Life cycle energy savings in office building

Summary

The Tokyo Gas Kohoku NT Building, completed in March 1996, was built with the objective of achieving overall savings of energy and natural resources throughout the entire life cycle of the building, from construction to demolition. The building is expected to reduce primary energy consumption by 35% and lifecycle CO_2 emissions by 25%. This was combined with the positive use of natural energy sources and the introduction of a cogeneration system with an absorption chiller-heater using waste heat as input for its generators. The life cycle costs are lower than those of conventional buildings.

Highlights

- Life cycle savings of energy and natural resources
- Effective utilisation of natural energy sources
- Cogeneration with absorption chiller-heater using waste heat
- Energy savings of 35%, reduction of life cycle CO_2 emissions of 25%

View of the Tokyo Gas Kohoku NT Building.

Aim of the Project

The Tokyo Gas Kohoku NT Building, completed in March 1996, was built on the basic concept of life cycle energy saving. This concept aims at minimising overall environmental loads throughout the entire lifespan of the building, from construction to demolition. In planning and designing the building, three principal targets were established. These targets comprised the saving of energy and resources, the extension of the building's service life, and the improvement of amenities.

The Principle

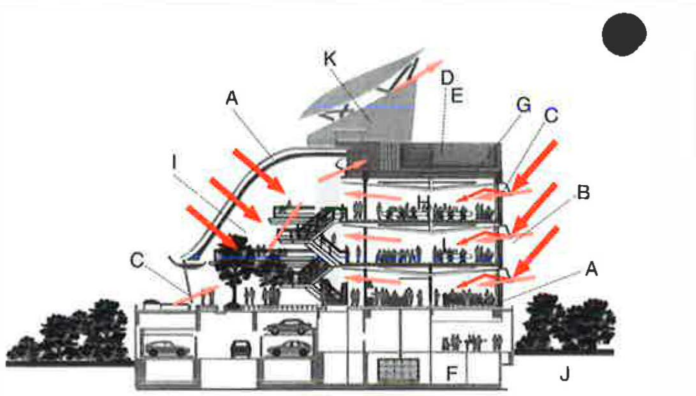
Figure 1 shows a section plan of the Tokyo Gas Kohoku NT Building, with its building area of 1,653 m² and a total floor area of 5,645 m². The facility is a four-storey office building with offices on the southern side and a glass-walled atrium (ecological core, I in Figure 1) used as showroom on the northern side. This ecological core plays an important role in one of the main approaches to energy savings in this building, i.e. to use natural energy sources as much as possible. Another major means of saving energy involves the introduction of a gas engine cogeneration system incorporating a newly developed double-effect absorption chiller-heater using waste heat as input for its generators. One way of obtaining savings of natural resources is to collect rainwater from the roof and waste water, such as that drained from wash basins, to flush toilets (F).

Heat load reduction and utilisation of natural energy sources is effected in various ways. Light shelves (B) above the windows on the south side prevent direct sunlight from getting into the offices. These windows and the glass-walled ecological core use high-transparency low-e double glazing (A) with very high heat insulation properties (U_{winter} = 1.49 W/m²K). The large windows on the south side (height: 3.4 m) and the glass-walled ecological core on the north side provide the offices with ample daylight. Sunlight reflected from the upper surfaces of the light shelves enters the rooms through fanlights (C; automatic ventilation windows) and illuminates the sloped light-reflection ceilings (L).

During the mild intermediate seasons, the automatic ventilation windows (C) are open and outside air is introduced into the building. The building has good natural ventilation regardless of wind directions and speeds. This is caused by the stack effect and by the induction effect of the ventilation tower (K).

At the rated output of 32 kW_e and 64 kW_{th}, the cogeneration system converts 28% of the total energy input into electricity and recovers 56% of the total energy input as heat, thus working at an overall efficiency of 84% (low heating value, LHV). A newly developed gas-fired absorption chiller-heater using waste heat as input for its generators (E) was incorporated into the system. A heat exchanger for waste heat recovery is inserted upstream of the high temperature generator in the absorption unit (Figure 2). The heat exchanger preheats the unit's lithium bromide using the waste heat from the engine, thereby reducing gas consumption in the high-temperature generator. This method removes the need

Figure 1: Section plan of the Tokyo Gas Kohoku NT Building.



A Custom-designed low-e double glazing
B Light shelf (Eaves)
C Automatic ventilation windows (Fanlight)
D Gas engine cogeneration system
E Waste heat input type gas-fired absorption chiller-heater
F Water reclaiming equipment
G Upper deck for equipment and machinery
H Columnless office space
I Ecological core (Atrium)
J Rainwater penetration
K Ventilation tower
L Light reflection ceiling (Sloping ceiling)

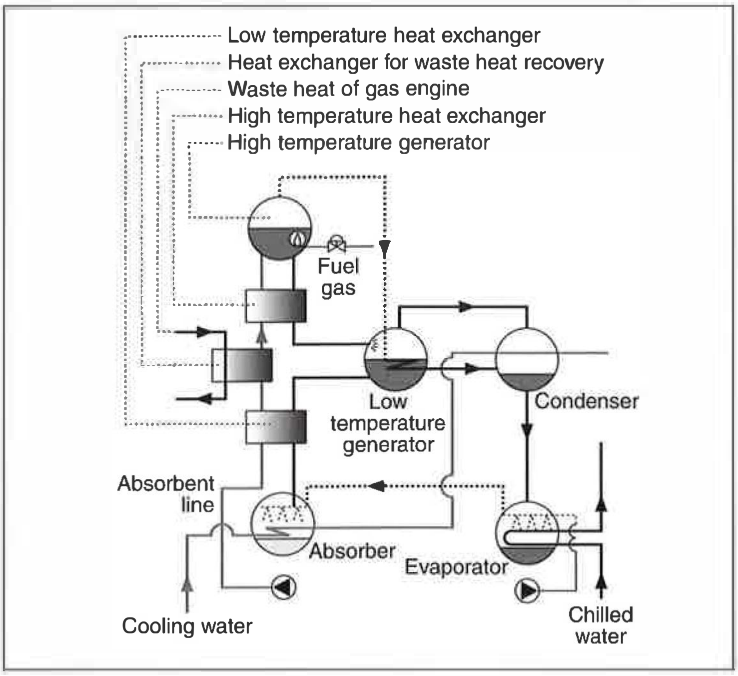


Figure 2: Flow diagram of the waste-heat input absorption chiller-heater.

for an absorption unit specifically to recover waste heat in conventional systems, saving investment costs and space for heat-source equipment.

Other than the ones described above, several energy-saving measures are taken. These measures include the differentiation between task and ambient lighting, continuous dimming according to daylight levels, and variable air volume (VAV), variable water volume (VWV), and variable water temperature (VWT) control.

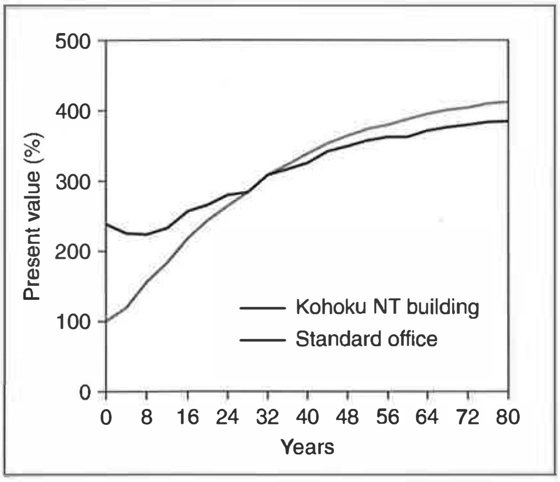
The entire aforementioned heating, ventilation, air-conditioning, and lighting system is monitored by a building energy and environment management system (BEMS), which eliminates hidden energy waste, thereby optimising the operation of the system. To extend the service life of the building, a highly durable glass-based material is used for the exterior wall. However, more effective measures are the ones enhancing flexibility in addressing ever-changing future needs, such as deep ceiling- and underfloor-support spaces that make it easier to modify piping and wiring.

The Situation

A simulation based on the execution design showed that these measures reduce the primary energy consumption of the building by 35% and the use of water by 40%. In addition, these energy savings and the expected extension of the building's service life to 80 years will reduce the life cycle CO_2 emissions by 25% from those of comparable standard office buildings.

The collected data on the energy consumption indicated that the expected energy-saving effects were attained. For example, in the offices on the fourth floor, natural lighting reduced the electricity consumption by 58% from August 1996 through January 1997. Similarly, the natural ventilation reduced the energy consumption of air conditioning by 30% in October 1996. The specific primary energy consumption of 219 W/m² (787 kJ/m²h) in the ecological core is less than that of a supposedly perfect heat-insulated showroom performing

Figure 3: Comparison between life cycle costs of the Kohoku NT Building and a standard office.



the same function (225 W/m²; 811 kJ/m²h). This demonstrates that the energy gained from using daylight completely covers the energy loss through the transparent glass wall. From August through September 1996, the cogeneration system operated at an average efficiency of 27.1% in power generation and 47.4% in waste-heat recovery (based on the heat actually used), recording an overall efficiency of 74.5% (LHV). Moreover, the cogeneration system supplied 10% of the building's power needs.

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The Company

Tokyo Gas Co. Ltd is the largest gas utility company in Japan serving more than 8 million customers, annually delivering 7,600 million m³ of gas. It employs approx. 12,700 staff.

Economics

Life cycle cost estimates shown in Figure 3 indicate that the Tokyo Gas Kohoku NT building is more cost-effective than ordinary office buildings after an operation period of approx. 30 years.

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* IEA: International Energy Agency
OECD: Organisation for Economic Co-operation and Development

IEA

The IEA was established in 1974 within the framework of the OECD to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the 24 IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology, and research and development (R&D).

This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 40 Implementing Agreements, containing a total of over 70 separate collaboration projects.

The Scheme

CADDET functions as the IEA Centre for Analysis and Dissemination of Demonstrated Energy Technologies. Currently, the Energy Efficiency programme is active in 15 member countries.

This project can now be repeated in CADDET Energy Efficiency member countries. Parties interested in adopting this process can contact their National Team or CADDET Energy Efficiency.

Demonstrations are a vital link between R&D or pilot studies and the end-use market. Projects are published as a CADDET Energy Efficiency 'Demo' or 'Result' respectively, for ongoing and finalised projects.

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