Volume : 2 | Issue : 11 | November 2013 • ISSN No 2277 - 8179

Growing Trend of Process off Gas and Waste Heat Recovery in Captive Power Generation

Engineering

KEYWORDS : Power, efficiency, heat, steam, turbine, economizer, condenser,thermal, coal, nuclear, wind, hydro, Temperature

S.Umamaheswari	Professor, EIE, Mahendra Engineering College, Mallasamudram, Namakkal-637 503
M.Suganthi	Professor, ECE, Mahendra College of Engineering, Minnampalli, Salem-636 106
P.Suresh	Professor, Mechanical Engineering, Karpagam College of Engineering, Coimbatore – 641 032
K.Kannan	Vice President, Engineering and Projects, Usha Martin Ltd, Jamshedpur

ABSTRACT

It is indeed a challenge for process industries to manage the captive power requirement, with the growing demand and availability of power through grid and its energy cost. A successful strategic that aims to generates the captive power through process off gas and waste heat recovery. In this paper , the efficient way to generate captive power through Waste Heat Recovery(WHR) to meet out of the needs of Iron and Steel Industries has been discussed. Captive power plants have reported that the generation costs competitive with grid power. WHR which has assumed as key role of energy management enterprises. As per estimates a potential 17000-20000 MW could be continued through industrial co-generation.

1. INTRODUCTION

The term "Growing" should be defined in such a way that it should reflect better efficiency with the environmental constraints. Increasing demand of power and its fulfillment is becoming a challenge for the industries and government. The government is also taking regular steps to fulfill the demand [1], but the limited resources and environmental constraints bind the government and the industries to work in limited boundaries or "Go Green".

Nowadays "Going green" is gaining a lot of importance among the Industries, but efficiency is the most crucial thing and it needs to be justified that how efficient it would be as per the cost. Thus the context for industrial energy efficiency can be said as shown in Figure.1

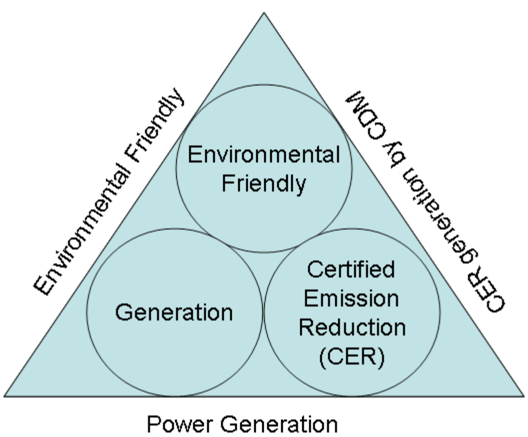

Fig 1: Schmatic diagram of context for industrial energy efficiency

Resources and techniques by which we generate power determine the efficiency of power generation. This paper captures how process industries in specific Iron and Steel sectors manage the captive power generation through waste heat recovery in an efficient or in an optimize way.

The Waste heat is a heat, which is generated by the process of fuel combustion or chemical reaction, which is then "dumped" in the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends substantially on the temperature of the waste heat gases and the economics involved. Large quantity of hot flue gases is generated from Boilers, Kilns, Ovens and Furnaces [2].

If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved [3]. The energy lost in waste gases cannot be fully recovered, however, much of this heat could be recovered in a significant way and the loss could be minimized by adopting the following measures and technologies:

- By minimizing exhaust gas temperatures
- By minimizing exhaust gas volume.

All processes may not be used for waste heat recovery because the Exhaust volumes and the temperature may be too low to be financially feasible, but if the exhaust temperature is above 510^0 C, waste heat recovery is worth investing.

2. INDUSTRIAL SCOPE

The following industries can use waste heat recovery for power generation.

Steel and sponge Plant ,Cement Plant, Chemical Plants, Refinery Industries, Preheating of boiler combustion air, Recovery of Waste heat from furnaces ,Reheating of fresh air for hot air driers, Recovery of waste heat from catalytic deodorizing equipment, Reuse of Furnace waste heat as heat source for other oven, Cooling of closed rooms with outside air, Drying, curing and baking ovens, Waste steam reclamation, Preheating of boiler feed water with waste heat recovery from flue gases in the heat pipe economizers, Brick kilns (secondary recovery),Reverberate furnaces (secondary recovery) Sponge and Steel plant.The most important parameter is "temperature" of the waste heat. Table 1 and 2 shows different sources for producing high and medium temperature

Table 1: Typical waste heat Temperature at high temperature range

Types of Device	Temperature (°C)
Nickel refining furnace	1370 –1650
Aluminum refining furnace	650-760
Zinc refining furnace	760-1100
Copper refining furnace	760- 815
Steel heating furnaces	925-1050

Copper reverberatory furnace	900-1100
Open hearth furnace	650-700
Cement kiln (Dry process)	620- 730
Glass melting furnace	1000-1550
Hydrogen plants	650-1000
Solid waste incinerators	650-1000
Fume incinerators	650-1450

Table 2: Typical waste heat Temperature at Medium temperature range

Types of Devices	Temperature (^{0}C)
Steam boiler exhaust	230 – 480
Gas turbine exhaust	370 – 540
Reciprocating engine	315 – 600 exhaust
Reciprocating engine	230 – 370 exhaust
Heat treatment furnace	425 – 650
Drying & baking ovens	230 – 60
Catalytic crackers	425-650
Annealing furnace cooling systems	425-650

3. POWER SCENARIO

Electricity is becoming the index for defining the quality of life and therefore the challenge before us is to ensure "Electricity for all". The different recourses for generating power is shown in Figure 2.

Figure 2 : Different resources of power sources

The National Electricity Policy envisages "Power for all by 2012". To achieve this, a total capacity addition of about 1, 00,000 MW is required during 10th and 11th Plan period. The capacity addition of 78,577 MW comprising of 39,865 MW (50.7%) in central sector, 27,952 MW (35.6%) in state sector and 10,760 MW (13.7%) in private sector has been proposed during 11th plan. The resource by which this status of power generation has been achieved is listed in Table 3. The captive generating capacity (MW) connected to the grid is approximately 10% of total generation installed capacity. Form the source of CEA as on 31-10-12, the total installed capacity is 2, 09,276.04 MW so the captive Generating capacity connected to the grid would be 20927.604 MW.

Table 3: Generation Installed Capacity (MW) All India Basis

	Mode Wise Breakup (As On 29-02-12)						Total
	Thermal						
	Coal	Gas	Diesel	Nuclear	Hydro (Renewable)	Res (Mnre)	
State	48112	4678	602	0	27338	3370	84107
Central	37615	6702	0	4780	8985	0	58082
Pvt. Sector	19710	6713	597	0	2525	18862	48408
Total	105437	18093	1199	4780	38848	22233	190598

The information provided from Planning Commission D & B industry Research Service the plan wise capacity addition is mentioned in Table 4. From Table 5 we can see that the total Power Generation in India by the private sector is 10760 MW. Recently the captive power generation is drawing the attention of industrialists to work on a big scale [4].

Table 4: Capacity Addition Plan Wise

Plan	Plan Period	Installed Cap (MW)	Cap Added (MW)	CAGR%
Sixth	1979-1985	42,585	15,905	9.80
Seventh	1985-1990	63,637	21,052	8.37
Eight	1992-1997	85,795	22,158	6.16
Ninth	1997-2002	105,046	19,251	4.13
Tenth	2002-2007	141,079	36,033	6.08
Eleven (Estimate)	2007-2012	219,656	78,577	9.26

Table 5: Generation Installed Capacity (MW) All India Basis

	Hydro (MW)	Total Thermal (MW)	Thermal Break up (MW)			Nuclear (MW)	Total (MW)
			Coal	Lignite	Gas		
Central Sector	9685	26800	24310	1000	1454	3380	39865
State Sector	3650	24347	23135	450	762	0	27952
Private Sector	3263	7497	5460	0	2037	0	10760
All – India	16553	58644	52905	1450	4289	3380	78577

According to CEA year wise energy generation and annual growth rate during the period are shown in Figure 3.

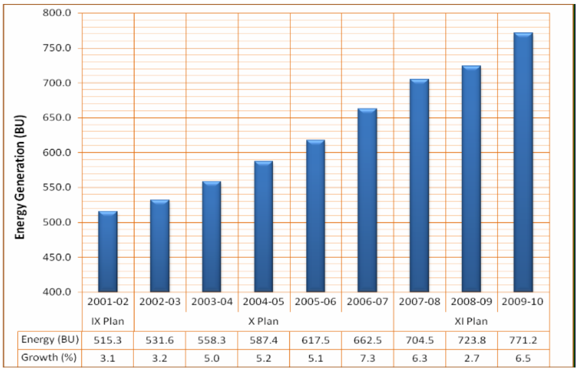

Figure 3: Annual energy generation & growth rate during the year 2001-02 to 2009-10

The highest growth rate of 7.3% is found in the year 2006-07 and during 2009-10 the growth rate is 6.5%. Hence are unable to maintain a constant growth rate which is very important to sustain the demand.

4. GROWTH OF CAPTIVE POWER PLANT

Captive power plants have been growing at a fairly aggressive pace in India. This constitutes around 17 % of the total installed capacity in India[5-7].

The power sector in India is facing significant shortages and there is a huge gap between the actual energy produced and the peak capacity which is to the tune of 10.1 % and 12.7 % respectively in 2010, and the deficit has been growing over the years.

Volume : 2 | Issue : 11 | November 2013 • ISSN No 2277 - 8179

From studies it has been inferred that it would be beneficial to encourage captive growth in India as this can add significantly to the much needed required capacity. National Electricity Policy stipulates liberal provisions for setting up captive power plants. Installed Capacity of Captive plants is 22,335 MW (10th Plan end) and 49000 MW by the end of 11th plan. Cogeneration and waste heat recovery as the best alternatives among all fuel types for CPPs

The growth of captive plants in India has been quite steep. The installed capacity of captive power plants with capacity of 1 MW and above is about 19500 MW. Out of this, about 14900 MW is connected to the grid and balance 4600 MW is operating in isolation to meet their own captive power requirements. A brief values are listed in Table 6.

Table 6: Installed capacity and their connection to grid

Type of prime movers	Installed Capacity is on 31-03-2006 (Provisional)	Capacity connected to the Grid	Capacity not Connected to the Grid
Steam Gas Diesel	9081 2928 7270	7148 2059 5524	1933 869 1746
Hydro	59	36	23
Wind	147	99	48
Total	19495	14866	4619

The captive capacity as of March 2007 was 22,335MW and expert feel that it may cross more then 49000 MW by the end of 11th plan**.** In that 17000-20,000 MW could be captured through industrial co-generation.

The growth of captive plants in India can be broadly attributed to: -
Need to generate electricity at costs lower than the high industrial tariffs set to cross subsidize other categories of consumers.

From India infrastructure Research the relative share in Captive capacity of metal and minerals industries is found 34.7%. The installed capacity across industries and states are listed in Table 7 and 8.

Table 7: The state-wise captive capacity in 2011

	Total Capacity (MW)	Relative Share (%)
Tamil Nadu	6748	13.9
Gujarat	6582	13.5
Maharashtra	5334	11.0
Orissa	5237	10.8
Chhattisgarh	4631	9.5
Karnataka	3802	7.8
Uttar Pradesh	3157	6.5
Rajasthan	3102	6.4
Haryana	595	1.2
Andhra Pradesh	2848	5.8
Jharkhand	2225	4.6
Madhya Pradesh	1527	3.1
West Bengal	1227	2.5
Haryana	595	1.2
Punjab	547	1.1
Kerala	271	0.6
Assam	271	0.6
Delhi	210	0.4
Bihar	149	0.3
Uttarakhand	85	0.2
Meghalaya	77	0.2
Goa	39	0.1
Himachal Pradesh	20	0.0
Pondicherry	8	0.0
Total	48692	100

Table 8: Captive contribution by various industry types Metal industries contribution is 34.7%.

Industry	Capacity (MW)	Relative Share %
Metals & Minerals	16918	34.7
Sugar	4583	9.4
Cement	4521	9.3
Petrochemicals	4085	8.4
Textile	3506	7.2
Chemicals	3503	7.2
Engineering	3231	6.6
Group Captives	1989	4.1
Paper	1009	2.1
Institutional users	525	1.1
Electronics	139	0.3
Miscellaneous	4682	9.6
Total	48692	100

5. CAPTIVE POWER GENERATION THROUGH PROCESS OFF GAS AND WASTE HEAT RECOVERY

In recent times, cogeneration and waste heat recovery are emerging as the best alternatives among all fuel types for CPPs, as companies get the Clean Development Mechanism (CDM) benefits under this system in addition to achieving energy efficiency [8].

Metal industries in specific gets the best benefits of Captive power generation through waste heat recovery and process off gas. Normally 50-60% of captive power generation is through waste heat recovery in any medium size steel plants**.**

5.1 Cogeneration from Steam Boilers

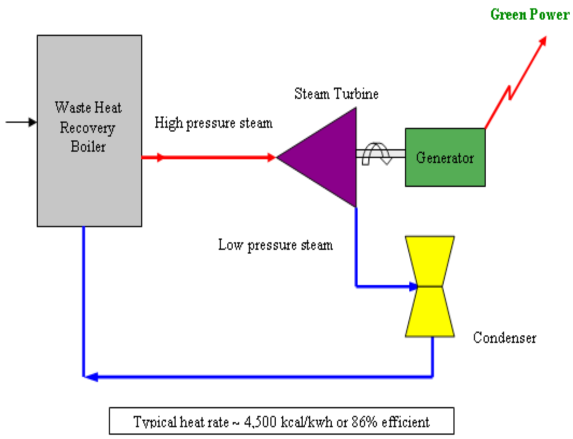

Figure 4: Process of cogeneration from stream Boiler

Waste Heat Recovery Boiler(WHRB) is used to extract maximum heat that can be recovered from the exhaust gas coming out of Coke Oven and DRI. This is done by arranging the gas flow from the coke oven/DRI in a direction that is counter to the water /steam circuit of WHRB. Gas from coke oven/DRI enters the primary and the secondary super heaters. The exhaust gas travels through the HP boiler evaporator and economizer modules from the super heaters before the gas is exhausted to the atmosphere through ESP to stack In order to achieve better controllability of final steam temperature on varying, three stage super heaters has been envisaged with an inter stage spray type attemperator. This process is shown in Figure 4.

Balancing vessel for the water and steam is served by the steam drum which is placed above the evaporator. Its function is to receive feed water from the economizer and maintain positive water supply to the evaporator modules.

The mixture of steam and water is received by the drum from the evaporator modules by the heat transfer. The saturated steam is supplied to the super heater after steam is separated from water mixture at drum. To preheat the feed water fed to the steam drum recovering heat energy from the exhaust gas economizers are installed [9, 10].

WHR applications in metal industries

It is very common to find Blast furnace (BF), DRI and Coke oven plant in medium/large scale integrated steel industries. The process off gas (BF gas) fro Blast furnace, waste hot gas from DRI and Coke Oven are acts as fuel for green power generation.

BF-gas also been used in Re-heating furnace, VD-Boiler, Sinter plant to replace oil. Normally proper gas balance is done to first replace oil and then power generation based on total process-off gas generation. In some cases metal industries uses producers gas (PG plant) to mix with BF gas for optimum performance and economics.

Waste hot gas generates in the process of DRI and Coke Oven directly pass through WHR boilers to extracts reusable heat and generate steams for green power generation.

WHR in Direct Reduce Iron (DRI) Plant

A vertical orientation Waste Heat Recovery Boiler connected to DRI plant is shown in Figure 5(a) and 5(b) is normally seen in metal industries each kiln have its own boiler ESP steam line connected to common steam headers to a power plant of correct capacity.

(a)

(b)

Figure 5: Horizontal and Vertical orientation of WHRB

For example DRI plants having capacity 350 TPD kiln generates approx. 90.000 Nm3/hr hot gas has gas consumption listed in Table.9 and the Boiler Specification connected with the boiler as per Table.10

Table 9: Sponge Iron kiln Gas Composition

Descriptions	Unit	Composition (Average)
CO_2	%	20.6
H_2O	%	22.8
N_2	%	56.4
O_2	%	0.2

Table 10: WHRB specification of Sponge Iron kiln Plant

Parameters	Unit	Value
Boiler capacity	TPH	35.6
Steam pressure Super heated Outlet	Kg/cm2(g)	50
Steam Temperature Super heater Outlet	0C	470 + 5
Fuel Gas Data		
Fuel gas volume	Nm3/hr	80000
Inlet Temperature	0C	900-1050
Outlet Temperature	0C	160-175

It can be estimated a 350 TPD DRI kiln connected with 36 TPH – 40 TPH boiler can generates about 8.5 MW – 10 MW of power. Normally based on plant configuration DRI plant in multiple has the potential of 45-50 MW power generations in medium scale of 1MTA steel plant.

Figure 6: Coke Oven WHRB plant

Table 11: Coke Oven Gas Composition

Descriptions	Unit	Composition (Average)
CO_2	%	8
H_2O	%	25
N_2	%	60
O_2	%	7
SO_2	%	Nil
CO	%	-
NOx	mg/Nm^3	-
SOx	mg/Nm^3	-
Dust Loading	mg/Nm^3	50

Table 12: WHRB specification of Coke oven Plant

Parameters	unit	value
Boiler capacity	TPH	65
Steam pressure Super heated Outlet	Ata	96
Steam Temperature Super heated Outlet	^{0}C	520 ± 5
Fuel Gas Data		
Fuel gas volume	Nm^3/hr	96000-1,20,000
Inlet Temperature	^{0}C	900-1050
Outlet Temperature	^{0}C	160-175

It can be estimated a non- recovery type 2x48 battery coke oven connected with 2 x 65 TPH boiler can generates about 35- 40 MW of green power.

Blast furnace Process - off gas (BF Gas)

Blast furnace of capacity 550m^3 working volume use cold blast of 90,000 Nm3/hr, 2 % oxygen enrichment and 100-200 kg/ton of coal injection generates about 1,25000 Nm3/hr of BF gas having composition as per Table 13.

Table 13: BF Gas Composition

Descriptions	Unit	Composition (Average)
CO_2	%	22-24
CO	%	22-24
N_2	%	45-50
H_2	%	1
CH_4	%	3
GCV		-800-850
Pressure	MMWC	900-1200

Blast furnace use BF gas for its 30-35 % of stove heating. Balance gas of 65-70% is 81250.Nm3/hr is available can be used for power generation. If a corrected capacity of boiler is connected to this a significant amount of power can be generates.

Figure 7: BF gas fired boiler for power generation

The boiler connected uses 1200 Nm^3/hr-1300 Nm^3/hr for generation of 1 ton steam i.e. 4800Nm^3/hr can generates 1 MW of energy. So, 48000-50000 Nm^3/hr can generates 10 MW of energy. It can be estimated the balance BF gas 81250 Nm^3/hr can generates up to 20 MW of energy. To produce 20 MW of energy needs an approx 80 TPH capacity of boiler or it can be achieve through plant integration by connecting two 40 TPH boiler or four 20 TPH boiler. Approx 40 TPH boiler specification would be similar to the Table 10. A BF gas fired boiler shown in Figure.7.

Heat - to Power ratio

Heat-to-power ratio is one of the most vital technical parameters influencing the selection of WHRB system. If the heat-to-power ratio of industry can be matched with the characteristics of the WHRB system being considered, the system optimization would be achieved in real sense[11]. Definition of heat-to-power ratio is thermal energy to electrical energy required by the industry. Basic heat-to power ratios of the WHRB system variants are shown in Table.14 below along with some technical parameters. The steam turbine based cogeneration system can be considered over a large range of heat-to-power ratios.

Table 14: Heat-to-power ratios and other parameter of Cogen system

Cogeneration System	Hear to power ratio	Power Output (as % of Fuel Input)	Overall efficiency %
Back-Pressure Steam turbine	4.0-4.3	14-28	84-92
Extraction-Condensing Steam turbine	2.0-10	22-40	60-80
Gas turbine	1.3-2.0	24-35	70-85
Combined Cycle(Gas plus steam turbine)	1.0-1.7	34-40	69-83
Reciprocating engine	1.1-2.5	33-53	75-85

Heat Loss: Calculation

Heat Recovery from heat treatment furnace

In a heat treatment furnace, the exhaust gases are leaving the furnace at 900°C at the rate of 2100 m^3/hour. The total heat recoverable at 180°C final exhaust can be calculated as

$Q = V \times \rho \times Cp \times \Delta T$ → (1)

Where

- Q is the heat content in kCal.
- V is the flow rate of the substance in m3/hr.
- ρ is density of the flue gas in kg/m^3.
- Cp is the specific heat of the substance in kCal/ kg°C
- ΔT is the temperature difference in °C.
- Cp (Specific heat of flue gas) = 0.24 kCal/kg/°C.
- Heat available (Q) = 2100 x 1.19 x 0.24 x (900-180) = 4,31,827 kCal/hr.
- By installing a recuperator, this heat can be recovered to pre-heat the combustion air. The fuel savings would be 33% (@ 1% fuel reduction for every 22°C reduction in temperature of flue gas.

Efficiency

Thermal efficiency of WHRB can be calculated as

$$\eta_{whrb} = \frac{W_s * (h_{11} - h_{10}) * 100}{W_{eg} * C_p (t_e - t_{exhaust})}$$

Where,

η_{whrb} = Thermal efficiency based on net Steam output, %

W_s = Steam rate, kg/sec

h_{11} = Steam enthalpy at boiler outlet, kJ/Kg

h_{10} = Steam enthalpy at boiler inlet, kJ/Kg

W_{eg} = Exhaust gas flow rate, kg/sec

C_p = Average value of specific heat of exhaust gas, kJ/kg0C

t_e = Exhaust gas temperature at WHRB inlet, ^{0}C

$t_{exhaust}$ = Exhaust temperature at WHRB outlet, °C

A Sample of WHRB Efficiency Calculations

From the combustion rection of methane

$CH_4 + 2O_2\ CO_2 + H_2O$ → (3)

It is clear that one mole of methane requires 2 moles of oxyzen for consumption. 2 mole of oxygen also contains 7.52 moles of nitrogen because air contains 79% nitrogen and 21% oxygen (79/21x2=7.52). combustion products include 1 mole of carbon dioxide and 2 mole of water vapors. It can be written as:

Chemical Reactants

CH_4	1 mole	9% (volume %)
O_2	2 mole	19%
N_2	7.52 mole	72%

Combustion Products

CH_4	1 mole	9% (volume %)
H_2O	2 mole	19%
N_2	7.52 mole	72%

On average 264m3 per hour is supplied to captive power plant at Nimra Ltd.

Gas	Molar Volume	Relative Volume	Volume
CH_4	1 mole	9%	264m3
O_2	2 mole	19%	528m3
N_2	7.52 mole	72%	1985.28m3
Total			2777.28m3

10% excess air is used for combustion so the above values of O2 and N2 will be as;

Gas	Molar Volume	Relative Volume	Volume
O_2	2.2 moles	21%	580.8m3
N_2	7.52 moles	72%	2183.8m3
Total			2764.6m3

Hence the reactants quantities become;

Gas	Molar Volume	Relative Volume	Volume
CH_4	1 mole	8.71%	264m3
O_2	2 mole	9.17%	580.8m3
N_2	8.27 mole	72.11%	2183.8m3
Total			3028.6m3

3028.6m3 air gas mixtures will produce same quantity of fuel gases with following quantities:

Gas	Molar Volume	Relative Volume	Volume
CO_2	1 mole	8.71%	264m3
O_2	0.2 mole	1.76%	50.80m3
N_2	8.27 mole	72.11%	2183.8m3
H_2O	2 mole	17.42%	528m3
Total			3028.6m3

Density of above gases;

Gas	Density(kg/m3)
N_2	1.23
CO_2	1.952
H_2O	0.8
O_2	1.428

Avrage density of the flue gases = 0.72 x 1.23 + 0.09 x 1.952 + 0.19 x 0.8 + 1.428 x 0.0176 = 1.21kg/m3

Specific heat of flue gases

Gas	Density(kg/m3)
N_2	1046j/kgC
CO_2	1004
H_2O	1882
O_2	1044.45

Average specific heat of gases = 0.72 x 1046 + 0.09 x 1004 + 0.19 x 1882 + 1044.45 x 0.0176 = 1189 j/kg-^{0}C

Energy in the flue gases = Q = m x cp x ΔT = 3028.6 x 1.221 x 1189 x (390-30) = **1583,460,748 j/hr**

Energy Delivered by Waste Heat Recovery Boiler having capacity 1.5 t/hr.

Capacity of WHB(Designed)	1.5t/hr
Quantity of water used per day	13 ton
Blow down per day	0.39 ton(@3% of total steam produced)
Steam produced per day	12.61 ton
Steam produced per hour	0.52 ton
Steam energy	mλ
Enthalpy (λ) at 100 psig	2761177 j/kg(@110psi)
Steam energy per hrs	0.52 x 1000 x 276117 = 1,435,812,378 j/hr

Energy in the hot water water into the boiler = hot water obtained from economiser due to the flue gases of boiler . Energy of flue gases from boiler to the atmosphere are wasted

Energy balance

Energy In	Energy Out
Flue gas to Boiler + Hot water	Steam + Hot water (economizer) +Exist Flue gas

So, Thermal efficiency of WHRB can also be defined as

Efficiency of boiler (Thermal)	(Energy in steam out / energy in flue gas in) x 100

i.e. Efficiency of boiler (1,435812378/ 1583460748) x 100. Which is equal to **91 %.**

Benefits of Power generation through WHRB

Recovery of waste heat and process off gas has a direct effect on the efficiency of the process. This is reflected by reduction in the utility consumption & cost, and process cost over and above the following intangible benefits [12].

Reduction in pollution:

A number of toxic combustible wastes such as carbon monoxide gas, sour gas, carbon black off gases, oil sludge, Acrylonitrile and other plastic chemicals etc, releasing to atmosphere if/ when burnt in the incinerators serves dual purpose i.e. recovers heat and reduces the environmental pollution levels. WHR application helps in controlling pollution and hence attracting CDM benefits.

Cost of power generation

As compare to the cost of power generation the coal based CPP, WHR based CPP has huge cost advantage. Normally power cost will be the order of .50 to .60 Rs/Kwh as compare it 3.00 – 3.50 Rs/Kwh of coal based power plant.

Auxiliary power consumption

Additional equipment required like coal handling large scale, Ash handling, ID/FD fans and auxiliary equipment are not needed for WHR based CPP hence auxiliary power consumption will be the order of 3 – 4% as against 7- 10 % coal based units.

Efficiency

Efficiency of WHRB is quite good and it is above 90 % as compared to coal based boiler

Comparisons between Coal based and WHR based Boiler.

A comparison has been made between coal based and WHR based boiler which is listed out in Table 15

Table 15: Comparisons between Coal based and WHR Boiler

S. No	Parameter	AFBC	CFBC	WHRB
1	Un burnt (%)	6-8	3-4	NA
2	Heat Rate (Kcal/kwh)	3800	3500	3200
3	Thermal Efficiency	82-84	86	88-90
4	Aux Power Consumption (%)	10.5	9.5	7.5
5	Sox (ppm)	75-85 %	(80 - 85) %	NA
6	Nox(ppm)	250 -300	<100	<50
7	Fuel flexibility	Good	Best	Best
8	Hot start-up time	6-7 hrs	5 – 6 hrs	3- 4 hrs
9	Bed material for start-up	80 ton	60 ton	Not Required
10	Consumption temperature	850 ^{0}C	850 ^{0}C	750 ^{0}C
11	ESP Emission	< 100 mg/ Nm^3	< 100 mg/ Nm^3	< 100 mg/ Nm^3

Volume : 2 | Issue : 11 | November 2013 • ISSN No 2277 - 8179

6. CONCLUSION

From the above study it has been seen that a total capacity addition of about 1,00,000 MW is needed in the 10^{th} and 11^{th} plan period but actual addition has been only 78,577 MW. Hence it is observed that there is a huge gap between the required capacity and the actual capacity which needs to be fulfilled. It is noticed that the forecasted growth rate should have been 9.26 % Compound Annual Growth Rate (CAGR) whereas only 6.5% has been actually achieved. There is a shortfall in the electric generation. The generation target for the year 2009-10 was proposed to be 789.5BU whereas the actual achieved generation is around 771.2BU. To fill up this gap the captive power generation is the best alternative to meet the shortage. It is also seen that the CAGR of captive power plant is 5% during the last five years. So, it would be beneficial to encourage captive growth and National electricity policy shall have liberal provisions for setting up captive power plant.

The challenges to meet the captive power requirements of process industries had given a wide scope for converting the waste heat and the process off gas for captive power generation. Captive power generation through process off gas and waste heat recovery can meet 50 - 60 % of captive power requirement of medium metal industries. Power generation cost through WHRB root is much cheaper which gives platform to sell surplus power at a profitable margin.

Cogeneration, waste heat recovery and process off gas are emerging as the best alternatives among all fuel types for CPPs, and as companies get the Clean Development Mechanism (CDM) benefits under this system in addition to achieving energy efficiency and to produce green power. The future of captive generation is very bright as industrial demand will keep on increasing and activities like trading through exchange will provide a platform to captive generators to sell surplus power at a profitable margin.

REFERENCE

[1]. Infraline, Power Sector Data Base Available at http://www.infraline.com | [2]. Central Electricity Authority (2005). Report on Tapping Surplus Power from Captive Power Plants, planning Wing, August. | [3]. Switchasia Programme, SCI – Pak, Report on Waste Heat Recovery Boiler. | [4]. Central Electricity Authority (2008). 'Captive Electricity Generation plant s (non-Utilities)' General review 2008 . | [5]. Central Electricity Authority (2009). 'Captive Electricity Energy Generation plants (non-Utilities)' General review 2009 . | [6]. Central Electricity Authority (2010). 'Electrical Energy Generation during the month of December 2009 | [7]. Central Electricity Authority 'Operation Performance of generating Stations in the Country during the year' 2009-2010 | [8]. India's first Power line magazine "Power Line" Vol. 17. No.2 Oct-12. www.indiainfrastructure.com | [9]. Power Sector at a Glance ALL INDIA. http:www.powermin.nic.in/india_electricity_scenario/introduction.htm. | [10]. Banerjee, R (2006). 'Comparison of Options for Distributed Generation in India', Energy Policy, 34(1), | January. | [11]. Barnes, D.F., J. Halpern (2000). Subsidies and Sustainable Rural Energy Services: Can we create incentives without distorting markets?, Energy Sector Management Assistance Programme (ESMAP) report. | [12]. Joseph, Kelli L. (2010). 'The Politics of Power: Electricity Reform in India', Energy Policy, 38(1), pp. 503–11, January 2010. Lars-Erik Schöring (2004). 'Lifecycle Costs—Th e Driver for Power Plant Investment Decisions', Energy News, 18, February 2004, Wartsila, Finland.