Energy Conservation for Office Buildings

Major points, measures, and successful cases of energy conservation for office buildings

The Energy Conservation Center, Japan

Introduction

The first commitment period of Kyoto Protocol started in FY2008, which requires us to achieve a target of reducing greenhouse gas emissions to 6% below the base year (FY1990) levels by FY2012. Approximately 87% of the greenhouse gas is comprised of carbon dioxide (CO_2) from energy consumption. The CO_2 emissions have been significantly growing especially in commercial business sectors and enhancement of drastic measures has become an urgent need.

This brochure is intended for owners of office buildings and persons in charge of energy conservation promotion or energy facility management, explaining the points, measures and the case examples of energy conservation based on our investigation data. We hope that you will find the information taking account of characteristics in energy consumption particularly seen in office building operations helpful for your activities toward better energy conservation practices.

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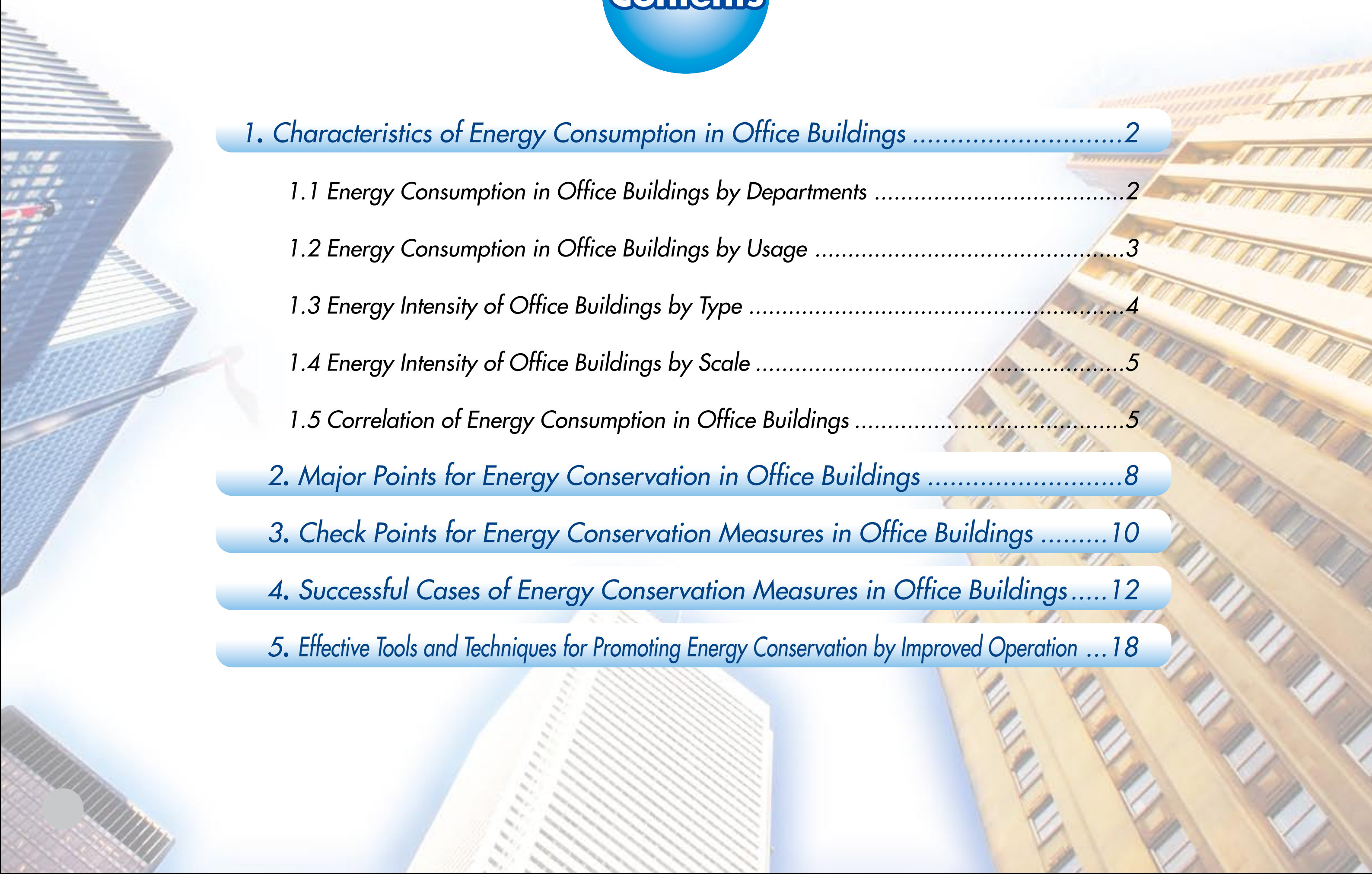


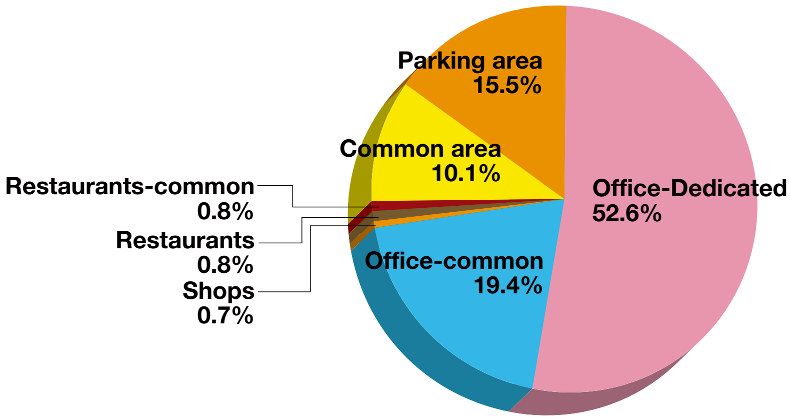
1.Characteristics of Energy Consumption in Office Buildings

1.1 Energy Consumption in Office Buildings by Departments

Types of office buildings become diversified as the scale gets larger; with larger area ratio of spaces other than general office use, including shops, etc. Taking an office building with a total floor space approximately 35 thousand square meters as an example, the graphs below show the area ratio and the energy consumption ratio, each by departments.

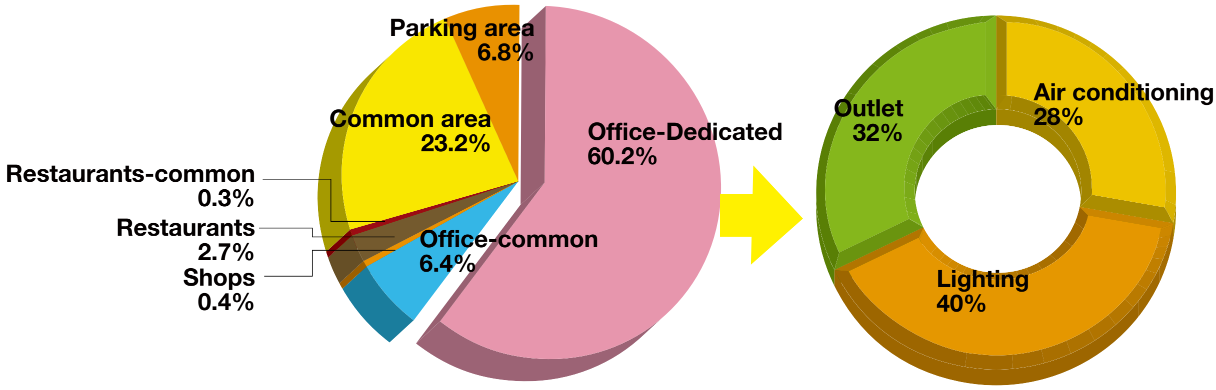
“Rentable ratio” (Area of general offices/Total floor space) is often used as an index to describe the type of an office building. In this example, the rentable ratio is 52.6% of the “office-dedicated space”. Also, note that “office-common space” indicates elevator halls, restrooms, etc. in office floors.

Area ratio by department



The values in the below graph indicate the ratio of the primary energy of fuel, heat, and electricity, consumed by air conditioning load, lightings, outlets, ventilation, and etc. The smaller graph indicates the consumption ratio of the office-dedicated department. The energy of the common space means the primary energy consumed at the facilities for the power receiving and transforming equipment, heat-distribution equipment, warehouses, and machine rooms. In addition, the energy of the office common space means the primary energy consumed at restrooms, elevators, meeting rooms, lounges, reception rooms, etc.

Energy consumption ratio by department

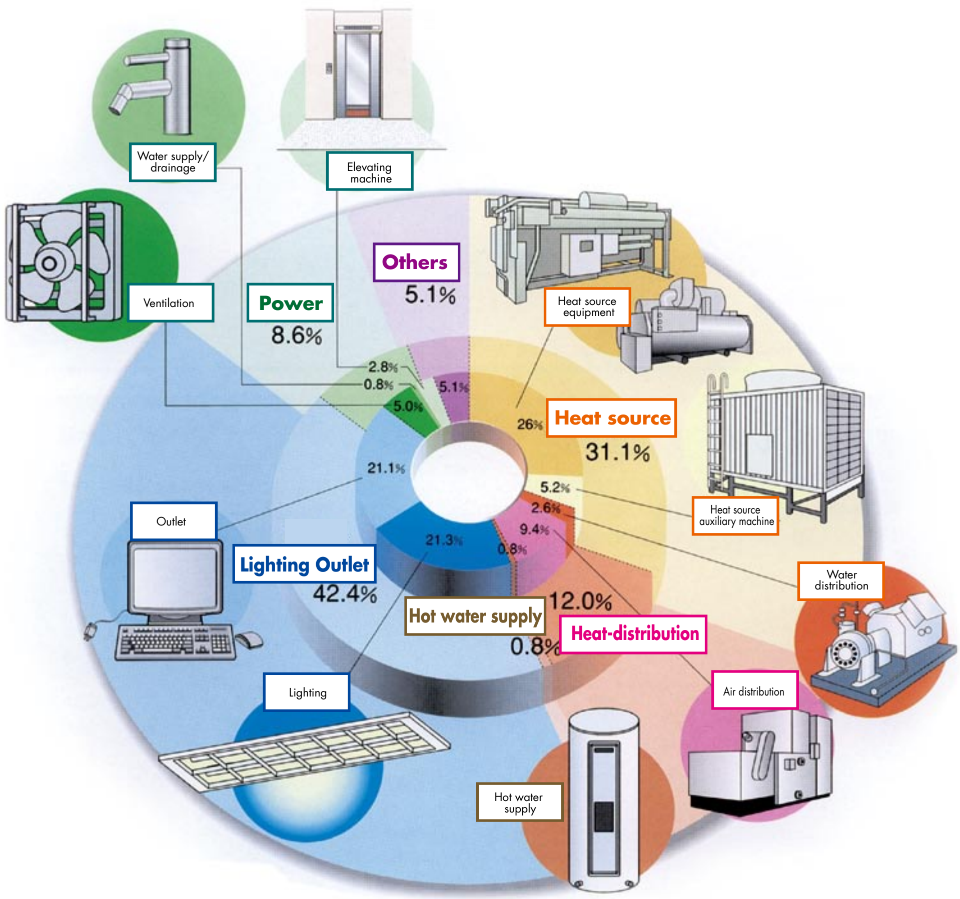


1.2 Energy Consumption in Office Buildings by Usage

With energy management in buildings, it is essential to understand the status of energy consumption; where and how much energy is being used. The below table describes the classifications of energy usage, and the below graph shows the energy consumption ratio of a tenant building with a rentable ratio of more than 60% (with heat source), which is classified according to the items and details of the table.

Energy consumption structure

Energy usage classification: Item	Energy usage classification: Detail	Major energy-consuming equipment
Heat source	Heat source main body	Chiller, water chiller/heater, boiler, etc.
	Auxiliary machine's power	Cooling water pump, cooling tower, chilled/hot water primary pump, etc.
Heat distribution	Water distribution	Chilled/hot water secondary pump
	Air distribution	Air conditioning unit, fan coil unit, etc.
Hot water supply	Heat source main body	Boiler, circulation pump, electric water heater, etc.
Lighting, outlet	Lighting	Lighting fixture
	Outlet	Office equipment, etc.
Power	Ventilation	Fans in parking, etc.
	Water supply/drainage	Lifting pump, etc.
	Elevating machine	Elevator, escalator, etc
Others	Others	Transformer loss, power of shops, etc.



1.3 Energy Intensity of Office Buildings by Type

The below graph indicates the energyintensity* (mid-value of the data group) by energy use derived by extracting 120 valid data whose energy consumption structure can be analyzed, and classified into government office, company-owned building, and tenant building, based on our investigation data of office buildings. As to tenant buildings, a stratified data by rentable ratio (rentable space ratio) is shown.

* Energy intensity: A value calculated by dividing the amount of energy use by production volume or a value strongly related to the building's total floor space and amount of other energy use.

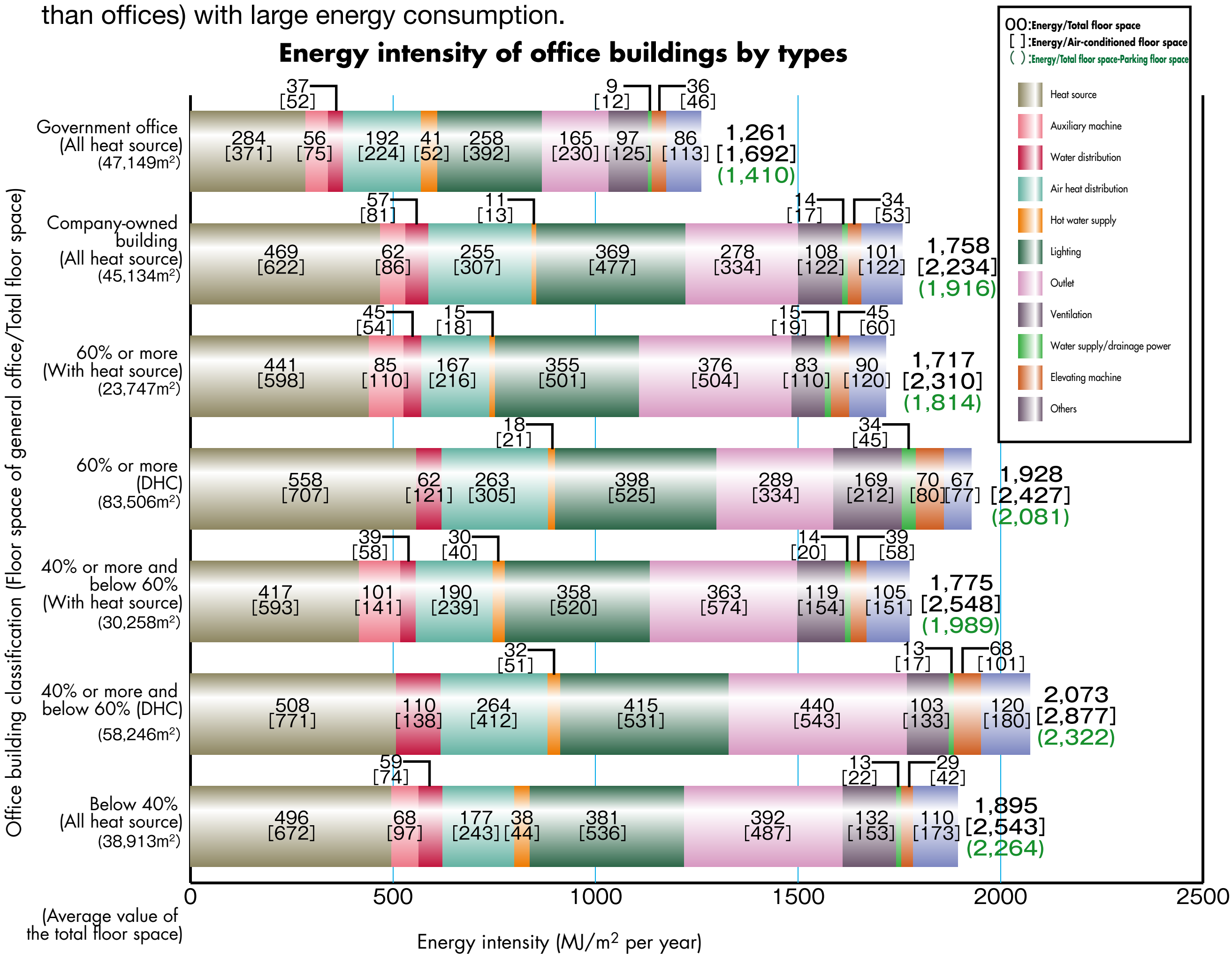
As a result, the following became clear.

(1) The operation period of air conditioning, indoor temperature, lights-out, and etc. in government offices are strictly controlled compared to general office buildings, and these efforts for energy conservation are demonstrated as intensity.
Note that areas which are not regularly used including assembly halls, etc. are also included in the space.

(2) Since most DHC (District Heating and Cooling) buildings are ultra-high/high rise buildings in the metropolitan areas, those structure with unopenable windows leads to longer air conditioning operation hours. Also with many tenants with longer working hours due to business characteristics, the intensity seems to be larger.

(3) It seems that smaller rentable ratio means larger. This may be due to higher area ratio of shops (other than offices) with large energy consumption.

Energy intensity of office buildings by types



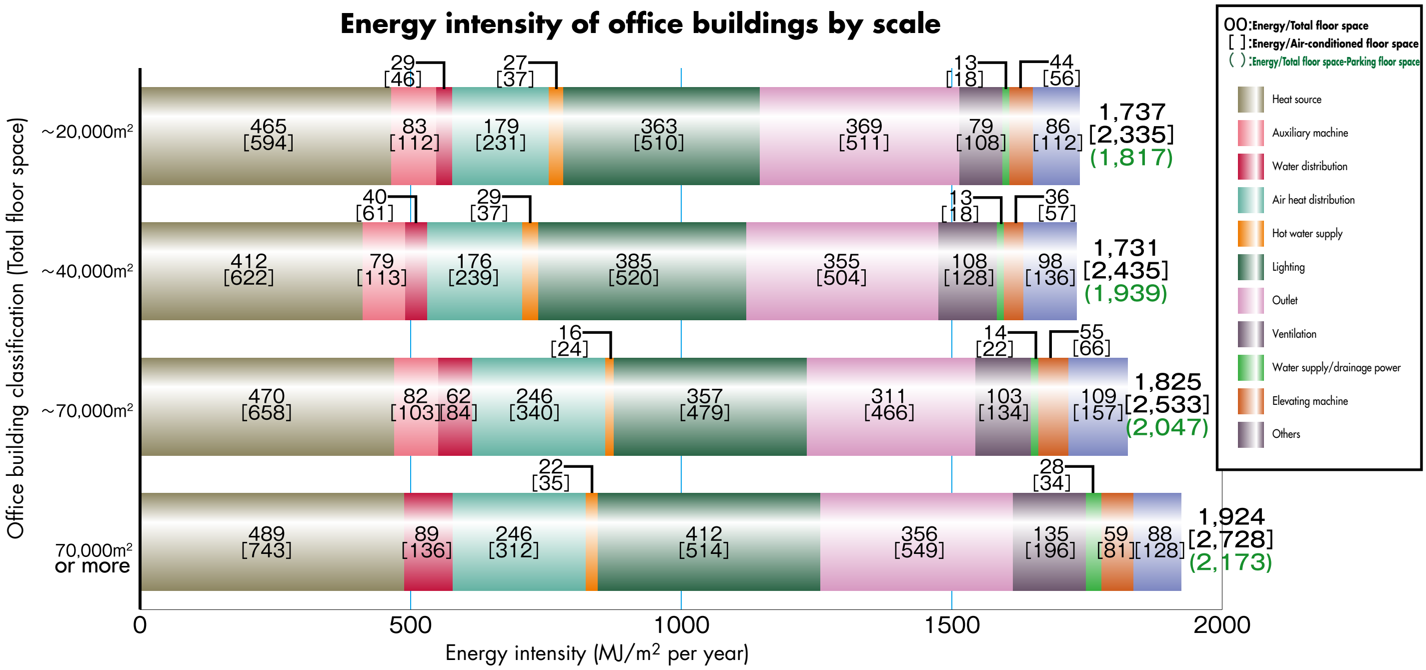
* Mid-value means the value placed in the middle when the data is aligned in descending order of value.

1.4 Energy Intensity of Office Buildings by Scale

The below graph indicates the energy intensity (mid-value of the data group) by office's scale derived by excluding the data of government offices and classified by area scale, based on our investigation data of office buildings.

As a result, it seems that larger scale means larger intensity. This may be due to water transfer power associated with the verticalization of buildings and increased energy of elevating machines.

Energy intensity of office buildings by scale

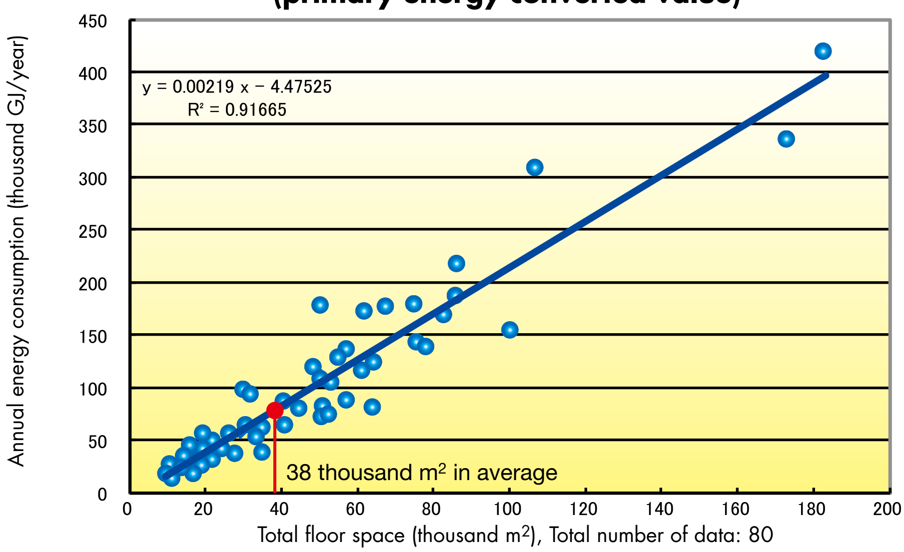


* Mid-value means the value placed in the middle when the data is aligned in descending order of value.

1.5 Correlation of Energy Consumption in Office Buildings

The below graph indicates the correlation of the total floor space and the annual gross energy consumption of the tenant building with rentable ratio of 40% or more, based on our investigation data of office buildings. It is clear from the graph that the total floor space has a high correlation with the annual gross energy consumption. Also, DHC (District Heating and Cooling) buildings have higher correlation than the heat source-owned buildings.

Correlation graph of the total floor space and energy use (primary energy converted value)



Correlation of air conditioning energy consumption with total floor space

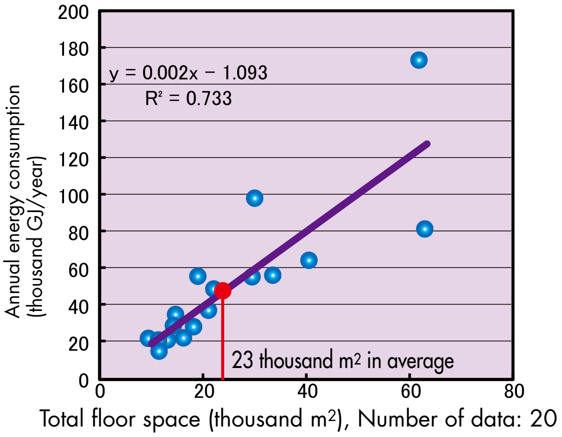
As to the relation of air conditioning energy and the scale (total floor space), “heat source (chiller/auxiliary machine) + heat distribution energy (pump/fan)” has higher correlation than the heat source energy consumption. Thus, when managing the intensity of air conditioning, the key is to manage “heat source + heat distribution energy”.

Correlation of lighting/outlet energy consumption with total floor space

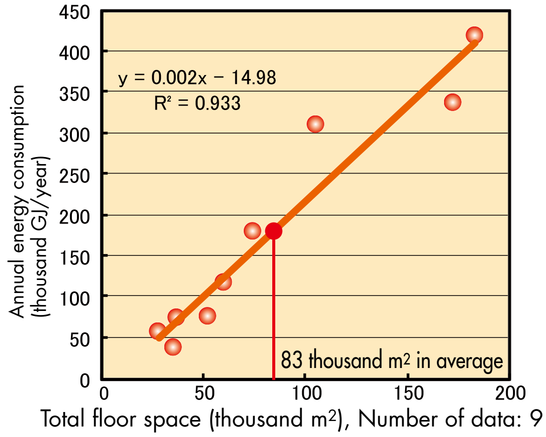
In general, lighting and outlet are measured together by a wattmeter (for accounting purpose, etc.) in office buildings. As shown in the graph, correlation is higher when the lighting energy is separated, compared to the bulk data. This may be due to the difference in the scale between the lighting and the outlet load, since the later depends on the installation condition of the OA equipments in offices, etc. Thus, from the view point of energy management, we consider that lighting and outlet should be measured by individual wattmeters.

With rentable ratio of 60% or more

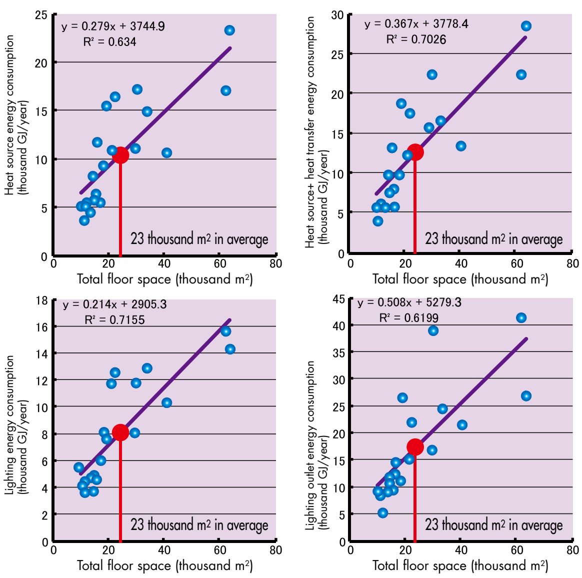
Heat source-owned building



DHC

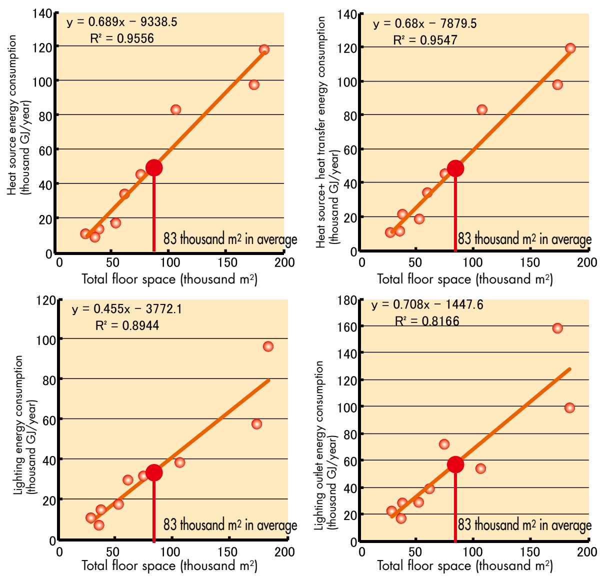


Heat source-owned building



As to the correlation with the total floor space, “heat source + heat transfer energy” has higher correlation than the “heat source energy” .

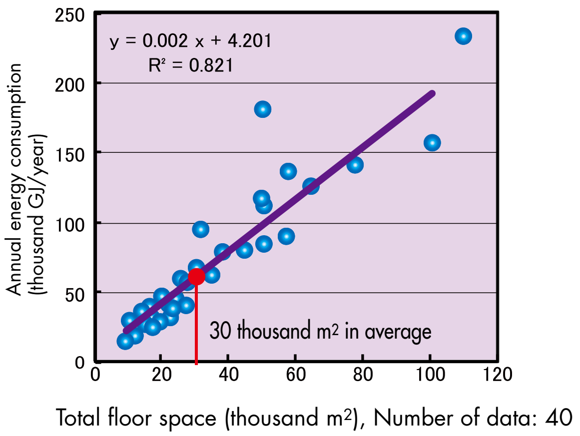
DHC



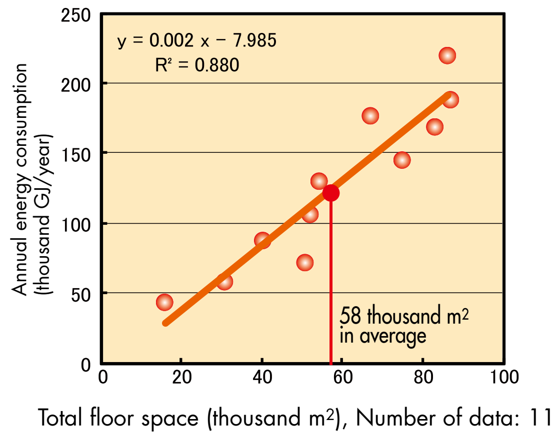
Both usages have high correlation with the total floor space.

With rentable ratio of 40% or more and below 60%

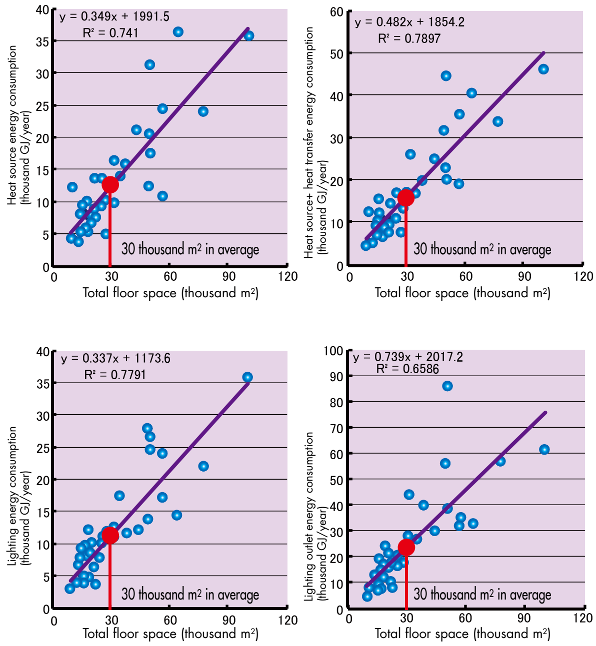
Heat source-owned building



DHC

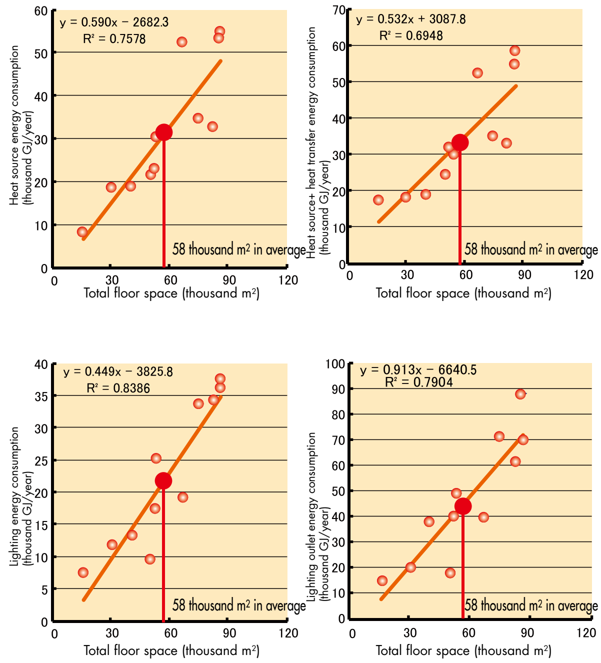


Heat source-owned building



"Heat source + heat transfer energy" and "lighting energy" have high correlation with the total floor space.

DHC

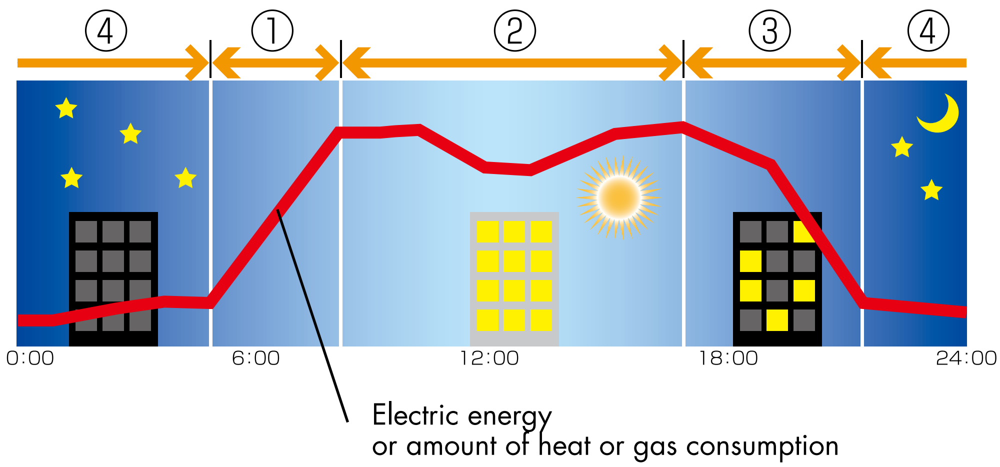


The correlation is lower than the DHC buildings with rentable ratio of 60% or more. This may be due to the usages of shops (other than offices) and IT related businesses which affect the amount of energy consumption.

2.Major Points for Energy Conservation in Office Buildings

As to office buildings, several points for energy conservation can be extracted from the trends in energy consumption according to time zone.

Though keeping track of energy by electricity, fuel, or the combination of these two, or by consumption structure classification is the best way, information analysis can also be realized only with the total amount of electricity. The following describes the major points for energy conservation based on the energy consumption characteristics of the four time zones.



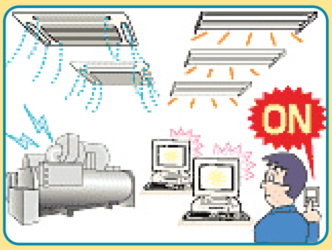
Classification of time zone

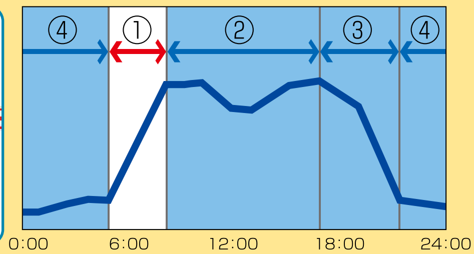
①Time before the start of business
②Operation time
③Overtime
④Non-used time (nighttime/holidays)

Time before the start of business

Since this is the time zone for starting businesses, a large amount of energy is consumed for air conditioning warm-ups. Energy consumption of this time zone reaches the maximum in the winter. Also, as employers arrive at the office to be in time for the start of business, lighting/outlet load increases sharply during this time zone.

Energy consumption characteristics of this time zone



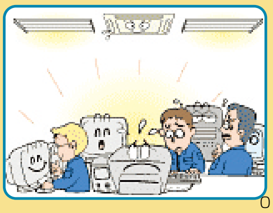


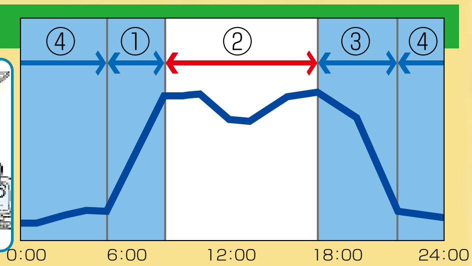
No.	Major energy conservation measures for this time zone
1	When the trend of the intermediate season with low heat load is similar to those of summer and winter, operation starting time of the air conditioning should be delayed.
2	At operation starting time of the air conditioning for cooling/heating, outside air intake should be stopped to reduce loads.
3	The blinds on the east side of the building should be closed at the end of the business hours to reduce solar load in the next morning.
4	Night-purge should be used before dawn of the cooling season to eliminate the heats storaged in the building frame, room loads during night time, and solar radiant load during holidays, in order to alleviate air conditioning load.
5	Install a through-flow boiler, etc.which requires less warm-up time, and delay the operation starting time for heating.

Operation time

Energy consumption characteristics of this time zone

This is the time zone in which the energy consumption is the highest in a day. The peak demand is recorded in the summer. Thus, users' actions for energy conservation greatly affect the amount of consumption. Also, due to the difference in the air conditioning load according to seasons, management of the facility's operation efficiency is the essential point for energy conservation.



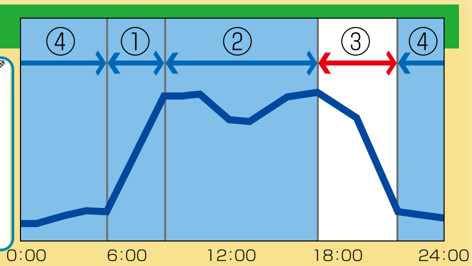


No.	Major energy conservation measures for this time zone
1	Employees should be lightly dressed in the summertime, and the indoor temperature should be adjusted appropriately. (By referring to the temperature setting recommended by the government.)
2	Lightings in offices should be turned off while the users are taking a lunch break.
3	According to the difference in the load by seasons, operation management to enhance overall energy efficiency of the equipments including air conditioning/heat source equipments and auxiliary machines should be conducted.
4	Management of CO_2 concentration and adjustment of minimum outside air intake should be carried out, and outside air intake controls including CO_2 sensor etc. should be employed at the time of the retrofit.
5	High-efficiency heat source equipment, variable air volume system, and variable water volume system should be installed at the time of the retrofit. It should be installed by dividing the number of units for the optimum capacity to enable efficient operation.

Over time

Energy consumption characteristics of this time zone

Energy consumption decreases gradually compared to the time zone before the start of business.Limited partitions and management of the facility's operation efficiency is the essential points for energy conservation during this time zone, since air conditioning/lighting/outlet load is partial during the overtime.

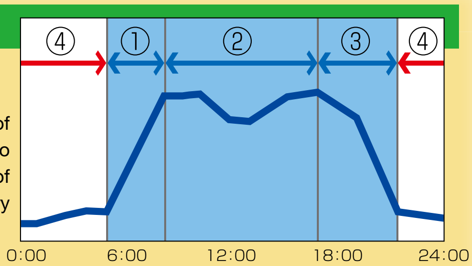


No.	Major energy conservation measures for this time zone
1	Lightings in the office should only be turned on in a zone where employees stay working, and the partitions should be limited.
2	Lightings in the common area should be turned on partially.
3	Heat source equipment operation should be turned off before end of office hours to use the heat inside the equipment in an effective way. (Only the pump should be operated to fully use the heat inside the heat source equipment and the piping.)
4	Effective operation should be carried out by selecting equipments which can operate in limited partitions, etc. (When the air conditioning and the heat pump are installed in the same zone.)
5	Switch the power of the hot water supplier and warm-water cleaning toilets in floors without any employer left to night mode.

Non-used time (night time/holidays)

Energy consumption characteristics of this time zone

Since this time zone does not include working hours, general air conditioning and most of the lightings are turned off, resulting in an extremely low energy consumption compared to daytime. However, as it is referred to as a "base load", amount of energy consumption of this time zone is consumed 24hours /7days. Thus, energy conservation will be very effective during this time zone.



No.	Major energy conservation measures for this time zone
1	Confirm whether lightings and ventilation are necessary by making a tour of inspection at midnight to eliminate waste.
2	Consolidate the load of electrical transformers, and reduce the number of operating transformers to cut down iron loss (no-load loss).
3	Reduce the number of elevators in operation.
4	Turn off the vending machines at night time by timer control.
5	Renew transformers to high-efficiency top runner transformers to minimize loss.

3.Check Points for Energy Conservation Measures in Office Buildings

1 Energy conservation measures by users

Energy conservation measures by users are carried out by the users and correspond to users' efforts as well as elimination of waste including "appropriate adjustment of room temperatures", "lights-off during lunch break", etc. These actions to minimize load are the first step towards energy conservation measures.

Classification	Major energy conservation measures	Result
Management	Maintain organizations for promoting energy conservation.	◎
Air conditioning	Adjust the indoor temperature appropriately. (Refer to the temperature setting recommended by the government.) Case example 1	◎
	Use outside air cooling in the intermediate season and winter. Case example 2	○
Hot water supply	Stop the hot water supply during the seasons other than winter.	◎
	Stop the circulation pump during the time zone with less usage.	○
Lighting/ electricity	Turn off the lights in unused rooms.	◎
	Turn off the lights during lunch break.	◎
	Turn off the vending machines at night time.	◎
Architecture	Manage the blinds of the east side of the building to reduce cooling load in the morning.	○
Elevating machine	Adjust the number of elevators in operation on Saturdays, holidays, and night time.	◎

2 Energy conservation measures by operations

Energy conservation measures by operation are to operate the current facility efficiently, and to rationalize the use of energy, such as "tuning of equipment/system". The measures are the basic of the energy management in which energy conservation is promoted without imposing a burden to users.

Classification	Major energy conservation measures	Result
Air conditioning/hot water supply	Adjust the air ratio of the boiler and combustion equipment.	○
	Maintain adequate boiler blowdown and water quality.	○
Air conditioning	Manage the setting of the chiller's outlet temperature and the efficiency of the combination of the auxiliary machine and distribution power. Case example 3	○
	Adjust the number of the distribution pumps, according to the cooling/heating load.	◎
	Manage the cooling water temperature for the chillers to enhance efficiency of them. Case example 4	◎
	Manage CO_2 concentration level to enable minimum ouside air intake. Case example 5	◎
	Stop outside air intake at the time of starting cooling/heating. Case example 6 Case example 7	○
	Turn off the heat source equipment before the end of operation time to use the heat inside the equipment and the piping effectively.	○
	Conduct bypass operation of the total heat exchanger while the outside air cooling is available.	◎
	Shorten the warm-up time of the air conditioning. Case example 8	◎
Lighting/ electricity	Manage the load ratio of the transformers and adjust the balance of them correlation.	○
	Review the temperature setting of the electric room to rduce cooling load and ventilation power.	○

3 Energy conservation measures by investments which are collectable in a short term

In general, energy conservation measures by investments which are collectable in a short term mean measures in which investments can be collected in three to five years by cost reduction due to the result of energy conservation. Even though the measures are the same, a payback year is different from the operation type of the building. Generally, a payback year is shorter when the efficiency of the current facility is poor, or with measures including inverterization of the pumps/fans whose operation times are long.

Classification	Major energy conservation measures	Result
Air conditioning	Install an inverter to the blower to adjust wind volume.	◎
	Install an inverter to the pump to realize operation according to the pressure and flow volume.	◎
	Exchange the filling material of the cooling tower depending on the clogging status.	○
Air conditioning/ hot water supply	Enhance thermal insulation of the steam valve, piping, etc.	◎
Ventilation	Install sensors to the ventilation equipment of the parking area to control start-stop and wind volume. Case example 10	○
Water supply/hot water supply	Employ water-saving top and equipment.	○
	Install imitation sound generation devices to ladies restrooms.	○
Lighting/ electricity	Subdivide the lighting circuits put it together the operations	○
	Exchange the stabilizer of the existing lighting fixtures to an inverter type.	◎

4 Energy conservation measures by retrofits

Energy conservation measures by retrofits are to introduce high-efficient equipments and systems at the time of a large-scale renovation work owing to the aging of facilities. Major measures are mentioned in the creation guideline for mid-and-long term plan in the Act on the Rational Use of Energy (Energy Conservation Act) as the subject to be discussed.

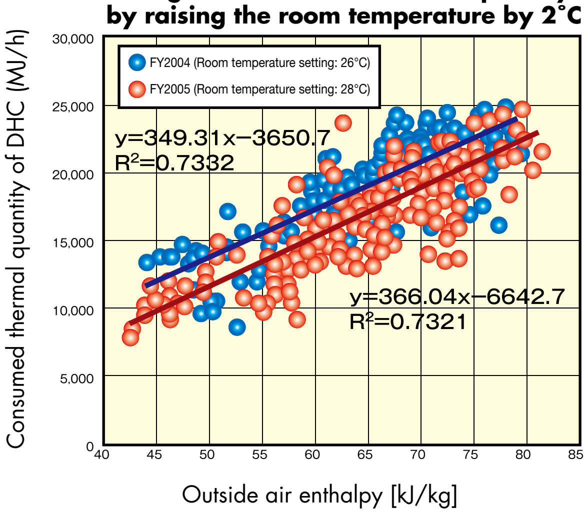
Classification	Major energy conservation measures	Result
Air conditioning	Enhance the efficiency at the time of partial load by appropriate adjustment of the heat source capacity and the number of units.	◎
	Introduce variable air volume system and variable water volume system. (VAV, VWV)	◎
	Employ CO_2 sensor system for outside air intake.	◎
	Employ total heat exchanger.	○
	Employ free-cooling for the cool demand during the intermediate and winter season.	○
	Introduce BEMS to enhance overall efficiency of the air conditioning equipments.	○
hot water supply	Consider introducing a local type hot water supply.	○
Lighting/ electricity	Renew to high-efficiency lighting fixtures.	◎
	Employ high-efficiency transformers and equalize the loads.	◎
	Renew condenser/reactor to low-loss type.	○

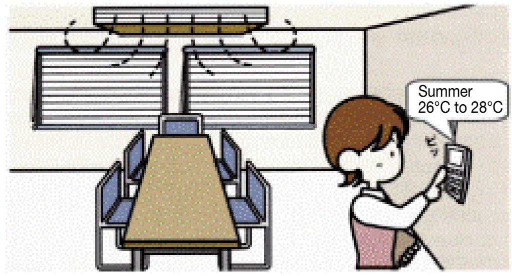
4.Successful Cases of Energy Conservation Measures in Office Buildings

Case example 1 Set the indoor temperature setting to energy conservation mode. (Summer: 28°C, Winter: 20°C)

By changing the room temperature setting for coolingfrom 26°C to 28°C, chilled water thermal quantity of the DHC reduced approximately 11%.

Changes in consumed thermal quantity by raising the room temperature by 2°C

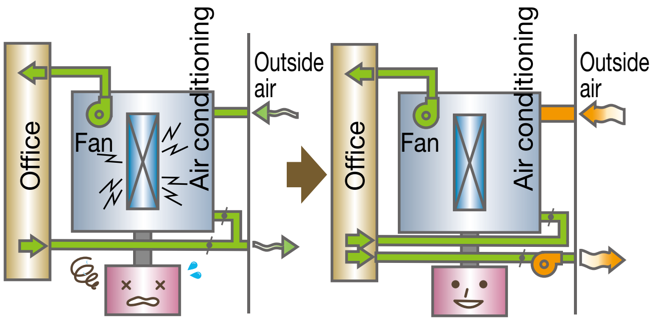


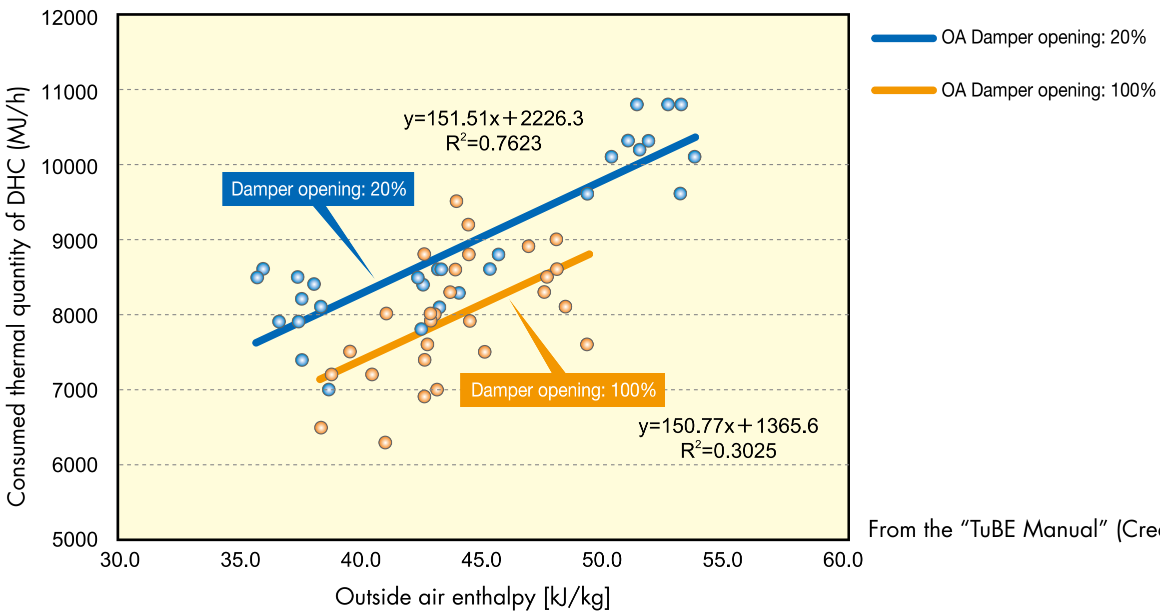


From the "TuBE Guidebook" (Created in March, 2006)

Case example 2 Outside air cooling

Use natural cooling by outside air during the intermediate season. When the outside air damper is broadened from 20% to 100% while employing outside air cooling, consumed thermal quantity of the DHC resulted in 10% energy conservation.



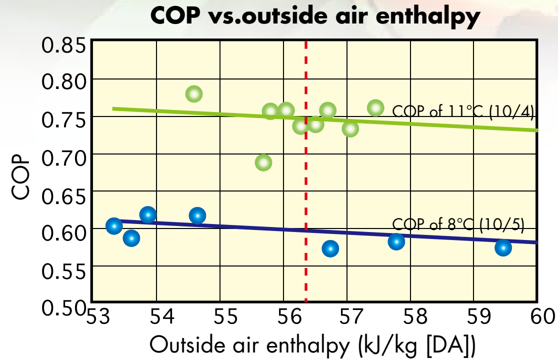


From the "TuBE Manual" (Created in March, 2006)

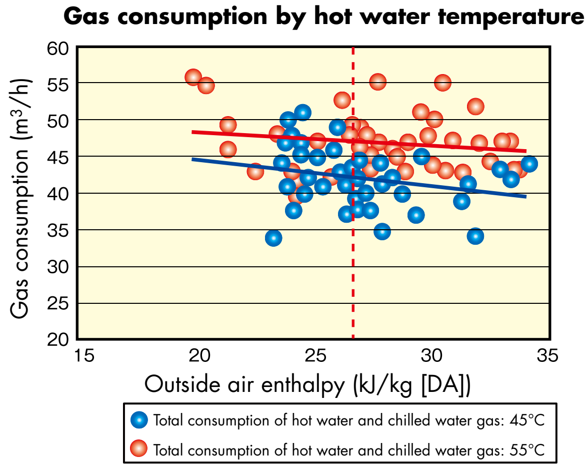
Case example 3

Setting change of the chilled/hot water outlet temperature

When the chilled water outlet temperature is changed from 8°C to 11°C during the intermediate season, COP of the chilled/hot water generator enhanced from 0.60 to 0.75, and resulted in 20% energy conservation.



When the hot water outlet temperature is changed from 55°C to 45°C during early winter, the average gas consumption of the chilled/hot water generator decreased from 47.0 to 42.5 m³/h, and resulted in 10% energy conservation.



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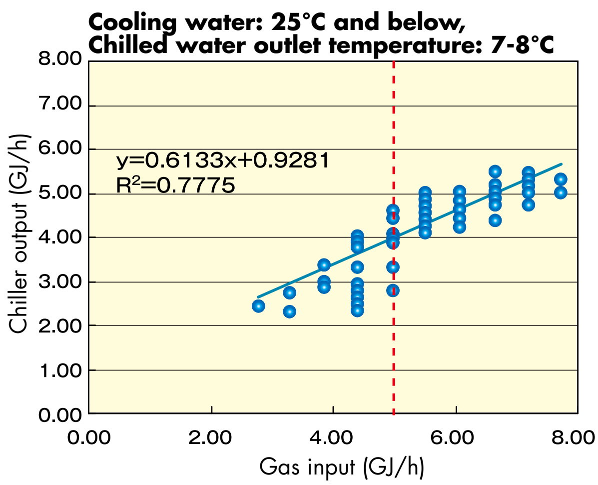
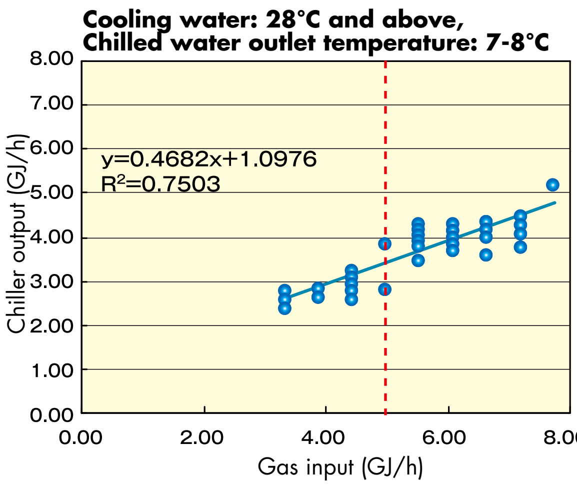
Case example 4

Setting change of the cooling water temperature

When the cooling water inlet temperature is changed from 28°C to 25°C during the intermediate season, the cooling water temperature of the chilled/hot water generator dropped about 3°C, and resulted in enhanced output by 16%





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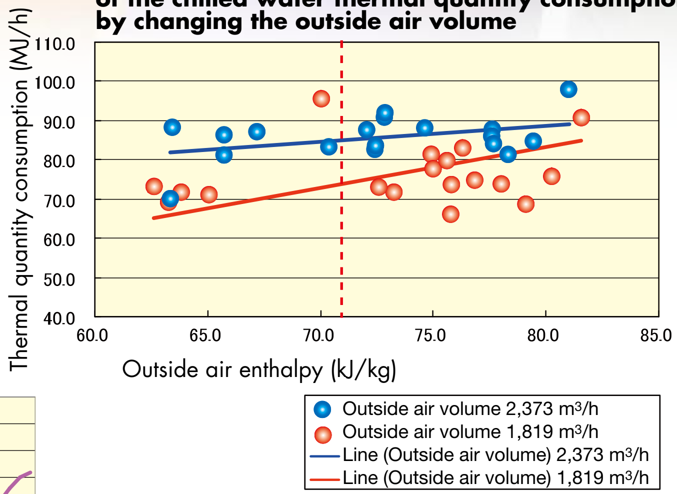
Case example 5

Reduction of outside air volume

By reducing the outside air volume by 23%, from 2,373 m³/h to 1,819 m³/h, chilled water thermal quantity reduced approximately 12% to 10 MJ/h. However, it should be adjusted to be below 1,000 ppm by monitoring CO_2 concentration.

Comparison of the outside air enthalpy of the chilled water thermal quantity consumption by changing the outside air volume



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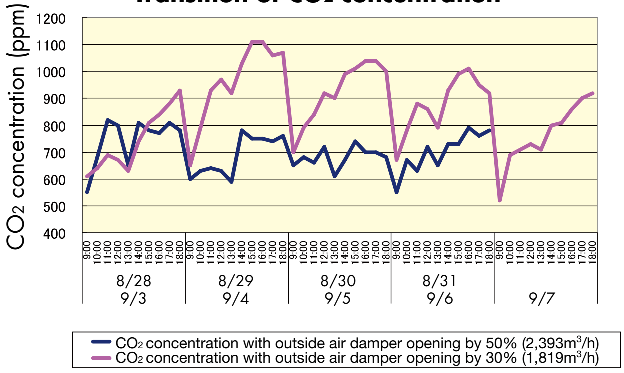
Transition of CO_2 concentration



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Convert the verification results to below 1,000 ppm.
Increase outsideair volume to 2,130 m³/h;
(1100 - 400)/(1000 - 400) = 1.17 times.
Chilled water thermal quantity will be reduced by 8.5 MJ/h; (10 MJ/h)/1.17 = 8.5 MJ/h.
Thus, when the outside air enthalpy is 72 kJ/kg, chilled water thermal quantity reduced by 10%.

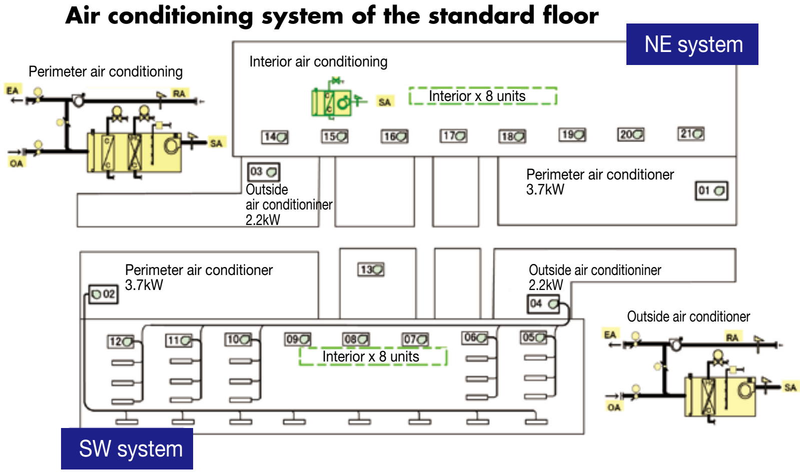
Case example 6

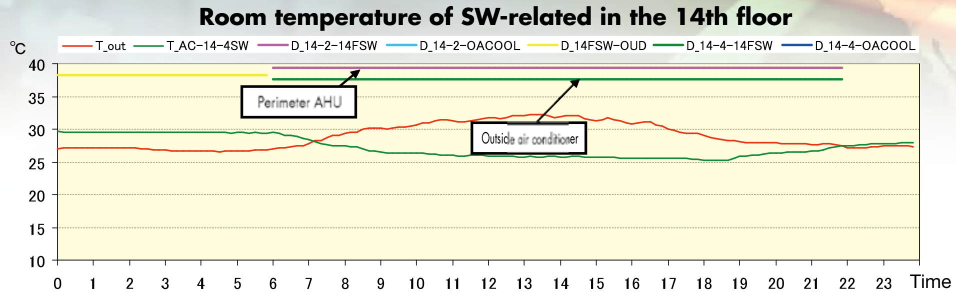
Cutback on outside air load by changing the start order of the air conditionings (cooling)

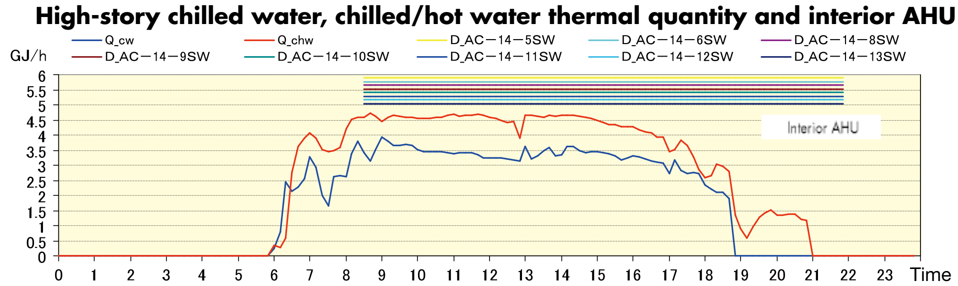
Reduction on outside air load of the outside air conditioner on activation (From June to September)

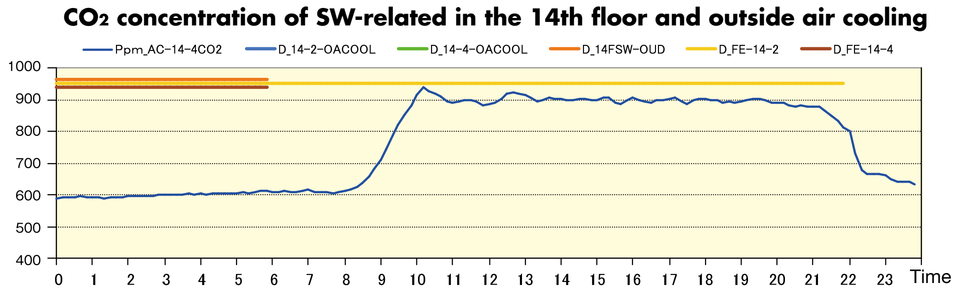
CO^2 concentration starts to rise from about 8:30; when employees begin to arrive, and reaches the setting value of 900 ppm in about 10:00 which is after hour and a half. Thus, until 8:30, outside air conditioner and perimeter air conditioner can be operated with outside air blocked.
Operate the interior air conditioner (for cooling only) which requires less consume power and no outside air intake and the perimeter air conditioner firstly, and then start the outside air conditioner at 8:30 to reduce outside air load.
Reduced thermal quantity by blocking outside air during activation (From June to September): 185 GJ
3.2% reduction compared to the chilled water load from June to September, 5786 GJ (Outside air cooling is used in May and October)

Air conditioning system of the standard floor







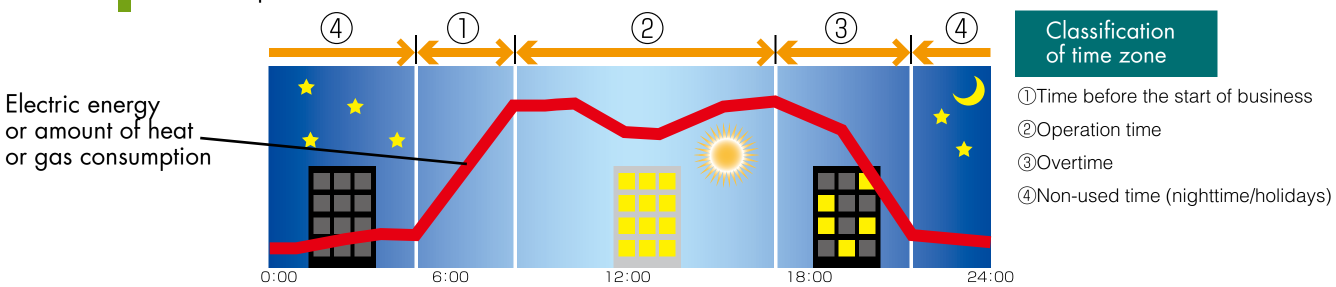


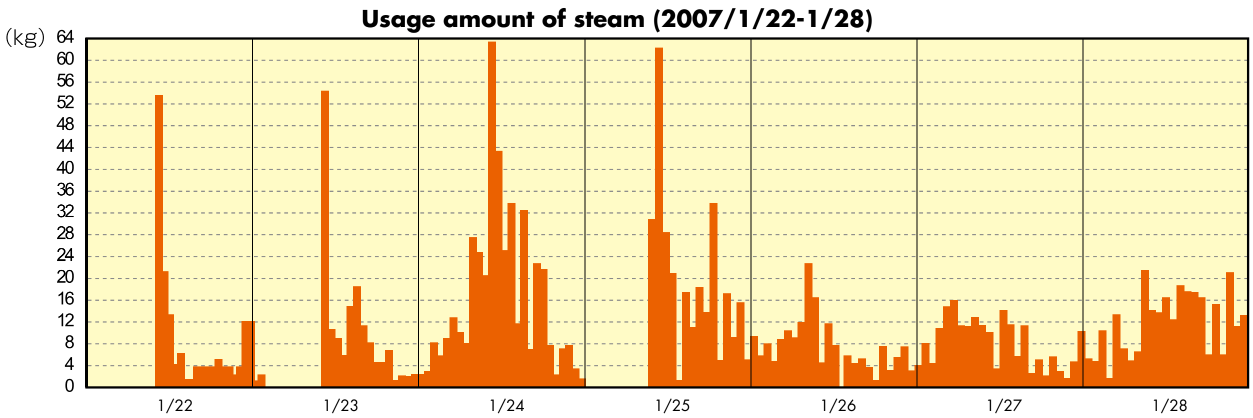
Case example 7

Stop outside air intake on warm-up and cool-down periods

The graph below shows an example of the trend in thermal quantity for heating in a building without warm-up control. It is clear that the load gets especially high during an hour required for warm-up the air conditioning.

Energy conservation can be enhanced by blocking the outside air-intake during warm-up and cool-down periods.





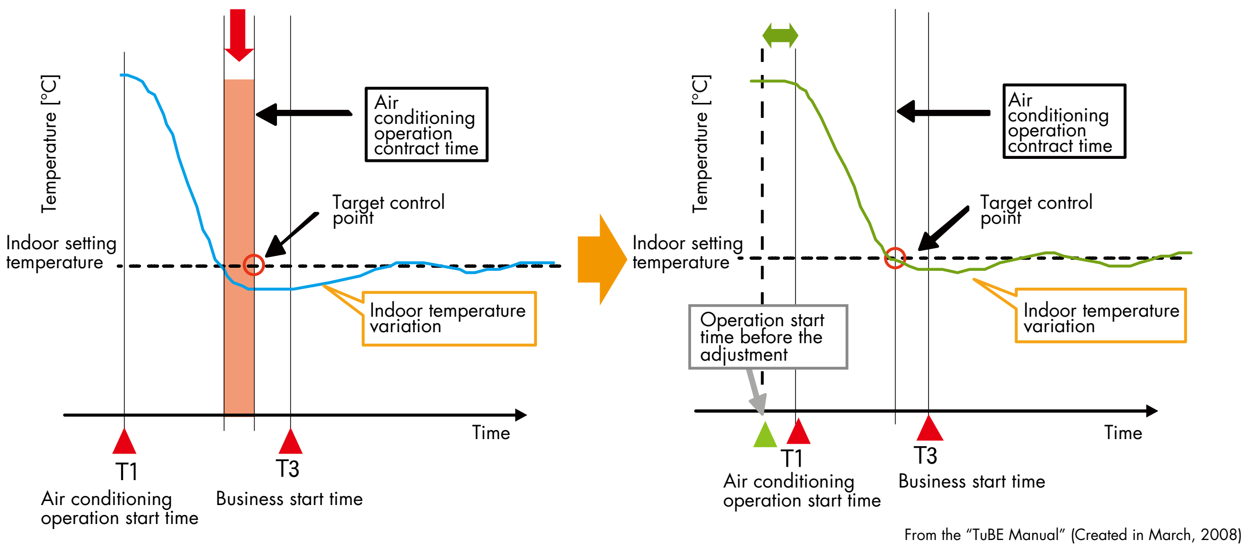
From the "TuBE Manual" (Created in March, 2008)

Case example 8

Improvement of air conditioning activation time (Cut-down on warm-up time)

The time reach to the appropriate temperature (setting or control temrature), varies the season, peak time, light-load season, and the chilled/hot water temperature. It leads to enhanced energy conservation by adjusting the air conditioning activation (operation) time according to the air conditioning load status.

Temperature change during air conditioning activation (Cooling operation)



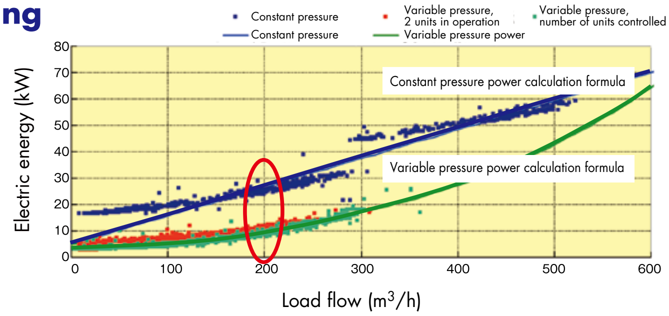
From the "TuBE Manual" (Created in March, 2008)

Case example 9

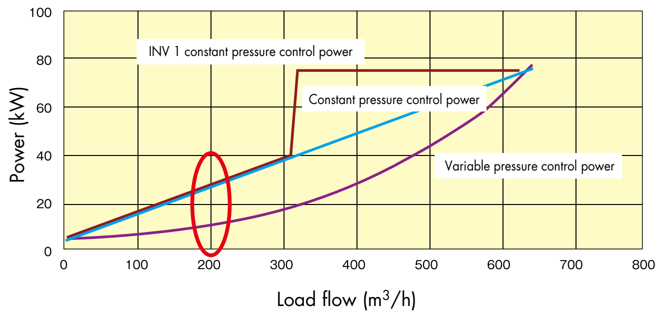
Power reduction by leveraging the difference in secondary pump control method

The annual consumption power of the variable pressure control was 50% of that of the constant pressure control, resulting in enhanced energy conservation.
The reason is because of decreased water flow, the piping resistance decreases as well.
This is effective if operation hours with load ratio about 50% is frequently.

Flow volume/ electric energy



Relation between load flow/power



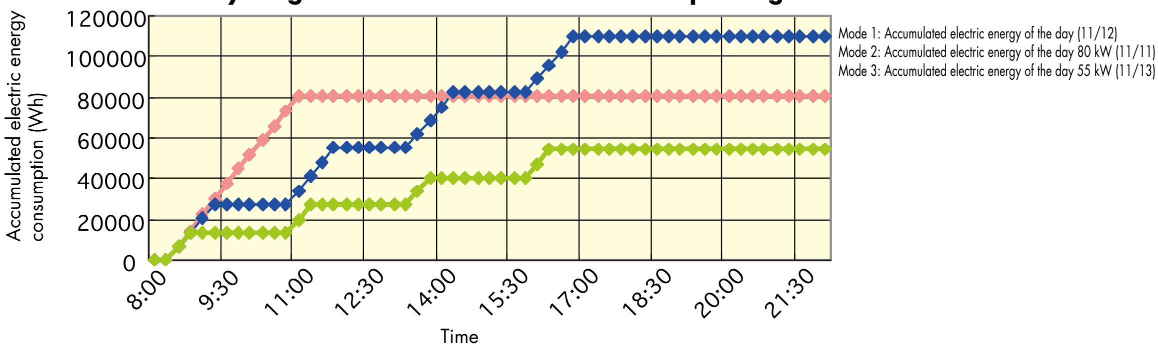
From the "TuBE Manual" (Created in March, 2008)

Case example **10**

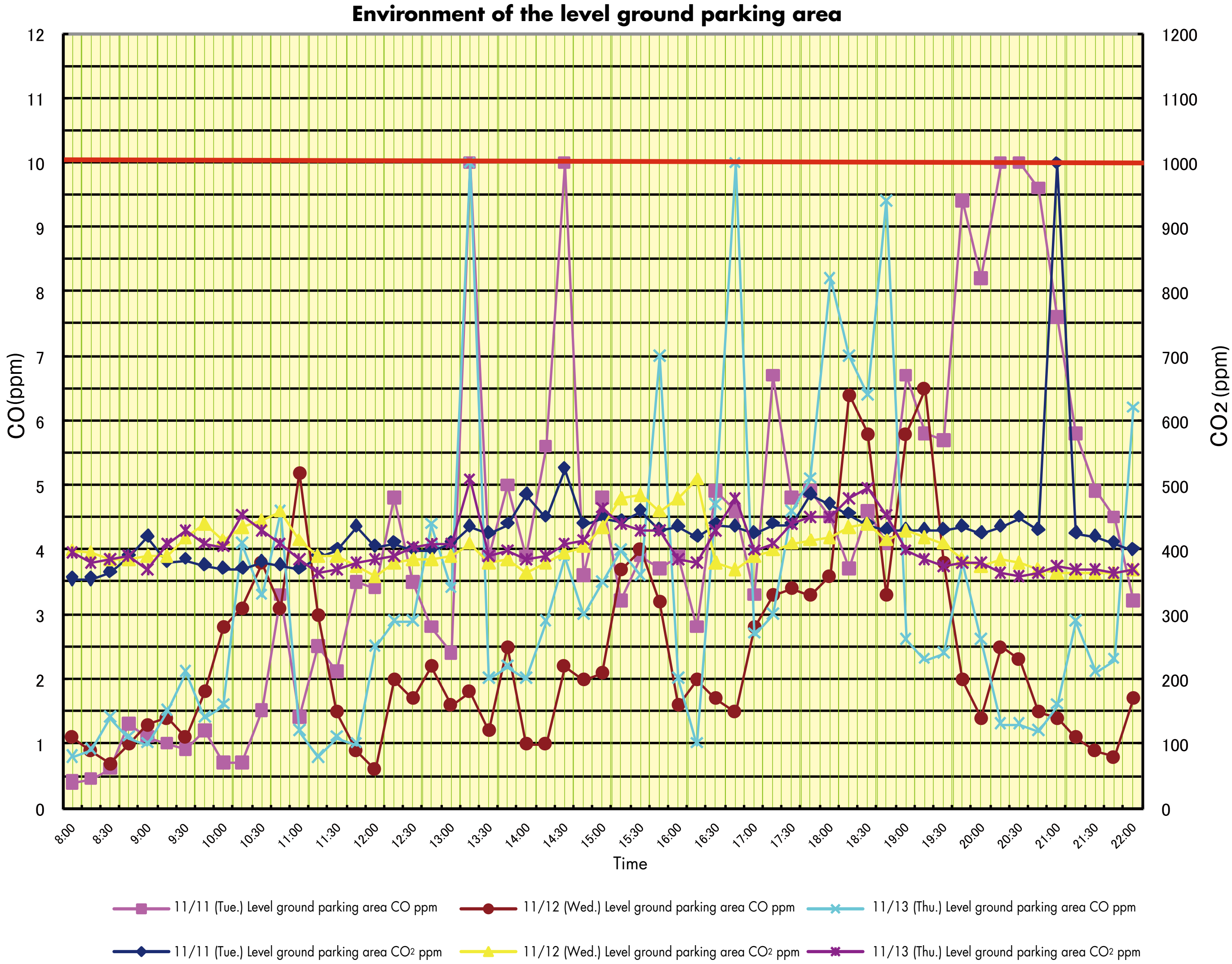
Intermittent operation of the ventilation fan in the parking area

As to the three patterns provided as the intermittent operation schedule of the ventilation fan in the parking area, accumulated electric energy of each pattern is measured.
As a result, by the difference in intermittent operation methods, mode 3 shown in the below figure had 50% difference in electric energy consumption, compared to mode 1. Indoor CO and CO_2 concentration maintain the environmental standard.

Electricity diagram of the ventilation fan in the parking area



Environment of the level ground parking area



From the "TuBE Guidebook" (Created in March, 2006)

5.Effective Tools and Techniques for Promoting Energy Conservation by Improved Operation

ECCJ provides tools and techniques for further energy conservation useful for improving operations of large-scale buildings for business use without charge.
The three tools and techniques are:

(1)ESUM : Energy Specific Unit Management Tool

ESUM is computer software which estimates energy consumptions of a building and compares the consumptions before and after implementing an energy conservation measure to demonstrate the energy reduction effect.

(2)TuBE :Tuning of Building Systems for Energy Conservation

TuBE is a document which defines how to select and carry out operational improvement actions among various energy conservation measures.

(3)EAST : Energy Analysis Support Tool

EAST is computer software which compiles operation process data of air-conditioning units and heat source equipment and make a graphic presentation of the trends to help you analyze their operation conditions.

Combined use of the above three tools helps your making smoother energy conservation activities throughout the necessary steps for the activities; analysis on operation status and conditions, selection of improvement method, estimation of its effectiveness, and implementation of the measure.

How to obtain more detailed information on energy conservation of buildings for business use

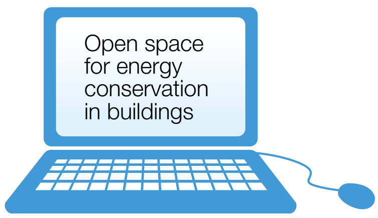
ECCJ has a website to provide various kind of information on energy conservation of buildings.

The site includes:

- inputs from actual users of tools (e.g. ESUM and EAST) useful for enhancing your energy conservation activities for buildings;
- various forums for different types of facilities (e.g. office buildings, commercial facilities, hotels, and hospitals), which serve as an information exchange forum among members; and
- invitations to seminars and lecture classes which provides information on successful cases of improved energy conservation of buildings for business use and examples of effective use of various tools as well as materials for those seminars and lectures

URL **http://eccj06.eccj.or.jp/bldg/index.php**

Owners of buildings for business use
Persons in charge of energy conservation promotion
Persons in charge of energy facility management
Energy conservation business operators



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This is translated from the original Japanese document.
For precise information and nuances, please refer to the original.

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