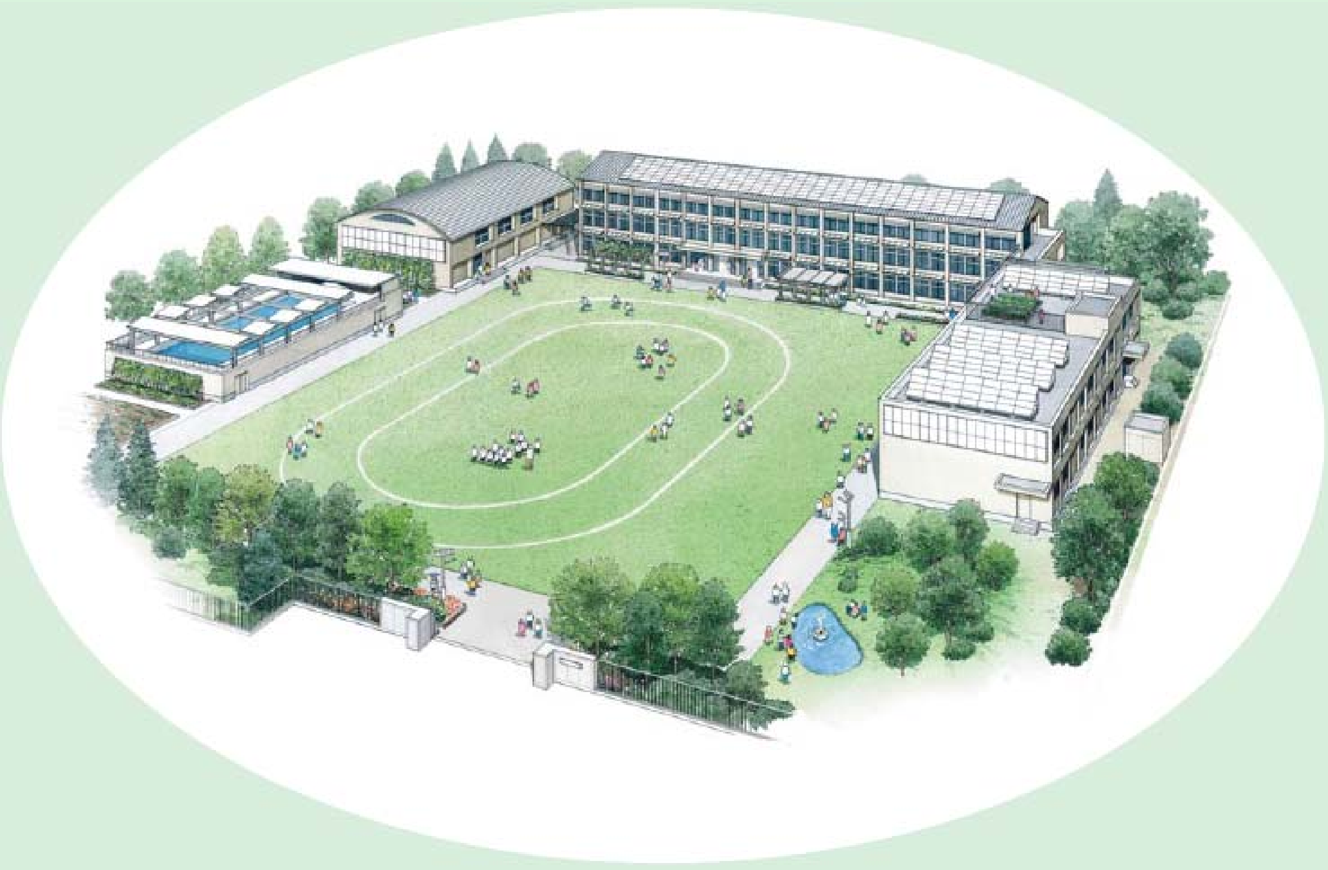
Promoting Environment-focused Renovations of School Buildings

Results of a Simulation of Environmental Measures in Model Plans (National)

Report on a Fundamental Study of School Facility Environments



Working Group on a Fundamental Study of School Facility Environments
Educational Facilities Research Center
National Institute for Educational Policy Research—Japan

*This report is available at the following URL:
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Contents

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1. General

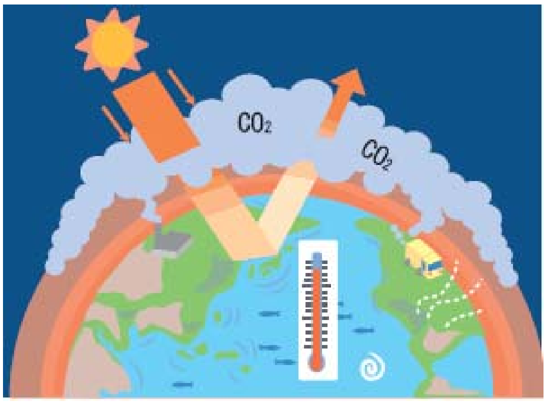
(1) Introduction

Hitherto, the renovation of school buildings has involved work such as earthquake resistance reinforcement work, replacement of dilapidated equipment and aging parts of the interior and exterior, and alterations to the room layout to adapt to new uses. By adding measures to these, such as insulating the building, shading it from sunlight and upgrading equipment to energy-conserving models, it is possible to improve the thermal environment of classrooms, as well as to conserve energy.
Accordingly, the National Institute for Educational Policy Research carried out the Fundamental Study of School Facility Environments (Project Leader: Hiromi Komine, Professor, Department of Architecture and Civil Engineering, Chiba Institute of Technology), by evaluating and considering the contents, effects, and initial costs regarding the environment-focused renovations of existing school buildings in the six regions nationwide, and then formulated the model plans for each region.

(2) Situations Requiring the Environment-focused Renovations

Climate Change in Japan

The average temperature in Japan has risen by about 1.1°C per 100 years since 1898. In particular, since 1990, high temperatures have been recorded frequently.
Along with the rise in temperature, the number of nights with a minimum temperature no lower than 25°C and the number of days with a maximum temperature no lower than 35°C are increasing, while the number of days with a minimum temperature no higher than 0°C is decreasing.



Changes in Annual Temperature in Japan

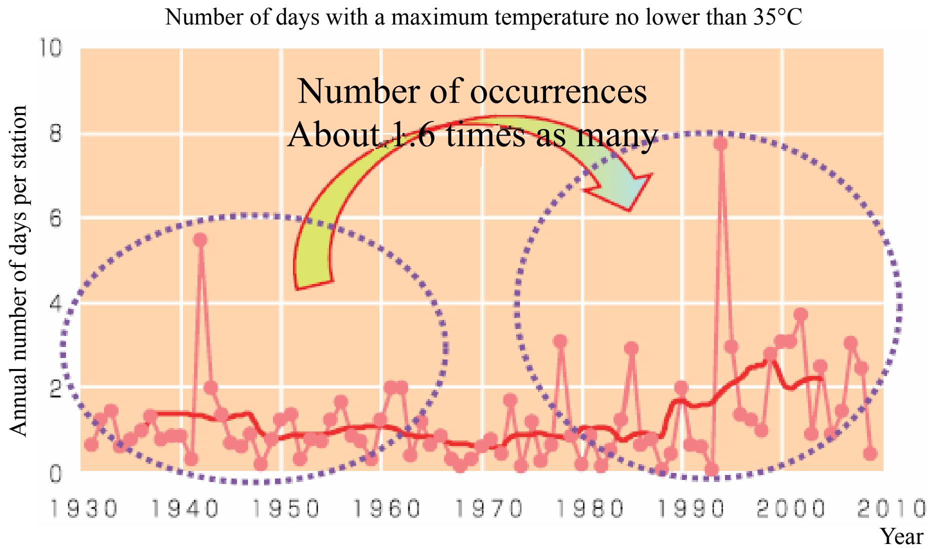
Changes in the annual temperature anomalies (from the normal 1971–2000 average) were calculated from the data in the 17 stations considered not to have been highly influenced by urbanization in terms of temperature.

(Source) *Knowledge of Global Warming* (August 2010, Japan Meteorological Agency)

Number of Days with a Maximum Temperature no less than 35°C

The annual number of days with a maximum temperature no lower than 35°C increased significantly in the 1931–2009 period, and the average number of such days in the most recent 30-year period was 1.6 times as large as the number in the 1931–1960 period.

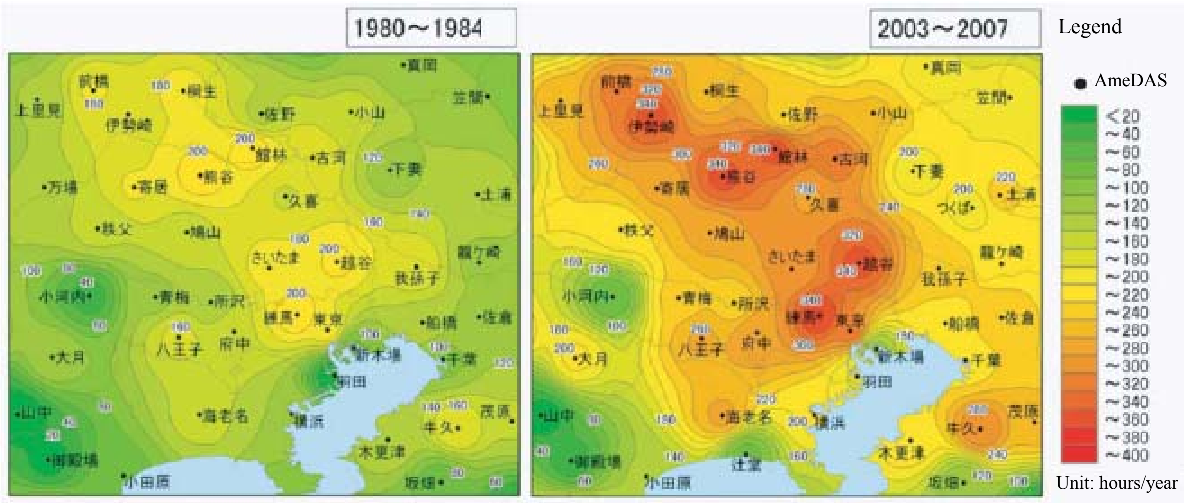
The number of such days increased in the 1980s, and has often been more than two per station since the middle of the 1990s.



Annual number of days with a maximum temperature no lower than 35°C
(The thin line indicates the value for each year, and the thick line indicates the 11-year running mean value.)
(Source) *Climate Change Monitoring Report 2009* (Japan Meteorological Agency)

Acceleration of Urban Heat Island Phenomenon

The urban heat island phenomenon, whereby the temperature at the city center is higher than that of the surrounding non-urban areas, occurred particularly often in large cities. In summer, the number of hours with temperatures above 30° C has increased.



Distribution of Cumulative Hours Exceeding 30° C in the Kanto Area (yearly average hours of five-year period)
(Source) Material from the Ministry of the Environment

The thermal environment in classrooms has worsened, accompanied by temperature rises and the heat island phenomenon.

Environment-focused renovations simultaneously resolve the issues of improvements in the thermal environment in the classroom and reducing CO_2 emissions

The results of a simulation of CO_2 emissions using model plans demonstrate that, by implementing the three main pillars described on the right in an integrated fashion, it is sufficiently possible to resolve the problems of heat and cold in classrooms, while simultaneously reducing CO_2 emissions.

(i) Improving the building performance through insulation and shading from sunlight
(ii) Introducing high-efficiency lighting, cooling and heating equipment
(iii) Enforcing appropriate running and management, such as temperature setting

(3) Basic Approaches of the Model Plans

●These model plans were formulated and targeted at dilapidated school buildings built 30 to 40 years ago, based on the premise of implementing environment-focused renovations, which add environmental measures to conventional earthquake resistance reinforcement and qualitative improvements.

Conventional large-scale renovations
- Earthquake resistance reinforcement
- Qualitative improvements & improvements to dilapidated facilities

Environment-focused renovations
- Earthquake resistance reinforcement
- Qualitative improvements & improvements to dilapidated facilities
- Environmental measures

●In CO_2 emissions simulation, the reduction rate of CO_2 emissions before and after environment-focused renovations was calculated, and only core factors were included, not the factors that vary in actual use from school to school. Note that the results of the calculations showed emissions that were different from the CO_2 emissions for the school as a whole. CO_2 emissions resulting from energy consumption at the places and times below were excluded.

Gymnasium, swimming pool, pantry, schoolyard lighting, antifreeze heater (colder regions), community open days, overtime, holiday work, standard outlet (PCs, etc.)

●The basic policy on formulating model plans is composed of the following five items.

(i) Implementing environmental measures with a strong effect of CO_2 emissions reduction, based on the characteristics of CO_2 emissions resulting from energy consumption at schools. For example, formulating renovation plans which contribute to the reduction of energy for heating in colder regions and to the reduction of electricity used for lighting in others.

(ii) Formulating renovation plans which ensure appropriate standards for the thermal environment in classrooms throughout the year.

(iii) Formulating renovation plans which consider the climate and conditions of the area where the school is located, such as measures to improve the winter thermal environment in colder regions, and the summer thermal environment in others.

(iv) Formulating renovation plans which contain improvements in building function, including building insulation and shading from sunlight, and utilization of natural energy, such as natural wind, as well as the introduction of high-efficiency equipment, such as lighting, heating and cooling equipment.

(v) Planning the feasible cost of renovation.

(4) The Region on Which the Model Plans Focus and Types of Plans

The model plans targeted at school facilities located in the major cities of Regions I to VI, specified in the Regional Classification Under the Energy Conservation Standard. The names of major cities, forms of school buildings, and assumptions of installed cooling and heating equipment are as follows.

Region I (Sapporo City)
Central corridor type school building
Both before and after renovations: only heating equipment

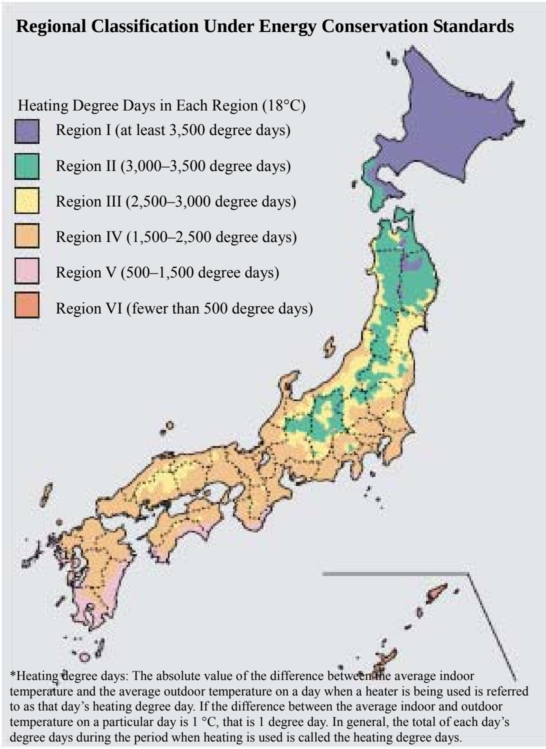
Region II (Morioka City)
Side corridor type school building
Both before and after renovations: only heating equipment

Region III (Fukushima City)
Side corridor type school building
Before renovation: only heating equipment
After renovations: (Plan A) only heating equipment
(Plan B) cooling and heating equipment

Region IV (Tokyo)
Side corridor type school building
Before renovations: only heating equipment
After renovations: (Plan A) only heating equipment
(Plan B) cooling and heating equipment

Region V (Kagoshima City)
Side corridor type school building
Before renovations: neither cooling nor heating equipment
After renovations: cooling and heating equipment

Region VI (Naha City)
Side corridor type school building
Both before and after renovations: only with cooling equipment



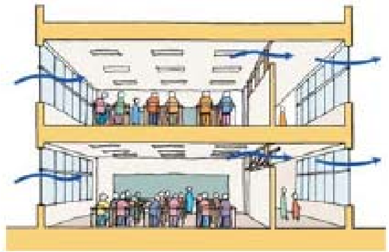
Regional Classification Under Energy Conservation Standards
(Source) Japan Center for Climate Change Actions
Website: http://www.jccca.org

2. Points Common to All Model Plans

(1) Plan Overview

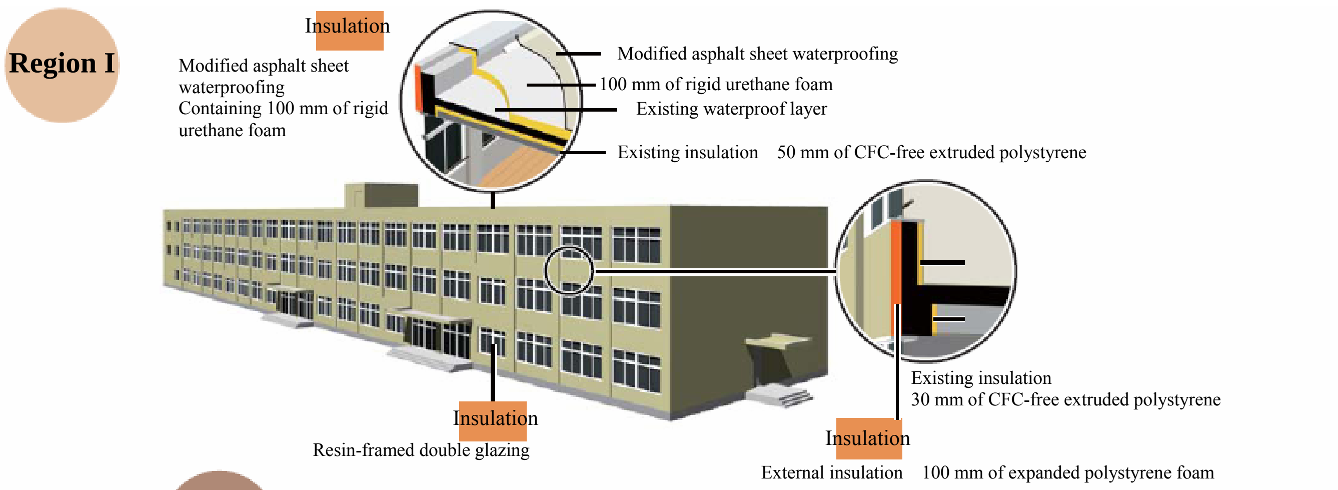
Outline of the Existing School Building Model

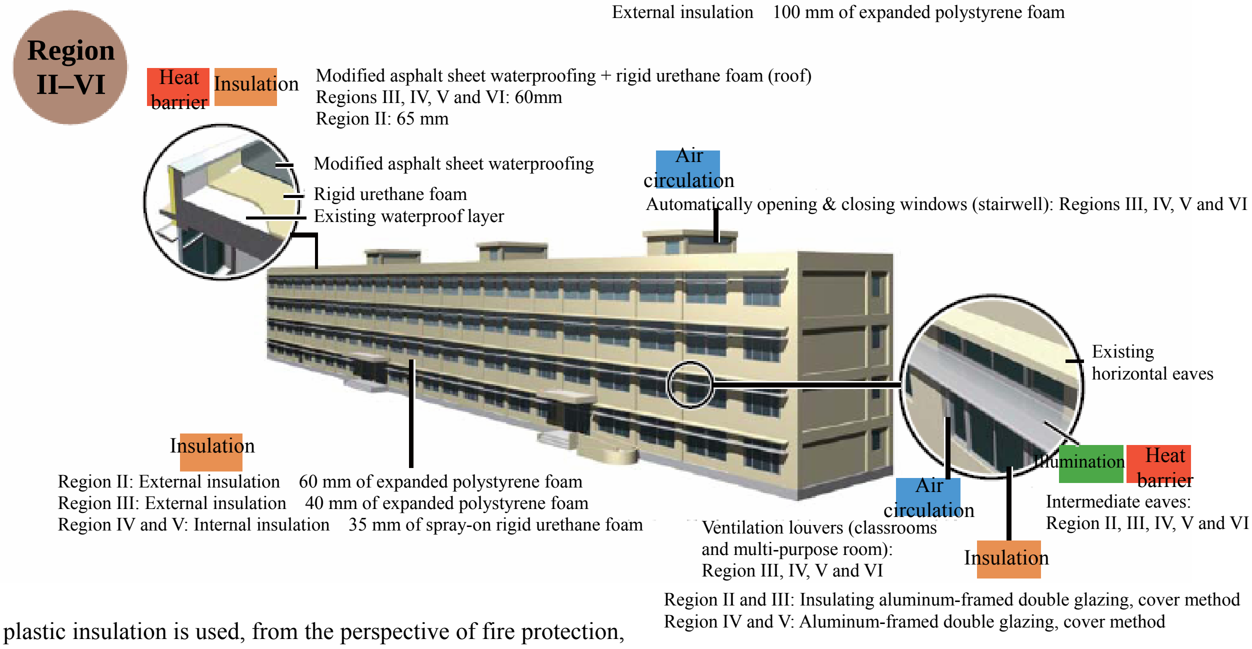
Type		Elementary School (35 years are envisaged to have passed since construction)
Structure & Number of Floors		Reinforced concrete (RC) structure with 4 stories (3 stories in Region I only)
Form of School Building		Side corridor type straight-formed school building (central corridor type only in Region I)
Total Floor Area		About 5,100 m^2
Number of Classrooms	Existing School Building	26 ordinary classrooms, special needs education class, special classrooms
	School Building After Renovation	12 ordinary classrooms, special needs education class, special classrooms, multi-purpose space (conversion of surplus classrooms)
Equipment		The heating & cooling equipment was updated 20 years after the building was constructed



Cross-section drawing of side corridor type straight-formed school building

View of the Outside of the School Building After Environment-focused Renovations





*When foamed plastic insulation is used, from the perspective of fire protection, it is important to implement the construction by i) using insulation containing flame retardant, ii) applying with adhesives, iii) making end treatment, including convoluted cell foam end, using reinforcing mesh, and iv) applying with finishing agent, etc.

● As for the content of earthquake resistance reinforcement and qualitative improvements and measures to deal with dilapidation other than environmental measures, please refer to the *Manual on Earthquake-proof Renovations Involving Qualitative Improvements to School Facilities* (December 2005, Educational Facilities Research Center, National Institute for Educational Policy Research).

(2) Evaluation Items of Simulations and Contents of Environment-focused Renovation

The model plans evaluate and examine annual CO_2 emissions at the operational phase, the thermal environment in classrooms, and initial costs regarding the environment-focused renovations.

- Improving insulation capacity
  - With the aim of reducing the cooling and heating load, insulation of the roof, external walls and windows is promoted.
- Shading from sunshine
  - Intermediate eaves are installed in order to shade direct sunlight.
- Equalization of illumination in rooms
  - Intermediate eaves are installed on the windows; these can also function as light shelves.
  - The partitions between classrooms and corridors have high windows, in order to provide natural light from the corridor.
- Utilizing natural wind
  - Automatically opening and closing windows are installed in the corridors.
  - The partitions between classrooms and corridors are partitions with high windows, which ensure ventilation from the corridor side.
  - Ventilation louvers are installed in the windows.
- High efficiency of energy
  - Cooling and heating equipment is upgraded to high-efficiency equipment.
  - Lighting in classrooms is upgraded to lighting with illumination sensors, while lighting in toilets is upgraded to lighting with sensors that detect human movement.
  - In order to conserve water, the taps are fitted with a device to create foam water, while the toilets are equipped with devices that imitate the sound of toilets being flushed, and urinals are equipped with an automatic flush.
- Appropriate temperature in rooms
  - Electric fans are installed.

(3) Main Conditions for the Simulations

- Calculations of CO_2 emissions were limited to school buildings themselves, so CO_2 emissions resulting from the use of gymnasiums, swimming pools, and schoolyard lighting were excluded.
- CO_2 emissions resulting from the running of facilities and equipment for community open days, the cooking of school meals, overtime, and holiday work were excluded.
- CO_2 emissions resulting from the running of facilities and equipment such as antifreeze heaters in colder regions were excluded.
- The heater operating periods were specified as follows. Region I: October 15 to May 15, Regions II–IV: November 1 to March 31, and Region V: December 1 to February 28. Of these periods, the winter holidays, weekends and national holidays were excluded.
- The heater operating condition was specified as the times when people are in the room in question, and when the room temperature falls below the set temperature for heating (18° C in classrooms and 23 °C in management rooms).
- The cooler operating periods were specified as follows: Regions III–V: June 1 to September 30, and Region VI: May 15 to October 15. Of these periods, the summer holidays, weekends and national holidays were excluded.
- The cooler operating condition was specified as the times when people are in the room in question, and when the room temperature rises above the set temperature for cooling (28° C).
- Corridor lighting was not used in sections where there are windows, while lighting in the toilets was assumed to be for a total of two hours per day.

(4) Points to Keep in Mind in Utilizing Model Plans

- When contemplating environment-focused renovations, it is necessary to take into consideration siting conditions and the climate in the area where the school is located and confirm the conditions based on the actual situation of the individual school.
- In order to grasp the energy consumption and CO_2 emissions of the school as a whole, it is necessary to base calculations on the actual usage situation of facilities and the operation of facilities and equipment.
- From the perspective of combining energy conservation with securing a good thermal environment, in the case of operating coolers in classrooms, it is important to consider the operating period and the temperature at which the coolers will be set.
- Solar photovoltaic power generation is presented as an option in these model plans. For example, if 10,000 kWh (corresponding to an annual electricity generation capacity of 10 kW) is covered annually using solar photovoltaic power generation in Tokyo, a reduction of approximately 4.2 t in CO_2 emissions annually is expected.
- When conducting in-depth deliberations on the effects of the renovations, there will be times when higher accuracy simulations under the input conditions based on the operating conditions of each school will be required. It is necessary to consider the costs of such simulations as separate from the design cost.

(5) CO_2 emission factors for Simulations

The following CO_2 emission factors were used for the calculation of the simulation.

- As for electricity, the actual emission factors (unit: kg-CO_2/kWh) of each electric power supplier based on the calculating, reporting and publishing system of greenhouse gas emissions pursuant to the Act on Promotion of Global Warming Countermeasures (Act No. 117 of 1998) were used.
  [Region I (Sapporo City)] Hokkaido Electric Power Co., Inc. 0.588
  [Region II (Morioka City), Region III (Fukushima City)] Tohoku Electric Power Co., Inc. 0.469
  [Region IV (Tokyo)] Tokyo Electric Power Co., Inc. 0.418
  [Region V (Kagoshima City)] Kyushu Electric Power Co., Inc. 0.374
  [Region VI (Naha City)] Okinawa Electric Power Co., Inc. 0.946

- As for kerosene and city gas, described values in the *Manual on Calculating and Reporting of Greenhouse Gas Emissions* (Ministry of the Environment) were used.
  ([All regions] Kerosene: 2.49 kg-CO_2/L, City gas: 2.08 kg-CO_2/m^3)

- As for water, described values in the *Immediate Measures against Global Warming* (October 2005, Ministry of the Environment) were used.
  ([All regions] Water: 0.58 kg-CO_2/m^3)

3. Plan Overview and Verification Results in Each Region

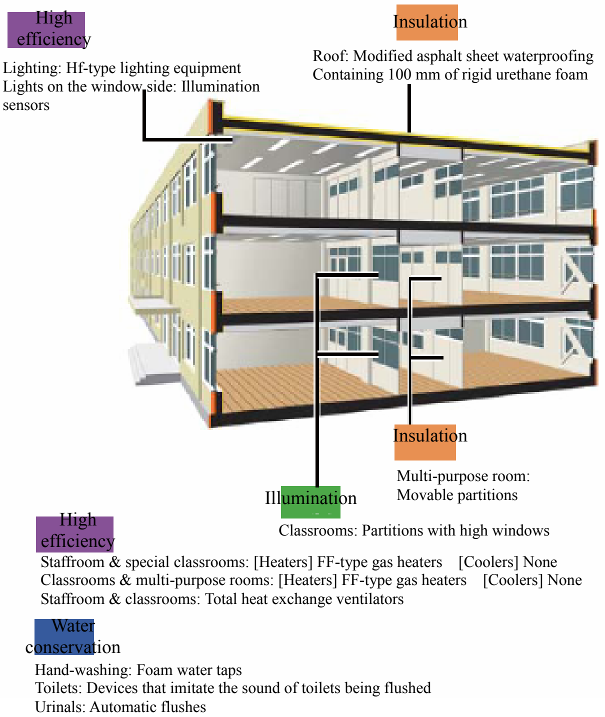
Region I

Plan Overview

<Points of highly effective environment-focused renovations>

(i) Roofs, external walls and windows are insulated.

(ii) Electric panel heaters are upgraded to FF-type gas heaters.



Total of Environment-focused Renovations

	Target area	Before renovations	Environment-focused renovation
(2) Insulation	External walls (inside the room)	Internal insulation: 30 mm (Lagging material with CFC-free extruded polystyrene)	External insulation: 100 mm (Extruded polystyrene foam)
	Windows	Double sash (External: aluminum sash, single panel; Internal: wooden sash, single panel)	Double-glazing with resin sash
	Roof	Internal insulation: 50 mm (Lagging material with CFC-free extruded polystyrene)	Modified asphalt sheet waterproofing (with 100 mm of rigid urethane foam)
	Heating zones (stairwell, foyer, etc.)	Permanently open fire doors	Installing doors that can be opened and closed
	Partitioning (between multi-purpose space and corridors)	-	Installing movable partitions
(4) Shading from sunshine	External walls	-	-
(6) Temperature adjustment	Ordinary classrooms and multi-purpose space	-	-
(8) Illumination	External walls	-	-
	Partitioning (between ordinary classrooms and corridor)	-	-
(10) Utilizing natural wind	Partitioning (between ordinary classrooms and corridor)	-	-
	Windows (ordinary classrooms, multi-purpose space)	-	-
	Windows (stairwells, corridors)	-	-
(12) Efficient use of energy & water conservation	Lighting (ordinary classrooms, multi-purpose space)	FL-type lighting equipment (40W × 16)	Hf-type lighting equipment (with illumination sensors near the windows)
	Lighting (toilets, stairs)	FL-type lighting equipment (20W × 2)	FL-type lighting equipment (with motion sensors)
	Heating and cooling facilities (management rooms)	Heating: Electric panel heaters	Heating: FF-type gas heaters Total heat exchange ventilators
	Heating and cooling facilities (special classrooms)	Heating: Electric panel heaters	Heating: FF-type gas heaters
	Heating and cooling facilities (ordinary classrooms, multi-purpose space)	Heating: Electric panel heaters	Heating: FF-type gas heaters Total heat exchange ventilators
	Sinks	Running taps	Foam water taps
	Toilets	The toilets have no devices that imitate the sound of toilets being flushed, urinals are the flush valve type	Toilets are equipped with devices imitating the sound of toilets being flushed, urinals are equipped with an automatic flush

Results of Simulations

(1) Reduction in CO_2 Emissions

● Annual CO_2 Emissions

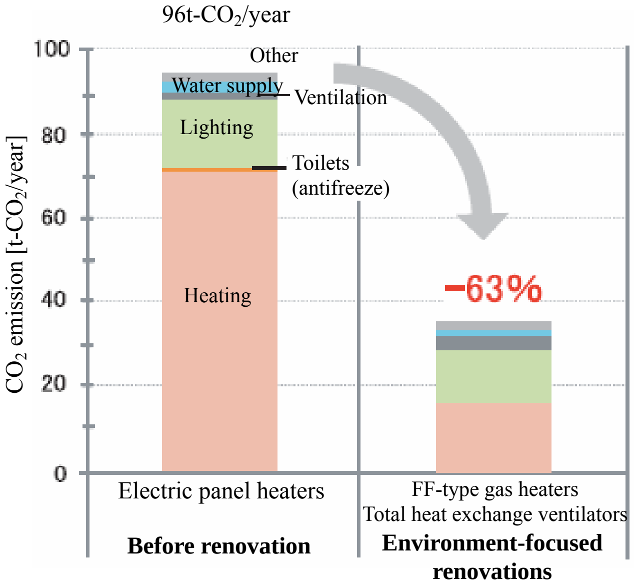
(i) Through environment-focused renovations, it is possible to reduce CO_2 emissions by approximately 63%.

(ii) In Region I, the share of energy use accounted for by heating in winter is extremely large, so it is effective to upgrade to more efficient heaters (upgrade from electric panel heaters [coefficient of performance: 0.369*] to FF-type gas heaters [coefficient of performance: 0.82*]).

* The coefficient of performance represents the energy ratio of the energy output from heating equipment to the energy input (primary energy conversion). The larger this value is, the more efficient the equipment is.

(iii) As a result of improved insulation capacity and introduction of external insulation, room temperature fluctuation is mitigated by utilizing the large heat capacity of RC structures.

(iv) The promotion of high-efficiency heating equipment and the introduction of total heat exchange ventilators are cost-effective. Therefore, CO_2 emissions of approximately 56 t can be reduced at the construction cost of approximately 20,000 yen/m^2.



Annual CO_2 Emissions (Region I)

Annual CO_2 Emissions Resulting from Heater Use

(i) CO_2 emissions resulting from heater use can be reduced by approximately 78%, from 73 to 16 t.

(ii) Heaters are scheduled to be upgraded from electric panel heaters to FF-type gas heaters.

(iii) It is planned to promote the insulation of external walls, windows and roofs to reduce heating load. It is also planned to power a part of heating with energy from the solar radiation falling in classrooms.

(iv) Through replacement with total heat exchange ventilators, CO_2 emissions from heaters and ventilation are reduced, resulting in a substantial contribution to the reduction effect on the heating

CO_2 Emissions [t-CO_2/year]

	Before Renovation	Environment-focused Renovation	
	Heating: Electric panel heaters	Heating: FF-type gas heaters + Total heat exchange ventilation	Contributing ratio of reduction effect (%)
Heating	72.6	16.3(−78%)	93.5
Antifreeze (Toilets)	1.0	0.0	1.7
Lighting	16.4	12.8(−22%)	6.0
Ventilation	1.8	3.6	– 3.0
Water Supply	2.4	1.3(−46%)	1.8
Other	1.6	1.6	0
Total	96	36(−63%)	100

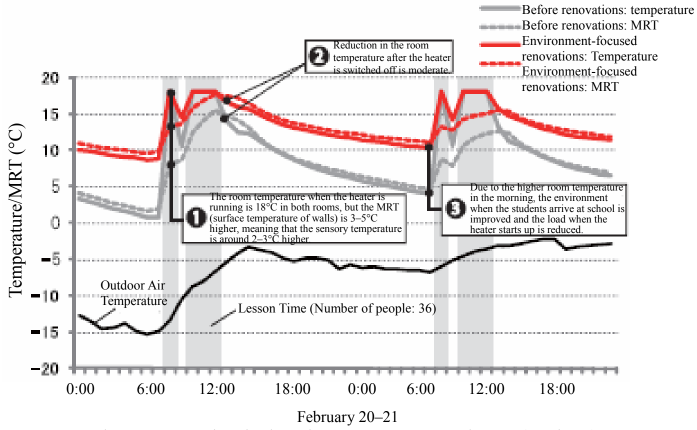
*Figures in parentheses represent the percentage share of the reduction in CO_2 emissions compared with the situation before renovations.

(2) Improvements in the Classroom Environment

(i) (In winter) Owing to enhanced insulation, the surface temperature of inside walls increases, so the sensory temperature is about 2–3°C higher than in the case of conventional renovations, even if the heater is set at the same temperature.

(ii) (In winter) The amount of heat lost overnight can be reduced by enhancing insulation. In addition, heat stored during the day in structures with large heat capacity is expected to be released in classrooms during the night due to external insulation. Therefore, the reduction in room temperature overnight after the heater is switched off can be mitigated.

(iii) (In winter) By keeping the room temperature at night above 8°C, the thermal environment in the classroom just after the students arrive at school can be improved, and the load when the heater starts up the next morning can be reduced.



Changes Over Time in the Winter Temperature and MRT (Region I)

*MRT expresses the surface temperature of the walls in rooms.

(3) Reduction of Running Costs Resulting from Environment-focused Renovations

(i) Through environment-focused renovations, it is possible to reduce energy costs by approximately 37%.

(ii) Heating costs account for approximately 70% of the energy costs before renovations. The majority of the reduction amounts are accounted for by heating costs.

(iii) The table on the right shows the results of the estimate under certain assumptions in order to provide a rough guide. It is necessary to calculate the actual energy costs based on the contract contents and charge systems of each school.

Estimates of Energy Costs Before and After Renovations (Per Year)

	Before Renovations	Environment-focused Renovations
	Electric panel heaters	FF-type gas heaters
Gas (Heating in classrooms)	¥0	¥1,120,000
Heating electricity	¥1,186,000	¥0
Heating electricity (basic charge)	¥1,196,000	¥0
Ordinary electricity (heating)	¥0	¥1,000
Ordinary electricity (lighting, etc.)	¥424,000	¥388,000
Ordinary electricity (basic charge)	¥637,000	¥653,000
Total	¥3,440,000	¥2,160,000
Comparison (%)	100	63 (−37)

(4) Initial Costs of Environment-focused Renovations

(i) The construction cost of environment-focused renovations is approximately 123,000 yen/m^2.

(ii) Of the construction costs of environment-focused renovations, the costs of upgrading heaters, lighting equipment and hygiene equipment account for just below 20%.

(iii) Of the construction costs of environment-focused renovations, the cost of enhancing insulation accounts for slightly over 80%.

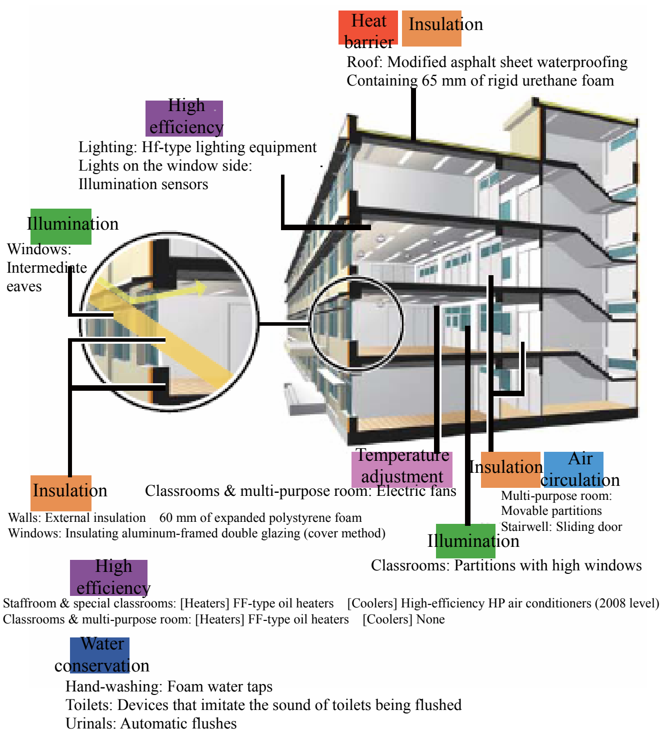
Estimated Construction Costs per Unit of Total Floor Area (yen/m^2)

Type of Work	Main Content	Environment-focused Renovations
		FF-type gas heaters + Total heat exchange ventilators
Construction work	Demolition work, renovation work (installing the interior and exterior of the building and the joinery), earthquake resistance reinforcement	99,700
Mechanical equipment work	Hygiene equipment work (replacing toilets, etc.), water supply & drainage work, heating & cooling equipment work, ventilation equipment work	19,200
Electrical equipment work	Lighting equipment work, power supply work	3,600
Total		122,500

Region II

Plan Overview

<Points of highly effective environment-focused renovations>
(i) Roofs, external walls and windows are insulated.
(ii) Lighting equipment is made more efficient. (Cost-effective)



Total of Environment-focused Renovations

	Target area	Before renovations	Environment-focused renovation
(1) Insulation	External walls (outside the room)	-	External insulation: 60 mm (Extruded polystyrene foam)
	Windows	Aluminum sash, float plate glass	All windows converted to double glazing with aluminum sashes (cover method, insulating frames)
	Roof	-	Modified asphalt sheet waterproofing (with 65 mm of rigid urethane foam)
	Heating zones (stairwell, foyer, etc.)	Permanently open fire doors	Installing doors that can be opened and closed
	Partitioning (between multi-purpose space and corridors)	-	Installing movable partitions
(2) Shading from sunshine	External walls	Existing horizontal eaves (W500)	Installing eaves midway across the windows (W600)
(3) Temperature adjustment	Ordinary classrooms and multi-purpose space	-	Electric fans (4 in each room)
(4) Illumination	Windows	-	Installing eaves midway across the windows (W600)
	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700mm)
(5) Utilizing natural wind	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700 mm)
	Windows (ordinary classrooms, multi-purpose space)	-	-
	Windows (stairwells, corridors)	-	-
(6) Efficient use of energy & water conservation	Lighting (ordinary classrooms, multi-purpose space)	FL-type lighting equipment (40W × 16)	Hf-type lighting equipment (with illumination sensors near the windows)
	Lighting (toilets, stairs)	FL-type lighting equipment (20W × 2)	FL-type lighting equipment (with motion sensors)
	Heating and cooling facilities (management rooms, special classrooms)	Heating: FF-type oil heaters Cooling: HP air conditioner (1995 equivalent)	Heating: FF-type oil heaters Cooling: HP air conditioner (1998 high-efficiency model)
	Heating and cooling facilities (ordinary classrooms, multi-purpose space)	Heating: FF-type oil heaters Cooling: None	Heating: FF-type oil heaters Cooling: None
	Sinks	Running taps	Foam water taps
	Toilets	The toilets have no devices that imitate the sound of toilets being flushed, urinals are the flush valve type	Toilets are equipped with devices imitating the sound of toilets being flushed, urinals are equipped with an automatic flush

Results of Simulations

(1) Reduction in CO_2 Emissions

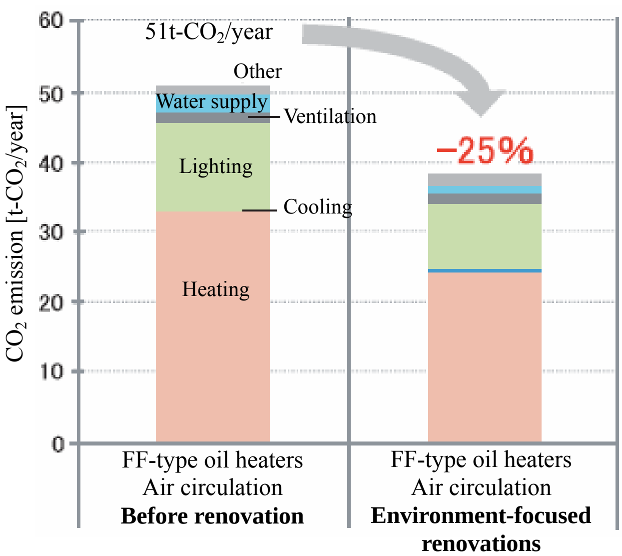
● Annual CO_2 Emissions

(i) In the event that environment-focused renovations are carried out, CO_2 emissions can be reduced by approximately 25%.

(ii) In Region II, the share of energy use accounted for by heating in winter is great, so it is effective to take measurements of increase in insulation performance.

(iii) As a result of the introduction of external insulation, room temperature fluctuation is mitigated by utilizing the large heat capacity of RC structures.

(iv) The introduction of high-efficiency lighting equipment and illumination sensors is cost-effective. Therefore, CO_2 emissions can be reduced by approximately 3 t at the construction cost of approximately 4,000 yen/m^2.



Annual CO_2 Emissions (Region II)

Annual CO_2 Emissions Resulting from Heater Use

(i) CO_2 emissions resulting from heater use can be reduced by approximately 26%, from 33 to 24 t.
(ii) It is planned to promote the insulation of windows, external walls and roofs to reduce heating load. It is also planned to power a part of heating by using energy from the solar radiation falling in classrooms.

Annual CO_2 Emissions Resulting from Lighting

(i) CO_2 emissions resulting from lighting can be reduced by approximately 23%, from 13 to 10 t.
(ii) By upgrading lighting equipment to high-efficiency models and introducing illumination sensors and motion sensors, energy conservation will be promoted.

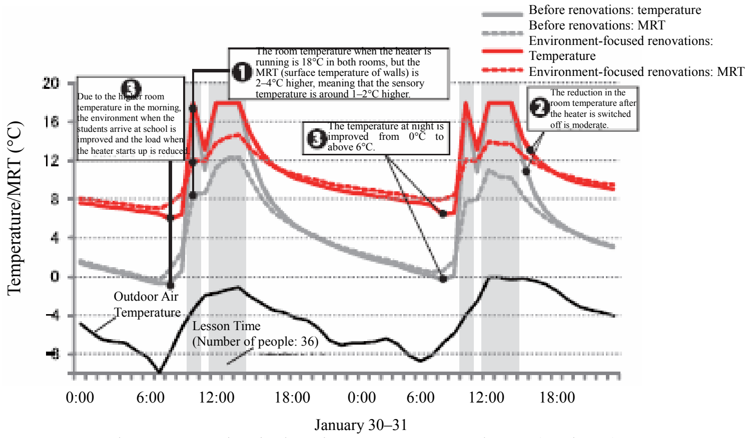
CO_2 Emissions [t-CO_2/year]

	Before Renovation	Environment-focused Renovation	
	Insulation: None	External insulation: FF-type oil heaters + air circulation	Contributing ratio of reduction effect (%)
Heating	33.1	24.4(−26%)	69.0
Cooling	0.1	0.1	0
Electric Fans	0.0	0.0	0
Lighting	12.5	9.6(−23%)	23.0
Ventilation	1.5	1.5	0
Water Supply	2.4	1.3(−46%)	8.7
Other	1.5	1.3	− 0.7
Total	51	38(−25%)	100

*Figures in parentheses represent the percentage share of the reduction in CO_2 emissions compared with the situation before renovations.

(2) Improvements in the Classroom Environment

(i) (In winter) Owing to enhanced insulation, the surface temperature of the inside walls increases, so the sensory temperature is about 1–2°C higher than in the case of conventional renovations, even if the heater is set at the same temperature.
(ii) (In winter) The amount of heat lost overnight can be reduced by enhancing insulation. In addition, heat stored during the day in structures with large heat capacity is expected to be released in classrooms during the night due to external insulation. Therefore, the reduction in the room temperature overnight after the heater is switched off can be mitigated.
(iii) (In winter) By keeping the room temperature at night above 6°C, the thermal environment in the classroom just after the students arrive at school can be improved, and the load when the heater starts up the next morning can be reduced.



Changes Over Time in the Winter Temperature and MRT (Region II)
*MRT expresses the surface temperature of the walls in rooms.

(3) Reduction of Running Costs Resulting from Environment-focused Renovations

(i) Through environment-focused renovations, it is possible to reduce energy costs by approximately 19%.
(ii) Heating costs account for approximately 50% of the energy costs before renovations. The majority of the reduction amounts are accounted for by heating costs.
(iii) The table on the right shows the results of the estimate under certain assumptions in order to provide a rough guide. It is necessary to calculate the actual energy costs based on the contract contents and charging systems of each school.

Estimates of Energy Costs Before and After Renovations (Per Year)

	Before Renovations	Environment-focused Renovations
	Insulation: none	External insulation: FF-type oil heaters + air circulation
Oil (heating in classrooms)	¥1,204,000	¥887,000
Ordinary electricity (cooling)	¥2,000	¥2,000
Ordinary electricity (lighting, etc.)	¥412,000	¥335,000
Ordinary electricity (basic charge)	¥782,000	¥732,000
Total	¥2,400,000	¥1,960,000
Comparison (%)	100	81 (−19)

(4) Initial Costs of Environment-focused Renovations

(i) The construction cost of environment-focused renovations is approximately 136,000 yen/m^2, and the increase in the unit cost attributable to adopting environmental measures is approximately 49,000 yen/m^2.
(ii) Of the construction costs of environment-focused renovations, the costs of upgrading heaters, lighting equipment and hygiene equipment account for just below 20%.
(iii) Of the construction costs of environment-focused renovations, the cost of enhancing insulation account for slightly over 80%.
(iv) The increase in the unit cost of construction work is relatively high compared to that in warmer regions, due to the promotion of external insulation and installing insulating aluminum sashes.

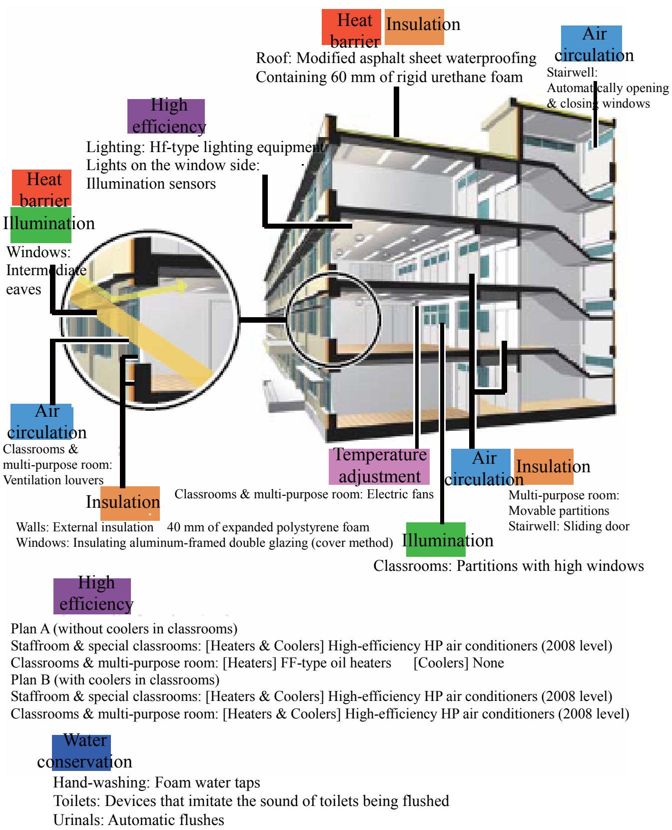
Estimated Construction Costs per Unit of Total Floor Area (yen/m^2)

Type of Work	Main Content	Conventional Renovations Earthquake resistance reinforcement + improvements to dilapidated facilities	Environment-focused Renovations FF-type gas heaters + Total heat exchange ventilators
Construction work	Demolition work, renovation work (installing the interior and exterior of the building and the joinery), earthquake resistance reinforcement	63,200	109,300
Mechanical equipment work	Hygiene equipment work (replacing toilets, etc.), water supply & drainage work, heating & cooling equipment work, ventilation equipment work	20,500	23,200
Electrical equipment work	Lighting equipment work, power supply work	3,300	3,700
Total		87,000	136,200

Region III *Plan B is the plan in which coolers are installed in ordinary classrooms.

Plan Overview

<Points of highly effective environment-focused renovations>
(i) Roofs, external walls and windows are insulated.
(ii) Lighting equipment is made more efficient. (Cost-effective)
(iii) Cooling and heating equipment is replaced by high-efficiency air conditioners. (Plan B)



Total of Environment-focused Renovations

	Target area	Before renovations	Environment-focused renovation
(1) Insulation	External walls (inside the room)	-	External insulation: 40 mm (Extruded polystyrene foam)
	Windows	Aluminum sash, float plate glass	All windows converted to double glazing with aluminum sashes (cover method, insulating frames)
	Roof	-	Modified asphalt sheet waterproofing (with 60 mm of rigid urethane foam)
	Heating zones (stairwell, foyer, etc.)	Permanently open fire doors	Installing doors that can be opened and closed
	Partitioning (between multi-purpose space and corridors)	-	Installing movable partitions
(2) Shading from sunshine	Windows	Existing horizontal eaves (W500)	Installing eaves midway across the windows (W600)
(3) Temperature adjustment	Ordinary classrooms and multi-purpose space	-	Electric fans (4 in each room)
(4) Illumination	Windows	-	Installing eaves midway across the windows (W600)
	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700 mm)
(5) Utilizing natural wind	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700 mm)
	Windows (ordinary classrooms, multi-purpose space)	-	Ventilation louvers
	Windows (stairwells, corridors)	-	Installing automatically opening & closing windows
(6) Efficient use of energy & water conservation	Lighting (ordinary classrooms, multi-purpose space)	FL-type lighting equipment (40W × 16)	Hf-type lighting equipment (with illumination sensors near the windows)
	Lighting (toilets, stairs)	FL-type lighting equipment (20W × 2)	FL-type lighting equipment (with motion sensors)
	Heating and cooling facilities (management rooms, special classrooms)	Heating: FF-type oil heaters Cooling: HP air conditioner (1995 equivalent)	Heating: HP air conditioner Cooling: HP air conditioner (2008 high-efficiency model)
	Heating and cooling facilities (ordinary classrooms, multi-purpose space)	Heating: FF-type oil heaters Cooling: None	<Plan A> Heating: FF-type oil heaters Cooling: None <Plan B> Heating: HP air conditioner Cooling: HP air conditioner (2008 high-efficiency model)
	Sinks	Running taps	Foam water taps
	Toilets	The toilets have no devices that imitate the sound of toilets being flushed, urinals are the flush valve type	Toilets are equipped with devices imitating the sound of toilets being flushed, urinals are equipped with an automatic flush

Results of Simulations

(1) Reduction in CO_2 Emissions

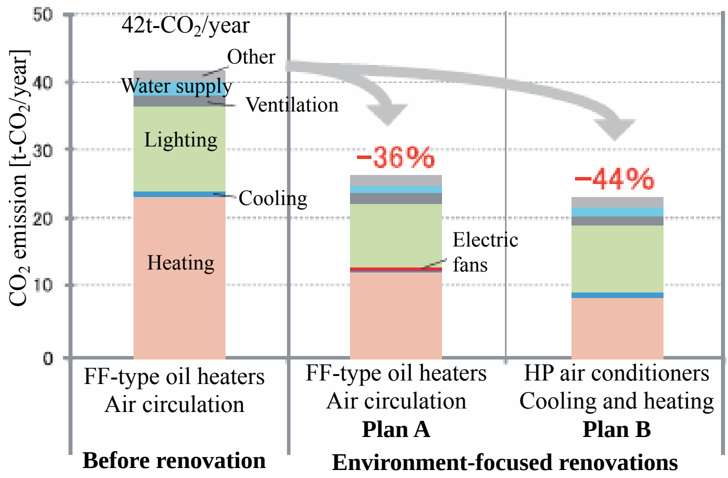
● Annual CO_2 Emissions

(i) In the event that environment-focused renovations are carried out, CO_2 emissions can be reduced by approximately 36% under Plan A and approximately 44% under Plan B.

(ii) In Region III, in addition to the share of energy use accounted for by heating in winter being great, there are hot days in summer, so it is effective to implement renovations focused on increased insulation performance and more effective cooling and heating equipment. This can improve the thermal environment in classrooms in winter and summer, and reduce CO_2 emissions.

(iii) In the case of Plan B, by installing more efficient air conditioners than FF-type oil heaters, the thermal environment in classrooms in summer is improved and CO_2 emissions in winter is largely reduced compared to Plan A.

(iv) The introduction of high-efficiency lighting equipment and illumination sensors is cost-effective. Therefore, CO_2 emissions can be reduced by approximately 3 t at the construction cost of approximately 5,000 yen/m^2.



Annual CO_2 Emissions (Region III)

Annual CO_2 Emissions Resulting from Heater Use

(i) CO_2 emissions resulting from heater use can be reduced by approximately 47%, from 24 to 13 t under Plan A, and by approximately 63%, from 24 to 9 t under Plan B.

(ii) It is planned to promote the insulation of windows, external walls and roofs.

(iii) In the case of Plan B, by using high-efficiency air conditioners for cooling and heating, CO_2 emissions can be reduced further than under Plan A.

* Although CO_2 emissions due to cooling are increased, those due to heating are largely reduced, and therefore, those from cooling and heating overall are reduced.

Annual CO_2 Emissions Resulting from Lighting

(i) CO_2 emissions resulting from lighting can be reduced by approximately 23%, from 13 to 10 t under both Plan A and B.

(ii) By upgrading lighting equipment to high-efficiency models and introducing illumination sensors and motion sensors, energy conservation will be promoted.

(2) Improvements in the Classroom Environment

(i) (In winter) Owing to enhanced insulation, the surface temperature of the inside walls increases, so the sensory temperature is about 1–2°C higher than in the case of conventional renovations, even if the heater is set at the same temperature.

(ii) (In winter) The amount of heat lost overnight can be reduced by enhancing insulation. In addition, heat stored during the day in structures with large heat capacity is expected to be released in classrooms during the night due to external insulation. Therefore, the reduction in the room temperature overnight after the heater is switched off can be mitigated.

(iii) (In winter) By keeping the room temperature at night above 7°C, the thermal environment in classrooms just after the students arrive at school can be improved, and the load when the heater starts up the next morning can be reduced.

(3) Reduction of Running Costs Resulting from Environment-focused Renovations

(i) Through environment-focused renovations, it is possible to reduce energy costs by approximately 28% under Plan A and by approximately 25% under Plan B.

(ii) Heating costs account for approximately 40% of the energy costs before renovations. The majority of the reduction amounts are accounted for by heating costs.

(iii) The table on the right shows the results of the estimate under certain assumptions in order to provide a rough guide. It is necessary to calculate the actual energy costs based on the contract contents and charge systems of each school.

(4) Initial Costs of Environment-focused Renovations

(i) The construction cost of environment-focused renovations is approximately 134,000 yen/m^2 under Plan A and approximately 136,000 yen/m^2 under Plan B, and the increase in unit cost attributable to adopting environmental measures is approximately 47,000–49,000 yen/m^2.

(ii) Of the construction costs of environment-focused renovations, costs of upgrading coolers, heaters, lighting equipment and hygiene equipment account for approximately 20%.

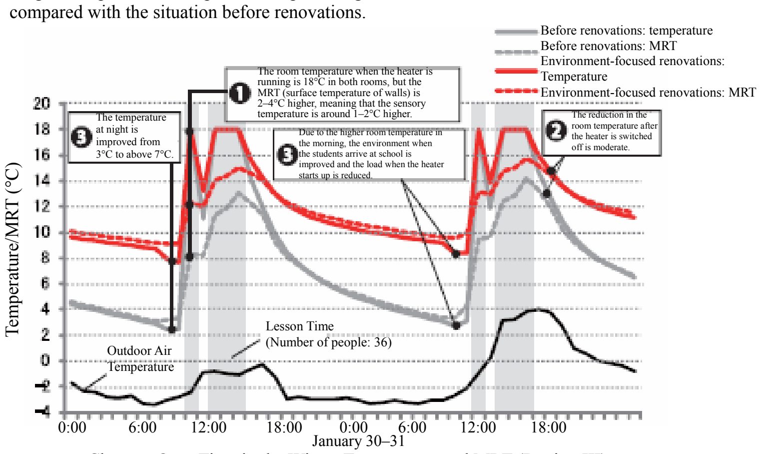
(iii) Of the construction costs of environment-focused renovations, the cost of enhancing insulation accounts for approximately 80%.

(iv) The increase in the unit cost of construction work is relatively high compared to that in warmer regions, due to promoting external insulation and installing insulating aluminum sashes.

CO_2 Emissions [t-CO_2/year]

	Before Renovation	Environment-focused Renovation			
		Plan A		Plan B	
	FF-type oil heaters + air circulation	Heating: FF-type oil heaters + air circulation	Contributing ratio of reduction effect (%)	Cooling and heating in classrooms: air conditioner	Contributing ratio of reduction effect (%)
Heating	23.8	12.7 (−47%)	73.5	8.9 (−63%)	81.4
Cooling	0.4	0.2	1.3	0.9	−2.7
Electric Fans	−	0.1	−0.7	−	−
Lighting	12.5	9.6 (−23%)	19.2	9.6 (−23%)	15.8
Ventilation	1.5	1.5	0	1.5	0
Water Supply	2.4	1.3 (−46%)	7.3	1.3 (−46%)	6.0
Other	1.2	1.3	−0.6	1.3	0.5
Total	42	27 (−36%)	100	23 (−44%)	100

*Figures in parentheses represent the percentage share of the reduction in CO_2 emissions compared with the situation before renovations.



Changes Over Time in the Winter Temperature and MRT (Region III)

*MRT expresses the surface temperature of the walls in rooms.

Estimates of Energy Costs Before and After Renovations (Per Year)

	Before Renovations	Environment-focused Renovations	
	FF-type oil heaters + air circulation	Plan A FF-type oil heaters + air circulation	Plan B Using air conditioners in classrooms
Oil (heating in classrooms)	¥864,000	¥271,000	¥0
Ordinary electricity (heating)	¥0	¥142,000	¥240,000
Ordinary electricity (cooling)	¥12,000	¥6,000	¥24,000
Ordinary electricity (lighting, etc.)	¥412,000	¥337,000	¥337,000
Ordinary electricity (basic charge)	¥939,000	¥838,000	¥1,067,000
Total	¥2,230,000	¥1,590,000	¥1,670,000
Comparison (%)	100	72 (−28)	75 (−25)

Estimated Construction Costs per Unit of Total Floor Area (yen/m^2)

Type of Work	Main Content	Conventional Renovations	Environment-focused Renovations	
		Earthquake resistance reinforcement + improvements to dilapidated facilities	Plan A Heating: FF-type oil heaters + air circulation	Plan B Using air conditioners in classrooms
Construction work	Demolition work, renovation work (installing the interior and exterior of the building and the joinery), earthquake resistance reinforcement	63,200	108,500	108,500
Mechanical equipment work	Hygiene equipment work (replacing toilets, etc.), water supply & drainage work, heating & cooling equipment work, ventilation equipment work	20,500	21,400	22,300
Electrical equipment work	Lighting equipment work, power supply work	3,300	3,600	5,000
Total		87,000	133,500	135,800

*Even in the environment-focused renovations under Plan A, high-efficiency air conditioners are installed for cooling and heating in management rooms and special classrooms.

Region IV

*Plan B is the plan in which coolers are installed in ordinary classrooms.

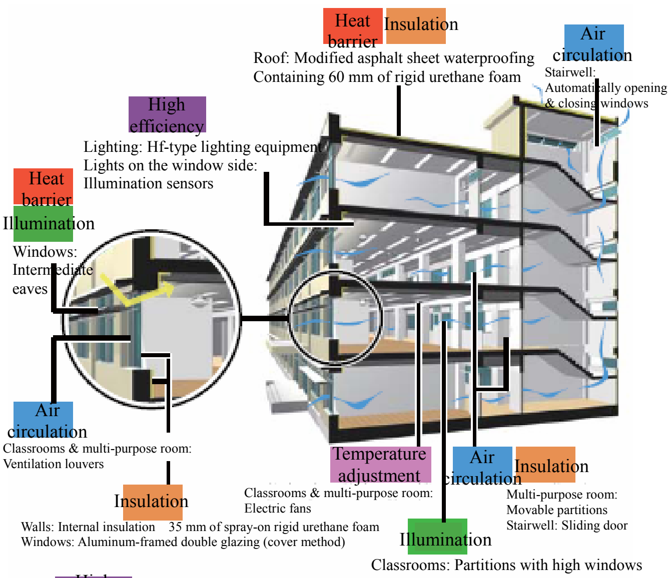
Plan Overview

<Points of Highly Effective Environment-Focused Renovation>

(i) Insulation of roofs, external walls and windows

(ii) Efficient use of energy for lighting equipment (highly cost-effective)

(iii) Converting heating & cooling facilities to high-efficiency air conditioners (Plan B)



High efficiency

Plan A (without coolers in classrooms)
Staffroom & special classrooms: [Heaters & Coolers] High-efficiency HP air conditioners (2008 level)
Classrooms & multi-purpose room: [Heaters] FF-type oil heaters [Coolers] None
Plan B (with coolers in classrooms)
Staffroom & special classrooms: [Heaters & Coolers] High-efficiency HP air conditioners (2008 level)
Classrooms & multi-purpose room: [Heaters & Coolers] High-efficiency HP air conditioners (2008 level)

Water conservation

Hand-washing: Foam water taps
Toilets: Devices that imitate the sound of toilets being flushed
Urinals: Automatic flushes

Total of Environment-focused Renovations

	Target area	Before renovations	Environment-focused renovation
(1) Insulation	External walls (inside the room)	-	Internal insulation: 35 mm (rigid urethane foam)
	Windows	Aluminum sash, float plate glass	All windows converted to double glazing with aluminum sashes (cover method)
	Roof	-	Modified asphalt sheet waterproofing (with 60 mm of rigid urethane foam)
	Heating zones (stairwell, foyer, etc.)	Permanently open fire doors	Installing doors that can be opened and closed
	Partitioning (between multi-purpose space and corridors)	-	Installing movable partitions
(2) Shading from sunshine	External walls	Existing horizontal eaves (W500)	Installing eaves midway across the windows (W600)
(3) Temperature adjustment	Ordinary classrooms and multi-purpose space	-	Electric fans (4 in each room)
(4) Illumination	Windows	-	Installing eaves midway across the windows (W600)
	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700 mm)
(5) Utilizing natural wind	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700 mm)
	Windows (ordinary classrooms, multi-purpose space)	-	Ventilation louvers
	Windows (stairwells, corridors)	-	Installing automatically opening & closing windows
(6) Efficient use of energy & water conservation	Lighting (ordinary classrooms, multi-purpose space)	FL-type lighting equipment (40W × 16)	Hf-type lighting equipment (with illumination sensors near the windows)
	Lighting (toilets, stairs)	FL-type lighting equipment (20W × 2)	FL-type lighting equipment (with motion sensors)
	Heating and cooling facilities (management rooms, special classrooms)	Heating: FF-type oil heaters Cooling: HP air conditioner (1995 equivalent)	Heating: HP air conditioner Cooling: HP air conditioner (2008 high-efficiency model)
	Heating and cooling facilities (ordinary classrooms, multi-purpose space)	Heating: FF-type oil heaters Cooling: None	<Plan A> Heating: FF-type oil heaters Cooling: None <Plan B> Heating: HP air conditioner Cooling: HP air conditioner (2008 high-efficiency model)
	Sinks	Running taps	Foam water taps
	Toilets	The toilets have no devices that imitate the sound of toilets being flushed, urinals are the flush valve type	Toilets are equipped with devices imitating the sound of toilets being flushed, urinals are equipped with an automatic flush

Results of Simulations

(1) Reduction in CO_2 Emissions

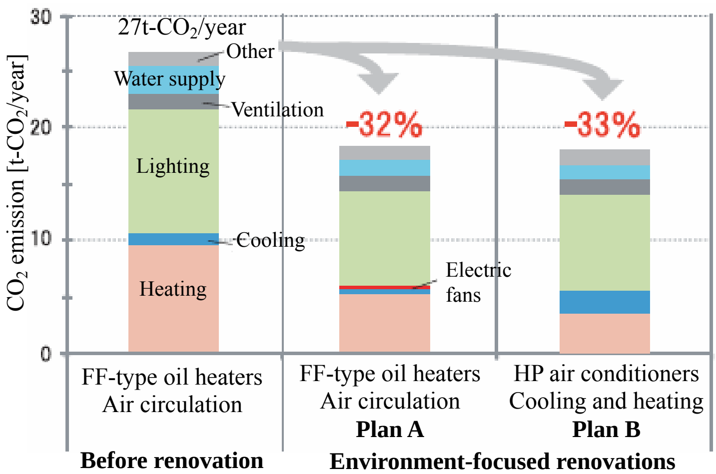
● Annual CO_2 Emissions

(i) In the event that environment-focused renovations are carried out, CO_2 emissions can be reduced by approximately 32% under Plan A, and 33% under Plan B

(ii) In Region IV, it is required to conduct measures to deal with summer heat and reduce the energy used for heating in winter simultaneously, so renovation focused on increasing insulation capacity, and upgrading cooling and heating facilities to high-efficiency models will be effective.

(iii) Under Plan B, with the introduction of high-efficiency cooling and heating equipment, it will become possible to reduce energy use from heating, and reduce overall CO_2 emissions, even when taking the increase through cooling into consideration.

(iv) The introduction of high-efficiency lighting equipment and illumination sensors is cost-effective. Therefore, CO_2 emissions can be reduced by approximately 3 t at the construction cost of approximately 5,000 yen/m^2



Annual CO_2 Emissions (Region IV)

Annual CO_2 Emissions Resulting from Heater Use

(i) CO_2 emissions resulting from heater use can be reduced by approximately 47%, from 24 to 13 t under Plan A, and by approximately 63%, from 24 to 9 t under Plan B.

(ii) Insulation in windows, external walls and roofs will be reinforced

(iii) In the case of Plan B, by using high-efficiency air conditioners for cooling and heating, CO_2 emissions can be reduced further than under Plan A.

* Although CO_2 emissions due to cooling are increased, those due to heating are largely reduced, and therefore, those from cooling and heating overall are reduced.

Annual CO_2 Emissions Resulting From Lighting

(i) Under both plans, annual CO_2 emissions are reduced by approximately 23%, from 11 to 9 t.

(ii) By upgrading lighting equipment to high-efficiency models and introducing illumination sensors and motion sensors, energy conservation will be promoted.

CO_2 Emissions [t-CO_2/year]

	Before Renovation	Environment-focused Renovation			
		Plan A		Plan B	
	FF-type oil heaters + air circulation	Heating: FF-type oil heaters + air circulation	Contributing ratio of reduction effect (%)	Cooling and heating in classrooms: air conditioner	Contributing ratio of reduction effect (%)
Heating	9.7	5.2 (–46%)	52.9	3.6 (–63%)	69.3
Cooling	0.9	0.5	4.7	1.9	–11.3
Electric Fans	–	0.1	–1.1	–	–
Lighting	11.2	8.6 (–23%)	30.6	8.6 (–23%)	29.5
Ventilation	1.4	1.4	0	1.4	0
Water Supply	2.4	1.3 (–46%)	12.9	1.3 (–46%)	12.5
Other	1.1	1.1	0	1.1	0
Total	27	18 (–32%)	100	18 (–33%)	100

*Figures in parentheses represent the percentage share of the reduction in CO_2 emissions compared with the situation before renovations.

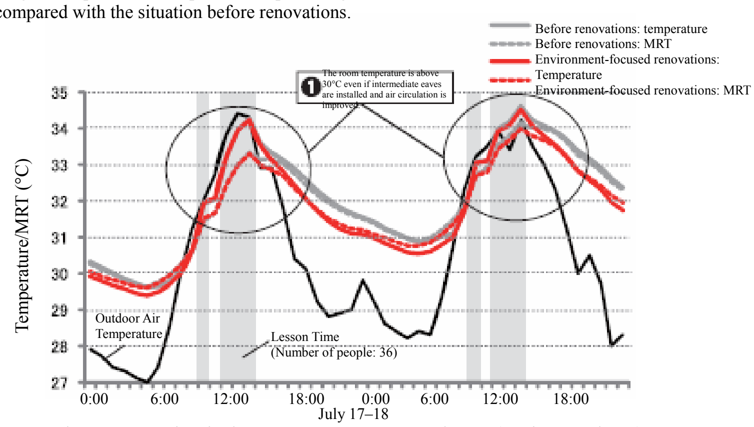
(2) Improvements in the Classroom Environment

(i) (In summer) Under Plan A, there are days when the room temperature in the classroom exceeds 30°C, even if the rooms are shaded from sunlight and air circulation is encouraged. Therefore, measures are taken to reduce sensory temperature by using fans.

(ii) (In winter) Owing to enhanced insulation, the surface temperature of the inside walls increases, so the sensory temperature is about 1–2°C higher than in the case of conventional renovations, even if the heater is set at the same temperature.

(iii) (In winter) The amount of heat lost overnight can be reduced by enhancing insulation. Therefore, the reduction in the room temperature overnight after the heater is switched off can be mitigated.

(iv) (In winter) By keeping the room temperature at night above 10°C, the thermal environment in classrooms just after the students arrive at school can be improved, and the load when the heater starts up the next morning can be reduced.



Changes Over Time in the Summer Temperature and MRT (Region IV, Plan A)

*MRT expresses the surface temperature of the walls in rooms.

(3) Reduction of Running Costs Through Environment-focused Renovations

(i) Through environment-focused renovations, it is possible to reduce energy costs by approximately 20% under Plan A, and 19% under Plan B.

(ii) Even when cooling is introduced into Plan B, the energy cost for heating will be decreased significantly, so a decrease in overall energy cost can be achieved.

(iii) The table on the right shows the results of the estimate under certain assumptions in order to provide a rough guide. It is necessary to calculate the actual energy costs based on the contract contents and charge systems of each school.

Estimates of Energy Costs Before and After Renovations (Per Year)

	Before Renovations	Environment-focused Renovations	
	FF-type oil heaters + air circulation	Plan A FF-type oil heaters + air circulation	Plan B Using air conditioners in classrooms
Oil (heating in classrooms)	¥169,000	¥86,000	¥0
Ordinary electricity (heating)	¥154,000	¥85,000	¥109,000
Ordinary electricity (cooling)	¥28,000	¥17,000	¥58,000
Ordinary electricity (lighting, etc.)	¥412,000	¥339,000	¥339,000
Ordinary electricity (basic charge)	¥1,044,000	¥922,000	¥959,000
Total	¥1,810,000	¥1,450,000	¥1,460,000
Comparison (%)	100	80 (–20)	81 (–19)

(4) Initial Costs of Environment-focused Renovations

(i) The construction cost of environment-focused renovations is approximately 120,000 yen/m^2 under Plan A, and approximately ¥123,000/m^2 under Plan B, and the increase in unit cost attributable to adopting environmental measures is around ¥33,000–36,000 yen/m^2.

(ii) The difference in the unit cost between the two plans for environment-focused renovations is only around 3,000 yen/m^2. Plan B is the preferred choice, considering that a significant improvement can be expected in the classroom thermal environment.

(iii) Of the construction costs of environment-focused renovations, the costs of upgrading the heating & cooling equipment, lighting equipment and hygiene equipment account for approximately 20%.

(iv) Of the construction costs of environment-focused renovations, the cost of enhancing insulation account for approximately 80%.

Estimated Construction Costs per Unit of Total Floor Area (yen/m^2)

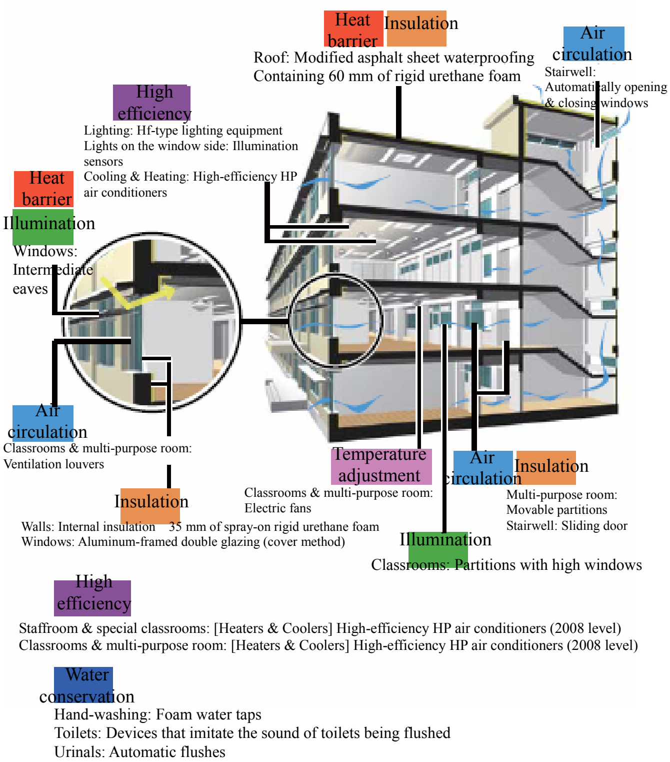
Type of Work	Main Content	Conventional Renovations	Environment-focused Renovations	
		Earthquake resistance reinforcement + improvements to dilapidated facilities	Plan A Heating: FF-type oil heaters + air circulation	Plan B Using air conditioners in classrooms
Construction work	Demolition work, renovation work (installing the interior and exterior of the building and the joinery), earthquake resistance reinforcement	63,200	95,700	95,700
Mechanical equipment work	Hygiene equipment work (replacing toilets, etc.), water supply & drainage work, heating & cooling equipment work, ventilation equipment work	20,500	20,700	21,900
Electrical equipment work	Lighting equipment work, power supply work	3,300	3,700	4,900
Total		87,000	120,100	122,500

*Even in the environment-focused renovations under Plan A, high-efficiency air conditioners are installed for cooling and heating in management rooms and special classrooms.

Region V

Plan Overview

<Points of highly effective environment-focused renovations>
(i) Roofs, external walls and windows are insulated.
(ii) Lighting equipment is made more efficient. (Cost-effective)



	Target area	Before renovations	Environment-focused renovation
(1) Insulation	External walls (inside the room)	-	Internal insulation: 35 mm (rigid urethane foam)
	Windows	Aluminum sash, float plate glass	All windows converted to double glazing with aluminum sashes (cover method)
	Roof	-	Modified asphalt sheet waterproofing (with 60 mm of rigid urethane foam)
	Heating zones (stairwell, foyer, etc.)	Permanently open fire doors	Installing doors that can be opened and closed
	Partitioning (between multi-purpose space and corridors)	-	Installing movable partitions
(2) Shading from sunshine	Windows	Existing horizontal eaves (W500)	Installing eaves midway across the windows (W600)
(3) Temperature adjustment	Ordinary classrooms and multi-purpose space	Electric fans (4 in each room)	Electric fans (4 in each room)
(4) Illumination	Windows	-	Installing eaves midway across the windows (W600)
	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700 mm)
(5) Utilizing natural wind	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700 mm)
	Windows (ordinary classrooms, multi-purpose space)	-	Ventilation louvers
	Windows (stairwells, corridors)	-	Installing automatically opening & closing windows
(6) Efficient use of energy & water conservation	Lighting (ordinary classrooms, multi-purpose space)	FL-type lighting equipment (40W × 16)	Hf-type lighting equipment (with illumination sensors near the windows)
	Lighting (toilets, stairs)	FL-type lighting equipment (20W × 2)	FL-type lighting equipment (with motion sensors)
	Heating and cooling facilities (management rooms)	Heating: HP air conditioner Cooling: HP air conditioner (1995 equivalent)	Heating: HP air conditioner Cooling: HP air conditioner (2008 high-efficiency model)
	Heating and cooling facilities (special classrooms)	Heating: None Cooling: None	Heating: HP air conditioner Cooling: HP air conditioner (2008 high-efficiency model)
	Heating and cooling facilities (ordinary classrooms, multi-purpose space)	Heating: None Cooling: None	Heating: HP air conditioner Cooling: HP air conditioner (2008 high-efficiency model)
	Sinks	Running taps	Foam water taps
	Toilets	The toilets have no devices that imitate the sound of toilets being flushed, urinals are the flush valve type	Toilets are equipped with devices imitating the sound of toilets being flushed, urinals are equipped with an automatic flush

Results of Simulations

(1) Reduction in CO_2 Emissions

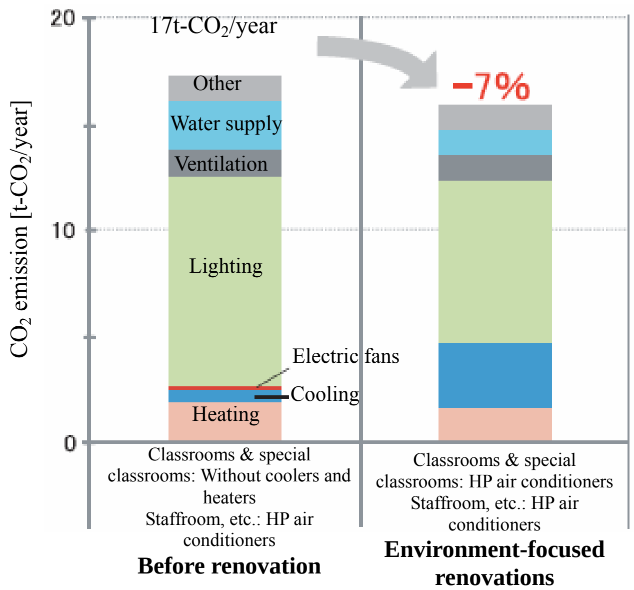
● Annual CO_2 Emissions

(i) In the event that environment-focused renovations are carried out, CO_2 emissions can be reduced by approximately 7%.

(ii) In Region V, energy used for cooling and heating is lower than in the other regions, so CO_2 emissions from lighting constitutes approximately 60% of the overall CO_2 emissions.

(iii) Energy consumption will increase through the introduction of cooling and heating. However, energy consumption will also decrease through the installation of high-efficiency equipment. This, being coupled with the introduction of high-efficiency lighting and water conservation equipment, an overall decrease in CO_2 emissions can be achieved.

(iv) The introduction of high-efficiency lighting equipment and illumination sensors is cost-effective. Therefore, CO_2 emissions can be reduced by approximately 2 t at the construction cost of approximately 5,000 yen/m^2.



Annual CO_2 Emissions (Region V)

Annual CO_2 Emissions Resulting From Heater and Cooler Use

(i) CO_2 emissions will increase by 2.5 t as a result of cooler use.

(ii) Heaters will be introduced into normal classrooms as well. However, there will be almost no change in the CO_2 emissions resulting from heaters, due to the enhancement of building capacity and equipment efficiency.

(iii) The insulation enhancement of windows, external walls and roofs is to be implemented.

Annual CO_2 Emissions Resulting From Lighting

(i) CO_2 emissions resulting from lighting can be reduced by approximately 23%, from 10 to 8 t.

(ii) By upgrading lighting equipment to high-efficiency models and introducing illumination sensors and motion sensors, energy conservation will be promoted.

CO_2 Emissions [t-CO_2/year]

	Before Renovation	Environment-focused Renovation	
	FF-type oil heaters + air circulation	Cooling and heating in classrooms: Air conditioners	Contributing ratio of reduction effect (%)
Heating	1.8	1.6 (−11%)	15.4
Cooling	0.6	3.1	−192.3
Electric Fans	0.2	−	15.4
Lighting	10.0	7.7 (−23%)	176.9
Ventilation	1.2	1.2	0
Water Supply	2.4	1.3 (−46%)	84.6
Other	1.0	1.0	0
Total	17	16 (−7%)	100

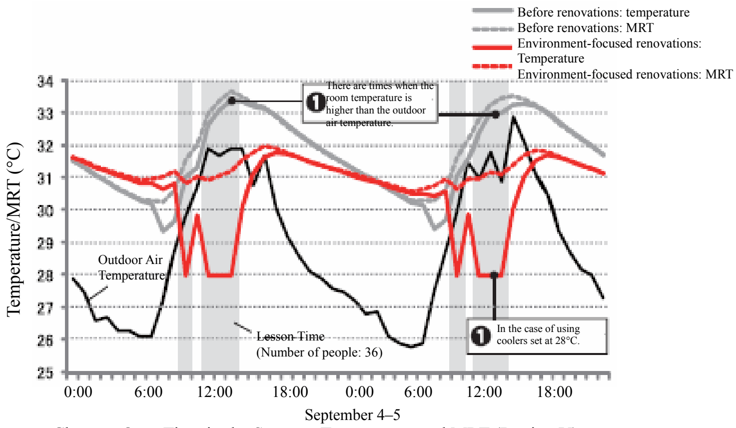
*Figures in parentheses represent the percentage share of the reduction in CO_2 emissions compared with the situation before renovations.

(2) Improvements in the Classroom Environment

(i) (In summer) Before renovation, there are days when the room temperature in the classroom exceeds the outside temperature, even exceeding 30°C on some days. Through the introduction of cooling equipment, and running it at a fixed temperature of 28°C, it is expected to improve the classroom thermal environment.

(ii) (In winter) Owing to the insulation enhancement of the building, it is possible to maintain room temperature through heat derived from sunlight and internal heat generation derived from body heat and lighting equipment, with minimal use of heating equipment.

(iii) (In winter) By keeping the room temperature at night above 7°C, the thermal environment in classrooms just after the students arrive at school can be improved, and the load when the heater starts up the next morning can be reduced.



Changes Over Time in the Summer Temperature and MRT (Region V)

*MRT expresses the surface temperature of the walls in rooms.

(3) Difference in Running Costs Resulting from Environment-focused Renovations

(i) Owing to the introduction of heaters & coolers to improve the indoor thermal environment, which were not present before renovation, the basic fee for general electricity will increase, and energy cost will increase by 32%.

(ii) The resulting energy cost will be restrained when compared with cases with inefficient heaters & coolers that were installed before renovation, or when inefficient heaters & coolers are installed in renovation.

(iii) The table on the right shows the results of the estimate under certain assumptions in order to provide a rough guide. It is necessary to calculate the actual energy costs based on the contract contents and charge systems of each school.

Estimates of Energy Costs Before and After Renovations (Per Year)

	Before Renovations	Environment-focused Renovations
	No coolers nor heaters in classrooms	Installed coolers and heaters in classrooms (high-efficiency HP air conditioners)
Ordinary electricity (heating)	¥60,000	¥56,000
Ordinary electricity (cooking)	¥19,000	¥105,000
Ordinary electricity (lighting, etc.)	¥418,000	¥335,000
Ordinary electricity (basic charge)	¥844,000	¥1,277,000
Total	¥1,340,000	¥1,770,000
Comparison (%)	100	132 (+32)

(4) Initial Costs of Environment-focused Renovations

(i) The construction cost of environment-focused renovations is approximately 123,000 yen/m^2, and the increase in unit cost attributable to adopting environmental measures is approximately 36,000 yen/m^2.

(ii) Of the construction costs of environment-focused renovations, the costs of upgrading the heating & cooling equipment, lighting equipment and hygiene equipment accounts for slightly more than 20%.

(iii) Of the construction costs of environment-focused renovations, the cost of insulation enhancement accounts for just below 80%.

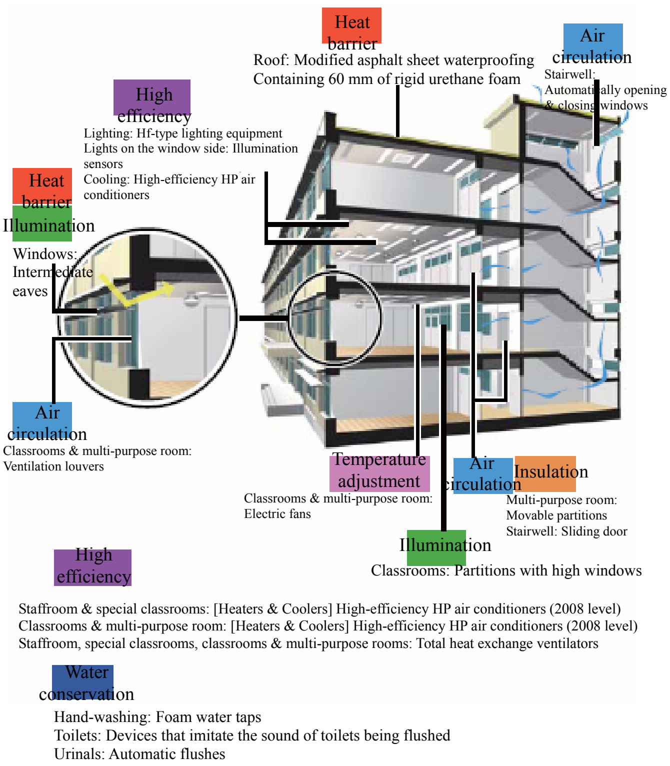
Estimated Construction Costs per Unit of Total Floor Area (yen/m^2)

Type of Work	Main Content	Conventional Renovations	Environment-focused Renovations
		Earthquake resistance reinforcement + improvements to dilapidated facilities	Cooling & Heating in classrooms: Using air conditioners
Construction work	Demolition work, renovation work (installing the interior and exterior of the building and the joinery), earthquake resistance reinforcement	63,200	95,600
Mechanical equipment work	Hygiene equipment work (replacing toilets, etc.), water supply & drainage work, heating & cooling equipment work, ventilation equipment work	20,500	22,600
Electrical equipment work	Lighting equipment work, power supply work	3,300	4,900
Total		87,000	123,100

Region VI

Plan Overview

<Points of highly effective environment-focused renovations>
(i) Roofs, external walls and windows are insulated.
(ii) Lighting equipment is made more efficient. (Cost-effective)
(iii) Cooling equipment is replaced by high-efficiency equipment



	Target area	Before renovations	Environment-focused renovation
(1) Insulation	External walls	-	-
	Windows	Aluminum sash, float plate glass	Aluminum sash. Single plate glass
	Roof	-	Modified asphalt sheet waterproofing (with 60 mm of rigid urethane foam)
	Cooling zones (stairwell, foyer, etc.)	Permanently open fire doors	Installing doors that can be opened and closed
	Partitioning (between multi-purpose space and corridors)	-	Installing movable partitions
(2) Shading from sunshine	Windows	Existing horizontal eaves (W500)	Installing eaves midway across the windows (W600)
(3) Temperature adjustment	Ordinary classrooms and multi-purpose space	Electric fans (4 in each room)	Electric fans (4 in each room)
(4) Illumination	External walls	-	Installing eaves midway across the windows (W600)
	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700 mm)
(5) Utilizing natural wind	Partitioning (between ordinary classrooms and corridor)	-	Steel partitions (with high windows, H: 1700 mm)
	Windows (ordinary classrooms, multi-purpose space)	-	Ventilation louvers (only at the places where earthquake-proof reinforcement is conducted)
	Windows (stairwells, corridors)	-	Installing automatically opening & closing windows
(6) Efficient use of energy & water conservation	Lighting (ordinary classrooms, multi-purpose space)	FL-type lighting equipment (40W × 16)	Hf-type lighting equipment (with illumination sensors near the windows)
	Lighting (toilets, stairs)	FL-type lighting equipment (20W × 2)	FL-type lighting equipment (with motion sensors)
	Heating and cooling facilities (management rooms, special classrooms)	Heating: None Cooling: HP air conditioner (1995 equivalent)	<2008 high-efficiency model> <ice thermal storage> Heating: none Cooling: HP air conditioner Total heat exchange ventilators
	Heating and cooling facilities (ordinary classrooms, multi-purpose space)	Heating: None Cooling: HP air conditioner (1995 equivalent)	<2008 high-efficiency model> <ice thermal storage> Heating: None Cooling: HP air conditioner Total heat exchange ventilators
	Sinks	Running taps	Foam water taps
	Toilets	The toilets have no devices that imitate the sound of toilets being flushed, urinals are the flush valve type	Toilets are equipped with devices imitating the sound of toilets being flushed, urinals are equipped with an automatic flush

Results of Simulations

(1) Reduction in CO_2 Emissions

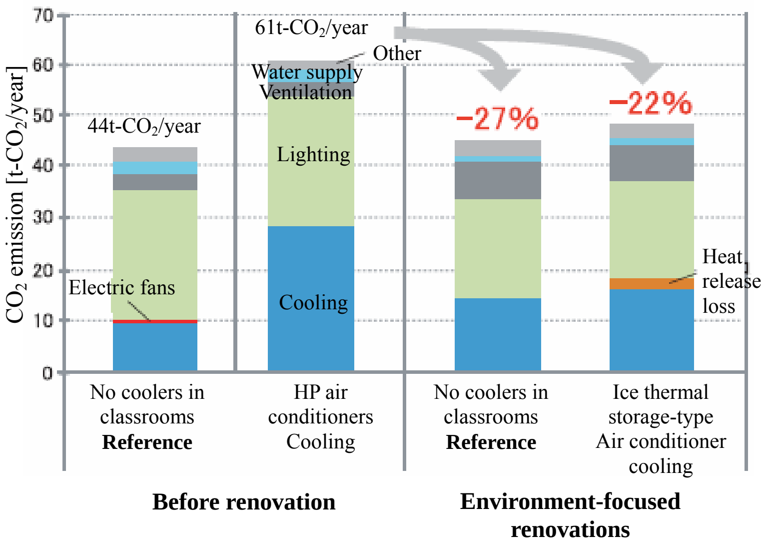
● Annual CO_2 Emissions

(i) In the event that coolers are installed in classrooms before the renovation, CO_2 emissions can be reduced by approximately 22–27% through the enhancement of building capacity and introduction of high-efficiency equipment.

(ii) In the event that coolers are not installed in classrooms before the renovation, the increase in CO_2 emissions can be limited to approximately 3–11% through simultaneously implementing the enhancement of building capacity and introduction of high-efficiency equipment.

(iii) In Region VI, the emphasis on dealing with the summer heat will be greater. Therefore, the renovation plan will focus on reducing the load on coolers through shading sunlight and introducing high-efficiency lighting equipment.

(iv) The introduction of high-efficiency lighting equipment and illumination sensors is cost-effective. Therefore, CO_2 emissions can be reduced by approximately 6 t at the construction cost of approximately 5,000 yen/m^2



Annual CO_2 Emissions (Region VI)

Annual CO_2 Emissions Resulting From Cooler Use

(i) CO_2 emissions resulting from cooler use can be reduced by approximately 43–48% in comparison with before renovation (if coolers are already installed).

(ii) It is planned to reduce the energy consumed by coolers through conducting insulation and shading of the roof, while at the same time introducing high-efficiency equipment.

Annual CO_2 Emissions Resulting from Lighting

(i) Annual CO_2 emissions can be reduced by approximately 23%, from 25 to 19 t.

(ii) By upgrading to high-efficiency equipment and introducing illumination sensors and motion sensors, energy conservation will be promoted.

CO_2 Emissions [t-CO_2/year]

	Before Renovation		Environment-focused Renovation			
	Ordinary classrooms: Without coolers	Ordinary classrooms: With coolers	Ordinary classrooms: Cooling high-efficiency air conditioners	Contributing ratio of reduction effect (%)	Ordinary classrooms: Cooling ice thermal storage-type air conditioners	Contributing ratio of reduction effect (%)
Cooling	9.6	28.5	14.7 (−48%)	83.1	16.2 (−43%)	93.2
Heat release loss	–	–	–	0.0	1.9	−14.3
Electric Fans	0.9	–	–	0.0	–	0.0
Lighting	25.2	25.2	19.4 (−23%)	34.9	19.4 (−23%)	43.9
Ventilation	3.1	3.1	7.1	−24.0	7.1	−30.3
Water Supply	2.4	2.4	1.3 (−46%)	6.6	1.3 (−46%)	8.3
Other	2.5	2.5	2.6	−0.6	2.6	−0.8
Total	44	62	45 (−27%)	100	48 (−22%)	100

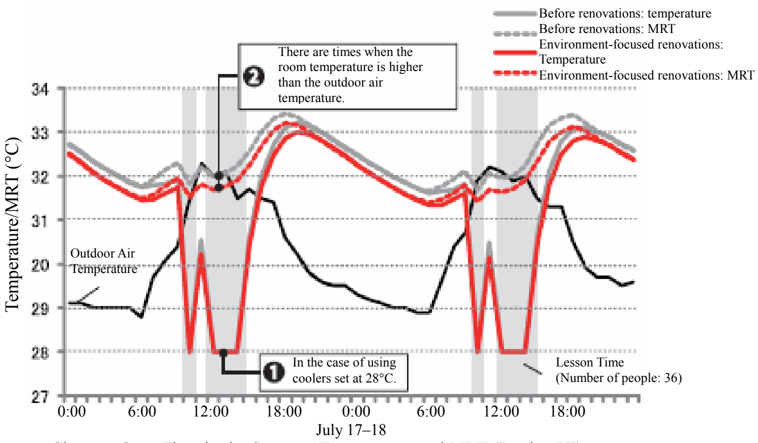
*Figures in parentheses represent the percentage share of the reduction in CO_2 emissions compared with the situation before renovations (in the case of installing coolers in classrooms).
*After environment-focused renovations, total heat exchange ventilators are installed in classrooms and management rooms.
*Heat release loss refers to heat storage electric energy used to replenish heat released from a thermal storage unit even on days when coolers are not used.

(2) Improvements in the Classroom Environment

(i) (In summer) Through the introduction of cooling equipment, and running it at a fixed temperature of 28°C, it is planned to improve the classroom thermal environment.

(ii) (In summer) Through shading sunlight by installing eaves, the surface temperature of internal walls will become lower, and the sensory temperature will become slightly lower, even under the same cooler temperature settings.

(iii) (In summer) When the windows in classrooms are closed during the night, heat is trapped inside, and the room temperature could exceed 32°C. Therefore, by implementing devices to allow ventilation at night, this will result in a reduction of cooling load in the morning.



Changes Over Time in the Summer Temperature and MRT (Region VI)
*MRT expresses the surface temperature of the walls in rooms.

(3) Reduction of Running Costs Resulting from Environment-focused Renovations

(i) Through environment-focused renovations, it is possible to reduce energy costs by approximately 20% if coolers are already installed.

(ii) If ice storage-type air conditioning is installed, it is possible to utilize late-night power, which has a cheaper electricity rate. Therefore, depending on the use ratio of late-night power, it is possible to restrain energy costs further than by high-efficiency air conditioners.

(iii) The table on the right shows the results of the estimate under certain assumptions in order to provide a rough guide. It is necessary to calculate the actual energy costs based on the contract contents and charge systems of each school.

Estimates of Energy Costs Before and After Renovations (Per Year)

	Before Renovations	Environment-focused Renovations
	Ordinary classrooms: With coolers	Ordinary classrooms: Cooling high-efficiency air conditioners
Ordinary electricity (cooking)	¥381,000	¥196,000
Ordinary electricity (lighting, etc.)	¥412,000	¥388,000
Ordinary electricity (basic charge)	¥2,556,000	¥2,090,000
Total	¥3,350,000	¥2,670,000
Comparison (%)	100	80 (20)

(4) Initial Costs of Environment-focused Renovations

(i) The construction cost of environment-focused renovations is approximately 119,000 yen/m^2, and the increase in unit cost attributable to adopting environmental measures is approximately 32,000 yen/m^2.

(ii) Of the construction costs of environment-focused renovations, costs of upgrading heaters, lighting equipment and hygiene equipment account for slightly over 30%.

(iii) Of the construction costs of environment-focused renovations, the cost of enhancing insulation accounts for just below 70%

Estimated Construction Costs per Unit of Total Floor Area (yen/m^2)

Type of Work	Main Content	Conventional Renovations	Environment-focused Renovations
		Earthquake resistance reinforcement + improvements to dilapidated facilities	Cooling & Heating in classrooms: Using air conditioners
Construction work	Demolition work, renovation work (installing the interior and exterior of the building and the joinery), earthquake resistance reinforcement	63,200	82,500
Mechanical equipment work	Hygiene equipment work (replacing toilets, etc.), water supply & drainage work, heating & cooling equipment work, ventilation equipment work	20,500	31,200
Electrical equipment work	Lighting equipment work, power supply work	3,300	4,900
Total		87,000	118,600

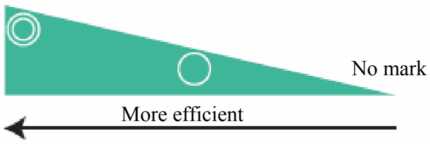
Environment-focused Renovation Model Plan Specifications and Effects

The table below shows the list of work conducted in each model plan for environment-focused renovations. It shows the efficiency of cost-effectiveness of each work for environment-focused renovations, as well as the effect of environmental improvement in rooms, energy conservation and measures to deal with dilapidation.

It is important to implement environment-focused renovations considering not only cost-effectiveness, but also the effect of environmental improvement in rooms, energy conservation and measures to deal with dilapidation in a comprehensive manner.

[How to use the table]

- The efficiency of cost-effectiveness



*If the efficiency of cost-effectiveness is high, it shows that the construction cost required for obtaining the same effect of CO_2 emissions becomes low.

- The ● in the table denotes the effect obtained by conducting the work for environment-focused renovation.
- The colored items ( ) denote the work conducted in each model plan for environment-focused renovations.

Renovation Item			Efficiency of Cost-effectiveness: Region Classification Under Energy Conservation Standards (See p.3)						Environment Improvement Effect in Room: Thermal Environment		Environment Improvement Effect in Room: Light Environment			Environment Improvement Effect in Room: Sound Environment	Energy Conservation Effect				Anti-dilapidation Measures
			I	II	III	IV	V	VI	Winter	Summer	Winter	Middle	Summer		Heating	Cooling	Lighting	Water	
Roofs & walls	1	Upgrading roof waterproofing																	●
	2	Roof insulation	○	○	○	○	○	○	●	●					●	●			●
	3	Internal wall insulation	/	/	/	○	○	/	●						●				
	4	External wall insulation	○	○	○	/	/	/	●						●				●
	5	Window insulation	○	○	○	○	○	/	●					●	●				●
	6	Installing ventilation louvers in classroom windows	/	/						●									
	7	Installing ventilation windows in stairwells	/	/						●									
	8	Adding eaves midway across the windows	/	○	○	○	○	○		●		●	●			●			
Internal Partitions	9	Installing doors that can be opened & closed in stairwells							●	●					●	●			●
	10	Changing to partitions with high windows between classrooms and the corridor									●	●	●						●
	11	Installing movable partitions between multi-purpose spaces and the corridor							●	●					●	●			●
Interior Finish	12	Internal walls are repainted white									●	●	●				●		●
	13	Floors are changed to cushioned flooring boards												●					●
	14	Ceilings are changed to decorative rock wool acoustic boards												●					●
Hygiene Facilities	15	Hand basins are changed to foam water taps	○	◎	○	○	◎	○										●	
	16	Changing to water-conserving toilets	○	◎	○	○	◎	○										●	●
	17	Toilets are installed with devices that imitate the sound of toilets being flushed	○	◎	○	○	◎	○										●	
	18	Urinals are changed to those with automatic flushes	○	◎	○	○	◎	○										●	●
Cooling & Heating Facilities	19	Upgrading from electric panel heaters to FF-type gas heaters	◎	/	/	/	/	/							●				●
	20	Upgrading air conditioners in special classrooms and management rooms to high-efficiency equipment	/		◎	◎	○	◎							●	●			●
	21	Installing air conditioners in ordinary classrooms, upgrading to high-efficiency equipment	/	/	○ B※	○ B※		◎		●					●				●
	22	Upgrading FF-type oil heaters	/		A※	A※	/	/											●
	23	Installing electric fans	/				/	/		●									
Lighting Facilities	24	Upgrading lighting equipment to high-efficiency equipment Installing sensors	◎	◎	◎	◎	◎	◎									●		●

*The A's and B's in the table show the work for renovations that only corresponds to Plan A or B in Regions III and IV.

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