CO-GENERATION – COMBINED HEAT & POWER (CHP)
CASE STUDIES ON IMPROVEMENT OPPORTUNITIES

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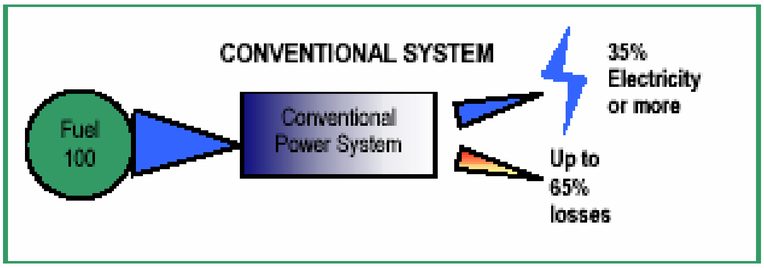
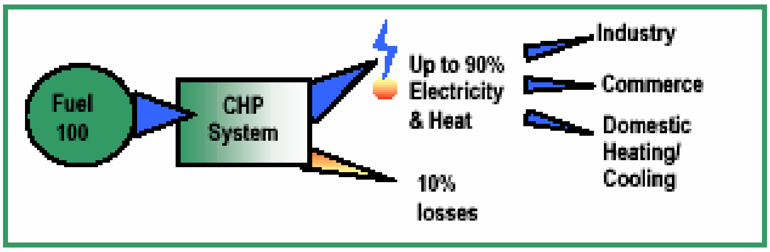
Co-generation or Combined Heat & Power

Co-generation or CHP is the simultaneous production of electricity and heat using a single fuel such as natural gas, and a variety of other fuels such as bagasses, coal, waste gas, liquid fuels (naphtha). In a conventional power plant, fuel is burnt in a boiler to generate high pressure steam. This steam is used to drive a turbine which in turn drives an alternator to produce electric power. The exhaust steam is generally condensed to water, which goes back to boiler. As the low pressure steam has a large quantity of latent heat which is lost in the process of condensing, efficiency of conventional power plant is only around 35%. In the CHP process, heat produced from electricity generator i.e. exhaust gases from gas turbine, different level of exhaust steam from steam turbine can be effectively utilized as a heat source both for industrial & domestic purposes. As a result , co-generation plants achieve high efficiency levels up to 90% In view of high cost of electricity and its shortage, this concept is highly beneficial to the process industries which require both steam and power. For older industries who are operating aging, inefficient boilers, concept of cogeneration is cost-effective modernization with Energy Conservation.



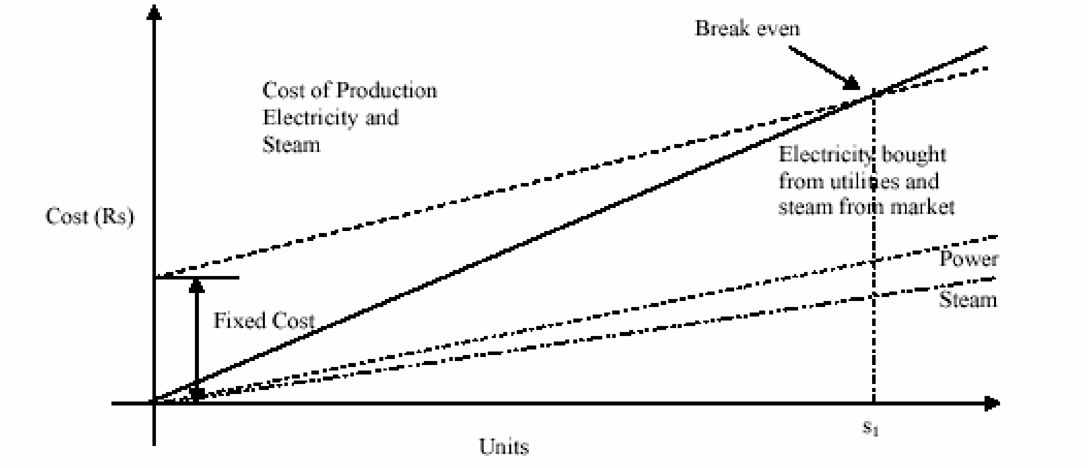


Trigeneration:

- **Conversion of Single fuel source into electricity, steam or hot water and chilled water.**
- **Conventional cogeneration can be coupled with a chiller either by compression (using heat to create cooling) or by absorption and it can be applied in district cooling, buildings, food industry.**
- **Main barrier high cost of the system.**

Cost Advantage equation for cogeneration.

Σ Volume of Steam X unit cost of procuring steam + Σ Electricity Units consumed X Industrial tariff ≥ Installation cost and other fixed costs of the CPP + Σ Volume of Steam generated by CPP X unit cost of steam + Σ Electricity units consumed X cost of generation.



Advantages of CHP:

- Increased efficiency of energy conversion and use. Most effective form of power generation.
- Lower emissions to the environment, in particular CO2 the main GHG Co-generation is the biggest solution to the Kyoto targets and CDM benefits to country like India.
- Large cost savings providing competitiveness for industrial and commercial users.
- Move towards more decentralized forms of electricity generation, where plant is designed to meet the needs of local consumers, providing high efficiency avoiding transmission losses (which is 8 to 10%) increased flexibility in System use, less dependency on state electricity grid supply, improved reliability

Essential requirements for the successful implementation of cogeneration

1.	Have all other energy saving measures been identified and either implemented or taken into consideration ?
2.	Is there a Simultaneous base load requirement for electricity and heat which exceeds 20 kW respectively for more then 4,500 hours/year ?
3.	Is there a suitable fuel supply ?
4.	Is there suitable access and space for a cogeneration unit and is the location suitable with respect to other site functions (e.g. noise and exhaust) ?
5.	Are the fuel and electricity consumption records available on a monthly or more frequent basis ?
6.	If there are any site changes/developments planned, have the possible effects on the cogeneration size/economics been taken into account ?
7.	Is there a requirement to upgrade any part of the existing heating, electrical distribution or control system as a result of the cogeneration installation ?
8.	Is the proposed heat user near to the proposed cogeneration location and electrical distribution system ?
9.	Is there a likelihood that direct funding or an alternative route to funding is available ?

CHP project development

Each potential CHP project is unique, hence there is ho substitute for a site specific study That is whilst there is thread as to where CHP is likely to be of benefit , there is diversity of fuel , cost of process steam or heat , and the general needs of the company. Typical elements of feasibility study include.

- Primary products produced by site
- Examination of electricity and heat demand , profile cost shutdown/holidays
- Current company thinking on system configurations and permutation included in the Investigation.
- Plant schematic and description of steam/hot water, cold water use on site
- Percentage and temperature of condensate to be returned from process
- Type of water treatment plant
- Requirement for waste incinerators, air compressors, refrigeration appropriate
- Whether there is somewhere that low- grade surplus heat can be disposed, etc. (Cooling through absorption cycle).
- Determination of age, condition and redundancy in exiting plant (equipment which could be retained)
- The sensitivity to loss of supply , and consequences if the supply is lost

Potential for CHP in India

TERI had carried out a detailed survey of 300 industrial units covering 10 different industrial sectors in the country and estimated CHP potential based on the analysis of the data obtained from the questionnaires. The investment required for the steam or/and gas turbines for each of the sector was also studied under the study . The CHP estimates are based on the internal heat to power ratios, which would meet the plants energy requirements and based on the exiting production capacities of the various industry categories. Of the total estimated potential 7,574 MW, nearly 68%is estimated to exits in the sugar industry alone. In the power maximization option, the CHP potential is expected to increase significantly. Since India is the largest producer of sugar in the world , bagasses-based cogeneration is being promoted . the potential for cogeneration thus lies in distilleries , petrochemical sector and industries such as fertilizers, steel, chemical, cement, pulp and paper , and aluminium

Table-I

Opportunity for application of co-generation:

- Include the process industries, commercial buildings, heating etc.
- Pharmaceuticals and fine chemicals
- Paper and board manufacturers
- Brewing, distillation, matting
- Ceramics, bricks and cements
- Food, Textile and Mineral processing
- Refineries, Petrochemicals, Fertilizers
- Iron & Steel
- Timber processing
- Sugar Industry
- Land fill sites, gasified Municipal solid waste
- Hospital waste incinerators
- Sewage treatment
- Agro wastes i.e. bio-gas
- Energy crops

Table-II

Potential of CHP in the Indian Industry

Industry	Potential (MW)	Investment for Turbines (Million Rs.)
Aluminium	59	590
Caustic Soda	394	3940
Cement	78	780
Cotton Textile	506	5060
Iron and Steel	362	5430
Man made Fibre	144	1440
Paper	594	5240
Refineries	232	3010
Sugar	5131	66700

Sulphuric Acid	74	740
Total CHP Potential	7574	93630
Source: Energy Technology News TERI : Issue 2 and 3 Jan – April - 2001		

Cogeneration in Cement Industry.

Cogeneration of power utilizing waste heat is an attractive proposition for cement plants for energy conservation and minimizing dependence on the grid. Further, cogeneration of power will also help reduce environmental pollution as well as strain on the economy because of reduction in consumption of diesel oil. The present scenario therefore, warrants adoption of cogeneration systems in the India cement industry to make them more economical and to ensure cleaner environment.

Cogeneration systems are already in use in cement industry in Japan, China and other south-east Asian countries. However, in Indian cement industry, this technology has not been implemented so far owing to the following reasons :

Non-availability of proven technology indigenously
Non-availability of installation or their operating experience in India
resulting in lack of confidence.
Design of waste heat boiler suiting to high dust load.
Large capital requirement and financial constraints owing to depressed
Cement marketing scenario.

Nevertheless, the cement industry is quite keen to adopt the cogeneration system provided its apprehension with regard to technology and economic risks are alleviated through installation of demonstration project, and financial assistance.

The Ministry of Commerce & Industry, Govt. of India, has identified NCB as the nodal agency for evaluation of various available cogeneration technologies. NCB is also making efforts to secure support from Global Environment Facility (GEF) for installation of a cogeneration system in a cement plant to serve as a demonstration Unit/Model.

NCB studies indicate that in the dry process cement plants, nearly 40 percent of the total heat input is rejected as waste heat from exit gases of preheater and grate cooler. The quantity of heat lost from PH exit gases ranges from 180-250 kcal/kg clinker at temperature range of 300-4000^0 C. In addition, 80-130 kcal/kg clinker heat is lost at a temperature range of 200-300^0 C from grate cooler. This waste heat can be utilized for electric power generation. There can be many combinations to work out the best scheme suited to a given situation. In existing plants. Cogeneration technologies based on bottoming cycles have potential to generate upto 25-30 percent of the power requirement of a plant.

The analysis of the data of 20 cement plants by NCB has indicated cogeneration potential ranging from 3.0 to 5.5 MW in different plants depending upon the temperature and quantity of waste gases from PH and cooler exhaust, number of PH stages, use of gases for drying of raw materials and coal etc. There is a total cogeneration potential of about 200 MW in 45 plants of 1 MTPA and more capacity.

Cogeneration in Sugar Industry.

India and Brazil are the largest producer of Sugar in the World hence bagasees based Cogeneration need to the promoted. Bagasses bases cogeneration plants are also good CDM projects. In Brazil out of 45 CDM projects registered, upto June 06, 21 projects are based on bagasees cogeneration project giving more than 0.35 Million CER per year.

In India Ministry of New & Renewable Energy MNES GOI is implementing the World's largest Co-generation programme in Sugar Mills. With established potential of more than 5000 MW, so far a capacity of 537 MW has been commissioned and 536 MW is under installation. Following are the notable initiatives for acceleration of bio-mass power generation programme.

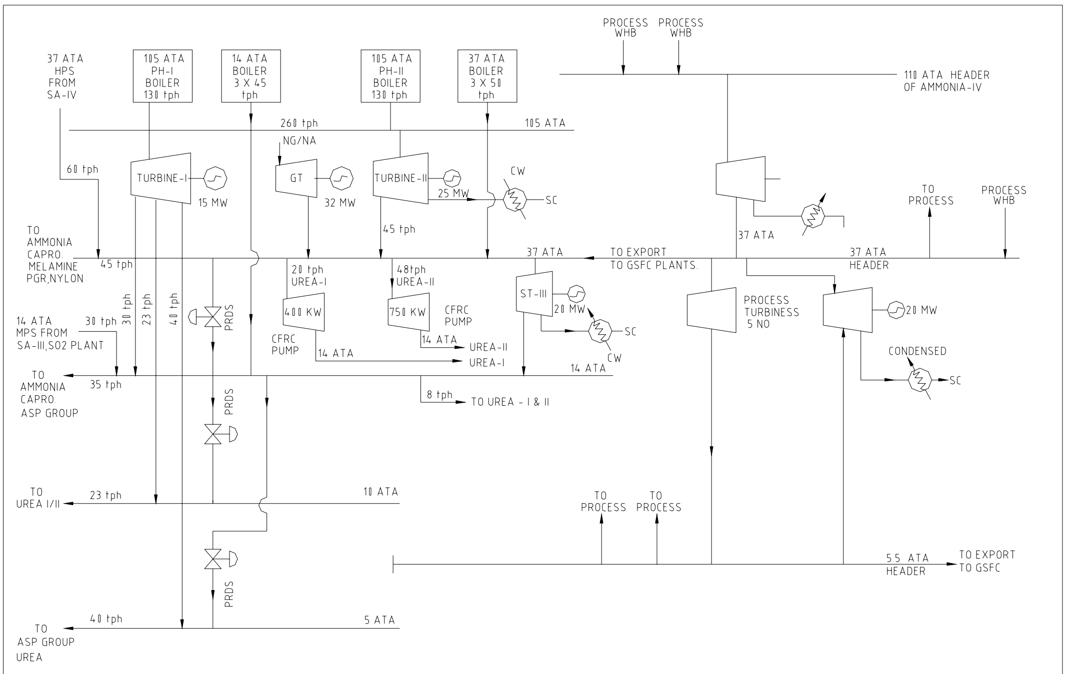
- Finalisation of Demonstration projects in co-operative sector Sugar Mills.
- US $ 65 Million UNDP/GEF bio-mass power programme.
- Schemes for Central Financial Assistance CFA in the form of grants in aid interest subsidies, fiscal incentives like accelerated depreciation (80% in the first year), 5 years income tax holding, exemption in General Sales Tax in certain states.
- Remunerative policies by State Government for purchase/wheeling /banking of power generated from bio-mass power project.

Cogeneration Of Power and Steam at GSFC Vadodara:

Gujarat State Fertilizers & Chemicals Ltd, Fertilizernagar, Vadodara is manufacturing Ammonia, Urea, Caprolactam, Melamine, Phosphoric Fertilizers and other Industrial products. As per original design, all electric power required was purchased from State Electricity Board. On the other side, three 15 ATA and two 37 ATA steam boilers were provided to cater process steam requirement of 150 MT/hour. Keeping in mind the obvious advantages of higher thermal efficiency, additional availability of power and increased operational flexibility of steam network, these old and aging boilers were replaced in a phase wise manner by two 105 ATA boilers with two turbo generators with suitable extraction and condensation stages for cogeneration of 40 MGW of electric power. These cogeneration units were installed at a total cost of Rs. 73 Crores. Still dependency on state grid for about 50- 60 MW of power affected plant operation particularly during deficit power generation condition in the state. Thus the need for self sufficiency on power front was realized, as any power cut imposed by SEB would adversely affect the production. This way, Phase-III combined cycle cogeneration steam and power plant consisting of 30 MW GT, 125 TPH WHRB & 20 MW ST was realized and commissioned in 1996. As a result, power availability has improved considerable and substantial energy savings has been achieved.

In the production of ammonia, the energy losses through cooling water, is quite substantial, to the tune of 30-40% of the total energy requirement. These losses mainly occur because of the process coolers / condensers and also surface condensers, which function as a heat sink for the condensing turbine. As is known, the process of ammonia formation is exothermic and lot of waste heat is generated during the process. This heat is best recovered as high-pressure steam. However, the low-grade heat is recovered for preheating of DM water and / or in the re-boilers of the purification section. Very low level heat is rejected through the process coolers / condensers. Most of Ammonia plants produce high-pressure steam at a pressure of about 105 kg / cm2. This steam is let down through a turbine to medium pressure. Medium pressure steam is generally used as process steam or in back pressure turbines which drive various pumps and compressors. The exhaust of back pressure turbines is used in the process. The over-all energy recovered from steam user in the process and in back pressure turbines is of the order of around 90%.

However, all the steam produced cannot be used for such process purposes within the ammonia plant. The balance steam is used for driving rotating machineries through condensing turbines, where the utilization of heat energy is only 20-30% as major part of heat (latent heat) of steam is rejected to the cooling water. Hence co-generation in a fertilizer plant needs major attention.



CONCEPT OF CO-GENERATION IN GSFC FERTILIZER COMPLEX

In GSFC's 1350 MTPD Ammonia Plant based on Linde Ammonia concept, a condensing type turbo generator of 25 MW is provided. The steam turbine of this unit is designed for utilizing 37 ATG steam as live steam while 5 ATG LP steam generated from various small back pressure turbine is used as admission steam.
Design Conditions:

Live Steam 34 barg : 70 MT / HR
Admission Steam 5.5 barg : : 40 MT HR
Power out put : : 20 MW

Problem faced / Improvement sought

- Lower power demand
- Shortage of Live steam
- High cost of Live steam

It was desired to reduced MP steam / LP steam control ratio to utilize all LP steam with minimum use of Live MP steam.

Implementation: After careful study of design , in house as well as By OEM, control Logic was modified.

Result: It was found possible to reduce loading of TG from 12 MW to 7 MW without venting of LP steam. Resulted in reduction in MP steam demand by almost 15 MT HR.

Further work for utilization of 5.5 barg steam in other process plant of GSFC also initiated.

Cogeneration – Steam Turbines in Process plants.

In process plants steam is produced at higher pressure and then reduced to different levels as per process requirement. Using the pressure drop to drive a steam turbines and an electricity generator rather then reduction through a pressure reducing valve could reduce electricity demand from Utility supplier. Best practices plant-wide assessment case study 3M by DOE - USA bring forth such example where, by adopting steam turbine in place of pressure reducing station (125 psig------15 psig), more than 3 Million KWH/year will be saved.

In GSFC's Urea plant, the process require major 14 ATA steam and the same was reduced from 37 ATA. On replacing 2 No. of carbamate recycle pumps from electric driven to steam turbine and by changing to pumps from Reciprocating to centrifugal type, we could reduce power consumption by 1150 KWH/year. This way a review of over-all steam balance of the process plant and Utility may bring forth such opportunity.

Improved performance of CHP through Inspection & Maintenance.

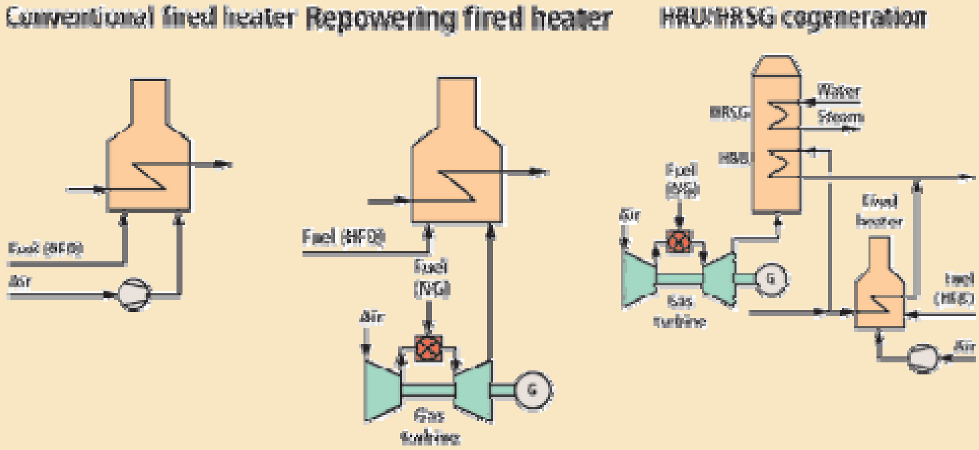
Regular maintenance and inspection of steam turbine pays rich dividend in establishing performance. Southern Petrochemicals Industries Corporation Limited, Tuticorin achieved Load enhancement of Turbogenerator. They had commissioned at 5.2 MW back pressure turbogenerator in year 1986. The Unit was designed for inlet steam pressure of 45 KSCG. Over a period of time, the output of the unit came down slowly. The output of the Unit could not be increased beyond 4.6 MW even after repeated over hauling and inspection. Various measures such as correction in nozzle profile, adjustment of diaphragm clearance, installation of spare rotor helped in achieving rated output of 5.25 MW.

CADDET Energy efficiency Result 341 has presented improvement in steam turbine performance at a Steel Mill. By rebuilding the turbine to incorporate the latest steam path technology, changing source of boiler feed water to warmer stream and by admitting Low pressure steam directly into the turbine, its output could be increased from 42 to 48 MW. It also helped in reducing discharge of warmer water and reduced emission.

Direct heat recovery of a co-generation Unit saves utilities and reduces emission.

In traditional co-generation, heat is recovered into a heat recovery steam generator (HRSG). However, opportunities also exist to recover heat directly into a process in an HRU provided there is an appropriate temperature match. Such is the case with most fired heaters in a refinery, Such an HRU co-generation was built and commissioned at the S/A Dansk Shell Refinery in Fredericio in 1991 as a part of de bottlenecking project. The only difference between its scheme and the above mentioned concept is that the remainder of the exhaust heat is not utilized for steam generation, but in a district heating scheme. It demonstrated that HRU/HRSG co-generation unit is a viable alternative to meet the increasingly stringent environmental requirement.

A comparison:	Conventional fired heater	Repowering fired heater	HRU/HRSG cogeneration



Energy savings	Reference	Approx. 5–10%	Approx. 10–20%
Upstream time	Reference	No improvement	Improved
Capacity increase	Reference	No improvement*	Possible**

* Capacity can even decrease due to limited gas flow through the fired heater.
** A capacity increase is possible if the fired heater represents the bottleneck of the refinery unit.

Performance Improvement of Gas Turbine Cycles.

The gas turbines are generally used for large scale power generation. The basic gas turbine cycle has low thermal efficiency. So it is important to look for improved gas turbine. The inlet air cooling helps in increasing the performance of has turbine. Another method for increasing the performance has been to introduce a high amount of water or steam at various points in the cycle. Cooling inlet air by water media could enhance power by 2 to 4% depending upon to weather. Cooling inlet air by absorption chiller can increase turbine output by 15-20%. Advance gas turbine cycles such as steam injected gas turbine cycles (STIG) Evaporation Regenerative Gas Turbine Cycle (ERGT). Humid Air Turbine (HAT) can also be examined for improved performance of gas turbines.

Concluding Remarks :

Any industry utilizing both heat & power will find certain application of concept of cogeneration. For green field plants. Application of CHP can be considered on the basis of process integration & other tools. For existing plants, detail steam & power balance could bring forth hidden opportunities. With rising cost of fuel, identifying & implementing small or big cogeneration scheme has become economic propositions. Large opportunity exist in Cement, Sugar & Petrochemical plants and they need to be utilized during modernisation and Debottlenecking existing plants. Case studies also bring out benefits of regular inspection, and maintenance of CHP equipment and performance up gradation measures.

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