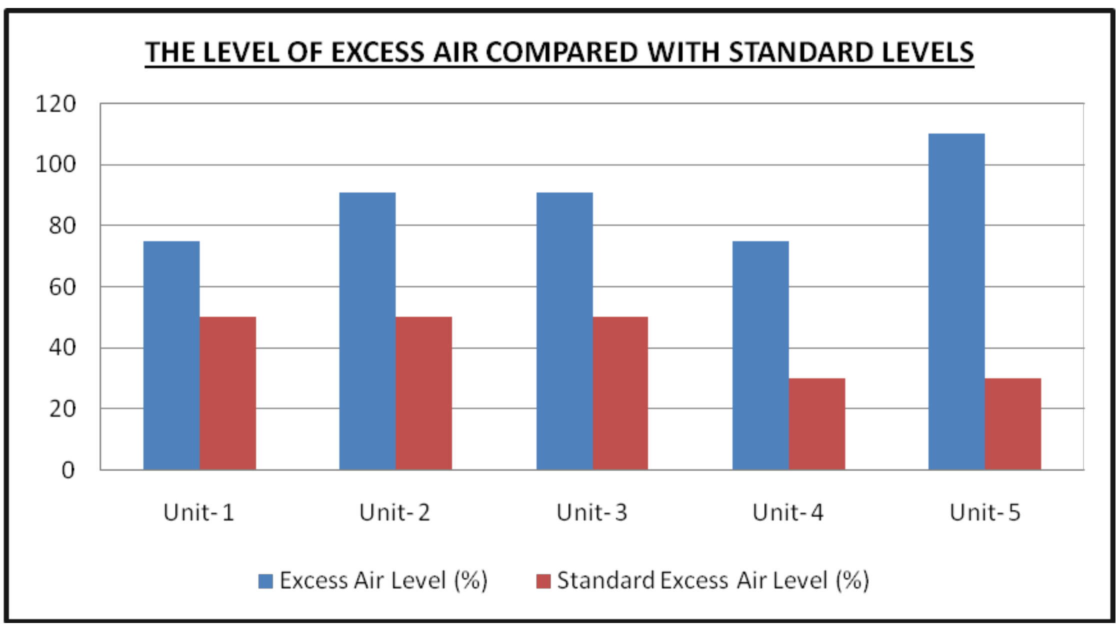
On the basis of energy audit conducted and the analysis of the heat losses and their causes, opportunities for improvement were identified to increase the efficiency of exiting boilers. The various measures identified are as follows:

1)CONTROL OF EXCESS AIR & FLUE GAS TEMPERATURE:

In the study units none of the units were having excess air control system. The levels of excess air and flue gas temperatures are shown in **Table No. 2** and graphically presented at **Figure No. 1.**

The excess air levels ranges from 75% to 110 % with oxygen level of 9 to 11%. As per the BEE Report, for under feed stroker boiler, excess air required for Coal fired boiler is in a range of 20-50 %, and for Wood fired 20-30%.E

Figure. No. 1
The levels of excess air and flue gas temperatures compared with standard range



Controlling excess air to an optimum level always results in reduction in flue gas losses. For every 1% reduction in excess air there is approximately 0.6% rise in efficiency. The units were suggested to control the excess air levels. The various available methods are as follows:

- Portable Oxygen analysers and draft gauges can be used to make periodic readings to guide the operator to manually adjust the flow of air for optimum operation. Excess air reduction up to 20% is feasible.
- The most common method is the continuous oxygen analyzer with a local read out mounted draft gauge, by which the operator can adjust air flow. A further reduction of 10-15% can be achieved over the previous system.

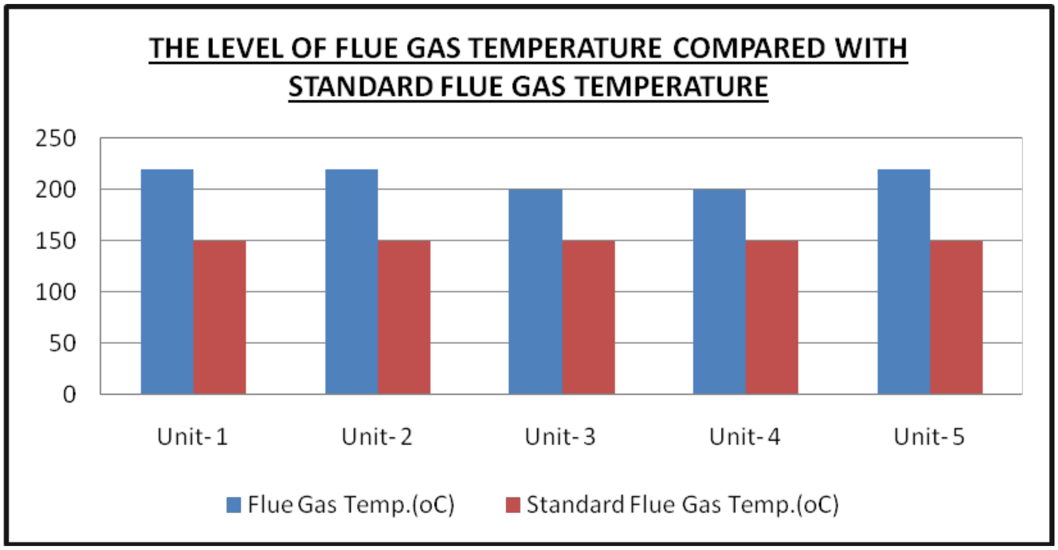
- The same continuous oxygen analyzer can have a remote controlled pneumatic damper positioned, by which the read outs are available in control room. This enables an operator to remotely control a number of firing systems simultaneously.

- The most sophisticated system is the automatic stack damper control, whose cost is really justified only for large systems. Automatic O_2 systems continuously monitor the flue gases and adjust the burner air supply. They are called "O_2 Trim Systems"

2) CONTROL OF FLUE GAS TEMPERATURE:

The flue gas exit temperature ranges from 200 to 220°C in study units. The levels flue gas temperatures are shown in **Table No. 2** and graphically presented at **Figure No. 2.**

Figure. No. 2
The level of flue gas Temperature Compared with Standard flue gas Temperature



None of the units were having heat recovery system. As per the BEE report, the excess temperature of flue gas must also be controlled and it should be between 140-160°C. (as per BEE Report). Approximately 1 % percent efficiency is gained per 40°F decrease in flue gas temperature.

The stack temperature should be as low as possible. However, it should not be so low that water in the exhaust condenses on the stack walls. This is important in fuels containing significant Sulphur as low temperature can lead to condensation of gaseous Sulphuric Acid on the surfaces of the metal when the gas temperature is lower than the acid dew point temperature(130-140°C).

Stack temperatures greater than 180-200°C indicates potential for recovery of waste heat. Energy efficiency can be increased by using waste heat gas recovery system to capture and use some of the heat in the flue gas. The most commonly used waste heat recovery methods are preheating combustion air- Air Preheater and water heating-Economisers.

3) Partial Conversion of 'C' to 'CO':

In all the study units the levels of 'CO' in the flue gas were found to the order of 1% i.e 10,000 ppm against the standard level of 200-400 ppm, (as per CEM Report, CPCB). When there is incomplete combustion, Carbon Monoxide (CO) is formed. "CO" is a product of incomplete combustion and less energy is released when it is formed, reducing combustion efficiency.

$$C + O_2 \rightarrow CO_2 + 8084 \text{ Kcal/kg}$$

$$2C + O_2 \rightarrow 2CO + 2430 \text{ Kcal/kg}$$

Incomplete combustion can arise due to poor air to fuel ratio or poor distribution of fuel. Non uniform fuel size could be one of the reasons for incomplete combustion.

In all the study units size of the fuel feed were varying from powder to lumps of 4-5 inch and Fuel feeding was manually. The large lumps may not burn out completely, while small pieces and fines may block the air passage, thus causing poor air distribution. The fuel should be of uniform in the size approx. 1 to 2 inch size/dia. Large pieces should be broken out. By applying automatic fuel feeding system the efficiency of boiler can be improved up to 4-5 %.

Based on the above discussions, we have suggested following energy efficiency measures to the study units:

a. To Control Excess Air – O_2 Trim System
b. To Control Flue Gas Temperature- Air Preheater
c. To improve Combustion- Auto Fuel Feeding System

By incorporating above measures, there will be increase of 10 to 17 % efficiency of boilers in study units based on the existing efficiency levels. The details of the same is presented in **Table No.4.**

TABLE NO. 4
BOILER EFFICIENCY AFTER IMPLEMENTING PROPOSED ENERGY EFFICIENCY MEASURES

Sr. No.	Particulars	Unit -I	Unit-II	Unit-III	Unit-IV	Unit-V
1	Type of Boiler	3-Pass, Wet Back, Horizontal Fire Tube, Package Boiler				
2	Type of Fuel	Coal (Lignite)			Wood Chips	
3	Fuel Feeding System	Manually				
4	Calorific Value of Fuel (kCal/kg)	4000	4000	4000	4200	4200
5	Boiler Capacity(kg/hr)	1500	3000	4000	1000	1000
6	Fuel Consumption (kg/hr)	298	595	794	190	190
7	Percentage of Oxygen in Flue Gas	6	6	6	5	5
8	Percentage of CO_2 in flue Gas	12	12	12	13	13
9	Percentage of CO in flue Gas	0.2	0.2	0.2	0.2	0.2
10	Percent of Excess Air	40	40	40	31.25	31.25
11	Actual Mass of Air Supplied (kg/kg of fuel)	8.84	8.84	8.84	8.2	8.2
12	Flue Gas Temperature	150	150	150	150	150
13	Ambient Temperature	30	30	30	30	30
14	HEAT LOSSES					
H1	Heat loss due to Dry flue gas loss	7.38	7.38	7.38	9.41	9.41
H2	Heat loss due to evaporation of water formed due to H_2 in fuel	5.43	5.43	5.43	9.89	9.89
H3	Heat loss due to moisture present in the fuel	4.79	4.79	4.79	1.89	1.89
H4	Heat loss due to moisture present in the air	0.21	0.21	0.21	0.27	0.27
H5	Heat loss due to radiation and other unaccounted losses	2.00	2.00	2.00	2	2
H6	Heat loss due to partial conversion of C to CO	1.08	1.08	1.08	1.01	1.01
H7	Heat loss due unburnt in flyash	0.21	0.21	0.21	0.04	0.04
H8	Heat loss due unburnt in bottom ash	3.61	3.61	3.61	0.69	0.69
BOILER EFFICIENCY		**75.29**	**75.29**	**75.29**	**74.81**	**74.81**

VI. ECONOMIC BENEFITS FROM PROPOSED ENERGY EFFICIENCY MEASURES

The economic benefits associated with proposed measures range from Rs. 15 lakhs to 42 lakhs per year with payback period of less than one year. Details of savings calculation is given at **Table No. 5.**

Table No. 5
Economic Benefits from Proposed Energy Efficiency Measures

Sr. No.	Particulars	Unit -I	Unit-II	Unit-III	Unit-IV	Unit-V
A	At Existing Level					
	Existing Boiler Efficiency (%)	62.18	60.09	62.01	64.74	57.59
	Fuel Firing (kg/hr)	361	746	964	220	259
B	After Implementing Energy Efficiency Measures					
	Existing Boiler Efficiency (%)	75.29	75.29	75.29	74.81	74.81
	Fuel Firing (kg/hr)	298	595	794	190	190
C	Fuel savings per hr. kg/hr.)	62.81	151.33	170.06	29.61	68.49
D	Yearly Fuel saving(t/Year)	452	1090	1224	213	493
% Reduction in Fuel Consumption		15.73	17.41	20.28	17.64	13.46
E	Cost of Fuel (Rs./kg)	3.5	3.5	3.5	5	5
Total Monetary Savings per Year (Rs. In lakh/Year)		15.83	38.13	42.86	10.66	24.66
Investment Required (Rs. In lakh)		10.00	10.00	10.00	10.00	10.00
Payback Period(Months)		9.0	4.0	3.0	10.0	5.0

VII. REDUCTION IN GHG EMISSIONS

The major GHG emission reduction source is CO_2. The improved combustion efficiencies will reduce fuel consumption and reduces CO_2 emissions ranging rom 380-2061 tonnes per Annum depending up on the boiler efficiency and type of fuel. The details are presented in **Table No. 6**

Table No.6
Reduction in GHG as CO_2

Particulars	Unit - I	Unit-II	Unit-III	Unit-IV	Unit-V
Yearly Fuel saving(t/Year)	452	1090	1224	213	493
% Carbon	45.9	45.9	45.9	48.6	48.6
Reduction in CO_2 Emissions(t/year)	**761**	**1834**	**2061**	**380**	**879**

VIII. CONCLUSION

The boiler efficiency analysis in the study units reveals that, Boiler efficiency can be increased from 10 to 17 % based on the existing efficiency levels by controlling the excess air levels, flue gas exit temperatures and by reducing incomplete combustion of ‘C’ to ‘CO’. These can be achieved by providing auto fuel feeding system in place of manual fuel feeding system, air pre-heater and excess air control systems. There will be reduction in CO_2 emissions to the tune of 380 to 2061 t/Annum depending up on the boiler efficiency and type of fuel.

In terms of monitory gain, the above measures will lead to fuel savings in the range of 15 to 42 Lakh per Annum for the boiler capacity of 1 to 4 t/hr respectively. The investment needed will be in the range of 8-10 Lakh (based on Boiler Capacity) with payback period of less than one year.

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