SYNOPSIS

KEY POINT SUMMARY

OBJECTIVES

The objectives were to study the impact of installing a combined heat and energy plant using natural gas on operating cost reduction and energy consumption over a 10-year lifespan of CHP engines at the two hospitals.

Optimal design of modular cogeneration plants for hospital facilities and robustness evaluation of the results

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Key Concepts/Context

Hospitals consume electricity and use other energy sources for heating. Instead of being heavy users of natural resources these facilities could produce more energy than they use. They could even return some of the unused power back to the main electrical grid. This study explores the installation modeling of combined heat and energy generating plants (CHPs) using natural gas at two hospitals in southern Italy, to evaluate how energy consumption can be reduced along with lowering utility bills.

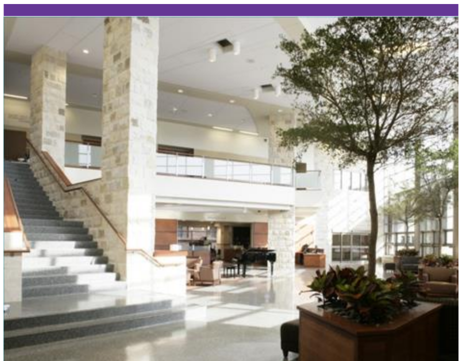
Methods

Data from two selected hospitals in Italy were collected to show annual energy and thermal loads. Retrospective data from energy and electric bills since 2012 was used. For the purpose of the study, reciprocating internal combustion engines running on natural gas were used to demonstrate calculated solutions.

Data analysis ensued and coded calculation algorithms developed by the authors were joined by a purchased optimization solver, namely the Pareto optimizer. Additionally, a genetic algorithm, Moga II, was added for robust design optimization. Several calculated solutions were comparatively analyzed and put into graphs to show the optimal combination based on the number of engines and their power output.

The data analysis methods used were:

1- The reference calculation algorithm – The algorithm input variables were the nominal electrical power of the CHP engine and the threshold thermal index which was a filter quantity within the developed calculation to guide the search for efficient plant configurations.



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2- The multi-objective optimization approach – An approach to demonstrate the importance of predictive investigation. It was conducted on a range of plant configurations to optimize energy and economic results.

3- The multi-objective robust design optimization approach – This approach was used to evaluate the robustness of the calculated results by solving the problem. Key decision variables or economic and energy parameters of the calculations were redefined with a probability distribution before the related multi-objective optimization problems were solved.

The variable sensitivity analysis of expected results included:

1- Actual availability of CHP gas – The CHP engine size was turned into a statistical variable of the optimization problem and described through uniform distribution.

2- Changes in reference energy and economic situations – A second multi-objective robust design optimization was performed using the following stochastic variables: the electricity selling price, the reference efficiency of the Italian thermoelectric generation, and the selling price of the energy efficiency certificates recognized by the Italian legislation to cogeneration plants.

Findings

The authors found a clear trade-off between total primary energy savings (TPES) and simple payback period (SPB). The study's calculated solutions using the Pareto non-dominance criterion for data optimization demonstrated that plant configurations maximizing overall energy savings lengthen the number of years in the payback period. Management strategies negatively affected the optimization, which collapsed the optimal solution to using one engine with an output of 540 kW. The optimal plant configuration and management strategy yielded energy savings of over 17% with a payback period of less than 4.6 years. There was also a reduction in carbon dioxide emissions to between 20% and 22%. Economic sensitivity (e.g., selling price of electricity, energy efficiency certificate value) was often found to be higher than the energetic sensitivity for most of the optimal solutions. The researchers also found that deterministic solutions could be overestimated as compared to the proposed robust approach.

Limitations

The study was based on calculated optimal solutions using actual electrical and energy consumption data plugged into algorithms without regard to any other hospital building variables other than CHP engine quantity and output. In addition, due to lack of detailed monitoring data, annual thermal and electrical load profiles were estimated by scaling.

Design Implications

The study suggested the use of three CHPs for balanced energy production and cost savings. The study provided an abstracted modeling tool to analyze several CHP scenarios to determine an optimal solution for hospital energy design. To be more useful, the modeling would require additional parameters for the algorithms such as heat loss and gain, natural light, and wall insulation, among others.