CO-GENERATION

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INTRODUCTION

It is a global wish and common responsibility to take right action to cope with challenges posed by environment and energy as well as to achieve sustainable development. Along with the global economic growth, energy shortage and environmental pollution have become an increasingly big problem. If it is not solved in a good and efficient manner, not only will human society not achieve the goal of sustainable development, but it will also make a serious impact on the living environment and quality of human society.

CURRENT SCENARIO

Most of the industries in India are becoming energy intensive. With more & more industrialization & ever increasing energy demand of industries, the current level of energy supply is not sufficient.
They have to depend on captive generation to meet their energy demands.
Under usual business scenario, the captive generation consists of DG sets, Gas Turbine, driven by fossil fuels, the prices of which will continue to attain new heights.
These D.G sets emit huge quantity of flue gases which under normal conditions are sent unutilized to the atmosphere.
Moreover these DG sets are only 35% efficient thereby decreasing the overall plant efficiency.
Co generating can increase the overall efficiency utpo 70% depending upon the type of application.
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NOVEL INVENTION

Keeping in view of the above mentioned scenario, novel Cogeneration involving low pressure heat recovery systems for steam, chilling & power generation etc have been developed which utilize heat from engine exhaust there by combinely generating power, steam & chilling.
This in turn reduces the fuel consumption in the fired equipment by utilizing the waste heat of exhaust gases.
Thus, the energy made available by the system is free of cost.
In addition, the Cogeneration System helps contribute greatly to energy conservation by saving fuel which is not only expensive and scarce but also a major cause for environment pollution.
The outlet temperatures of waste heat recovery boiler in these kinds of Cogeneration system is around 135-140degC depending upon the system. Generally temperatures in this range are considered to be a safe level limit of the flue gas temperature depending on the type of fuel used.

Therefore, the development of such a technology for recovering the heat from the waste flue gases is good news particularly when fuel prices are spiraling up.
There are more than 200 Cogeneration operating systems, which have improved the efficiency for a wide spectrum of industries by recovering heat from engine exhausts.

SYSTEM OVERVIEW

Typical Cogeneration System involves

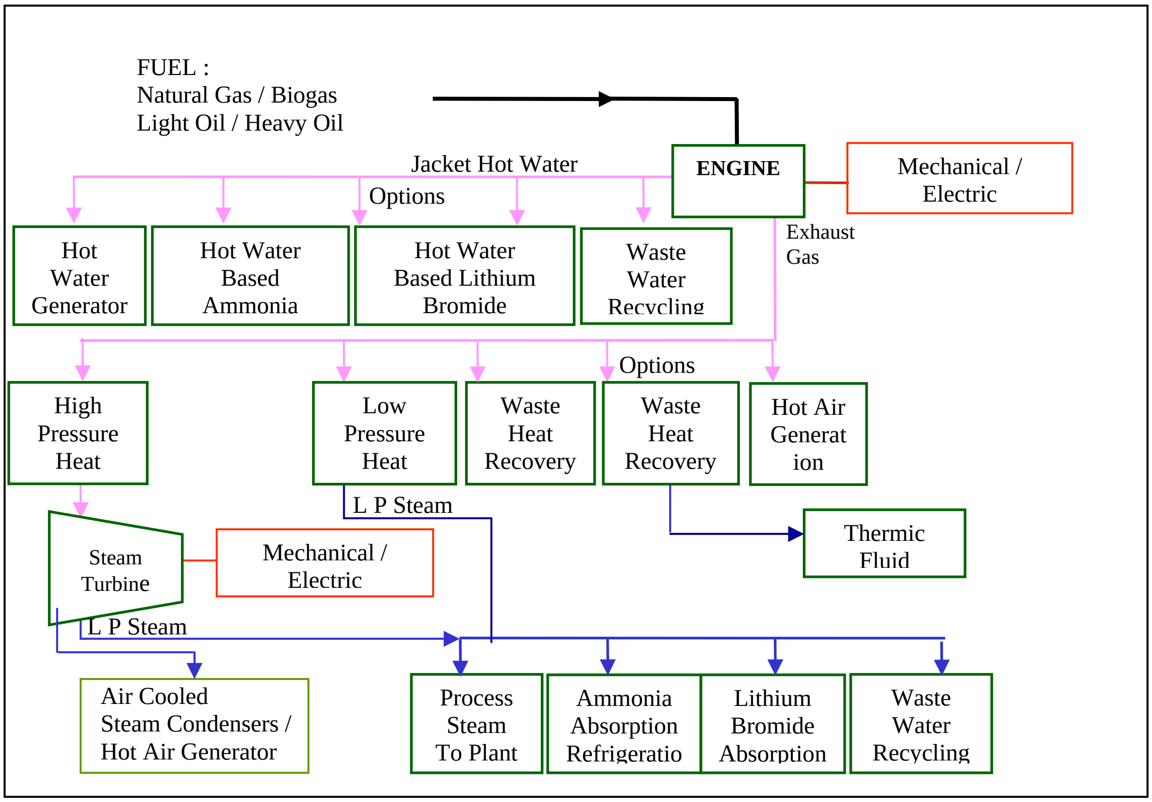
1. Prime mover consisting of a either FO or Gas fired Engine or a Gas turbine.
2. Waste Heat Recovery systems or equipments like Ammonia absorption refrigeration plant, Lithium bromide chillers to convert the waste heat into useful form.

Waste Heat is available from sources like

1. Flue gases from Engine exhaust. These flue gases are available at a temperature around 300-600degC.
2. Hot water From Engine jacket heat. The hot water from engine jacket generally flows in a loop of 99degc as outlet from engine & 90degC back to engine. These temperatures may vary depending upon the engine capacity.
3. Flue gases from Gas turbine exhaust. The temperature of flue gas may go up to a maximum 0f 500-600degC.

The waste heat available from different heat sources can be converted into various useful forms depending upon the need of the customer. All these systems are tailor made and designed to suit customer's requirement, there by increasing overall efficiency of plant.
Customization is one of the key aspects for success of these kinds of systems. This feature has made the technical as well as commercial viability of the system possible.

RECIPROCATING ENGINE BASED CYCLE CO-GENERATION



(Fig.1)

The fig shows an Engine based cogeneration plant. All possible options of cogeneration have been shown.

There are various options available to convert the waste heat into useful forms. The waste heat can be converted into

1. Steam generation for process heating. The steam can be generated at the desired pressure and temperature.
2. Thermic fluid heating.
3. Hot air generation for dryers
4. Combustion air preheating
5. Feed water heating for boilers
6. Hot water generation for process use (close loop/ open loop)
7. Refrigeration with Ammonia absorption refrigeration plants (AARP) for brine cooling / Ice making
8. Chilled water generation for process use / Air-conditioning/ Inlet air cooling for gas turbines / Engines
9. Power generation
10. Waste water recycling (multiple effect evaporation)

Apart from these options, we can also work out a combination of above options. A customer can be provided with a combination of steam with chilling or a combination of steam, chilling and hot water depending upon customer's requirement. This type of various options can be possible depending upon the heat source availability and
Customer's requirement.

Matrix for converting waste heat into useful forms

	HOEE	LOEE	GEE	EJH	GTE	IEG	CPKG	SPF	HGP	GFG	FGFH	AC	HPC
Low Pressure Steam	√	√	√		√	√	√	√	√	√	√		√
Medium Pressure Steam	√	√	√		√	√	√	√	√	√			
High Pressure Steam		√	√		√	√	√	√					
Hot Thermic Fluid	√	√	√		√	√	√	√	√	√			
Hot Water (Pressurized)	√	√	√		√	√	√	√	√	√	√		√
Hot Water (Non Pressurized)	√	√	√	√	√	√	√	√	√	√	√	√	√
Hot Air for Process (Dryer	√	√	√	√	√	√	√	√	√	√	√	√	√
Chilled Water	√	√	√	√	√	√	√	√	√	√	√	√	√
Chilled Brine	√	√	√	√	√	√	√	√	√	√	√	√	√
Ice Making	√	√	√		√	√	√	√	√	√	√	√	√
Cold Storage	√	√	√	√	√	√	√	√	√	√	√	√	√
Waste Water Recycling	√	√	√	√	√	√	√	√	√	√	√	√	√
Power	√	√	√		√	√	√	√	√	√			
Combustion Air Preheating						√		√			√		
Inlet Air Cooling	√		√		√								

HOEE : Heavy Oil Engine Exhaust
LOEE : Light Oil Engine Exhaust
GEE : Gas Engine Exhaust
EJH : Engine Jacket Heat
GTE : Gas Turbine Exhaust
IEG : Incinerator Exit Gases
CPKG : Cement Plant Kiln Gases
SPF : Steel Plant Furnaces
HGP : Hot Gases From Process
GFG : Glass Furnace Gases
FGFH : Flue Gases From Fired Heaters
AC : Air Compressors
HPC : High Pressure Condensate

Based on our experience in the waste heat recovery and Cogeneration field, we have made the above matrix which provides information regarding various options available from different waste heat sources. For e.g, From Engine jacket heat, Hot water, hot air, chilled water, chilled brine can be obtained.

However the biggest question mark in developing this system was to how to convert the waste heat into above mentioned useful forms while maintaining the commercial viability of the system.
Today with advancement in technology it is possible to convert the waste heat into so many types of useful forms depending on individual needs.
To make the system commercially feasible certain technologies are available.

TECHNOLOGY

The basic equipment used for waste heat conversion is a **Waste Heat Recovery Boiler**.
The common options available are

- **Finned Water tube IBR.**
- **Smoke tube IBR.**
- **Bare Water tube, IBR.**

Similar options are available in Non IBR category for **Hot water generator** also.

The choice between the above three options depends on many factors, however the following table can be very helpful to make the comparison and decide the suitability.

Comparison & Suitability

Sr. No	Parameters	Smoke Tube Type	Water Tube Type with Finned Tubes	Water Tube Type with Bare Tubes
1	Application Suitability	- All types of exhausts gases - Ideally suited for dirty gases, typically F.O. fired D G set Exhaust - Generally used whose Relatively high back pressure acceptable	- Suitable for clean exhaust gases - Not suitable for dirty gases - Non-IBR waste Heat Recovery Boilers	- All types of exhaust gases - Can also work On dirty gases
2	Size	Normally suitable upto 5 MW D G set or equivalent heat source	Suitable for all sizes of D G sets, Gas Turbines & other heat sources	Suitable for all sizes of D G sets, Gas Turbines & other heat sources
3	Access for Inspection - Flue gas side - Water side	 Good Good	 Good Reasonable	 Good Reasonable
4	Access for cleaning	Good	Good	Good
5	Time required for cleaning	Short	Long	Medium
6	Installation with multiple Heat Sources (e.g. Battery of D G sets or Furnaces)	Separate W.H.R.B. for each source is generally preferred.	Separate evaporator module for each source with common steam drum can be nstalled	Separate evaporator module for each source with common steam drum can be installed
7	Working Pressure	Application limited to Low/Medium pressure (Upto 20-25 bar)	No limit of Working Pressure	No limit of Working Pressure

The above table makes it very clear that smoke tube type boilers have a good capacity to withstand high dust laden gases and are suitable where the D.G sets are in the range up to 5MW.they require less time for cleaning. Similarly finned water tube type boiler is suitable for all ranges of D.G sets with no working pressure limit. They are not suitable where the gases are highly dust laden as dust gets accumulated between the fins causing choking up of boiler.
Water tube boiler with bare tubes is mostly used where gases are highly dust laden. This type of arrangement makes cleaning of tubes very convenient.

Issues To Be Addressed In Designing

- System, works within the back pressure constraints of primary equipment. Normally a back pressure 400-500 mmwc is allowed by the Engine Manufacturer. These systems are designed well within these permissible limits. Pressure drop of 100-150 mmwc is sufficient on boiler for the safety of the heat source equipment.
- Mixing of gases. Generally the mixing of gases from two heat sources is not advisible.In case of an Engine, mixing of gases can damage the turbo charger.
- Isolation & bypass arrangement should be provided for exhaust gases. The most important point in designing a waste heat recovery & cogen system is the safety of the source equipment. Under any circumstances if the waste heat recovery boiler fails it should not affect the normal operation of the source equipment. Hence a 3 way diverter valve is used which under normal working conditions passes the gases through the waste heat recovery boiler & during any emergency or maintenance bypasses the gases to keep the normal working of source equipment.
- Easy access to heating surface for cleaning on gas side.
- Flexibility in design to suit space available at existing installation. For this Purpose both horizontal as well as vertical designs can be used.
- Location of heat recovery boiler can be indoor as well as outdoor.

TYPICAL INDUSTRY APPLICATIONS

TYPICAL INDUSTRY APPLICATIONS	
Dairy	Edible Oil Industry
Paper Mill	Distilleries
Textile Industry	Wood & Timber
Software Park	Rice Mills
Hotel	Automobiles
Ceramic Industry	Solvent Extraction Plants
Commercial Complex	Refineries
Chemical & Process Industry	Fertilizer
Food Industry	Pesticides
Sugar Industry	Breweries
Five Star Industrial Estate	Sugar Mill
Cement Industry	Waste to Energy Plants
Steel Industry	Refuse Incineration Plants
Residential Complex	Biomethanation of Waste

(Fig.3)

The Cogeneration systems find application in almost every kind of industry. The table is provided to list out the various industry applications. We have experience of installing the Cogeneration systems in the above industries.

ADVANTAGES

No one can deny the fact that Cogeneration systems have become the need of the hour.
With the energy crisis faced by our country & ever increasing energy demand such systems will become more & more popular. The benefits include

a) Reduces the power and other energy costs. It has drastically reduced the use of fossil fuels by industries
b) Improves productivity and reduces the costs of production through reliable uninterrupted availability of quality power from Cogeneration plant.
c) Cogeneration system also helps to locate manufacturing facility in remote low cost areas.

d) Improves the overall plant efficiency, thereby increasing the profitability of the customer.
e) The system reduces CO2 emissions therefore it supports sustainable development initiatives. The system collects carbon credits which can be traded to earn revenue.
f) Due to uninterrupted power supply it improves working conditions of employees raising their motivation. This indirectly benefits in higher and better quality production.
g) Cogeneration System saves water consumption & water costs.
h) Improves brand image and social standing.

SUCCESS STORIES

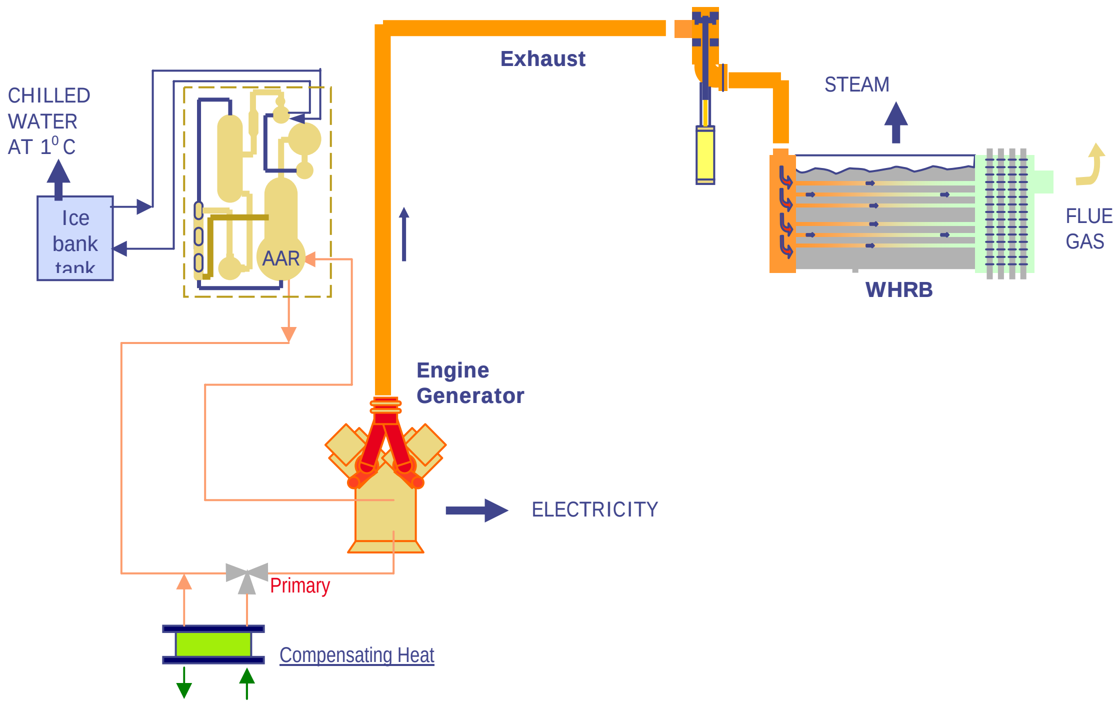
Engine based cogeneration systems are very popular and find more and more application in different industries. We have a large experience of implementing such Cogeneration projects in various industries like colour, chemical, textile, dairy, jute etc.We would like to mention our success stories in Engine based cogeneration where we have made these cogeneration systems both technically as well as commercially feasible in industries.

Two of such success stories are at

1. Reputed Dairy in Maharashtra.
2. Textile Company in Maharashtra.

Case Study- Dairy

We have implemented a cogeneration project at on of the Dairy in Maharashtra.



(Fig.4**)**

SYSTEM OVERVIEW

In dairy industry, cogeneration system consists of Power generation, steam generation as well as chilling.
The Cogeneration is carried out on a HFO fired 2.2MW Mirless Blackstone Engine.
Before installing the cogeneration system the chilling requirement was met by refrigeration system based on compression cycle which works on the electricity. The power requirement was met partly by grid power and partly through HFO fired engine.
Steam requirement was met using a fired boiler. Thus if we observe the operating cost of the plant was very high as fuel was required for both engine firing as well boiler firing. Moreover the fuel used was very costly and the prices of fuel are continuously rising. Also the cost of power from grid for running the refrigeration plant was a major factor in
high operating cost. All these factors contributed in reduction of the overall efficiency of the plant.
In a view of reducing the operating cost and increasing the overall plant efficiency it was decided to carry out a engine based cogeneration which will fulfill the energy requirements of the dairy viz. power, steam, & chilling.
Power was generated through the Engine and the waste heat from flue gases of engine exhaust which were earlier sent unutilized to the chimney are now used to produce the steam and the Hot water in engine jacket is utilized as a heat input to produce the refrigeration using Ammonia absorption refrigeration plant which works on Vapor absorption technique there by eliminating the use of power.
Thus using such energy efficient cogeneration technique huge amount of saving was done by reduction in fuel consumption as well as consuming lesser amount of units from grid
All these techniques increased the overall plant efficiency from 39 % to 66%. This has helped the dairy to increase its profitability to great extent.

Cogeneration Plant Efficiency

Engine Make - Mirlees Blackstone
Flue Gas Temp - 350 degC
Fuel - Heavy fuel oil
No. of engine - One
Electricity - 2200 KW

Steam Generated - 1632 Kg/Hr. @ 10.54 bars
Chilling - 124 TR

Input (KW) - 5513(Kcal in terms of fuel fired converted to KW)

OUTPUTS
Electricity (KW) -2200
Steam (KW) - 1024
Chilling (KW) - 436
Total Output (KW) - 3660
System Efficiency - 66.38 %
Engine Efficiency - 39.9%

This case represents how the use of cogeneration system helped the dairy to increase the overall system efficiency upto 66% there by increasing the overall plant efficiency.

Total Heat Recovery (Boiler)-881280 Kcal/hr

SAVINGS & PAYBACK(Boiler)

Fuel		Furnace Oil	
Efficiency	%	88	
Net Cal Value	kcal/kg	9710	
Sp. Gravity		0.95	
Cost of Fuel	Rs./Lit	25	
Hourly Fuel Savings	Lit/hr		108.56
Annual Working Hours		8400	
Total Heat Recovery	**Kcal/hr**	881280	
Annual Fuel Cost Saving	**Rs. In Lacs**		**227.79**
Total Initial Cost	**Rs. In Lacs**		**156.00**
Payback Period	**Months**		**6.74**

Jacket Water Heat Recovery-

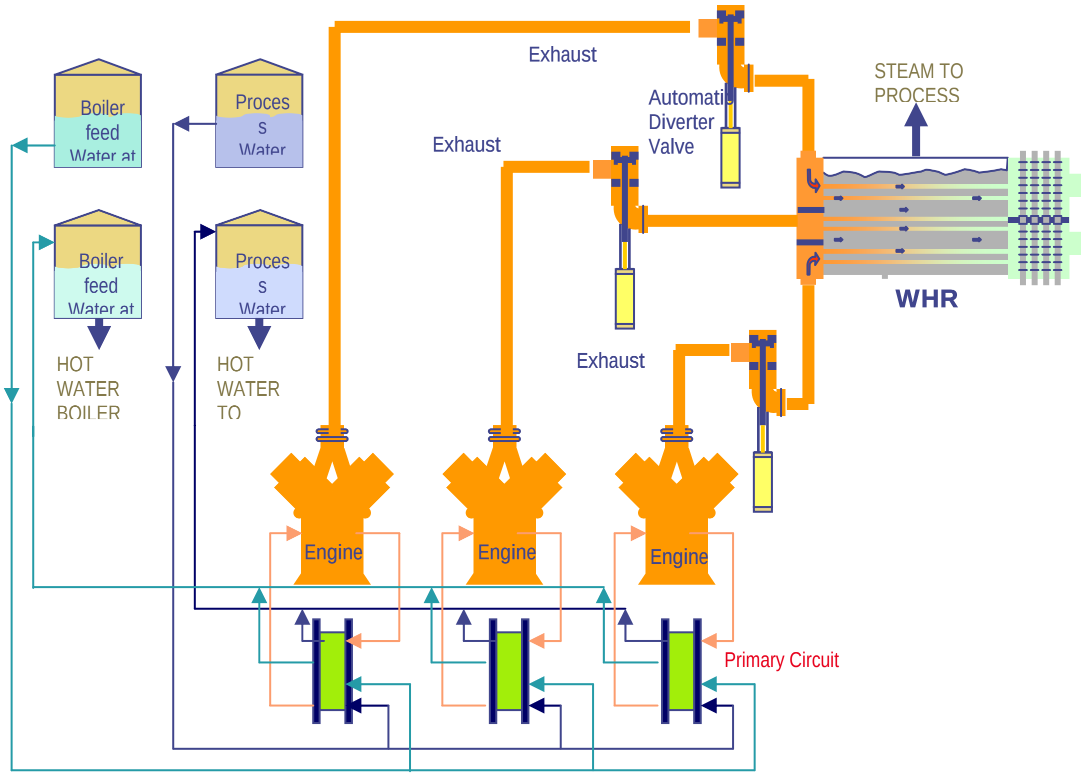
JACKET WATER HEAT RECOVERY SYSTEM		
DESCRIPTION	**UNIT**	**Parameter**
Engine Make		Mirless blackstone
Rated Capacity	MW	2.2
Heat Rejection	kcal/hr	650000
Flow Rate	Cu.m./hr	81
Inlet Temperature	Deg C	88
Outlet Temperature	Deg C	80

SAVINGS & PAYBACK(AARP)
Tons of refrigeration - 124
Power saving - 1Kw/TR
Power saving per hour - 124 Kw
Avg Power cost (Grid + Engine) - Rs 5
Total working Hours/annum - 8400
Annual saving - Rs 52.08 Lac
Total investment - Rs 156 Lac
Pay back Period - 35.94(Months)

Thus as compared to the compression cycle the absorption cycle is very attractive both in terms of technical as well as commercial feasibility.

Case Study-Textile Industry

We have implemented a cogeneration project at one of the reputed Textile Company in Maharashtra.



(Fig.5)

SYSTEM OVERVIEW

In this Textile Industry the cogeneration system consisted of Power generation, steam generation, Boiler feed water heating & Process water heating.
The plant was having 1MW X 3 HFO fired Man B&W Engine for power generation & a fired boiler for steam generation.
The basic requirement of the plant was power generation, steam, heating the boiler feed water to improve the efficiency of boiler, & heating the water required for process from 55 to 80 degC.
Considering the above requirements, Cogeneration was carried out on a HFO fired
1MW X 3 Man B&W Engine.
Before installing the cogeneration system the. The power requirement was met partly by grid power and partly through HFO fired engine.
Steam requirement was met using a fired boiler. Since the feed water to the boiler was supplied at 30degC, Boiler required more Heat to increase the temperature of water from 30degC to saturation temperature which meant that more consumption of fuel by boiler.
Similar case existed with process water also. Process water was required at 80degC where as the water was available to the plant at 55degC.To raise the temperature from 55-80 degC it required additional fuel firing.
Thus if we observe the operating cost of the plant was very high as fuel was required for engine firing, boiler firing, & process water heating Moreover the fuel used was very costly and the prices of fuel are continuously rising.. All these factors contributed in reduction of the overall efficiency of the plant.
In a view of reducing the operating cost and increasing the overall plant efficiency it was decided to carry out a engine based cogeneration which will fulfill the energy requirements of the Textile company viz. power, steam, Boiler feed water heating, & process water heating.

Power was generated through the Engine and the waste heat from flue gases of engine exhaust which were earlier sent unutilized to the chimney are now used to produce the steam using a smoke tube type waste heat recovery boiler and the heat in Hot water in engine jacket from all the 3 engines is used for

1. Heating the boiler feed water from 30 to 80 degC.
2. Heating the process water fro 55 to 80 degC.

This is accomplished by using plate heat exchangers in the Engine jacket hot water circuit.

Thus using such energy efficient cogeneration technique huge amount of saving was done by reduction in fuel consumption.

All these techniques helped in increasing the overall plant efficiency significantly.
This has helped the company to increase its profitability to great extent.

EXHAUST HEAT RECOVERY BOILER				
TECHNICAL SPECIFICATIONS				
DESCRIPTION	**UNIT**	**Parameter**		
Engine Make		Man B&W		
Rated Capacity	MW	1MW X 3 Nos.		
Exhaust Gas Flow	kg/hr	26460		
Exhaust Gas Temperature	Deg. C	310		
Heat Rejection to Exhaust	kcal/hr	2132676		
Fuel Used for Engine		Furnace oil		
Max Allowable Back Pressure	Mm WC	250		
Heat Recovery Unit		Boiler	Economiser	Total
Design Code		IBR	IBR	-
Safety Valve Set Pressure	Kg/sq.cm.g	17.5		-
Exhaust Gas Temperature	Deg C			
	Inlet	365	220	365
	Outlet	220	182	182
Net Heat Recovery	**kcal/hr**	**640491**	**148324**	**788815**
Steam Generation	**kg/hr**			
- f & a 100 Deg C		**1186**	**275**	**1461**
- f 90 Deg C & at 14kg/sq.cm(g)		**1111**	**257**	**1369**
- f 80 Deg C & at 14kg/sq.cm(g)		**1092**	**253**	**1345**

JACKET WATER HEAT RECOVERY SYSTEM		
DESCRIPTION	**UNIT**	**Parameter**
Engine Make		Man B&W
Rated Capacity	MW	1MW X 3 Nos.
Heat Rejection	kcal/hr	784320
Flow Rate	Cu.m./hr	102
Inlet Temperature	Deg C	85
Outlet Temperature	Deg C	77
Heat Recovery:		
a)Process Water Heating		
Quantity	Lit/day	160000
Inlet Temperature	Deg C	55
Outlet Temperature	Deg C	80
Heat Recovery	**Kcal/day**	**4000000**
b)Boiler Feed water Preheating		
Quantity	Lit/day	96816
Inlet Temperature	Deg C	30
Outlet Temperature	Deg C	80

Heat recovery	**Kcal/day**	**4840800**
Total Heat Recovery	**Kcal/day**	**8840800**
	Kcal/hr	**368367**

SAVINGS & PAYBACK

Fuel		Furnace Oil	
Efficiency	%	96	
Net Cal Value	kcal/kg	9710	
Sp. Gravity		0.95	
Cost of Fuel	Rs./Lit	25	
Hourly Fuel Savings	Lit/hr		132.04
Annual Working Hours		8400	
Total Heat Recovery	**Kcal/hr**	**1157182**	
Annual Fuel Cost Saving	**Rs. In Lacs**		**277.72**
Total Initial Cost	**Rs. In Lacs**		**156.00**
Payback Period	**Months**		**6.74**

CONCLUSION

Considering the energy crisis faced by our country and ever increasing energy demand, there is no denial to the fact that Cogeneration systems are the need of the hour. They have proven to be a very useful tool to combat the increasing energy demand. With the exhaustion & rising prices of fossil fuels the only viable solution for increasing the energy efficiency & optimizing the production facility lies with the cogeneration systems.