CENTRE FOR TECHNOLOGY AND POLICY

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Techno-economic And Environmental Benefits of Large scale Deployment of Combined Heating and Power (CHP) Systems on Production of Sustainable Electricity: Challenges and Opportunities

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1.0. Introduction

Many industries claim entitlement to use certain "common goods" (such as fossil fuels), which evidently affect the quality of life and the air we breathe, and more importantly our ability to use more effectively such energy for other uses. Use of fossil fuel in present scenario is a necessary evil since we don't have any other energy source having comparable energy density to meet our energy requirement. The challenge is to use this scarce good to its fullest potential. As of now there is no standard methodology to assess whether users of fossil fuel use fuel to its full potential. Such a standard is the necessary for assessing the extent to which fuel is wasted. Less fuel consumed for our need, not only means efficient utilization but also reduction in the burden of environmental pollution.

In this context, there have been various actions on the part of governments and concerned citizens to "conserve" energy. However the phrase "Energy Conservation" is a misnomer as energy is conserved in nature. It is one of the fundamental laws and no action is needed to conserve it. Energy conservation in conventional wisdom refers to conservation (minimization of destruction) of its potential to perform useful work. Had energy or its availability been a problem, it could have been overcome by using the energy around us, for e.g., the infinite energy available in air around us. However, this is not possible as energy available with air is already in its "potential less" form and cannot be used for constructive work. Hence, a more appropriate measure called "*Exergetic efficiency*" is useful and should be employed while assessing energy conversion in any process. Exergy is a term used to denote the available potential to perform useful work. For example, steam from a boiler at higher pressure and temperature is said to possess more exergy as compared to steam generated in a pressure cooker at home.

Consider a typical example, where fossil fuel is used in industry primarily for generation of steam for process heating and compare the exergetic efficiency of use of coal in process plants v/s power plant: the utilization efficiency (i.e., exergetic efficiency) is much lower in process plants. This forces the community as a whole to pay for the extravaganza and also to face its fall outs such as climate change. The primary reasons for low exergetic efficiency of a process plant are irreversibility in the system caused by use of low-pressure (hence temperature) steam boilers and pressure-reducing valves (PRV). Low-pressure boilers are commonly used owing to their simple design and cost economics. PRVs are employed to cater to process specific temperature (by controlling pressure). However to improve the exergetic efficiency of the system, thermodynamics dictates that boilers be operated at high temperatures (hence pressure) and minimization of destruction of potential across subsystems (such as PRVs). Combined heat and power generation (CHP) or Cogen can be a means to improve the exergetic efficiency of process plants. In this article an attempt has been made to understand CHP in process industries, its advantages, factors that seem to impede its implementation and explore possible ways and means by which adoption of CHP/Cogen is more widespread and could become a success story.

2.0. Cogeneration: An Overview

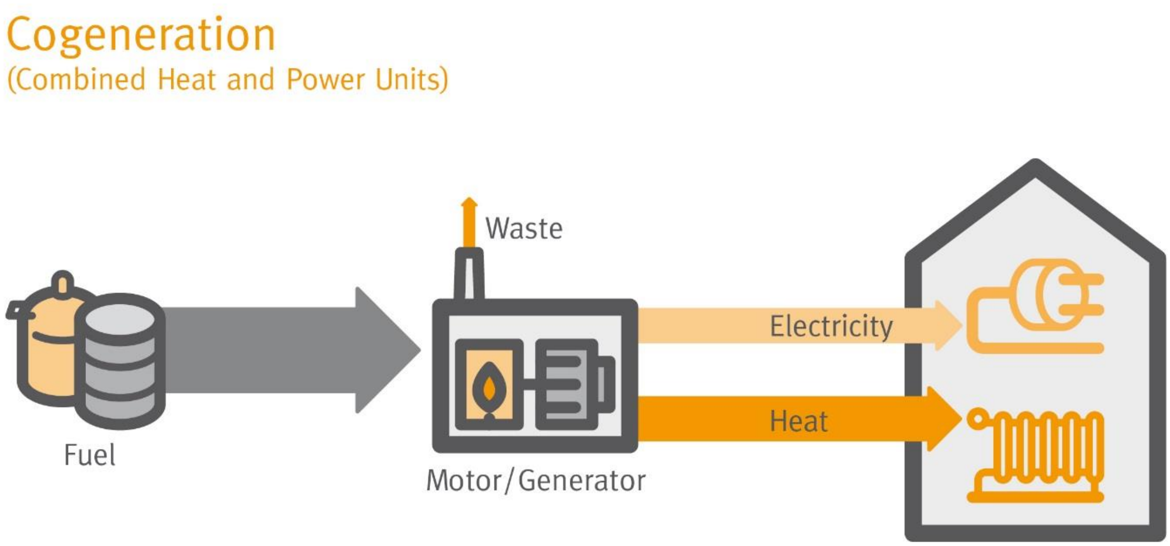


Figure 1: CHP – cogeneration is the combined generation of power and heat.

In colder countries, this concept is widely used for supply of warm tap water for domestic use and space heating, commonly known as district heating. Through cogen, the utilization of fuel potential is increased. This approach is conceptually shown in figure 1, where, the fuel is burnt at the highest feasible temperature in an engine and work is extracted in the form of electricity. Further, the heat left in the exhaust gases are recovered for district heating. Conventionally, the fuel would have been burnt only at the lowest desired temperature in a gas burner and hence most/all of the available potential would have been lost. By way of regulation, many European countries, such as Norway, have brought CHP to mainstream in those geographies.

Figure 2: Common process industries

In the Indian scenario, CHP is mainly applicable to process industries and selected applications where the heat output from CHP could be converted to cater to cooling loads. In conventional plants a boiler produces steam at a pressure higher than the process requirement due to ease transport, reduced pipe size and insulation, reduced boiler size, and increased boiler efficiency. This steam is passed through a pressure reducing station (throttling) to reduce it to process pressure. The above process is assumed to happen without change in energy of the steam (enthalpy), but it considerably reduces its work potential. The primary sites of entropy generation or this work potential reduction in process industries are not in PRVs, but the boiler itself. This is because steam generation in boilers used in process plants for heating needs happens at much lower pressure as compared to power plants where steam is produced for electricity generation.

In order to increase the overall exergetic efficiency of the process industry it is essential to increase the temperature of generation of steam and to use an expander instead of PRV. If boiler change is not feasible, it would be desirable to at least use the expander alone. The later is schematically shown in figure 4.

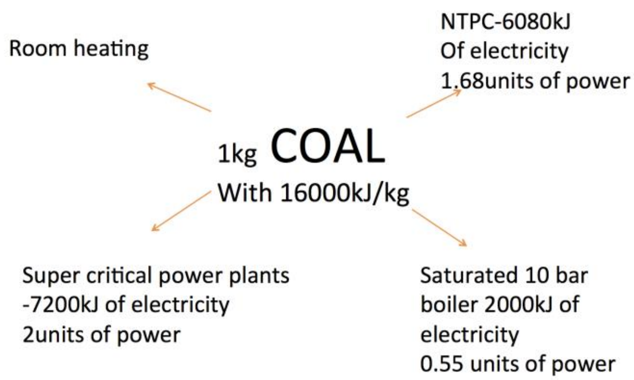


Figure 3: Energy output from 1 kg of coal

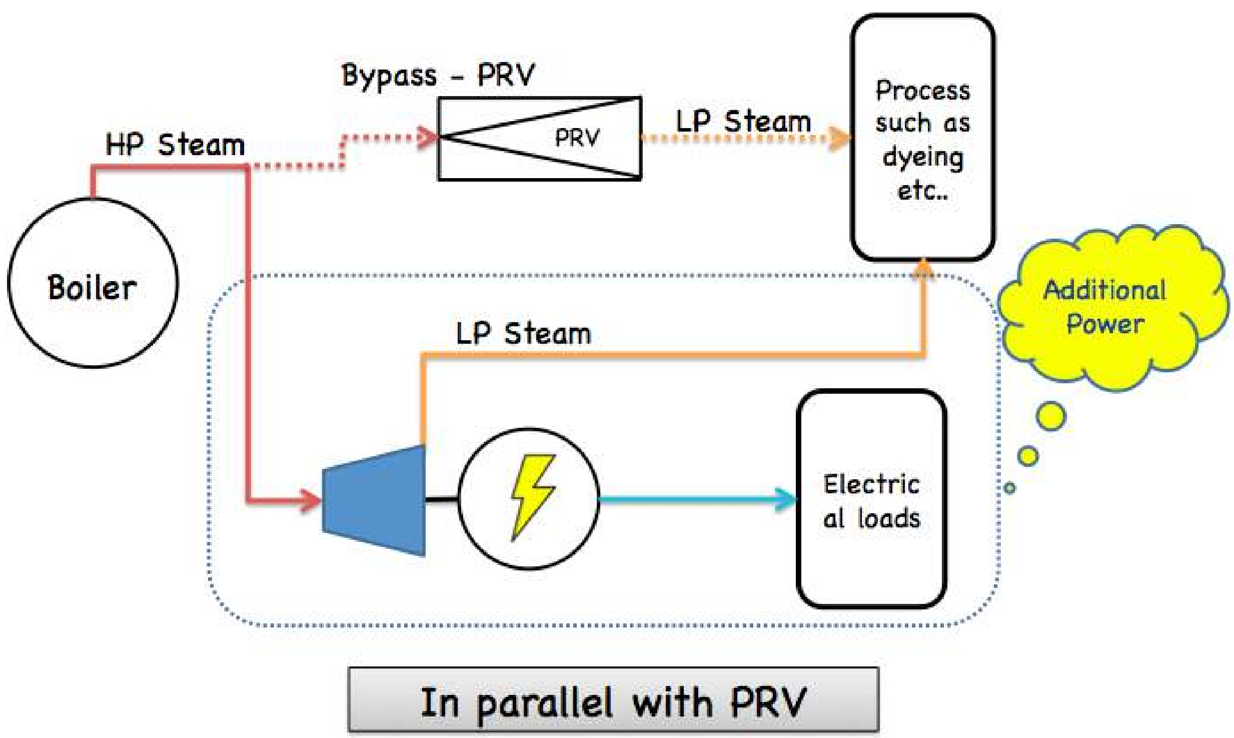


Figure 4: Applicability of expander for incidental power production across PRV

3.0. Cogen in Process Industries

3.1.1. Fossil Fuel in Process Industries

Coal is the primary fuel used for steam generation in process industries. Most of these industries use boilers that produce steam in the pressure range of 10 - 21 Bar. The usage of steam happens typically at pressures ranging from 0.5 - 7 Bar, with a significant portion at 3 Bar. From 1kg of coal, supercritical power plants can generate 2 kWh of power. If this power is to be utilized for providing thermal energy (by electric resistance heating or using heat pumps, to process at 145 °C, 3 Bar), it can generate 1.7 times the energy to the process than provided by process boiler at 10 Bar. It is evident from this calculation that process plants immensely destroy coal's potential to perform useful work. This usefulness of coal is destroyed primarily in process boilers and the later in throttling by pressure reducing stations. It is worthwhile to consider the effectiveness of energy utilization in process plants spread across India. Energy, Economy and Environment, all three must be looked at together.

3.1.2. Methods to Improve Exergetic Efficiency of Process Plants

Broadly, the following three options can be pursued:

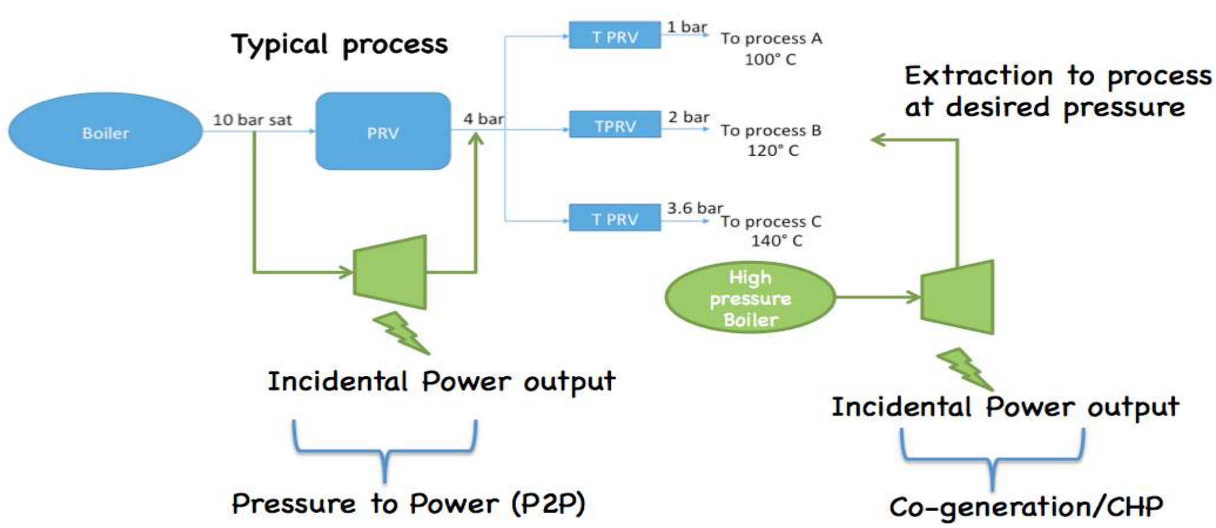
1. Replacing low pressure boilers with high pressure systems, and use a back-pressure extraction or condensing turbine to cater to process heat;
2. Set-up P2P (pressure to power) stations across pressure reducing stations; and
3. Legislate exergy accounting and reporting as part of environmental performance metrics and incentivize replacement of obsolete technologies.

3.2. Cogeneration in Indian process industries

Cogeneration is not widely adopted in India, even though it has enormous potential to save fuel and help combat effectively the burden of climate change. Cogen is more commonly used in large sugar processing plants, where bagasse based cogeneration is very common. Cogen is also deployed (though not so widely as in Sugar industry) in cement, textile and dairy industries. Even with existing plants where cogen has been deployed, the results have not been uniform. A few of them have performed exceptionally well, while many have been rendered non-operational. During a limited field survey, we observed quite a few dysfunctional units with cogen. The following four reasons were often put forward to explain using these units remained dysfunctional:

1. Turbine could not handle load fluctuation
2. Maintenance issues of the turbine
3. Found economically unfeasible with current mode of operation.
4. Wetness in steam causing turbine blade erosion.

Since most of the existing cogen systems are turbine based, it could be inferred that the issues may be due to the system not being designed in accordance to the operating requirements of respective process plants. In addition, process load fluctuations pose significant difficulty to the operation of turbine-based systems, limiting its availability to produce power and hence impacting the economic feasibility. Load fluctuations are particularly problematic as turbine design efficiency is very specific to an operating point and drops off rapidly as we move away from the design point. One takeaway from the field studies is that specific "expander technologies" need to be developed to cater to the unique operating conditions of process plants.



4.0. Challenges and Opportunities for promotion of Cogen

4.1. Challenges:

International Energy Agency (IEA) identifies cogen as one of the green energy sources with the potential to reach the renewable energy obligations/commitments. Cogen, especially when fossil fuel is the primary fuel, is **not renewable energy**. But the efficiency gains and corresponding offset to primary fuel consumption could be counted towards green power obligations. Specific reports of IEA on India's CHP and DC market and its policy potential point out the following reasons as barriers for low penetration of CHP in Indian market [1] [2]

1. Lack of government policy guidance on CHP;
2. Absence of a clear methodology for calculation of CO_2 emission reduction from CHP; and
3. Tax and duty structure for CHP capital equipment is not as attractive as for other renewable energy technologies.

Large-scale implementation of cogen can be made possible by framing appropriate policies. At present promotion of CHP appears feasible only with captive power usage by industries, and with enormous drive for awareness and promotion. Even with the current solar energy boom, cogen can be a success story because, at present the energy cost through cogen is cheaper than conventional power sources and other renewable sources. Also the area required for implementation of cogen is only a fraction as compared to that of solar. The cost of generation of power through cogen is about Rs1.2/kWh. [3]

4.2. Policy Initiatives

Many EU countries have aggressively taken up CHP and they have promoted favourable policies, such as RE tagging, tax incentives etc., to enable uptake [4]. Most CHP installations in these nations are in the domestic sector, specifically catering to supply of warm tap water. This does not apply to the Indian domestic sector. Hence CHP in India will have to acquire predominantly an industrial flavor. We would therefore need industry-focused policies. A few do exist already such as the "Perform Achieve and Trade" (PAT) schemes for designated industries. However, implementation, tracking and promotion have not been very aggressive like the ones we have seen for solar PV. Even existing national missions such as the NMEEE (National Mission for Enhanced Energy Efficiency) does not have clearly laid out guidelines for targeting exergetic efficiency and promotion of CHP

4.2.1. Emission rating

A big positive impact of energy efficiency technologies such as CHP is on the environment. Hence there is a need to device a mechanism, which in addition to the energy star rating, would also account for the emission/ecological impact of a particular product. One such mechanism, which promotes a holistic view of a product's ecological footprint, could be emission rating. Once could argue that a higher emission rating could be simply achieved by pushing out/outsourcing manufacturing to sub component suppliers/vendors. This could be taken care of by a system that accounts for the ecological impact of the entire supply chain, there by gradually greening the whole link. Like energy rating, various consumer products coming from process industries can be rated based on emission, which is accounted from raw material to product. Emission star rating could be used as an advantage in promoting the product through advertisement. Tax concessions can be given for firms to produce goods with higher emission star rating, thereby bringing ecological footprint in to public mind space. Effectiveness of star ratings on public perception has been very successfully achieved by the BEE's energy star rating campaign

4.2.2. Mandatory power generation from cogen in process plants

Policy could also be framed at the approval stages of process plants to implement mandatory power recovery to the extent it is feasible technologically, before usage of captive power generation using onsite diesel generators.

4.2.3. Local load consumption and penalty for using DG

As discussed above, cogen can account for only a part of the entire load of a plant. Industries should thus be encouraged to consider cogen for a part of their load whenever possible. Penalty to be imposed on DG set usage if potential for cogen exists in the plant. Pooling of energy resources, both heat and power could also be considered in situations where the demand for heat and power varies throughout the day and it becomes difficult for the plant to manage the loads. This option will also enhance the attractiveness on the CHP plant to potential investors.

4.2.4. Use of high-pressure Boilers

Industries should be advised to buy high pressure, preferably biomass boiler for their plants. Any future expansion needs to be mandatorily done with high-pressure boilers. This will ensure that the energy potential of the fuel burnt could be effectively used and the emission impact could be curtailed.

5.0. Conclusions

Cogeneration or CHP is a green technology, which has the potential to achieve considerable portion of the renewable energy targets and other green technologies like biomass boilers by incorporating cogen in it. One of the main advantages is that a P2P system can be retrofitted into the existing plants with incorporation of an expander circuit. The space requirement is negligible compared to other renewable resources. Much of the existing 20 GW potential is exploitable through proper policy framing and by creating awareness among industrialists [5]. Accounting and monetizing carbon credits could further improve CHP's attractiveness. Moreover initiatives such as emission rating for an end use product from a green manufacturing plant can really push this technology towards increased deployment. Much work needs to be done as far as development of dedicated technologies, which can handle the variations, and unique operating conditions of process industries. With right policy incentives, innovations in technology and other market mechanisms, the future of CHP/Cogen in India could become bright.

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