Cost-effectiveness of greenhouse gas emissions reduction with hybrid CHP technology in the process industries

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Project goal and motivation

The aim of this project is to investigate performance and greenhouse gas (GHG) emissions of industrial combined heat and power (CHP) systems using two or more different fuels simultaneously, hence the name HYBRID. The project focuses specifically on gas turbine CHP plants using biomass fuels for supplementary firing in the GT exhaust stream at the inlet to the exhaust heat recovery boiler in which process steam is produced. The gas turbine is assumed to be fired on standard gaseous gas turbine fuel, i.e. LPG or natural gas. The different systems investigated are evaluated with respect to their cost-effectiveness for reducing global greenhouse gas emissions

The potential advantages of hybrid gas turbine CHP systems are:

?? Investment costs for biomass fuel firing are low. Combined usage of high grade gas turbine gaseous fuel and biomass fuel results in low GHG emissions;
?? LPG or natural gas are used as the gas turbine fuel, expensive biomass gasification and associated gas clean-up systems required for biomass firing in the gas turbine are avoided;
?? The biofuel is used in “upgraded” form (pellets in this case). In this way, storage and handling problems are minimised. This is assumed to be a key condition for usage of biofuels to increase in non-forest industries;
?? All technology is proven (including dual fuel or dedicated burners for firing of pulverised wood);
?? If the condensate return stream from process heaters is substantially subcooled, supplementary firing can significantly improve the total efficiency of the system.

Investigation procedure

The investigation procedure was as follows:

1. Using heat-and-mass balance power plant simulation software, the performance of a hybrid gas turbine CHP plant as described above delivering heat to a typical industrial process was evaluated. The following process heat demand was considered: 26 MW heat demand – hot utility: 9 bar steam, return condensate subcooled to 100ºC or lower. The following performance figures-of-merit were computed: electric power output, electrical and total efficiencies, fuel usage, local and global CO_2 emissions (global emissions account for an emissions credit corresponding to electric power production displaced from the reference power generation system).
2. Step 1 was repeated for different gas turbine types and sizes with varying degrees of biofuel supplementary firing.
3. For each system, the associated annual heating costs were computed. Sensitivity analysis was performed with respect to fuel prices, electricity prices, CO_2 tax levels, investment costs.
4. Greenhouse gas system performance was then computed, i.e. the cost per kg reduced global CO_2 emissions. Different CO_2 emissions for the reference electrical power generation system were considered. The cost per unit reduction of global CO_2 emissions were then compared with the respective single-fuel technologies, i.e. natural gas fuelled GT CHP and biomass fuelled steam turbine CHP.

Results

The table below shows the key results of the study for a representative system with a small gas turbine (Solar Taurus 60 – 5 MW electrical output) and maximum biofuel supplementary firing in the exhaust stream. The marginal CO_2 reduction costs are computed with respect to the natural gas GT CHP system, which is thus the reference. Results are shown for the base case scenario and for a number of scenarios that were considered in the sensitivity analysis. It is important to point out that the base case scenario is based upon current fuel and electricity prices for Sweden. Current energy and environmental taxes valid for Swedish industry are assumed for the study.

Table 1. Sensitivity analyses for a representative Hybrid CHP system. Engine: Solar Taurus 60, Electrical Output: 4.98 MW, SFF: 49.85 %.

	Hybrid CHP System		**NG CHP system**	**Biofuel ST CHP**	
	Total Annual Heating Cost [M$/yr]	Marginal Global CO_2 Reduction Cost [$/kg CO_2]	Total Annual Heating Cost [M$/yr]	Total Annual Heating Cost [M$/yr]	Marginal Global CO_2 Reduction Cost [$/kg CO_2]
Base Case NG 18.1 $/MWh Biof. 16.8 $/MWh Elec. 30.0 $/MWh	4.7412	0.0045	4.5725	4.9287	0.0048
NG price +20% and biofuel Price 15 $/MWh	4.8784	-0.0122	5.3309	4.9287	-0.0054
Alternative Electricity Production Price = 15 $/MWh	5.3389	0.0045	5.1703	5.5127	0.0047
Lower Inv. Cost (-20%) Biofuel SF facility	4.6723	0.0027	4.5725	4.9287	0.0048
Total Fuel Usage Taxation Rule. Electricity Price 37$/MWh	4.6256	0.0045	4.4570	4.6561	0.0027

Conclusions

?? The natural gas GT CHP system has the lowest total annual heating cost for most conditions considered.

?? The biofuel steam turbine CHP system is the most expensive alternative but has the lowest marginal CO_2 reduction cost.

?? For current energy market conditions, a substantial decrease of the biofuel supplementary firing facility investment cost is necessary for Hybrid systems to be competitive.

?? Hybrid CHP systems become attractive when the natural gas price increases and the biofuel pellets price decreases.

?? Variations in electricity prices do not affect the relative ranking of the technologies considered in this study.

For the conditions considered in this study, Hybrid gas turbine CHP technology therefore does not appear attractive for cost-effective reduction of greenhouse gas emissions compared to the relevant single-fuel alternatives. Natural gas fired gas turbine CHP is cheaper, and is thus the most attractive option for industry. Biofuel steam turbine CHP has the lowest marginal CO_2 reduction cost, and is therefore the most attractive option from an environmental policy viewpoint.