Combined Heat and Power

Highlights

- **Process and Technology Status –** Combined heat and power (CHP), also known as cogeneration, is a system that generates electricity (or shaft power) while using the residual heat generated in the process for residential heating or production of hot water and steam for other applications. CHP currently accounts for around 9% of global power generation. CHP plants consist of a prime mover (turbine, engine), an electricity generator, a heat recovery system, and a control system. Various fuels (natural gas, coal, and biomass) and power generation technologies can be used for CHP. The most frequently used natural gas-based technologies are: 1) Gas turbines with heat recovery steam generators (HRSG); 2) Combined-cycle gas turbines (CCGT) consisting of a gas turbine with HRSG, which drives a steam turbine with a back pressure or a steam extraction system; 3) Internal combustion engines with electrical generators and heat extraction systems. Among coal-based technologies, fluidised-bed combustion (FBC) is often used to fulfill the demand for industrial steam or to feed district heating systems. Fossil fuel-based CHP technologies are relatively mature. Among more advanced technologies, fuel cell-based CHP provides opportunities for new applications and improved efficiency, however it needs to offer a significant reduction in the fuel cell cost.
- **Costs –** The investment costs of a gas-turbine CHP plant ranges from $\$900/kW_e$ to $\$1500/kW_e$, with a typical cost figure of $\$1000/kW_e$ (US\$2008). The annual operation and maintenance (O&M) costs are approximately $\$40/kW_e$. The investment costs of a combined-cycle (CCGT) CHP plant range from $\$1100/kW_e$ to $\$1800/kW_e$ and more, with a typical cost figure of $\$1300/kW_e$. The annual O&M costs are approximately $\$50/kW_e$. The investment costs of a fluidised-bed combustion (FBC) CHP plant based on coal ranges from $\$3000/kW_e$ to $\$4000/kW_e$ and more, with a typical cost figure of $\$3250/kW_e$ and annual O&M costs of approximately $\$100/kW_e$. The investment costs of a gas-engine CHP plant are in the range of $\$850–1950/kW_e$, with a typical cost figure of $\$1,150/kW_e$. Its annual O&M costs are about $\$250/kW_e$. If biogas from anaerobic digestion is used in combination with a gas engine, the cost of the digestion and gas cleaning equipment has to be added to the above mentioned cost. Much higher costs are quoted for fuel cell based CHP.
- **Potential and Barriers –** CHP is the most efficient way to convert fossil fuels and biomass into useful energy and can make a significant contribution to meeting energy efficiency improvement targets. If natural gas is available at an affordable price, gas-based CHP may offer competitive power and heat. Coal-based CHP may also be a competitive option depending on location, generation mix and heat and power demand. In the past years, the natural gas-based CHP market has been driven by the need to exploit the energy content of costly natural gas as much as possible, and lower the overall heat and power generation costs. The increasing efficiency of the gas turbines and CCGT has provided another advantage to using CHP plants. However, governmental incentives and policies are needed to exploit the full potential of CHP technology. At present, China is a high potential market for CHP.

Process and Technology Status – Electricity generation based on fossil fuels is rather inefficient. A combined-cycle gas turbine (CCGT) plant – the most efficient technology for electricity generation (see ETSAP TB E02) - has an electrical efficiency of between 52% and 60% at full load, and some 40-48% of the fuel energy content is wasted as residual heat. Combined heat and power (CHP), or cogeneration, enables an efficient use of this waste heat. Figure 1 shows the energy flows and energy losses in global electricity generation (IEA, 2008). CHP is largely used in the industrial sector for combined production of power and steam, and for district heating of nearby cities. Small-scale CHP may also be based on internal combustion engine generators, with heat recovery from exhaust gas and cooling water. Fuel cell- based CHP is currently a high-cost option, but it offers potential for cost reduction and further efficiency improvement. CHP currently accounts for about 9% of the global power generation (IEA, 2008). In Denmark and Finland, CHP accounts for 47% and 65% of the thermal electricity generation respectively, thus excluding generation from wind, solar PV, hydro, etc. (IEA, 2009a). Table 1 lists the CHP technologies and their respective markets and/or applications (IEA, 2008). CHP plants based on natural gas or coal are usually derived from power generation technologies.

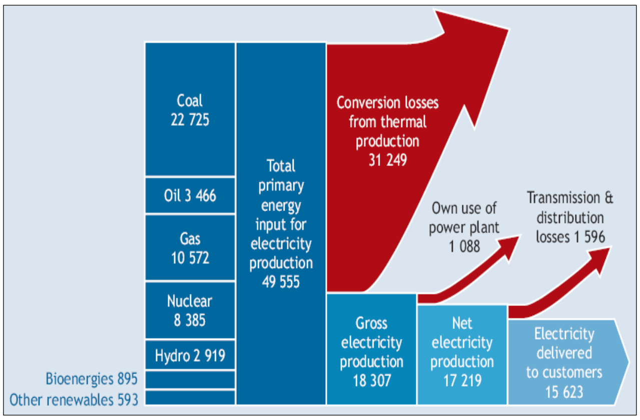

Fig. 1 - Typical Energy Flows in Global Electricity Generation (IEA, 2008) - Nuclear energy is accounted for, based on thermal energy equivalent.

Natural gas CHP technologies are: 1) gas turbines with heat recovery steam generators **(GT-HRSG)**; 2) combined-cycles consisting of a gas turbine **(CCGT)**, a HRSG which drives and a steam turbine with back pressure or steam extraction system; and (3) gas-fired internal combustion engine **(ICE)** generators with heat extraction systems. Simple-cycle or combined-cycle gas turbines are largely used for industrial cogeneration.

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