COMBINED HEAT & POWER
A TECHNOLOGY THAT COMBINES
ECONOMIC AND ENVIRONMENT DEVELOPMENTS

Prof.Vijay K.Patel
(Energy Consultant & Certified Energy Auditor by Bureau of Energy Efficiency,Govt. of India.)
EnerzeeCare Technology Services
N.G.PATEL Engineering College
Isroli-Afwa.Bardoli,Surat,INDIA-394620.
Tel-(02622)225591,223841, Fax-(02622)227613
vijaykpatel22@yahoo.co.in

Abstract
Cogeneration is 'simultaneous generation of two useful forms of energy (such as power and heat) from the same plant using one single primary energy source'.

Cogeneration or CHP (combined Heat & Power) system produce power either in from of mechanical or electrical energy and heat energy which is utilized for the heating or cooling in industrial process or buildings.
Because CHP captures the heat that would be otherwise rejected in traditional separate generation of heat and electrical energy, the overall efficiency of these integrated systems is much greater than separate individual generation systems.

Cogeneration is not a specific technology but rather an application of technologies to meet end-user demands for heating and/or cooling energy, mechanical and/or electrical power.
Recent technology development has 'enabled' new CHP system configurations that make a wider range of applications cost-effective and environment friendly.

New generation of turbines and its materials, sterling engines, fuel cells and reciprocating engines are the result of intensive, collobrative research, development and demonstration by government, research centre and private sector industries.

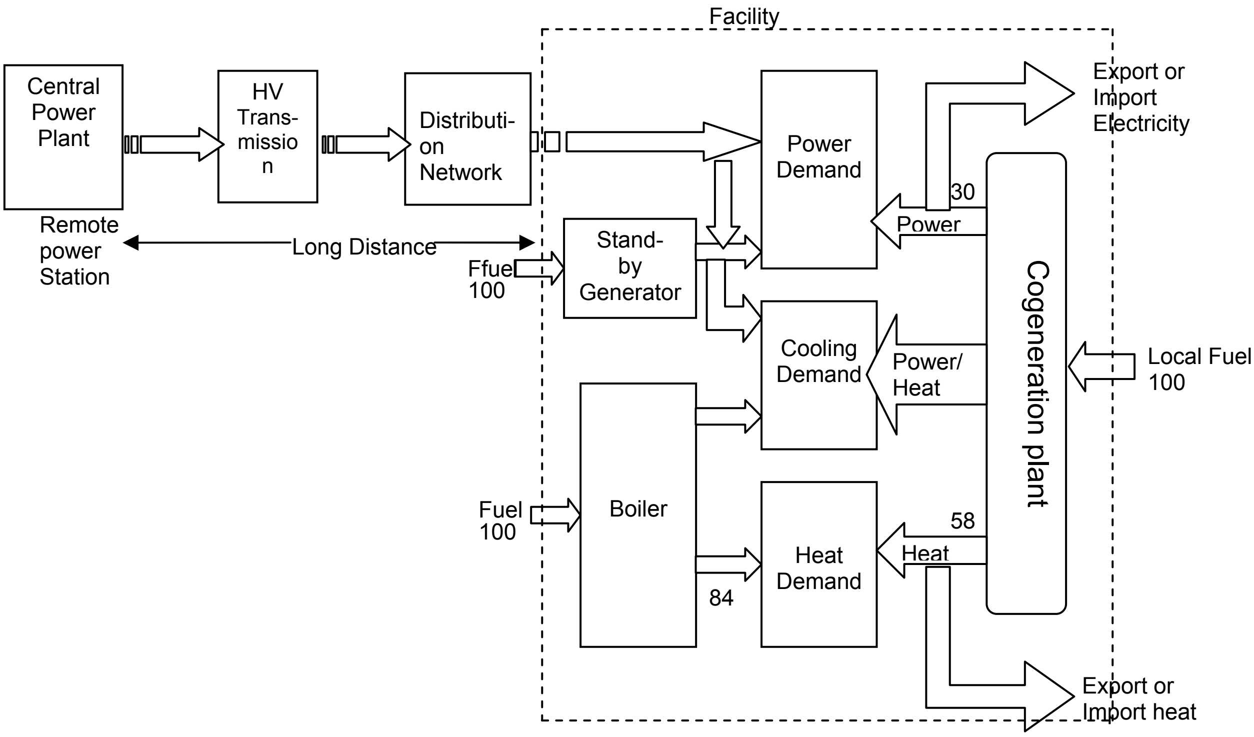
Advanced materials and computer-aided design techniques have dramatically increased equipment and system efficiency and reliability with reducing cost, time for installation and carbon emission, which will raise the economical benefits and help for funding carbon credits.

Introduction
Most of the industrial processes and commercial activities needs both type of energies generally, heat and electricity to operate their manufacturing processes, store their products and maintain comfortable working condition for man and machines.

Conventionally, the electrical energy would be supplied by a distribution network from remote, large power stations through an extensive and expensive long transmission and low voltage distribution lines. The cascade efficiency of the power system is 80-86 % and efficiency of the power generation is around 30-34 %,thus overall efficiency of the power system is around 26-32 % only.

The heat energy could also supplied by electrical or by on-site fuel combustion in a boiler. Cooling energy could be provided by local refrigeration system, which is utilizing either additional power or heat.

Conventional Plant **Cogeneratiion/Decentralised Plant**



The separate generation of heat and electricity are inherently inefficient, less reliable costlier and dump large amounts of pollutants like CO2, NOx and Sox into our valuable environment. CHP is an economically productive approach to lowering pollution through pollution prevention, whereas traditional pollution control achieved solely through flue gas treatment provides no profitable output and actually reduces efficiency and useful energy output.
CHP system can be viewed as two subsystems, the power system(usually engine/turbine and alternator) and heat recovery system(which is usually some type of heat exchanger/boiler).The efficiency of the overall system results from an integrated interaction between the individual systems efficiencies of the power and heat recovery.
The CHP process may be based on the use of steam turbine, gas turbine, combined cycles, reciprocating engines, microturnines, sterling engines or fuel cells.

In short, CHP or cogeneration offers significant, economy-wide energy efficiency improvement and emission reductions.Oue existing systems of centralized electricity generation charts an unsustainable energy path, with increasing fuel consumption and carbon emission, while continuing to squander over two-third of the energy contained in the fuel.At least half this wasted energy could be recaptured if we shift from centralized electricity generation to distributed generation systems that cogenerate power and thermal energy.

Besides saving energy and reducing emerging pollutant emissions, cogeneration also decreases emerging congestion problems within the electricity transmission and distribution grid.

CHP help to make significant progress towards our Kyoto commitments on GHGs reductions.CHP also present opportunities to improve the bottom-line for business and public organization, while also providing a path for improving the environment.

Cogeneration Technology

There are three main technoliges of cogeneration(CHP) systems are :

- Topping cycle
- Bottoming ycle
- Combined cycle

These will be briefly explained in turn.

Topping Cycle

In topping cycle cogeneration plant, the power is produced prior to the recovery of useful residual heat. The plants that generate mechanical power may produce electricity for their own use and then sell any excess power if available to a utility.
There are four types of topping cycle cogeneration systems, are

-steam turbine topping cycle
-gas turbine topping cycle
-reciprocating engine topping cycle
-combined cycle topping cycle

In steam turbine topping cycle, the fossil fuels is burnt in the boiler and produce steam which is dumped into the steam turbine to drive the alternator and generate the electricity. The steam is extracted from the steam turbine and utilized for the process heat duties.

In Gas turbine topping cycle or reciprocating topping cycle plant,the premium fuel is burnt in combustion chamber and expand in gas turbine or diesel engine to produce mechanical power or otherwise electricity. The engine cooling and exhaust provides heat which goes to a heat recovery boiler to generate steam to drive a secondary steam turbine. This is a combined cycle power plant.

Usually, the topping cycle plant is used where the electrical power requirement is more that heat demands (for lesser heat-to-power ratios).

Bottoming Cycle

In bottoming cycle cogeneration plant, heat is produced first and utilized for various industrial heat process and than waste heat is recaptured from heating process to power a turbine.

Bottoming cycle plants relatively uncommon but does specifically used in heavy industries such as glass or metals manufacturing, where there is a considerable heat of reactions. Since the fuel is burnt first in the boiler, no extra fuel is generally required to produce electricity.

Combined Cycle

A combined cycle cogeneration plants combines the Rankine cycle (of steam turbine) and Brayton cycle (of gas turbine) for raising the overall efficiency.

Usually, natural gas or naptha burns in the gas engine/turbine to produce electricity. The exhaust of gas turbine have very high temperature around 500-600 C.This hot exhaust gas from gas turbine utilized in heat recovery steam generator(HRSG),which produced high pressure steam for the steam turbine to generate the electricity.

The fuel used in the combined cycle power plant are usually common as used for the gas turbine,i.e.natural gas, fuel oil, gasoline etc.

There are two prime movers ,gas turbine and steam turbine.Typicall overall efficiency of combined cycle plant is about 90 % depending on the type of fuel, quality of fuel and system configuration used.

Cogeneration Systems-Prime Movers

Cogeneration systems can be classified in respect of prime movers used also.

- Steam turbine system
- Gas turbine system
- Reciprocating engine system
- Micro turbine system
- Sterling engine system
- Fuel Cell system
- Trigeneration System
- Combined cycle system

Steam Turbine System

Steam turbine system is the most common system for the cogeneration. It is used from small unit well below 1 MW to the largest utility plant. Fuel is burnt in the boiler and produce high pressure steam which drive the steam turbine, which is coupled with the alternator to produce electricity. The exhausted low temperature steam is utilized for the process heat applications or condensed into the condenser and again fed to the boiler. There are two typical systems are used,

(1) Back-pressure steam turbine
(2) Extraction-condensing steam turbine

For viable power generation, steam input must be at a high pressure and temperature, The plant is capital intensive because a high pressure boiler is required to produce the motive steam. Steam cycle typically produce a large amount of heat compared to the electricity, resulting in a high cost installation in terms of Rs./KWh.

Gas Turbine System

The gas turbine has become the most widely used for the large scale cogeneration in recent years, typically in size of 1-300 MW.This gas turbine plant is the compact in size, more cleaner ,easy to install and more reliable one.

The main components of this gas turbine system are-

- Compressor
- Combustion Chamber
- Expander (Turbine)

Compressor compresses the atmospheric air after filteration.The fuel commonly natural gas or fuel oil, or combination of these, is burnt with compressed air into the combustion chamber. This hot gas/air mixture expands in the turbine, which drives the alternator to generate the electricity.
The hot gas is exhausted from the gas turbine at a very high temperature about 500-600 C ,The residual heat energy into the exhausted gas can be recovered to meet, wholly or partially, the heat demands of the plant.
High temperature exhaust gas, making gas turbine particularly suitable for high grade heat supply. The common heat-to-power ratio ranges from 1.5:1 to 3:1., depending in the configuration of the gas turbine system.Supplementry firing may be used to increase exhaust gas temperature to 1000-11000 c or more, raising the overall heat-to-power ratio to as much as 10:1.Supplemetry firing is highly efficient (more than 90 %)because no additional combustion air is required to burn extra fuel.

Reciprocating Engine System (IC Engine System)
The reciprocating engines used for the industrial cogeneration and power plants are the internal combustion(IC) Engines operating in the otto and diesel cycles.Although, conceptually the system differs very little from that of gas turbine,there are significant variations. Reciprocating engines give a higher electrical efficiency, but it is more difficult to use the thermal energy they produe,since it is generally at lower temperature and is dispersed between exhaust gases and cooling systems.
The familiar fuel for the reciprocating engine is fuel oil, gasoline, diesel and gaseus fuel. High temperature (high grade) heat can be recovered from the exhaust gases for the steam generation. Low temperature (lowe grade) heat can also be recovered from the engines cooling system(lube oil, jacket cooling)for hot water generation.
The useable heat-to power ratio ranges from 0.5:1 to 2:1.Typicall sizes of reciprocating engines cogeneration system is from 1 KW to 20 MW.Thermal electrical efficiency is around 25-45 % and overall system efficiency is about 60-86 %.

Microturbine System
Microturbine are comparatively new technology comcept.Microturbines are compact, high speed gas turbines ranging from 25-200 KW.Microturbines are primarily fueled with natural gas or biogas, which have relatively low capital and O & M costs as no coolant and lubricants.
Microturnines have a numerous applications as a packaged distributed generation unit such as-
-Small traditional cogeneration, hotels, hospitals
-Back-up power source
-Remote power utility
-Peak shaving
The typical electrical efficiency and overall efficiency are 20-30 % and 75-85 % respectively.

Stirling Engines System
The stirling engines are an external combustion engine, where heat is supplied and removed at constant temperature.
Thus this engine works on the same principle to the theoretically high efficient Carnot cycle.
Heat is supplied to the stirling engine by an external source, such as burning gas, and this makes a working fluid e.g. helium or hydrogen, expand and cause one of the two pistons to move inside a cylinder.
The stirling engine has fewer moving parts and no valves,tappets,fuel injectors or spark ignition system.
The merits of stirling engine system are
- Compact size
- Less moving parts hence less O&M cost
- High theoretical efficiency
- No internal burner chamber
- No need for an extra boiler
The striling engine has been used for several applications such as in submarine, small-scale power cogeneration and hybrid cars.
The electrical efficiency of the stirling engine is about 25-30 % in the 10 to 30 KW ranges, but still there is a potential to raise the performances. The external burners allow a very clean exhaust gas and gives the possibility of controlling the electrical output of the engine by reducing the temperature at the hot-side. Hence there are the possibilities of varying the electrical power generation regardless of the need for thermal heat demand.

Organic Rankine Cycle
An organic Rankine cycle plant is the slide modification of steam turnibe system, where the working media is an organic fluid (hydrogen or ammonia) instead of water. This system is being developed for small-scale cogeneration and geothermal power generation systems.
The electrical efficiency of ORC system is about 10-25 % in the ranges 200 to 1500 KW,there may be possibility to raise the performances in ORC systems.

Fuel Cell System

Fuel cells converts chemical energy of hydrogen and oxygen directly into the electrical energy without combustion and any mechanical works. Fuel cells produce electricity, heat and water simultaneously through an electrochemical process.

In Fuel Cell,a gaseous fuel(hydrogen) is feed to the anode and oxidant(Oxygen) is feed to the cathode. The electrochemical reactions occur at the electrodes and ions ar exchanged between anode and cathode through electrolytes, in both directions.

Usually, all Fuel Cells are based on the oxidation of hydrogen.The hydrogen is used as a fuel can be derived from verify of sources such as natural gas, methanol, ethanol, propane or from electrolysis of water.

There are both low (<2000 C) and high temperature fuel cell available commercial. High temp. fuel cell have comparatively higher efficiency and could be connected to gas turbines and/or steam turbines in combined cycle systems, resulting very high efficiency. The efficiency of fuel cell ranging % depending of the fuel cell type.

Fuel cell types

Type	Operating temp.	Electrolyte
PEM(Polymer Exchange Membrane)	~ 80-1000 C	Solid
PAFC(Phosphoric Acide Fuel cell)	~ 80-1000 C	Aqueous
MCFC(Molten Carbonate Fuel Cll)	~ 80-1000 C	Liquid
SOFC(Solid Oxide Carbonate Fuel Cell)	~ 80-1000 C	Solid

Trigeneration System

Trigeneration system produces the three energies simultaneously. i.e. electrical energy, heating energy & cooling energy from the same plant. By using cogeneration, the electricity & heat is produced. This heat is further used in vapour absorption refrigeration (VAR) system to cool the water or air. As the driving force in VAR system is heat instead of electrical power as in vapour compression refrigeration (VCR) system, the waste heat from cogeneration is used for VAR system. The overall efficiency of trigeneration system is around 60-80%.

Benefits of CHP

CHP provide a potentially cost-effective way of servicing the both heating & electrical demands of industrial & commercial processes.

The major advantages of using CHP system are :-

1. Raise efficiency & reduce fuel consumption.
2. Reduce energy costs.
3. Reduce carbon emission.
4. Reduce or differed cost for HV transmission lines because it is a decentralized plant.
5. Enhanced energy security
6. Conservation of valuable fossile fuels.
7. Elimination of T & D losses.
8. Lower CO2, NOX, & SOX, dust, ash pollutants.
9. Ensure efficient use of capital investment.
10. Less time of installation (2-3 years compared to 5-7 years for conventional power plant)
11. Increased reliability of the service.

Selection of CHP System

Certain parameters should be considered additionally with the specific data & informations for the proper selection of the CHP plant such as:-

1. Electrical load profile.
2. Thermal load profile.
3. Future variation in both the demands.
4. Availability of fuel (Natural gas, Fuel oil etc.)
5. Cost of electricity & fuel.
6. Cost of supplying & installing the equipment.
7. Space requirement.
8. Environmental impact.
9. Overall efficiency & heat–to-power ratio suitability.
10. Suitability of alternative supply.
11. Cost/benefit analysis and financial arrangements.
12. Selection of appropriate prime-mover.

13. Maintenance & operation flexibility.

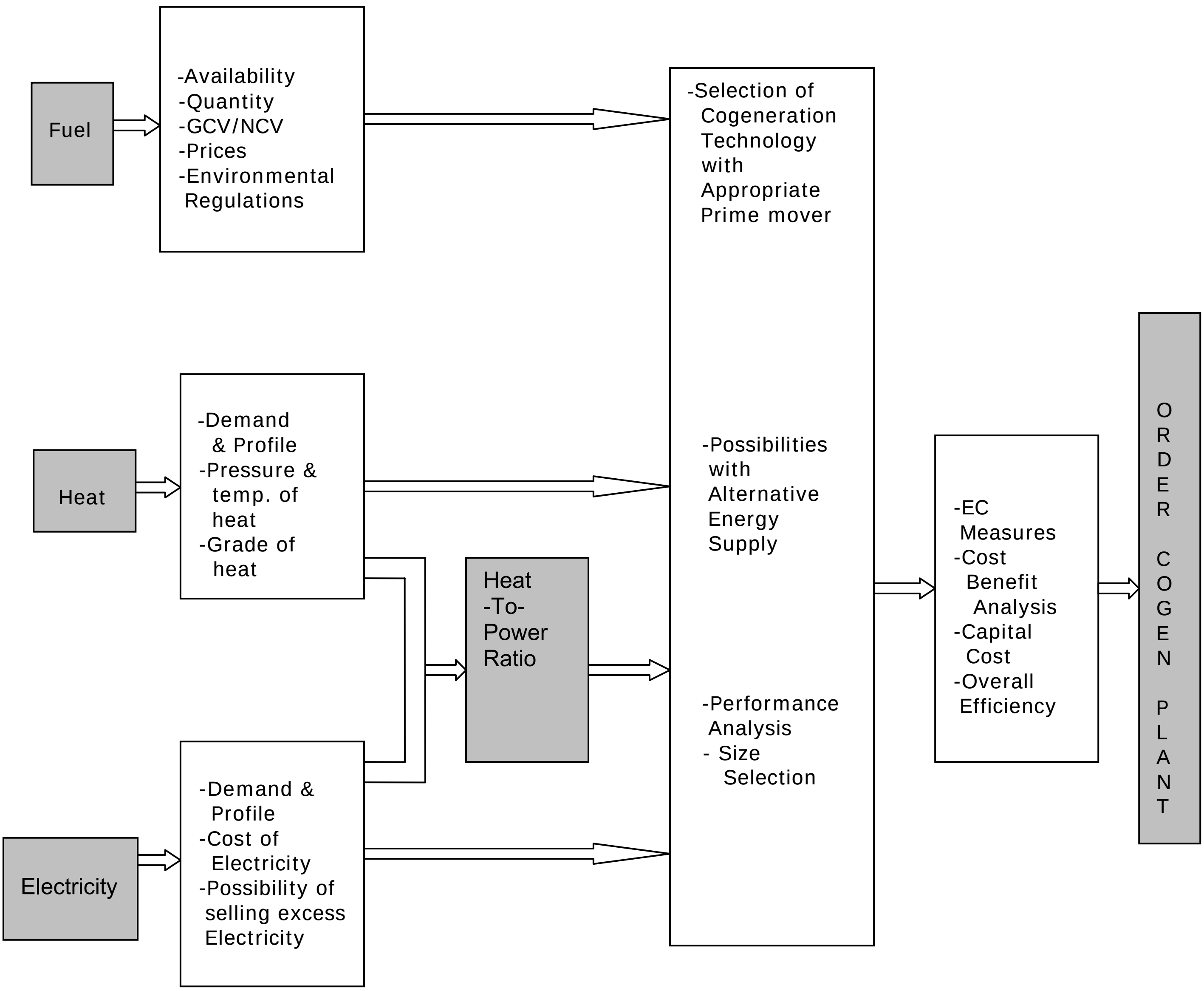


Fig. Steps for Technical Analysis of cogeneration (CHP) system

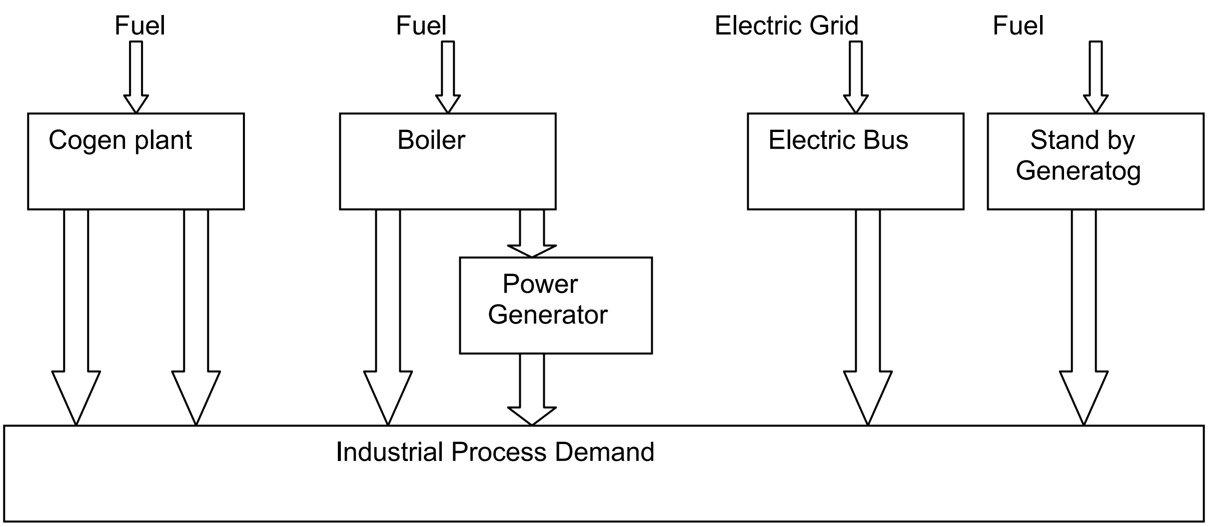


Fig. Alternative Energy Supply With Cogeneration

Selection OF CHP technology

Sector	Capacity	Coal + Product	Heavy Fuel oil	Biomass	Wastes	Biogas	LFO	Gas
Domestic	<15KW						GE	GE
Commercial	15-100KW			ST	ST	GE	GE	GE
	100KW-1MW			ST	ST	GE	GE	GE
	1-5MW	ST	ST	ST	ST	GT/GT	GT/GT	GT/GT
Industry	15MW	ST	ST	ST	ST	GT/GT	GT/GT	GT/GT
	5.50 MW	ST	ST	ST	ST	COGT	COGT	CCGT
	>500MW	ST	ST	ST	ST	CCGT	CCGT	CCGT

LFO : Light Fuel Oil
CCGT : Combined cycle gas turbine
GE : Gas engine
GT : Gas turbine
OCGT : Open cycle gas turbine
ST : Steam turbine
Source:- the future of CHP in the European market- the European Co-generation study; SAVE/future COGEN,2001.

CHP System Performance

There are components such as steam turbine, and/or gas turbine, heat recovery boiler & compressor (in case of gas turbine cogeneration system). The performance test of cogeneration plant includes determination of the electrical power out put, heat rate, heat-to-power ratio (H/E ratio) & efficiencies of each component such as steam turbine, compressor, gas turbine & heat recovery equipment. The following are the typical parameters being used in evaluation of the performance of Co-generation plant.

Steam turbine performance

$\eta ST = \Delta HA / \Delta HTH \times 100$

Where ηST = Steam turbine efficiency
ΔHA= Actual enthalpy difference Across the turbine (Kcal/Kg)
ΔHTH= Theoretical enthalpy (Kcal/Kg) Theoretical enthalpy (Kcal/Kg)

Gas turbine performance

$\eta COMP = \Delta TTH/\Delta TA \times 100$

Where $\eta COMP$ = Compressor efficiency
ΔTTH = Theoretical temp. rise across the compressor (0C)
ΔTA = Actual Across the compressor (0C) actual Across the compressor (0C)

Heat recovery Boiler performance

$\eta boiler = QS\ (hS – hW) /[QFl \times P \times \Delta t] + [QFL \times GCV]$

Where $\eta boiler$ = Boiler efficiency
QS = Steam flow rate (Kg/hr)
QF = Flue gas flow rate (Kg/hr)
QFL = Fuel consumption (Kg/hr)
hS = Enthalpy of steam
hW = Enthalpy of water
GCV= Gross calorific value of fuel (Kcal/Kg)
Δt = (Inlet temp. –Outlet temp.) Of flue gas in degree Celsius .

Also, the efficiencies can be computed as :-
Electrical efficiency $\eta ELE = QE /QFUEL$

Heat efficiency ηHEAT = QHEAT/QFUEL

Overall efficiency ηTOTAL= QE + QHEAT/QFUEL

Heat-to –power ratio = QHEAT/QE

Where
QE = Gross electrical output, kt e
QHEAT = Useful heat output, kt th
QFUEL = Fuel energy input (NCV), kt th

Cogeneration efficiency & heat-to- power ratio are two important key for the selection of the cogeneration technology & performance evaluation of exiting system.

CHP Promotion/Policies Reformation

For the promotion of the CHP technologies, some concrete steps to be taken with certain reformation of the policies such as :

- Reform central and state electricity utility regulations to provide fair and open access to the grid for procurement of standby power and excess generation sales.
- Provide3 financing helps and incentives, subsidies, tax credits to spur interest in CHP system.
- Reform of environmental permitting regulations and the permitting process to provide credit the inherent efficiency of CHP technology.
- Modernize the depreciations schedule for the CHP equipments and materials to reflect current markets and technologies.
- Develop educational and technical assistance programmes to increase awareness of CHP opportunities and benefits.
- Installation of CHP system in government premises to demonstrate the benefits and provide guidelines and market leadership.
- Initiate research and development programmes and activities to find new advancements, new materials, to expand ranges of CHP system to increase efficiency and effectiveness, to commercialize small-scale CHP system etc.

■ **Advantages and Disadvantages of different Cogeneration Systems**

Cogen. System	**Typical range**	**Electrical Efficiency**	**Overall efficiency**	**Power-to-heat ratio**	**Usual fuel**	**Advantages**	**Disadvantages**
Steam turbine	O.25-300MW	10-40%	<80	0.15-o.75	Coal bagase	-Suitable for low-premium fuel -fuel flexibility -easy retrof-ting of exiting boiler	-Moderator efficiency -Large capital cost -Huge O & M Cost -more pollution
Gas turbine	0.5-300MW	25-45%	65-90	0.45-0.75	Natural gas, naptha	-simple plant in respect of design, construction& control -Cleaner plant -Quick start/stop -Low investment	-Moderate part load efficiency -Limited suitability for low-premium fuel.
Combined cycle	10-300 MW	35-50%	75-90	0.75-1.8	Natural gas, naptha, fuel oil	-High electrical efficiency -High suitable as back up supply -Less space requirement	-Low overall efficiency -Not economic for small scale generation

Reciprocating engine	1-20 MW	25-45 %	65-85	0.5-1.8	Diesel, Fuel oil Gasoli-ne	-high overall efficiency - Quick start/stop	Limited suitability for low premium fuel
Cogen. System	Typical range	Electrical Efficiency	Overall efficiency	Power-to-heat ratio	Usual fuel	Advantages	Disadvantages
						-High flexibility in operation -cleaner plant	-Less suitable for low quality fuel
Stirling engine	10-100 KW	25-30%	40-75		Natural gas, Fuel oil	-Fewer moving parts -Compact size -Less O & M cost	-Commercially hot available for large generation
Micro turbine	25-200KW	25-30%	40-80	0.5-0.75	Natural gas	-Use as small traditional cogeneration -Back up supply -Remote power supply -Compact size	- Commercially hot available for large generation
Fuel cell	30-100KW	30-45 %	40-80	0.5-0.75	Hydro-gen	-Compact size -Decentralized generation package available	Commercially hot available for large generation

Barriers to CHP

Although technology used in CHP system have improved in recent years, significant hurdles exist that limit widespread uses of CHP.Importantly,these hurdles have the effect of tending to “lock in” continued use of polluting and less-efficient electricity generation equipment.
The certain barriers to CHP system are:
→ A site-by-site environmental permitting system that is complex, costly, time consuming and uncertain.
→ Current regulations do not recognize the overall efficiency for CHP or credit the emissions avoided from displaced grid electricity generation.
→ Depreciation schedule of CHP investments vary depending on system ownership and may not reflect the true economic evaluation of the investment.
→ The market is unaware of CHP system and its development that have expanded the potential for CHP.
→ Considering the local fuels like bagases, biogases as a less valuable byproducts from the plant sell it or loss it undesirably.
→ Large initial cost and limited financial helps are may be restrictions for the CHP adoptions.
→ Unawareness about the retrofitting of CHP system in the existing plant without more modifications.
→ Many electrical utilities currently charges discriminatory backup and require prohibitive interconnection arrangement.

<u>Case Study</u>
A simple comparison of the economics of the conventional separate generation of the steam and the electricity, and cogeneration system.

■ **Scheme-I (Cogen System)**
<u>Gas Turbine Specification :-</u>
Capacity : 6 MW
PLF : 90 %
Heat Rate of Gas Turbine : 3077.41 Kcal/KWh.

WHR Boiler Specifications :-
Capacity(Unfired) : 20 THP @ 200 C and 11.3 Kg/sq. cm
Steam Enthalpy : 678.33 Kcal/Kg

Fuel Details :-
GCV 10000 Kcal/ s. cubic metres.
Price : 6.54 Rs./s. cubic metres.

Project Details :-
Time of installation : 8-10 months.
Capital Investment : Rs. 2600 lakhs.

Economy of Scheme-I

Estimated energy output per annum = PLF **x** Capacity of Gas Turbine **x** operating hours/annum
= (90 **x** 6000 **x** 8000) / 100
= 43200000
= 432 lakhs KWH/annum.

Heat input to generate above units = Kwh per annum **x** Heat rate
= 432 **x** 3077.41
= 1329441.12 lakhs Kcal

Fuel(Gas) quantity required = Heat Input / GCV of natural gas
= 1329441.12 / 100000
= 132.94 lahs s. cubic meters per annum.

Fuel Cost = Fuel Consumption per annum **x** price of fuel
= 132.92 **x** 6.54
= 869.29 lakhs Rs. per annum.

O&M+other cost = 694 lakhs Rs. per annum.

Total Cost = 869.29 **+** 694
= 1563.29 lakhs Rs. per annum

Unit cost of electricity = total cost / total units generation
= 1563.29 / 432
= 3.62 Rs/KWh

■ **Scheme –II (Conventional Generation of Heat & Power)**

Electricity from Grid
Energy price including demand charges = 4 Rs./KWh

Heat Generation by Separate Boiler

Boiler Capacity: 20 TPH @ 200 C and 11.3 Kg/sq.cm
Cost of Boiler : 180 lakhs Rs.
Efficiency : 88 %

Economy of Scheme-II
Electricity Charges = Electricity price **x** total KWh per annum
= 4 **x** 432
= 1728 lakhs Rs./annum

Heat output from Boiler = Steam quantity x Enthalpy **x** Operating Hours/annum
= (20x1000) **x** 678.33 x 80000
1085328 lakhs Kcal/annum

Heat input = Heat output / efficiency of the Boiler
= 1085328 / 0.88
= 1233327.27 lakhs Kcal / annum

Gas Quantity required per annum = Heat input / GCV of Gas
= 1233327.27 / 100000
= 123.33 lakhs s. cubic meters/annum

Fuel Cost per annum = Gas Quantity **x** Gas price
= 123.33 **x** 6.54
= 806.57 lakhs Rs./annum

Total cost per annum = Electricity cost **+** Fuel Cost **+** O&M Cost including others.
= 1728 **+** 806.57 **+** 710
= 3244.57 lakhs Rs./annum

Cost/Benefit Analysis

Net Benefits from Scheme-**I** = 3244.57 – 1563.29
= 1681.28 lakhs Rs.

Simple payback time = Capital Investment /Net Savings per annum
= 2600 / (1681.28-694)
= **2.63 years**

Conclusion

Cogeneration or CHP is a proven technology that has been around for over many years. Cogeneration is not the latest industry buzz-word being touted as the solution to our nation's energy woes. Also, to the extent that cogeneration represents a good economic opportunities in sugar,paper and pulp and textile mills throughout India, it increase their financial and health of the agricultural sector as a whole.

Due to competitive pressure to cut and reduce emission of pollutants and greenhouse gases, owners and operators of industrial and commercial facilities are actively looking for ways to use energy more efficiently. One option is cogeneration, which is a tested technology.

Barring that development, improved technology and cooperation among industries,business,utilities,financer and government should provide impetus to the continued development of both cogeneration projects and independent power production projects.

Cogeneration is the environmentally-friendly, economically-sensible way to produce heat and power, simultaneously saving significant amounts of money and also dramatically reducing total polluting emissions.

FOOTNOTES / REFERENCES

1.Munson R. and T.Kaarsberg, "Unleasing Innovation in Electricity Generation",Issues in Science and Technoclogy,National Academy of Sciences,Spring 1998,Washington D.C. http://www.nemw.org/unleasedelec.htm.

2. Onsite Energy,Pulp and Paper Industry, On-site Power Market Assessment, Final Report,2006,Carlsbad,CA.

3. Energy Information Administration, emission of GHGs in the US,1996,DOE/EA-0573(96), Washington D.C.,http://www.doe.eia.gov.

4. Gas Research Institute, The 2004 Edition of the GRI Baseline Projections,Arlington,VA.

5. Kaarsberg T. and R.Neal Elliot, "Combined Heat and Power : Saving Energy and Environment"
The Northeast-Midwest Economic Review, Washington DC.

6 Whitney Colella,Design consideration for effective control of afterburner sub-systemia combined heat and power, fuel cell system(FCS),Journal Of Power Sources,118,2003.

7. Sims E.H,Gigler J, "The Brilliance of Bioenergy" Renewable Energy World Jan/Feb, 2002.

8. World survey of Decentralized Energy 2002/2003.(WADE)

10. EC directives on "the promotion of cogeneration based on an useful heat demand in the Internal energy market"

11. Danish OPET Energy center – sustainable Energy technology.

12. UN "Guidebook on Co-generation as a mean of pollution control & energy efficiency in Asia" United Nation 2000.

13. Chemical Engineer's Handbook
R.H.Perry, McGraw Hill Kogokkusha Ltd.

14. IEEE Transactions of Industry Applications, Journals, Institute of Electrical & Electronics Engineers, Piscataway NJ 08855-1331, USA.

15 Energy engineering , Association of energy Engineers(AEE) Indian Trail, Lilburn, GA 30247, USA.

16 Energy the international journal,

17. Energy cogeneration Handbook, George Polimeros, Industrial Press Inc.