**Evaluation of Hybrid Electric Steam Generation for a Chemical Plant under Future Energy Market Scenarios**

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**Highlights**

* Hybrid electric steam generation can be economically feasible already today
* The cost-optimal capacities are very sensitive to future energy market conditions
* Electricity is compared with biomethane as fuel for steam generation

**1. Introduction**

Industrial processes currently account for 25–35% of the world’s total energy demand and related emissions. During recent years, the amount of low-carbon electricity from renewable energy sources (such as wind and solar) has increased continuously while the corresponding electricity generation cost has fallen. This leads to an increasing interest in process electrification to reach long-term goals for reduction of greenhouse gas emissions. One option to reduce CO2 emissions from the utility system of chemical plants is to implement hybrid electric steam generation concepts in which electric and gas boilers are coupled. It is assumed that the gas boiler can switch freely between natural gas and bio-methane fuels.

The objective of this study was to evaluate hybrid electric steam generation for a specific chemical plant in terms of CO2 emissions and cost under future energy price and policy conditions.

**2. Methods**

In the first step, an optimization model was used to identify the optimal boiler capacities to reach the lowest total annualized cost for a hybrid system. The model takes into account the specific characteristics of the steam demand and the steam generation technologies. It was applied to a refence scenario with current Swedish energy market conditions, as well as two sets of future energy market scenarios from the ENPAC model [1]. ENPAC is a tool to generate consistent scenarios for energy prices and marginal CO2 emissions associated with the use of energy for large-volume industrial customers based on forecasted prices for fossil fuels on the commodity market and costs associated with emitting CO2. The scenarios used in this work were generated based primarily on output from the “New policies” and “Sustainable development” scenarios from the IEA’s World Energy Outlook [2]. For these scenarios, power grid capacity additions are assumed to generate electric power from renewable sources with no CO2 emissions with wind power as marginal electricity production technology. The scenarios also include data for costs for biomass fuel as well as CO2 emissions related to increased use of biomass, under the assumption that biomass is a limited resource. In both scenarios, the significant increase over time of the charge for emitting fossil CO2 leads to a major increase of the market price of natural gas, but it also leads indirectly to a significant increase of the cost of the biomass feedstock for production of bio-methane.

In this work, steam generation capacities were fixed to values corresponding to the average optimal values resulting from the “New policies” scenarios for the period 2025-2040 in order to simulate an investment decision. The boiler system performance was then evaluated by a what-if analysis in terms of CO2 emissions and cost for the “New policies” and the “Sustainable Development” scenarios for 2025, 2030 and 2040. Additional runs were performed in which the system was forced to follow an emission reduction path at the lowest cost, allowing the gas boiler to switch from natural gas to biomethane if necessary. The emission reduction was in line with the Swedish target of net zero emission of greenhouse gases by 2045.

**3. Results and discussion**

Results from the first step show that hybrid steam generation concepts can be economically feasible even under today’s energy price conditions. In the “New policies” scenario, the optimal capacity for the electric boiler for the energy market conditions in 2030 and 2040 are only slightly higher than the one in 2025. In contrast, the optimal electric boiler capacity for 2030 and 2040 in the “Sustainable Development” scenario is equal to the maximum steam demand, meaning that there would be no investment in a gas boiler.

The what-if analysis with fixed capacities reveals for the “New policies” scenario that there is only a slight increase in total annualized cost when emission constraints that are in line with the Swedish emission reduction goals need to be respected. Under these conditions, there is a shift of boiler load from the gas to the electric boiler. In 2040, the electric boiler even replaces the gas boiler as baseload technology. For the “Sustainable Development” scenario, there is no change in total annualized cost when adding the emission constraint. This is due to the higher cost associated with natural gas. For both scenarios, the choice of biomethane to reduce CO2 emissions would be much more expensive than replacing natural gas by electric boiler.

This study takes only yearly values for the electricity price, the natural gas price and cost associated with CO2 emissions into account. An assessment on an hourly basis would allow a more detailed assessment and would enable a correspondent operational scheduling of the technologies.

**4. Conclusions**

Electric and hybrid steam generation can reduce emissions of the utility system and can be economically feasible even today. The emission reduction and cost-benefits of the electric steam generation is amplified when taking assumed future energy market conditions into account. From a cost perspective, electricity as fuel to produce steam is more attractive than biomethane.

**References**

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2. IEA, World Energy Outlook 2018, Paris, 2018.