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Combined Heat and Power Scenario in Commercial Sector

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ABSTRACT: CHP systems are increasingly finding acceptance for situations demanding simultaneous use of electricity and heat. In this paper, combined heat and power (CHP) has huge potential to deliver energy savings, and in many cases cost reductions too. But the market and regulatory framework is the key to delivering large-scale installations, and government has a poor record in delivering an appropriate framework. Technology is central to the future competitiveness and therefore uptake of CHP. It could lead to more efficient CHP electricity generation, including CHP in heat & power networks. The key issue is the creation of the saving in energy to by CHP, and part of this is support for the energy services approach. Combined heat and power (CHP) is the simultaneous generation of heat and power, usually, in a single process. The term CHP is synonymous with cogeneration. CHP can use a variety of fuels and technologies across a wide range of sites and sizes of scheme. As well as reducing losses in transmission and distribution, it can provide important network services such as black start when the electricity networks go down, improvements to power quality, and the ability to operate in island mode if the grid goes down.

Keywords: CHP, Cogeneration, Distributed System.

I. INTRODUCTION

A combined heat and power (CHP) system or cogeneration generation is defined as the simultaneous production of thermal energy and power – electrical and/or mechanical or the recovery of “low level” heat for power generation. It has been applied worldwide for a number of years. The turn to new investigations and totally new innovative ways of waste of energy utilization was due to the increase of fuel prices during the last decades, having undesirable results on the economy of many countries around the world. The abrupt increase in energy demand and fuel prices and the uncertainty of the world future energy situation has led engineers to investigate new schemes and techniques of energy saving. A CHP system can convert fuels, such as gas or fuel oil, into high value electricity and heat. It can generate “home – made” electricity more cheaply than it can purchased.CHP (Combined Heat & Power) is the simultaneous production of useful heat and power within the home / industry / hotel / hospital / shopping complex/university campus. It works very much like the gas boiler in a central heating system and heats the home in just the same way. However, at the same time it generates electricity, some of which you will use in your own home: the remainder is exported to grid to be used by your neighbors. Combined Heat Power (CHP) Cogeneration is a highly efficient means of generating heat and electric power at the same time from the same energy source. Displacing fossil fuel combustion with heat that would normally be wasted in the process of power generation, it reaches efficienciences that can triple or even quadruple, conventional power generation. Although cogeneration has been in use for nearly a century, in the mid-1980s relatively low natural gas prices made it a widely attractive alternative for new power generation.

Combined heat and power (CHP) is the simultaneous generation of heat and power, usually, in a single process. The term CHP is synonymous with cogeneration. CHP can use a variety of fuels and technologies across a wide range of sites and sizes of scheme. The basic elements of a CHP plant comprise one or more prime movers (a reciprocating engine, gas turbine, or steam turbine) driving electrical generators. The steam or hot water generated by this process is used in industrial processes or for space and water heating. CHP is typically sized to make use of the available heat produced in the process of generating electricity. CHP is typically connected to the lower voltage distribution system (‘embedded’). As well as reducing losses in transmission and distribution, it can provide important network services such as black start when the electricity networks go down, improvements to power quality, and the ability to operate in island mode if the grid goes down.

A. Existing CHP Systems in Punjab

Combined generation of heat and power in industry is termed as co-generation. The fuel for generating steam and power in sugar mill, bagasse is available as a by product of sugar production. Normally, bagasse is used to generate captive steam and power during off season making the sugar industry self sustaining where energy (steam and electricity) needs are concerned. State of Punjab has an established industrial base, which is expanding. The Sugar, paper, fertilizer chemical, textile and other industries are having an estimated co-generation potential of 500 MW. Adoption of co-generation by these industrial units/undertakings would not only augment the state grid capacity but would also create conducive conditions for providing employment generation, utilisation of clean environment friendly resources.

Bagasse / Biomass co-generation in sugar mills and industry has the following inherent advantages over thermal power generation :

- It is environmentally friendly because of relatively lower CO_2 and particulate emissions.
- It displaces fossil fuels such as coal.
- It is a decentralised, load based means of generation, because it is produced and consumed locally, losses associated with transmission and distribution are reduced.
- It offers employment opportunities to locals.
- It has a low gestation period and low capital investment.
- It helps in local revenue generation and up liftment of the rural population.
- It is an established and commercially viable technology option.
- A bagasse based co-generation project of 12MW will reduce emission at least 511960 tones of CO_2 e.g. for a crediting period of 10 years i.e. 51196 tones of CO_2 per annum. This will provide additional revenue stream.

PEDA has facilitated co-generation projects in the assisted sector. Many other co-generation projects are in the pipeline which shall be commissioned in the near future.

It is planned to achieve a target of 500MW through co-generation in the next years. The State govt. has formulated a New and Renewable Sources of Energy Policy (NRSE Policy) in 2006. Cogeneration projects of 67 Bar pressure and above with the qualifying criteria i.e. for the co-generation facility to qualify under topping cycle mode, the sum of useful power output and one half the useful thermal output be greater than 45% of the facility's energy consumption, shall only be eligible for consideration under this policy.

The govt. has offered following financial and fiscal incentives for co-generation projects as under: To promote manufacturing and sale of NRSE devices/ systems, and equipments/ machinery required for NRSE Power Projects, Value Added Tax (VAT) shall be levied @ 4%.

1. Octroi: on energy generation and NRSE devices/ equipment/ machinery for NRSE Power Projects shall be exempted.
2. Wheeling: The PSEB/LICENSEES will undertake to transmit through its grid the power generated from NRSE projects set up inside or outside the State and make it available to the producer for captive use in the same company units located in the state or third party sale within the State at a uniform wheeling charge of 2% of the energy fed to the grid, irrespective of the distance from the generating station.
3. Sale of power: Baggasse/ Biomass Cogeneration Projects- Rs. 5.32 per unit (Year 2012-13)
4. Banking: The banking facility for the power generated shall be allowed for a period of one year by the PSPCL/ Licensees.
5. Exemption from Electricity duty.

B. The potential for CHP System in India

Combined heat and power systems use fuel very efficiently. A CHP system provides electricity and heat at a combined efficiency approaching 90%. This is a significant improvement over the combination of the 35% efficient electric utility and a conventional heating boiler with a 65% seasonal efficiency.

The CHP systems offer an attractive solution to meet the industrial energy requirements in an efficient manner, while conserving the national resources. These systems offer numerous direct benefits to industry and institutional applications and also positive carry-over benefits to utilities and society at large. The opportunities for the industry, utilities, and society are given in Table1.

Table 1: Opportunities of CHP Systems in Industry, Utility and Society.

CHP System Opportunities for Industry	CHP System Opportunities for Utility	CHP System for Society and Ratepayers
-Reduce energy costs	-Defer capacity needs	-More efficient use of resources
-Enhance revenues	-Reduce line losses	-Reduce emission
-Offer fuel flexibility	-Reduce risk	-Lower electricity rates
-Protect the company from power interruptions	-Expand business opportunities	-Increase employment
-Increase power quality		-Reduce utility dept
-Offer short-up times		
-Reduce wastes		

The estimated potential of CHP system is between 17,000 to 20,000 MW based on conservative estimates. It is difficult to give accurate figures as many small-scale industrial applications and industrial estates may also have these plants and no estimates are available for these areas. Table 2 presents potential of CHP systems in India.

Table 2: CHP System Potential in India.

Indust Industry	**Potential (MW)**
Alumina	59
Caustic Soda	394
Cement	78-100
Cotton textile	506
Iron & steel	362
Manmade fibers	144
Breweries	250-400
Coke oven batteries	200
Commercial sector	175-350
Dairies	70
Distilleries	2900
Fertilizer	850-1000
Petrochemical	250-500
Plywood manufacturing industry	50
Rice mills	1000
Solvent extraction	220-350
Sponge iron	225
Tyre plants	160-200
Paper & pulp	850
Refineries	232
Sugar	5200
Sulfuric acid	74-125
Total	14628-15586

II. THE ROLE OF TECHNOLOGY

In the long term, technological change will influence the amount of CHP installed. Its first role is to improve the efficiency of electricity generation. CHP uses the waste heat from the generation of electricity to supply process or space and water heating needs. The energy used, and thus the costs is principally dependent on electrical efficiency, because central electricity generation is so inefficient, and secondarily on improved heat recovery.

This means that any improvement in the efficiency of electrical generators, especially small ones, benefits CHP as well as conventional power generation. In contrast, the ability to maximise the recovery of heat is principally driven by site-specific issues, the correct sizing of plant to the heat demands of a specific site, and operational regimes. It is optimised by good practice rather than by technology.

A. Improvements in Electrical Efficiency

Engines can use internal or external combustion. Internal combustion or conversion devices include reciprocating engines, gas turbines and fuel cells. Other prime mover technologies can use a combustion of solids or liquids in conventional boilers based outside the device, and use hot gases or steam to generate power. They include steam turbines, Stirling engines and Organic Rankine Cycle engines.

B. Classification of CHP Systems

a. CHP system can be classified on the following basis:

1. Topping Cycles
2. Bottoming Cycles

1. Topping Cycles. In topping cycles, in the cogeneration system heat rejection is used as the thermal energy required in the process and/or plant heating operations. In topping cogeneration systems fuel utilization increases. The typical fuel use of a modern coal-fired facility designed to generate electric power alone is about 35% of the total energy input, the largest loss is the heat rejected to the condenser. This loss an inherent cycle limitation is the primary reason why the plant efficiency is low. The improved overall efficiency of fuel is 84%. This is equivalent to a fuel reduction of approximately 60%. Besides steam turbine cycles, gas turbine with heat recovery, combined steam-gas turbine cycles and diesel engine cycle with heat recovery are likely candidates when considering topping cogeneration systems. Furthermore, assuming that appropriate performance levels comparables to the cogeneration steam turbine performance. For example a diesel engine set with exhaust heat recovery providing process steam can have an "effectiveness of energy use" of about 55 to 60%. Also, a gas turbine with exhaust heat recovery producing process steam can provide around 75 to 80% of the input fuel energy as shaft power and heat for process use.

(i) Gas Turbines System. Gas turbines have been used for many years as prime movers in industrial plants. Their versatility and reliability have been proven by installation in chemical, petroleum, metal, pulp and paper industries as well as other applications.

Process use of a large portion of thermal energy associated with the hot exhaust gases of a gas turbine qualifies this prime mover for cogeneration application. The hot exhaust gases can be used to heat water or other fluids required in the process or every they can be used as preheated combustion air for a process fluid heater or a reformer. However, the most common application of the gas turbine exhaust energy is generation of steam which is ultimately used in operation.

If the turbine exhaust energy is used to generate steam, the selection of the appropriate steam conditions is a factor that must be evaluated. The steam generation at higher initial steam conditions will permit the use of combined cycles which results in a greater shaft output per unit of heat required I a process relative to that available with non condensing steam turbines or gas turbine providing steam at the maximum pressure level required in the process.

Gas turbines are available from many manufacturers for both mechanical and generation drive application in wide ranges of sizes. Units can be purchased having ratings as low as 50 kW to ratings approaching 100,000 kW or more. However since units are available in discrete sizes, matching the appropriate gas turbine to a plant's energy needs is important to fully realize the fuel saving potential of this cogeneration system.

(ii) Steam Turbine Types. Steam turbines are available in variety of designs for cogeneration applications. The factors that determine which units should be considered for a given application include the magnitude of the process steam demands, the process pressure or pressures required, as well as the loads to be driven. The basic arrangement is straight non condensing steam turbine which exhausts into process steam header. The automatic extraction non condensing design can simultaneously provide steam to two process steam pressure levels. The automatic extraction condensing unit combines the automatic extraction feature with the flexibility afforded by condensing section.

The economic merit of the steam turbine cogeneration system is due, in part, to the ability of the turbine control system to respond to various demands imposed by the energy system. The control options available include speed control speed load control and pressure governing which can regulate the amount of thermal energy being supplied to match varying process needs. The actual control mode that is ultimately selected will be a function of the driven load as well as process energy demands.

(iii) Combined Cycles. A CHP system where high pressure steam generated in the HRSG is expanded in a steam turbine extracting and/or exhausting to the process steam header is a combined cycle. A combined cycle can provide significantly more power per unit of heat input in comparison of steam turbine or gas turbine HRSG cogeneration systems. The wide range of conditions can be satisfied through combined cycle.

(iv) Diesel Engines. The diesel engine is another prime mover that can be use for cogeneration applications. It qualifies as a cogeneration by using the thermal energy in the engine exhaust and jacket cooling in the system in which the engine is applied. The prime interest in the diesel engine is its relatively attractive full-load thermal performance. Its flat heat characteristics at reduced loads and its high output per unit of exhaust heat rejected. However, the thermal performance of a diesel cogeneration system can approach that of steam or gas turbine cogeneration system only if the process has need for the large quantities for this prime mover. If only the diesel exhaust energy can be used in process, the effectiveness of the fuel energy use will approach 60%.

Diesel engines have been available in sizes ranging from several horsepower to large units rated at 40,000 B.H.P. (30 MW) Diesel engines are available in speeds as low as 100 rpm to speed in excess of 1800 rpm. Units designed to operate at 450 rpm or less is categorized as low-speed engines. Speeds to 900 rpm are considered medium speed and 120 rpm units are considered high sped engines.

2. Bottoming Cycle. Bottoming cycles are being touted as a mean of providing shaft output by recovering energy normally rejected from process discharge streams. The method of energy recovery should be more economically attractive as energy costs increase since no fuel is directly used for production of power in a bottoming cycle.

In many industrial plants, the largest amount of energy rejection is associated with hot discharge gases, hot water and in some instances, vented steam. However, because of the low temperature level of many of these streams, energy recovery is usually difficult to justify economically because of the high capital cost for the equipment required relative to the resulting operating cost savings. If gases are rejected are available in sufficient quantities at temperature levels of 700 ºF or greater heat recovery equipment similar to that associated with gas turbines or diesel engines may prove economically feasible. If the process rejects large quantities of hot water, its uses for comfort heating and/or cooling or "hotel services" may merit considerations.

III. WASTE HEAT RECOVERY

A. Significance of Waste Heat Recovery

There are the basic reasons for recovering waste heat:

1. Economic: Energy costs are skyrocketing and recovery can reduce overall costs. Many investments are cost effective and payback period of two year or less are not unusual.
2. Heat availability: Scarce energy supplies can cause plant shutdowns. Heat is readily available in most plants in the form of waste heat.
3. Conservation of natural resources: Waste heat recovery conserves scarce energy supplies.

The economic recovery of waste heat depends upon a number of factors. First, there must be a use for waste heat within the plant or facility. Second, an adequate quantity of waste heat must be available. Third, the heat must be of adequate quantity; for example, heat available at 90 ºF cannot be used for a process requiring 200 ºF. Fourth, the heat must be transported from the waste stream to the process or material where it is to be used. This is problem of heat transfer. Fifth, the process must be economic or have a fairly short payback time.

B. Methods for Utilizing the Waste Heat

1. Direct utilization, e.g. for drying or preheating process materials when no heat exchanger is employed.

2. Recuperation, in which heat from waste gases and air or other gas preheating are separated by a metallic or in cases of very high temperature, a refractory heat exchanger surface. Transfer of energy occurs continuously.

3. Regeneration, in which heat waste gas is conducted to and stored in a heat exchanger medium, in a refractory or in metallic materials and subsequently heats air for preheating

The gas flow alternately shares the same heat transfer surfaces and is switched either by means of a flow reversing valve or by rotating the heat storage matrix.

4. Waste heat boiler, a form of recuperation in which hot gases generate process steam or hot water. Both water tube and fire tube can be used.

5. Energy cascading, in which the energy is used at its highest quality first and then used at lower qualities in other associated processes, until the energy if of such low quality that it is no longer useful. The chemical industry has been proficient in the use of energy cascading, in which the heat condensation form one distillation column operates a second unit. The food industry also has many opportunities for energy cascading.

6. Co-generation in which electricity and process steam are generated together.

C. Application of Waste Heat Recovery

1. Medium to high temperature exhaust gases can be used to preheat the combustion air for:
    a. Boiler using air preheaters.
    b. Furnaces using recuperators.
    c. Ovens using recuperators.
    d. Gas turbine using regenerators.
2. Low to medium temperature exhaust gases can be used to preheat boiler feed water or boiler makeup using economizers, which are simply gas to liquid water heating devices.
3. Exhaust gases and cooling water from condensers can be used to preheat liquid and /or solid feedstock's in industrial processes. Finned tubes and tube heat exchangers are used.
4. Exhaust gases can used to generate steam in waste heat boilers for the production of electrical power, mechanical power, process steam and any combination of the above.
5. Waste heat may be transferred to an intermediate fluid by heat exchangers or waste heat boilers, or it may be used by circulating the hot exit gas through pipes or ducts.

Waste heat can be used to operate an absorption cooling unit for air-conditioning or refrigeration.

Essential considerations for making optional choice of waste heat recovery devices are:

1. Temperature (quality) of waste of waste heat.
2. Flow rate of waste heat.
3. Chemical composition and pollutants in the waste heat.
4. Temperature requirements of the heated fluid or materials.

D. Distributed generation issues

CHP is most environmentally beneficial when heat generated is utilised on site. This means that devices need to be sized to avoid producing more heat than is needed. This implies that for large-scale uptake devices need to be embedded in the electrical network, close to heat users. It will include new ways of analysing the industry, changes to electrical network design, changed systems of connecting new generation, and new payment mechanisms.

IV. THE ROLE OF POLICY

While CHP entails higher capital costs than separate sources, it is more energy efficient than the separate generation of heat and power. Savings in energy and money mean that, in many applications, higher capital costs can be paid back over time, depending on assumptions about future energy prices and the cost of borrowing. Energy prices include the relative cost of fuel (principally natural gas) and the value that can be realised for electricity, especially if it is exported back to the network. The difference between the price of electricity and the price of gas required to generate that electricity is known as the 'spark spread'. This represents the revenue available to finance annual fixed costs, capital costs, investment and profits and needs to be high enough to incentivise new CHP build. Energy price considerations vary for schemes of different sizes and in different industries. In recent years, rising gas prices and competitive electricity prices have meant that the spark spread has been regarded as too small to provide an adequate return on investment, especially compared to other calls on capital in industry, commerce, and the public sector. Many, but not all, energy-intensive industrial sites already have some CHP capacity. A good portion of the remaining market is for smaller industrial, commercial and private buildings, where complex energy management decisions are less easily handled.

CHP is a complex investment, requiring power generation capacity to be installed where users are more used to seeing simpler heat generating capacity. Heat users are concerned about increasing cost, complexity and risk. Power generators do not want to build and manage many small projects on heat users' sites, preferring to build one large central plant on their own sites. Often, the solution is an energy services arrangement, where the generator can offer some combination of design, build, finance, operation, and maintenance of CHP plant, providing heat and power to the host site or to a community. For businesses, this enables the host company to concentrate on its core business, to divest itself of the risk associated with trading in the energy market, and to use off-balance sheet financing for the project.

V. CONCLUSIONS

CHP has a huge potential to deliver energy savings and thus cost. The extent of the potential is strongly dependent on a range of assumptions. Technology has a key role to play in the future competitiveness and therefore uptake of CHP through

- Additional heat and energy production can be exported / used by local communities.
- High overall efficiency – up to 80% or more at the point of use.
- Additional guarantee of continuity in energy supplies for operator & consumer.
- Reduced energy costs.
- Enhanced security of energy supply.

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