Project Title:	Formulation of Sustainable Trigeneration System Design for High-rise Commercial Buildings in Hong Kong
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Project ID:	CICR/05/12
Research Institution:	City University of Hong Kong
Subject Area:	Environment and Sustainability

Objective

To explore the potential of trigeneration system for high-rise commercial buildings in Hong Kong.

Background

In 2010, the HKSAR Government has proposed to reduce carbon intensity by 50-60% by 2020 compared with 2005. In the construction industry, development of zero carbon building is an effective strategy to support the Government. In order to attain zero energy target for a building, self-sustained energy resources should be available. Renewable technologies, like solar and wind power, demand large spatial requirement and unobstructed environment, so it is difficult for them to be widely adopted in a crowded city like Hong Kong.

Trigeneration is a centralised plant to simultaneously generate three essential provisions for buildings – electrical power, air-conditioning, and space and water heating. It can have a remarkable overall efficiency up to 80%, since waste heat is captured for cooling and heating production. The existing trigeneration plants are largely energised by natural gas. A report of The US Department of Energy reported that they have set an aggressive goal of achieving 40 GW of new and cost-effective cogeneration/trigeneration in US by 2020. This implies an increase of the total capacity by 50% in less than a decade. Sydney has committed to trigeneration using waste-derived renewable feedstock. It has developed a master plan of trigeneration utilisation to align the policy of abandoning coal fired electricity by 2030. It is a global trend for the deployment of trigeneration system.

Data and Methodology

Survey on biofuel supply

Trigeneration depends very much on the sources of local and overseas bioenergy and the available feedstock would determine the alternatives of system design. In the survey, information on the reliability and choice of supply of biofuel, and the environmental and economic factors affecting the supply was collected.

Model development of potential trigeneration systems

The academic dynamic simulation platform TRNSYS and its component library TESS were used for providing an overall picture of the trigeneration operation throughout a year in Hong Kong. By performing a year-round dynamic system simulation using TRNSYS, the primary energy consumption (PEC) and the carbon dioxide emission (CDE) of the various trigeneration systems for different building types were computed and compared with those based on the conventional design.

Energy, environmental and economic evaluation of trigeneration systems

In the environmental evaluation, carbon dioxide emission reduction and air quality impact of each potential trigeneration system were calculated. The trigeneration designs with both energy and environmental advantages were considered in the life cycle economic analysis. Economic benefit of trigeneration included the surplus of electricity selling back to the grid when appropriate.

Investigation on trigeneration in various building types

- The building load characteristics (power-to-cooling-to-heating ratio) of five types of multi-story buildings, including offices, hotels, retails, hospitals and sports centers, were investigated.
- Four feasible options of prime movers for trigeneration were considered, including diesel engines, gas engines, gas turbines with recuperators, and combined gas turbine cycle, for each types of buildings except sports centers.

Development of recommendations on sustainable trigeneration design

Based on the simulation results and analysis, recommendations were made on the types of buildings which offered the best potential for the implementation of trigeneration designs according to their energy, environmental and economic merits. If current situations did not favor the adoption of trigeneration system, suggestions were proposed for the promotion of the system.

Results and Findings

Biofuel supply

The supply of biofuel in Hong Kong generally fell into two categories: biogas and biodiesel. Biogas was mainly generated from landfill sites and the sewage treatment plants, but its utilization was limited to on-site electricity generation and thermal treatment. There would be a potential opportunity of biogas supply from large-scale organic waste treatment facilities if a pipe network for biogas delivery was developed.

Biodiesel was another biofuel available in the market. The supply mainly came from automobiles in a form of blended fuel. The main obstacle for the use of biodiesel was more expensive than that of conventional diesel oil. Although biodiesel could also be imported from the Mainland, the biodiesel industry was facing continual loss due to the non-competitive price.

Energy and environmental performances

- By performing year-round dynamic system simulation using TRNSYS, the primary energy consumption (PEC) and the carbon dioxide emission (CDE) of the various trigeneration systems for different building types were computed and compared with those based on the conventional design.
- Among different building types, hotel building offered the highest PEC reduction among all kinds of prime movers investigated, which exceeded 23% with a diesel engine primed trigeneration system. The hospital building had the second highest reduction in PEC. It was demonstrated that both hotel and hospital buildings had high year-round space and water heating demand and this was essential in achieving a good energy performance in trigeneration.
- Among the various kinds of prime movers considered, diesel engines offered the highest reduction in PEC, followed closely by gas engines because they had better part-load performances as compared to the gas turbines and the combined gas turbine cycle systems. This highlighted the advantage of using internal combustion engines as prime movers in trigeneration for building application.

- Despite the better energy performances, diesel engines generally yielded the lowest CDE savings among all the prime movers because the CDE index of diesel oil was 27% higher than that of natural gas. On the other hand, gas engines offered the largest CDE savings which measured up to 37% when applying to the hotel buildings.

Economic analysis

- An initial economic analysis showed that only the use of gas engines could guarantee a reduction in running energy cost. In consideration of both energy and environmental performances, the use of gas engine was deemed to be the only possible choice for building use in Hong Kong.
- In further economic evaluation of the gas-engine-primed trigeneration systems, it was found that the payback periods were not encouraging with the lowest being 13 years for use in hotel buildings.

Recommendations

To promote the green and new technologies in Hong Kong, the trigeneration systems should be supported by the government through promotion, subsidies or funding. These may include subsidy on fuel and investment, tangible feed-in tariff scheme and incentive on reduction of carbon dioxide emission.

Another critical factor is electricity-to-fuel price ratio. Investment subsidies and subsidies for demonstration projects help reduce the initial cost and hence the payback period.

A tangible feed-in tariff scheme could be worked out so that the local power companies would be obligated to purchase the spill power generated from the trigeneration systems where appropriate. The feed-in tariff scheme is one of the common policies enacted in those countries (like USA, Europe, Japan, etc.) that are advocating the distributed power supply and the renewable energy installations.