Combined Heat & Power: CHP Present and Future

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Combined Heat and Power (CHP) is an efficient way to generate electricity and heat by utilizing the waste heat from the electric generator in place of heat from a separate boiler. Currently, most electricity is purchased from a central utility company that generates power at 35% efficiency; the balance of fuel input energy is lost as heat. With CHP some of the electricity is generated onsite and the waste heat from the generator (water jacket and exhaust) is used for space and water heating and other industrial processes that require heat. This reduces the fuel requirements to the boiler which also reduces emissions of Green House Gases (GHG) and other pollutants. Overall CHP efficiencies can make up to 85%. CHP is also known as Buildings Cooling, Heating & Power (BCHP), CHP for buildings (CHPB), Integrated Energy Systems (IES), Total Energy System (TES), Tri-generation (Trigen) and Cogeneration. CHP is best fit where there is demand for heat (or cooling load) and electricity is simultaneous e.g. hospitals, the hotel industry, educational institutes. Exhaust heat can be applied to support cooling loads with absorption chillers.

CHP position in current energy market

There are more than 4,100 CHP sites in the USA with 81,800 MW installed capacity. As per ICF International there is 65 GW of industrial technical potential for CHP systems based on thermal demand of the site which does not include the potential for producing electricity for export to the grid beyond the site/facilitys demand. There is 130 GW of potential for CHP systems based on thermal demand of the site with exporting the over produced electricity to the grid or sold to adjacent users. A country like Denmark uses district heating & CHP to drive towards efficiency and energy self-sufficiency. Over 50% of power is generated by CHP systems in Denmark vs 8% to 9% power generated by CHP in the United States, considering the total power generation in the USA is way bigger than Denmark.

CHP Systems:

There are different types of fuels and prime movers used to run the CHP system. Natural Gas, Propane, Methane, Oil, Coal, Landfill Gas, Digester Gas, and Hydrogen are commonly used fuels. The role of the prime mover is to convert fuel energy directly to mechanical energy, shaft power. The mechanical energy can then drive a generator to produce utility grade electricity technologies used for generating electricity on-site or near the site. There are many proven prime movers. Reciprocating Engines, Gas Turbines, Microturbines, and Steam Turbines are commonly used prime movers.

Energy Reliability:

CHP offers a variety of commercial, environmental and societal benefits; including grid reliability and energy efficiency. CHP can significantly reduce emission of carbon dioxide and air pollutants like nitrogen oxide, sulfur dioxide and volatile organic particles. CHP facilities are located on-site or close to consumers so electricity transmission and distribution losses are reduced and delivery reliability is enhanced. Compared with large, interconnected grids, CHP is more resilient when weather or security events interrupt energy supplies. CHP can be integrated with microgrids for grid reliability and resiliency. Many facilities can come online quickly after outages and can operate off the grid during a blackout. These CHP features allow businesses to keep going and to maintain critical infrastructure powered.
CHP present Challenges:

Financial:

Because CHP equipment has significant upfront costs and its a long-term financial commitment, CHP is a costly financial decision. There are two types of financial budgeting decisions made by financial institutes 1) Capital budgeting decision and 2) Operational budgeting decision. Capital budgeting decisions mean investments that are spread over multiple years such as electric generating facilities. Operational budgeting is generally restricted to one year. For capital budgeting, there are several quantitative methods that have been developed. These can be divided into two groups 1) Time value of money e.g. Present value method or the internal rate of return method 2) Simple payback method which ignores the time value of money. Net present value involves calculating the present value of the expected cash flows of the project using the cost of capital as the discount rate, and comparing the total present value of the cash flow to the amount of investment required. The net present value is positive if the cash flow is greater than the investment. It means the rate of return of the project is greater than the cost of capital. The Internal rate of return is the interest rate received for an investment consisting of payments and income that occur at regular periods. Capital budgeting for CHP is a complex process. Energy efficiency is maximized when a system is sized to match a facility thermal load. This often results in more power than the site needed. This makes the CHP system big and financially expensive. Gas price volatility creates uncertainty in savings. Most CHP systems stay connected to the grid & contract with the utility for electricity, during scheduled or unscheduled outage of CHP utilities charge (standby charges) for the backup service. Many potential industrial project decision makers are not fully aware of the full array of benefits provided by CHP or are overly sensitive to perceived CHP investment risks.5–10

Local Permitting & Siting issues:

CHP installations need interactions with a number of local agencies, including fire districts, water districts and planning commissions, which are largely unfamiliar with CHP. CHP systems reduce global emissions, but add emission to the local site. Because the facility now produces electricity, on-site emissions will be increased, which may prevent hosts from pursuing projects. During the CHP project development process it is essential to obtain interconnection, environmental compliance and a construction permit. The permitting process for a CHP project may take from 3 to 12 months to complete, depending on site location and technology. CHP installation typically needs local utility interconnection study and approval, local jurisdictional pre-construction and construction approvals & local jurisdiction post construction and operating approvals. Siting and permitting demands significant investment of money and time in filling applications, researching, planning, meeting with officials and paying fees. Permitting and government agency approval may take 3 to 5 percent of the project cost depending on CHP system size.

Environment policies:

Most environmental regulations for power generators and boilers have established emissions limits based on heat input or exhaust concentration: thats how emission is measured in pounds per million British thermal units (lb/MMBtu) of heat input or in parts per million (ppm) of pollutants in the exhaust stream. These traditional input-based limits do not account for the pollution prevention benefits of process efficiency in ways that encourage reduced energy use. Output based environmental regulations (OBR) encourage energy efficiency and clean energy supply. OBR have been used for years in regulating some industrial process. OBR encourage energy efficiency and clean energy supply. CHP units produce both electrical and thermal energy output. OBR can be designed for both types of output in compliance computation. Thermal output is very important because CHP achieves its best energy efficiency by generating both electrical & thermal energy from a single fuel source. Although CHP has many environmental benefits, there are very few incentive programs or policies to support it like other renewable energy programs.

Whats next to overcome challenges?

Third Party ownership structure

In deregulated states, electric utilities cannot own electric generation directly, but there are some models that allow them to employ CHP. A united illuminating company in Connecticut developed a zero-capital program where the third party owner works with customer interested in having CHP on-site. Five to ten year contracts are encouraged between the third party (CHP Owner) and customer. An electric and natural gas utility (at this stage decided to be unnamed) developing a model where CHP Initial capital investment will be made by a financial institution or investor but the CHP system will be sited at the customers facility. The customer gets the direct benefits of the electricity and heat generated from CHP system. The customer will pay a flat fixed rate each month for ten or fifteen years as per contract and after that customer will be allowed using electricity and thermal energy produced on-site for no additional cost. The customer will enjoy a lower monthly payment operating budget than capital investment and the investor will enjoy a fixed monthly payment that offers a rate of return on its investment.7
Figure 2 shows the flow of money and electricity provider and user. Per contract CHP owner gets money from the customer and utility, the customer gets electricity and heat from CHP system, and utility receives over produced electricity from the customer. Utility does not have to make any initial investment to update the grid to meet the customer increased demand. CHP owner owns the system based on contract terms and conditions. It is win-win situation for utility, CHP owner and the customer. In Regulated states, electric utilities own CHP or enter in PPAs (Power Purchase Agreements) for power produced by CHP. CHP cost is aggregated with other costs and embedded in the utilities rate base. In Alabama Power territory, Southern Company owns over 700 MW of CHP across six plants in which the utility, customers and rate paying customers enjoy benefits of CHP.

$CO_2$ emission saving calculation:

EPA and state air regulatory authorities have supported CHP deployment due to significant reduction in harmful emissions. CHP projects need to quantify the fuel and carbon dioxide emission savings compared to conventional separate heat and power (SHP). To calculate the fuel and $CO_2$ emission saving for the CHP system, thermal and electricity output should be calculated separately for heat & power. Here is the example of a CHP emission calculator based on 10 MW natural gas-fired combustion turbine and heat recovery with default values in the calculator at the facility (e.g. Hospital, College campus) in Illinois state. Operation hours 7500 per year and the fuel heat rate 11,728 HHV have been assumed for input values. In this example output heat has not been utilized for absorption chiller but CHP system can be designed to utilize the heat for absorption chiller.

Emmission Reduction due to CHP system

Figure 3 shows the output results of the calculation based on Table I inputs. 10 MW CHP systems can reduce the 67,581 tons of carbon dioxide equivalent, which is equivalent to approx. 12,814 passenger vehicles. Depending on the geographical location, $CO_2$ emission calculation is an important factor to show the CHP environment benefits. EPA has updated the CO2 emission calculator in January 2015.

A number of federal, regional, and state programs have adopted output based emission regulations. EPA used output based emission regulation (OBR) approach to revise the electric utility boiler New Source Performance Standards (NSPS). This action reflected a major change for NSPS and provided an efficiency based rationale for transitioning to output based regulation. OBR approach is very important for CHP systems. CHP & EPA Partnership (CHPP) developed a handbook to assist state, local, and tribal regulators to develop output based regulations. The handbook provides practical information to help regulators decide if they want to use output-based regulations and explains how to develop an output-based emission standard.

**Clean Air Act Section 111**

EPA has released the final version of the Clean Power Plan, a rule that sets performance rates and individual state targets for $CO_2$ emission from an existing power plant on August 3, 2015. Under the Clean Air Act emis-
sion reduction is set for 32% nationwide by 2030 respect to 2005 level. CHP can help states to meet their Clean Power Plan targets. ACEEE develops the CHP template to help states to understand how to document and claim emission reduction by CHP. ICF International estimates an additional 40 GW of CHP would reduce about 150 million metric tons CO\textsubscript{2} annually, which is equivalent to the emissions of over 25 million cars.\textsuperscript{7} Under Clean Air Act section 111d plan, states have engaged in a variety of policies and programs to support CHP. Here are the examples:

- Interconnection standards and procedures: Statewide technical standards and streamlined procedure for connecting CHP to transmission and distribution network.
- Energy saving target: Allowing CHP to qualify in state energy saving standards.
- Financial assistance: Incentives, grants and eliminate loan programs, barriers to CHP deployment.
- Streamlined permitting: Output-based emissions regulations (OBR) & fast-track air permitting for qualified systems encourage CHP deployment. Shorter time for permitting can make a significant impact on CHP deployment and financial saving.

For example, one fast-track air permit for CHP in Texas reduced well over 1 year time to acquire the state level air permit to 4-6 weeks. Such short permitting time saves lot money on CHP projects. EPA has developed a handbook for output based emission guideline.

**Conclusion**

CHP is a proven solution for meeting growing energy demand efficiently, cleanly and economically. CHP is a clean energy solution that immediately addresses a number of national priorities, including improving the competitiveness of U.S. manufacturing, increasing energy efficiency, reducing emissions, enhancing our energy infrastructure, and improving energy security. CHP has its own challenges, but the future is good with new Clean Air Act section 111 & third party investment structure. The Obama Administration is supporting a national goal of achieving 40 GW of new cost effective CHP in the United States by the end of 2020. To meet this goal by 2020 barriers to CHP development needs to be removed, and effective policies, programs and financing opportunities promoted.