

Cogeneration & Combined Heat & Power (CHP)

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There are several industries, such as paper Mills, textile Mills, chemical factories, drying plants, rubber manufacturing plants, sugar factories, metal extraction, pharmaceutical, fertilizer, hotels, hospitals, and commercial buildings etc, where a continuous demand for both heat and power exists. Saturated steam at desired temperature is required for heating, drying etc. Apart from process heat, the factory also needs electric power to drive various machines, for lighting, and for other purposes.

Formerly it was practice to generate steam for power purposes at a moderate/high pressure and to generate saturated steam separately for process work (heating/drying) at a pressure, which gave the desired heating temperature. Having two separate units for process heat & power is wasteful. Because **approximately 60-65 % of total heat input** supplied to conventional condensing steam power plant will be carried away by the cooling water in the condenser & flu gases. The major portion of this rejected heat can be utilised for industrial process heating and district heating / cooling purpose on cogeneration principle.

Combined Heat and Power or Cogeneration is the simultaneous generation of usable heat and power (usually electricity) in a single process. In other words, it utilises the heat rejected in electricity generation rather than releasing it wastefully into the atmosphere through cooling tower. CHP is sometimes referred to as co-generation in short "Cogen" or as 'total energy'

By modifying the initial steam pressure and exhaust pressure, it is possible to generate the required power and make available the required quantity of exhaust steam at desired temperature from the turbine for process heating. In this case the process heater replaces the condenser of the ordinary Rankin cycle. For constant temperature heating (or drying), steam is a very good medium, since isothermal condition can be maintained by allowing saturated steam to condense at that temperature and utilising the latent heat released for heating purpose.

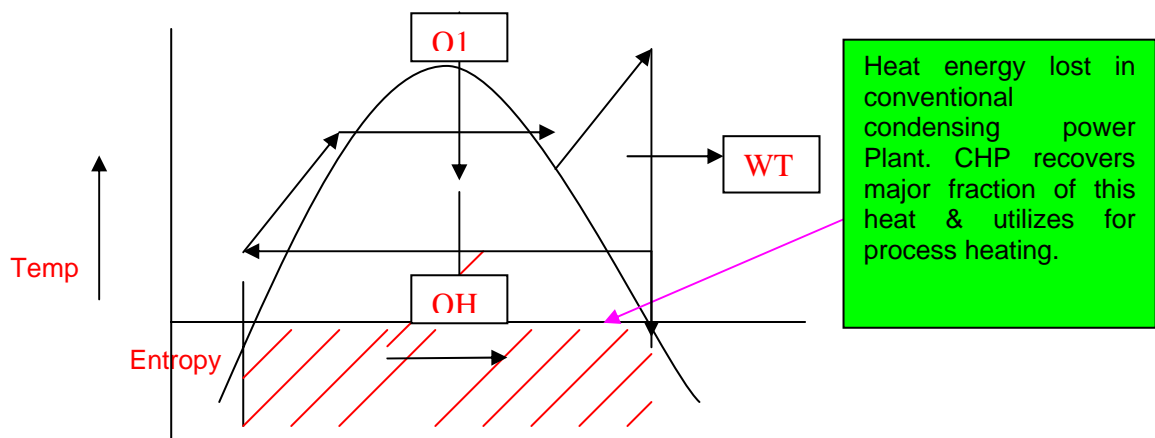
The following figure shows TS plot of such a cycle. If turbine work output WT in kW. The process heat QH in kJ/h and w is the steam flow rate in kg/h.

$$WT \times 3600 = w (h_1 - h_2)$$

$$w (h_2 - h_3) = \text{Process heat, (QH)}$$

$$WT \times 3600 = QH (h_1 - h_2) / (h_2 - h_3)$$

$$\text{Process heat} = \text{Turbine work} \times 3600 \times (h_2 - h_3) / (h_1 - h_2) \text{ kJ/h}$$



Of the total energy input Q1 as heat to the cycle, WT turbine work part of it only is converted into shaft work (or electricity). The remaining energy (Q1-WT), which would otherwise have been a waste, as in the Rankin cycle (by the second law of thermodynamics), is utilised as process heat.

Fraction of energy (Q1) utilised in form of work (WT), and process heat (QH) in a CHP cycle
= (WT+QH)/Q1

Condenser loss, which is the biggest loss in a steam plant, is zero here and thus the fraction of energy utilized is very high. This tremendous efficiency opportunity of combining electricity generation with thermal loads in industries is exploited through CHP.

The pressure at exhaust from the turbine, in case of CHP is the saturated pressure corresponding to the temperature desired in the process heater, such a turbine is called a backpressure turbine. In a backpressure turbine the steam is taken out of the turbine at a higher pressure than in a condensing power plant and the steam is used for heating purposes.

The main advantages to customers of using CHP are:

- Reduced energy costs by a highly efficient use of energy, which means lower costs for energy.
- Enhanced security of energy supply.
- Reduced CO₂ emissions, making a valuable contribution to the environment, particularly in light of Kyoto Protocol obligations & CDM
- Conservation of valuable fuel resources.
- No Transmission & distribution losses.

Thus combined heat & power preserves the quality of environment while enhancing the profitability, productivity or usefulness of energy input.

The cogeneration & combined heat & have following suitability as compared to separate option for power (Power Boiler) & heating/drying (Auxiliary Boiler)

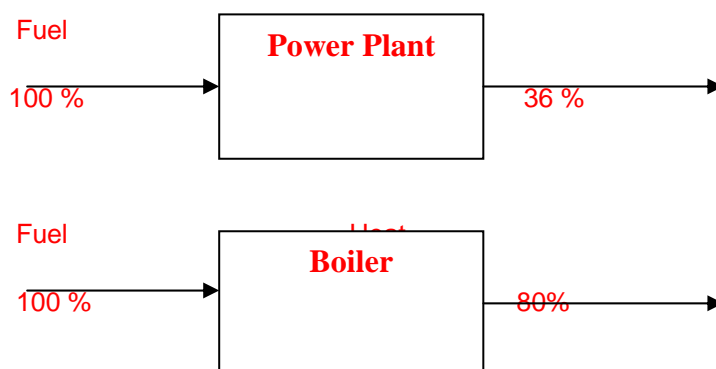
(1) Higher Overall efficiency of the system:

Co-generation is the concept of producing two forms of energy from one fuel. One of the forms of energy must always be heat and the other may be electricity or mechanical energy. 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 through a steam turbine to produce electric power. The exhaust steam is generally condensed to water, which goes back to the boiler.

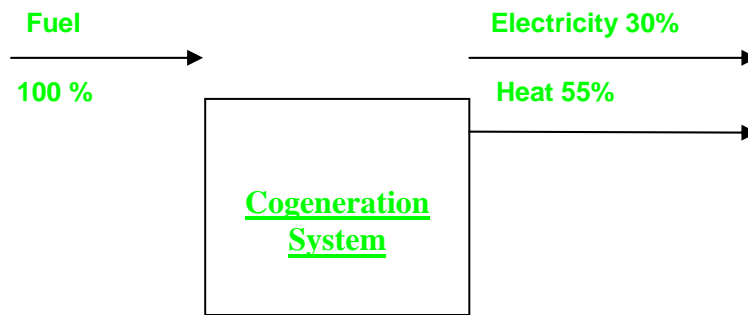
As the low-pressure steam has a large quantum of heat, which is lost in the process of condensing, the efficiency of conventional power plants is only around 35%. In a cogeneration plant, very high efficiency levels, in the range of 75%–90%, can be reached. This is so, because the low-pressure exhaust steam coming out of the turbine is not condensed, but used for heating purposes in process or houses. The overall cogeneration efficiency is in the range of 75 to 90% in which the thermal efficiency is 55 % & electrical efficiency lies between 30 to 36 %.

The second law of thermodynamics states that complete conversion of low-grade energy (Heat) into high-grade energy (Work) in a cycle is impossible. This thermodynamic limitation can be converted to opportunity where the optimum heat energy is converted to work (Mechanical/ Electrical Work) & balance low grade energy is utilized for process heating purpose instead of rejecting it to heat sink.

Efficiency comparison between separate Power & Heat unit & Cogeneration



Overall Efficiency= (36+80)/200 = 58 %



Overall Efficiency=(30 +55)/100 = 85 %

Efficient & Environment Friendly mode of Energy conversion

(2) Lower energy cost in terms of Rupees/ k calorie:

By utilizing / recovering the majority of what would otherwise be waste heat, overall energy savings in the range of 20 per cent and 40 per cent may be achieved. For an energy intensive business this can be a very substantial saving. Combined with other energy efficiency measures CHP can deliver even greater cost savings for customers. The Project cost is approximately Rs. 2.1 crore per MW. The margins from Cogeneration plant has gone up many folds due to escalating fuel cost.

(3) Operational flexibility:

Whenever process heating is not required, power can be produced and vice versa. Batch process can be planned in such a way that heating is not required during peak load hours. Similarly during non-peak hours higher quantity of steam can be made available for process heating. Excess power can be also be supplied to grid.

(4) Cleaner Environment:

The new UN climate report released on 6th April 2007 has projected a gloomy picture of the consequence of global warming. It is believed that we are at the threshold of a massive destruction. Even if we stop producing all green house gases right now it will take more than one century to control global warming.

The installation of CHP has been widely recognized as a key measure to reduce harmful emissions of carbon dioxide, the main greenhouse gas, while delivering the same amount of useful energy. Carbon dioxide (Green house gases) emission in terms of tons of CO₂/MW is lower. It is estimated that for every 1 MW of CHP installed, CO₂ emissions are reduced by at least 1,000 tones per annum. On balance, cogeneration can result in savings of up to 50 per cent of CO₂ emissions compared with conventional sources of heat and power. Reduced emissions of Sulphur dioxide and particulates are further benefits.

CHP Greenhouse Gas Impact Estimated net reduction in emissions per kWh of Gas electricity produced (g/kWh) CO₂ 1,000 SO₂ 17 NO_x 4.6 CO (3) CH₄ 3.9.

(5) Lower operation & maintenance cost:

In Cogeneration, a single unit serves both electric power & heating requirement i.e. single boiler instead of two (one for power generation "Power Boiler" & one for steam generation "Auxiliary/Utility boiler"). Hence the operation & maintenance cost is lower.

The energy efficiency of CHP is being recognized throughout the energy world. The full advantage CHP technology is achieved when the production of power and heat is combined. For this to be technically and economically feasible, it generally requires a simultaneous demand for heat and electricity on the premises. The continuous demand of Power & Heat increases the attractiveness of cogeneration for particular industrial applications. By changing from separate systems producing heat and power to a single industrial unit considerable amount of energy are saved.

Typically, up to 85 % of the primary energy input is used in industrial CHP or cogeneration systems. This is a very high level of efficiency compared to all other forms of conventional generation.

Technical Modes/Options for Cogeneration

- (1) Back Pressure Turbine. When the process heat is the basic need, and the power produced incidentally as a by-product, the cycle is sometimes called a by-product cycle.
- (2) Extraction condensing Turbine.
- (3) Gas Turbine Heat Recovery cogeneration system.
- (4) Combined Cycle
- (5) Reciprocating Engine cogeneration system.
- (6) Biomass gasification for combined heat & power.

Cogeneration systems are normally classified according to the sequence of energy use and the operating scheme adopted.

A cogeneration system can be classified as either a topping or a bottoming cycle on the basis of the sequence of energy use. In a topping cycle, the fuel supplied is used to first produce power and then thermal energy, which is the by-product of the cycle and is used to satisfy process heat or other thermal requirements. Topping cycle cogeneration is widely used and is the most popular method of cogeneration. In a bottoming cycle the primary fuel produces high temperature thermal energy and the heat rejected from the process is used to generate power through a recovery boiler and a turbine generator. Bottoming cycle is suitable for manufacturing process that requires heat at high temperature in furnaces & kilns, and rejects heat at significantly high temperatures. The waste gases coming out of the furnace is utilized in a boiler to generate steam, which drives the turbine to produce electricity. The following factors influence the selection of Cogeneration route of captive power generation.

Base Electrical load

- (1) Base Thermal load
 - (2) Heat to power ratio
 - (3) Duty Cycle
 - (4) Fuel Available
 - (5) System Reliability
 - (6) Retrofitting versus new installation
 - (7) Electricity By Back
 - (8) Local environmental regulations.
- (10) Space Available & Site Location

Success Stories

The concept of Co generation in sugar factories was explored in early 90's. The ample cane availability and the feasibility of using high-pressure equipments, many Bagasse based cogeneration plants capacity in the range 20-30 MW co-generation plant was installed and commissioned in 1990's. After meeting the in-house power demand, the surplus power to the tune of 14 to 15 MW is being exported to the grid. The Bagasse generated from mills and trashes from sugar cane are being used as fuel for the boilers. Building distributed cogeneration plants at different locations has resulted in significant efficiencies in the design, procurement, and construction of the projects. Individual site conditions exert substantial influence over how a project is designed and built. Cogeneration will remain the most efficient way to produce electricity and heat (or cooling).

Conventionally low/medium pressure boilers and turbines were catering to the captive power and Low-pressure process steam requirement of the Sugar mills. These LP equipments were energy and maintenance Intensive. Implementation of bagasse based CHP technology in sugar industries is a major thrust to the Energy Conservation Movement in India. It is the one of the most energy efficient technology being practiced in Indian industry after implementation of Energy Conservation Act 2001. The cogeneration plant fuelled by Biomass, Rice Husk & Gaseous fuels are also coming up. Sometime the plant uses bagasse in season and other biomass products such as jute sticks, cotton stems, cane thrash, groundnut shells, as fuel in off season.

The following case shows utility of cogeneration plant compared to two separate units for Power & Heat.

A typical sugar plant has requirement of 7 MW peak electrical loads & approximately 12 ton of steam for process heating. Looking into

Requirement there were two options

Option I

AFBC Condensing Power plant of 9 MW with following specifications

Steam generator capacity: 51.5 TPH

Pressure: 44 Bar

Steam temperature: 400 degree centigrade.

Condensing steam turbine & Turbo Generator

10 TPH Gas/Heavy fuel fired Boiler for process Heating

Boiler Specification

Maximum working pressure: 12-kg/square cm.

Steam Discharge temp: 192.5 degree centigrade

Option II

Bagasse fuel fired AFBC Boiler & Back Pressure turbine

Back Pressure turbine with Extraction steam 12 TPH at 6 Bar & 250 Degree centigrade with 9 MW electrical outputs.

Once we compare these two options on the basis of % of Total Heat input utilized it, in the option II the % of total energy input utilized is approximately 30 % higher than the option I.

For further success, we must change the entrenched mindsets of governments, energy companies & process industries in the India. The view that the optimum solution for energy delivery is through conventional central electricity generation, connected to remote consumers by high-cost transmission and distribution networks, and separate heating and cooling. We have surely reached the time when we can say with confidence that this view is wrong. Consider the impact of this the waste of energy, the waste of money, the inefficiency, the unnecessary pollution, the disruption of the world's climate and the constraint on economic development.

Consider also the commercial impact on the many companies involved in the cogeneration industry and other decentralized forms of power generation. Government & ESCOS should work to change this view - but it will need support from new members to do this. **Barriers:**

Although technologies used in CHP systems have improved in recent years, significant hurdles exist that limit widespread uses of CHP. Importantly, these hurdles have the effect of tending to use of conventional polluting and less-efficient electricity generation equipment. The main hurdles to CHP are:

- The market is unaware of technology developments that have expanded the potential for CHP.
- High Technology Cost
- High utility backup connection cost charged by state electricity companies (SEBs)
- A site-by-site environmental clearance system that is complex, costly, time consuming, and uncertain.
- Current regulations do not recognize the overall energy efficiency of CHP or credit the emissions avoided from displaced grid electricity generation.

- Many utilities currently charge discriminatory backup rates and require prohibitive interconnection arrangements. Increasingly, utilities are charging (or are proposing to charge) prohibitive "exit fees" as part of utility restructuring to customers who build CHP facilities.
- Depreciation schedules for CHP investments vary depending on system ownership and may not reflect the true economic lives of the equipment.

The private sector also needs to take a leadership role. The primary barriers to greater CHP use are regulatory and institutional, not technical or economic. The private sector must work with government regulators and policy makers to ensure that competition and incentives for innovation are preserved, while creating a favorable regulatory environment for CHP. The private sector should actively pursue adoption of CHP — both for environmental and "bottom-line" benefits.

Suggestion & Comments

Since co-generation can meet both power and heat needs, it has other advantages as well in the form of significant cost savings for the plant and reduction in emissions of pollutants due to reduced fuel consumption. Even at conservative estimates, the potential of power generation from co-generation in India is more than 20,000 MW. Since India is the largest producer of sugar in the world, bagasse-based cogeneration is must be promoted. The potential for cogeneration thus lies in facilities with joint requirement of heat and electricity, primarily sugar and rice mills, distilleries, petrochemical sector and industries such as fertilizers, steel, chemical, cement, pulp and paper, and aluminum. Support to energy professionals engaged in energy intensive industries and those using electricity and heat in their operations should be provided by Government & BEE for its wide spread application & tapping its full potential.

Recommendation to make this technology implemental in industries.

The following recommendations will make this technology wide acceptable in India.

- (1) Regular work Shop for creating awareness of State-of-Art energy efficient technologies like CHP, its efficiency & effectiveness by Indian Industry experts & foreign experts.
- (2) Interest Subsidy on Retrofitting or new installation of Cogeneration plant.
- (3) Financial assistance/incentives for setting up of Biomass/Bagasse/Gas power Cogeneration Plant.
- (4) Promotional incentives for industrial co-generation projects in core industry sector for surplus power generation.
- (5) Captive generation through cogeneration route. Co-generation and small power production should be incorporated as an important ingredient of private power policy.
- (6) Open access to the transmission system of the State grid on payment of mutually agreed wheeling charges for facilitating new entrants in the power sector on the co-generation route. The States should promote such an entry to the new proposed captive/co-generation power plants.
- (7) Create an institutional mechanism that may allow captive power units through cogeneration route an easy and automatic entry into the Power Sector by quickly clearing captive power applications by State Governments, and giving them rational tariff for purchase of surplus power by the grid and third party access for direct sale of power to the other industrial units.

Comment on Present Polices in Support to CHP.

The Government of India, Ministry of Environment and Forests in its letter-dated 19.5.97 stated that the following amendments to Environmental Impact Assessment Notification, 1994, (published in the extraordinary Gazette of India dated 10.4.97 Part II, Section 3, sub-section (ii)): -

S.O.318(E) Public Hearing has been made mandatory for all the projects covered in Schedule I of the Environmental Impact Assessment Notification, 1994 from 10.4.97. Powers have been delegated to State Department of Environment for issue of Environmental Clearance to those categories of thermal power plants, which are listed in Schedule I of the EIA Notification of 10.4.97. The amended Notification will apply to all projects, which are received after 10th April 1997.

In respect of Thermal Power Plant, the Government of India in their Notification, published in the Gazette of India Extraordinary Part II, Section 3, sub-section (ii), dated 10.4.97 S.O.319 (E) Schedule I have specified the following category of Thermal Power Plans requiring environmental clearance from the State Government. **This includes Co-generation plants irrespective of the installed capacities.**

The Government of India have also stated in the said Notification dated 10.4.97 that any project proposed to be located within the radius of twenty five km. boundary of reserved forests, ecologically sensitive area which may include National parks, Sanctuaries, Biosphere reserves, critically polluted area and within fifty

kms of inter-state boundary shall require environmental clearance from the Central Government. In the said Notification Schedule II the procedure for seeking environmental clearance and in Schedule III the composition of the Expert Committee to be constituted by the State Governments for Environmental Impact Assessment have been specified.

One of the reasons often cited for the delays encountered while setting up private projects in India, is the numerous clearances and permits which are required to be obtained. Approximately, over 50 clearances and permits are required to be obtained. Approximately, over 50 clearances and permits are required. However, most of the clearances are routine in nature. Two of the most important clearances are Techno-economic clearance from the Central Electricity Authority (CEA) and the Under Section 29 of the Electricity Supply Act, 1948, projects, involving capital expenditure above certain limits requires clearance from the CEA. CEA clearance is a two stages process, at the first stage CEA grants "in principle clearance" to the project and the final "techno-economic clearance" is granted at the second stage even for schemes for renovation and modernisation of existing power plants. Some of the key environmental legislation in India includes:

The Environment (Protection) Act, 1986;
The Air (Prevention and Control of Pollution) Act, 1981;
The Water (Prevention and Control of Pollution) Act, 1974;
The Forest (Conservation) Act, 1980; and
The Wildlife (Protection) Act, 1972.

The Ministry of Environment and Forests, of the Government of India grants the final environment clearance to a project. The Central Government has transferred to power to state governments for granting environmental clearance to certain categories of thermal power plants, both utility and captive. Such plants including all cogeneration plants irrespective of their installed capacities.

Foreign investment approval. The power sector has been identified as a "high priority industry". There is no ownership restriction upon the quantum of foreign equity; even 100% foreign equity is permitted, depending upon the merits of the case. Proposals involving foreign equity up to 74% are cleared on an automatic basis by the Reserve Bank of India. Proposals involving foreign equity above 74% are approved by the Government of India on a case-by-case basis.

CAPTIVE/COGENERATION PLANTS

In view of the delays in the implementation of the independent power projects, the Government of India has denied to actively encourage the setting up of captive and cogeneration projects. A policy on cogeneration projects has also been published. The SEBs provides wheeling and banking services to such captive/cogeneration projects. Surplus power from these projects is bought by SEB at a mutually negotiated tariff.

The process of according clearance to captive/cogeneration projects has been simplified. Proposals for captive power/cogeneration plants require the approval of the SEB. In cases where the capacity of the generating station exceeds 25 MW, the SEB has to simply refer the proposal to the CEA for consultation under Section 44 (2A) of the Electricity (Supply) Act, 1948. A detailed examination of the project by CEA as undertaken for purposes of techno-economic clearance is unnecessary for such plants.

Recommendation to make CHP Technology implemental in industries.

(1) Private sector companies shall be encouraged to set up using cogeneration technology. All private sector companies shall be allowed a debt equity ratio of up to 4:1.

(2) Capital Cost Limits for power projects requiring Central Electricity Authority (CEA) approval to be enhanced.

(3) A five-year tax holiday shall be allowed. Soft loans required for renovation and modernisation of existing power plants shall be made available. The rates for depreciation in respect of certain assets should be rationalised. Duty on import of power equipment shall be further reduced and this reduced rate shall also been extended to machinery Liberalisation of access to external commercial borrowings for power sector borrowers. In order to encourage cogeneration plants, guidelines shall be issued to state governments recommending the creation of a mechanism for early clearance of such proposals and also to ensure effective measures such as purchasing or wheeling of surplus power from such plants.

(4) The excise duty on a large number of capital goods and equipment in the power sector shall be further reduced. The transactions, the State taxes paid shall be fully reimbursed.

(5) Abolish electricity duty imposed by SEBS. States shall be exempted from payment of electricity duty for a period of 10 years. State Taxes, Duties, local taxes and levies shall be exempted. If due to tax system constraints, it is not advisable to grant direct exemption to all industrial units irrespective of their location within the State, they shall be exempted from payment of Stamp Duty.

The following recommendation of Electricity Act 2003 shall be implemented to achieve targeted generation through cogeneration route.

(1) Sugar industry can generate 4,000 MW surplus powers by using bagasse as by-product

(2) 10% power in India to come from renewable energy source

(3) Power generation from bagasse comes under clean power, hence it must be encouraged at top most priority.

(4) Soft loans to be provided from Sugar Development Fund to encourage co-generation at 4% interest.

(5) Power distributors in India have to buy a certain percentage of power from renewable energy source

(6) Establishing Cogeneration as a National Priority.

(7) Promoting Cogeneration through strategies and measures.

Role of BEE for Implementation of CHP in Industry.

(1) Identifying ways to increase the potential, for maximum exploitation.

(2) Projecting the benefits and potential, particularly to applicable industries & commercial establishments.

(3) Promoting congruence of attitudes and mindsets of the stakeholders.

(4) Interacting with Central and State governments, national and international bodies.

(5) Encouraging and supporting the functioning of state-level organizations.

(6) Initiating development finance from national and international sources.

(7) Taking steps to ensure commercial viability.

(8) Disseminating evaluated information.

(9) Sharing of experience, national & international workshop.

(10) Providing information on expertise, capabilities, products, processes, services etc.

(11) Advising on planning, formulation, appraisal, financing, implementation, management and monitoring of projects.

(12) Consultancy and advice on scientific, technical, engineering and managerial aspects, market development, financing & training.

(13) Undertaking and coordinating conferences, research, publications & capacity building programs.

Conclusion: What is good and what requires improvement.

Combined heat and power can contribute to the transformation of the future on energy front & environmental front. CHP offers significant, economy-wide energy efficiency improvement and emissions reductions. Our existing system of centralized electricity generation charts an unsustainable energy path, with increasing fuel consumption and carbon dioxide emissions, while continuing to dissipate over two-thirds of the energy contained in the fuel. At least half this wasted energy could be recaptured if we shift from centralized generation to distributed systems that co generate power and thermal energy. Besides saving energy and reducing emissions, distributed generation also addresses emerging congestion problems within the electricity transmission and distribution grid.

CHP represents an opportunity to make significant progress toward meeting our Kyoto commitments on greenhouse gas reductions. The local air quality improvements and opportunities for economic growth presented by CHP are equally compelling. CHP presents an opportunity to improve the "bottom line" for businesses and public organizations, while also providing a path for improving the environment.

During the past few years, CHP has become an important element of the national energy debate. The government has taken steps toward setting in place policies to promote CHP by establishing a national target. The Ministry of power & Ministry of non-Renewable energy source have begun to review the means for achieving this target. The target now needs to be translated into concrete policies and programs at both the central and state levels for overcoming the significant hurdles to greater use of CHP.