Promoting Environment-focused Renovations of School Buildings (Gymnasiums)

Menu of Environment-focused Renovations and Results of a Simulation of Environmental Measures in Model Plans

—Report on a Fundamental Study of School Facility Environments—

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

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) since fiscal 2008, 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 in November 2010.

Among school facilities other than school buildings, it is very important to improve the exercise environment of gymnasiums in winter cold and summer heat for the maintenance and promotion of children's health.

In addition, school facilities are not only learning and living places where children carrying the next generation spend most of the day, but also have an important role as an emergency evacuation site for the local population in the time of disaster. It is widely known that, in the Great East Japan Earthquake that occurred on March 11, 2011, a large number of school facilities, especially gymnasiums, served as emergency evacuation sites for the local population. However, there were various issues concerning the indoor conditions of the gymnasiums as emergency evacuation sites, which include winter cold, summer heat and insufficient ventilation.

In July 2011, an advisory committee organized by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) compiled the Urgent Recommendation "*Concerning School Facility Improvement in Light of the Damage Caused by the Great East Japan Earthquake.*" The recommendation suggested that to improve the indoor environment "It is necessary to consider how to ensure heat insulation performance," "- In cold regions, it is effective to install heating facilities" and "When planning measures against heat in summer, it is important to design (omitted) with attention given to ventilation while ensuring heat insulation performance."

In addition, combining environmental measures with renovation of aging buildings which is expected soon to be firmly underway is effective for both improving the indoor environment required for today's school facilities and for reducing the environmental burden.

From such background, the institute started a study of environmental measures including the improvement of the indoor environment of existing gymnasiums as part of the Fundamental Study of School Facility Environments.

This report analyzed issues concerning the indoor environment of school gymnasiums and environmental considerations and, based on the effects on the reduction of environmental burden, promotion of resource/energy conservation and environmental education, proposes environmental measures that can be implemented when renovating existing gymnasiums. We expect this report will widely spread as useful material among people involved in school facilities.

March 2012

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Chapter 1 Overview of the Investigative Research

1 Current Situation of School Facilities (Gymnasiums)

(1) Aging of Gymnasiums

- School facilities are learning and living places for children while having an important role as emergency evacuation sites for the local population in the time of disaster.
- However, 42.9% of gymnasiums of public elementary/junior high schools were built more than 30 years ago while those built more than 20 years ago account for 72.7%. Addressing the aging of existing gymnasiums is a major challenge for the future.

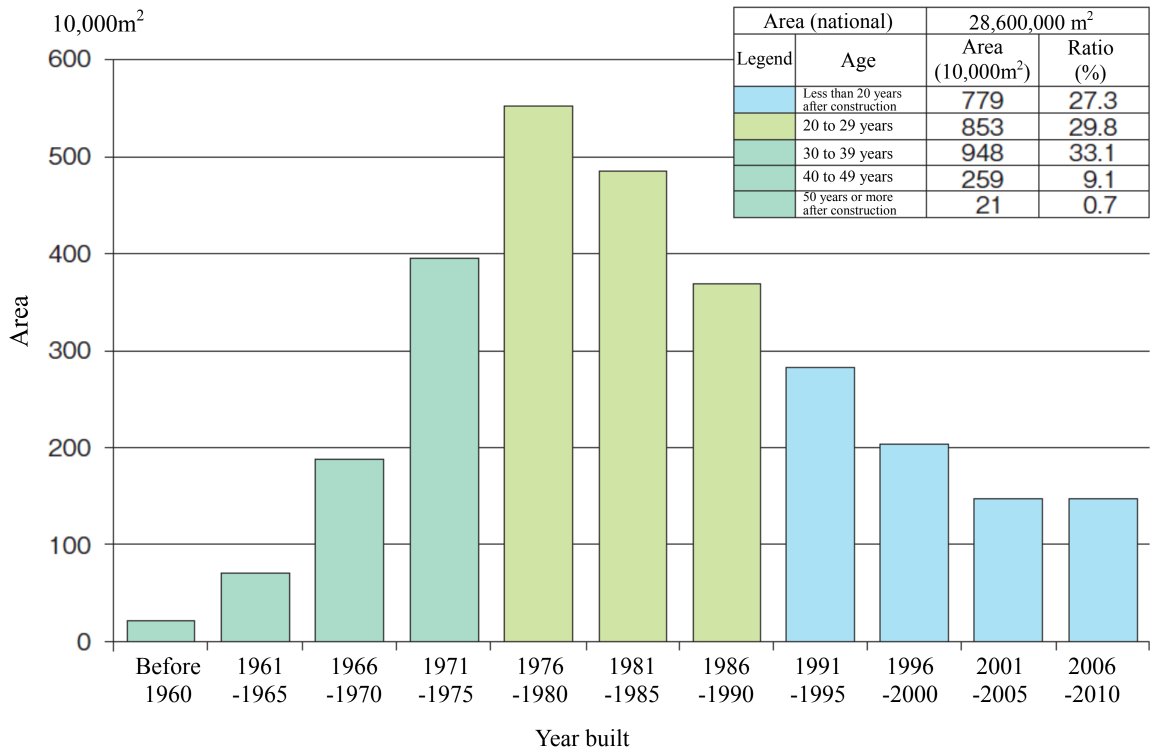
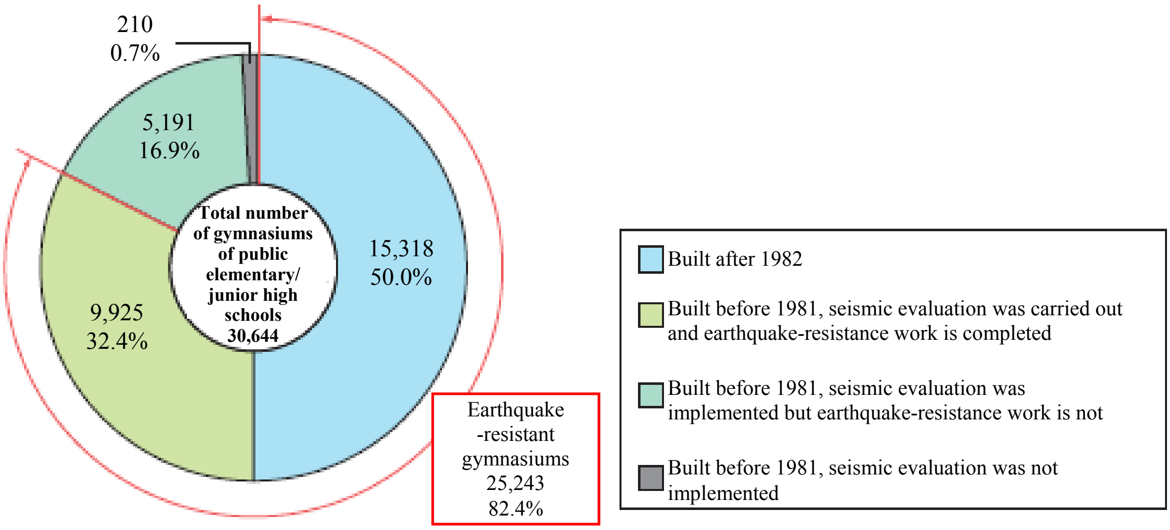


Figure 1 Area of Gymnasiums of Public Elementary/Junior-high Schools by Age (As of May 1, 2010)

Created based on the data of Local Facilities Aid Division, Department of Facilities Planning and Administration, MEXT

(2) Rate of Earthquake-Resistant Gymnasiums

- Earthquake-resistance retrofitting of school facilities is underway, with 25,243 out of 30,644 gymnasiums of elementary/junior high schools nationwide (excluding Iwate, Miyagi and Fukushima Prefectures) already earthquake-resistant as of April 1, 2011, making the rate of earthquake-resistant gymnasiums 82.4%.
- In the “Basic Policy for Improvement of Public Compulsory Education School Facilities” (Public Notice No.89 of the Ministry of Education, Culture, Sports, Science and Technology in 2011), MEXT aimed to complete earthquake-resistance retrofitting of public elementary/junior high school facilities as early as possible and is urging local governments to advance earthquake-resistance retrofitting including that of gymnasiums.



Created based on the data of Local Facilities Aid Division, Department of Facilities Planning and Administration, MEXT

		Number of gymnasiums	Ratio (%)		Remarks
Built after 1982		15,318	50.0	82.4	Earthquake-resistant
Built before 1981	Seismic evaluation was carried out and earthquake-resistance work is completed	9,925	32.4		
	Seismic evaluation was carried out but earthquake-resistance work is not yet completed	5,191	16.9	17.6	Not earthquake-resistant
	Seismic evaluation was not carried out	210	0.7		
Total		30,644	100.0	100.0	

*The total number does not include gymnasiums in Iwate, Miyagi and Fukushima Prefectures

* Gymnasiums that are not earthquake-resistant include those for which earthquake-resistance is not yet confirmed.

Figure 2 Earthquake-resistance Status of Public Elementary/Junior-high School Gymnasiums (As of April 1, 2011)

2 Investigative Research Goals and Contents

(1) Background and Goals

- For school gymnasiums, the urgent task of earthquake-resistance retrofitting has advanced at a rapid pace, making the rate of earthquake-resistant public elementary/junior high school gymnasiums 82.4%. Many municipalities have completed the work for all of their gymnasiums. On the other hand, aging of gymnasiums is in a serious state with 72.7% of them having been built 20 years ago or more. School establishers are expected to earnestly take measures against aging. In this process, it may be important to advance environment-focused renovation for reduction of environmental burden and symbiosis with nature while improving their indoor environment, giving consideration to maintenance and promotion of children's health, their likelihood to be used as emergency evacuation sites and contribution to creating a low-carbon society.
- MEXT and the National Institute for Educational Policy Research have set forth key points in designing facilities considering the reduction of environmental burden and symbiosis with nature in the past study reports while promoting the equipping of environmentally-conscious school facilities (eco school). However, detailed study of gymnasiums, the structure and use of which are different from those of school buildings has not been conducted. Therefore, it was decided to conduct Investigative Research on environmental measures including indoor environment improvement of existing gymnasiums.

(2) Investigative Research Contents

- Contents of the Investigative Research is as follows:
  (i) Identification of menus of environment-focused renovation that may be used for existing gymnasiums
  (ii) Assessment/examination of the effects and initial cost of introducing the menus of environment-focused renovation
  (iii) Formulation of the model plans of environment-focused renovation with consideration of the gymnasium environment for each region, considering the results of the evaluation above and weather conditions of each region. The model plans for each region were formulated based on the comprehensive assessment of renovation contents, effects, initial cost and other factors.

(3) Implementation system of the Investigative Research

- The Working Group on a Fundamental Study of School Facility Environments was set up as a working group of the National Institute for Educational Policy Research (decision by the Director General of the National Institute for Educational Policy Research on October 24, 2007) and started Investigative Research on the issue in FY 2010 (see Reference 5, the outline for setting up of the working group)

Chapter 2 Considering Environment-Focused Renovation

1 Basic Concept and Menus of Environment-Focused Renovation

(1) Basic Concept of Environment-focused Renovation of Gymnasiums

(i) Improvement of indoor environment

(Thermal environment)

- Gymnasiums are places for children to do physical exercise and at the same time have roles as auditoriums for school events and emergency evacuation sites for the local population in the time of disaster*. Environment-focused renovation is effective to ensure an adequate thermal environment for gymnasiums to fulfill these roles.

  * For improvement of school facilities as emergency evacuation sites in the time of disaster, see *Urgent Recommendation "Concerning School Facility Improvement in Light of the Damage Caused by the Great East Japan Earthquake"* (http://www.nier.go.jp/shisetsu/pdf/e_Urgent_Recommendationl_Body.pdf)
- To secure a comfortable thermal environment in a gymnasium, it is necessary to consider insulating the building to prevent the loss and entering of heat (through rooftop, walls, windows, etc.) and shading from sunshine (covers, louvers) in accordance with the climate of each region. In order to secure a comfortable thermal environment in a large space such as a gymnasium in winter, it is effective to improve airtightness to reduce drafts.
- Nationwide, few gymnasiums are equipped with cooling installation. It is necessary to take measures such as natural ventilation using the temperature difference between the near-floor part and the higher part. Gymnasiums other than those in Hokkaido and Tohoku are not equipped with heating installations. It is necessary to improve insulation and airtightness to address winter cold in order to prevent injury during physical education class as well.

(Light environment)

- In order to secure a comfortable light environment in gymnasiums and energy conservation of lighting equipment, it is important to actively use daylight through openings at the high level (top light, high sidelight.) In addition, it is necessary to consider shielding direct sunlight that interferes with exercise and installing black-out curtains if it is necessary to darken the gymnasium for school events/gatherings.

(ii) Efficient Use and Operational Management of Energy

- Because a large part of electric energy in a gymnasium is used for lighting equipment, it is necessary to replace them with energy-saving equipment while considering introducing switch panels to enable zone control of lighting.
- It is necessary to conduct adequate operational management including review of the set temperatures for heating, modifying timetables of classes for consecutive use of heating/lighting equipment and regular lamp replacement to increase lighting efficiency.

(iii) Introduction of installations which utilize natural energy

- It is desirable to introduce installations which utilize natural energy such as photovoltaic generation, hot air floor heating system using solar heat and rain water utilizing installations.

(iv) Other

- When installing a suspended ceiling in a gymnasium, it is necessary to take safety measures including an anti-drop mechanism. Considering that gymnasiums may serve as evacuation sites for the community, it is also important to consider enhancement of disaster-prevention functions including communication equipment.

(2) Structure of Menu of Environment-focused Renovation

- Based on the basic concept, we have selected subjects thought to be effective as environmental measures for gymnasiums and organized and classified them in Table 1 as a menu of environment-focused renovation.
- Each menu consists of "concepts," "keywords" and "specific methods of improvement." Based on the "key words" derived from the "concepts," "specific methods of improvement" thought to be effective are examined.

Table 1 menu of environment-focused renovation thought to be effective for gymnasiums

Concept		Key word	Specific methods of improvement
Built in a Friendly Manner*	Preserving an Appropriate Indoor Environment	1 Improving Insulation Performance (**improving airtightness performance)	(1) Rooftop insulation (2) Insulation of floor/ in walls (3) Insulation in openings
		2 Shading from Sunshine/Preventing Reflection	(4) Outside shade (louver type) (5) Wall vegetation
		3 Appropriate Indoor Temperature	(6) Heating of a large space
		4 Equalizing Indoor Illumination	(7) Finishing with high rate of reflection
Use Wisely for Many Years*	Utilizing the Blessings of Nature	5 Use of Natural Ventilation	(8) Securing ventilation utilizing temperature difference
		6 Use of Natural Light	(9) Use of daylight
		7 Utilizing as a Source of Energy	(10) Solar energy generation (11) Use of heat emitted by sun (12) Utilization of rain water
	Using Efficiently and Economically	8 Efficient Use of Energy	(13) Replacement with energy conserving lighting equipment
		9 Appropriate Operational Management	(14) Zoning of lighting equipment (15) Consecutive use
Utilized for Learning*	Environmental Education	10 Ideas for Learning about Environmental Problems	(16) Implementing into environmental education

* Basic Concept of *Concerning the Equipping of Environmentally-conscious School Facilities (eco school)* (Investigative Research Report Concerning Environmentally-conscious Measures Within School Facilities in March 1996)

** To secure a good indoor environment in a large space, improving airtightness performance of openings is an important key word in addition to insulation performance.

(3) How to Utilize Menu of Environment-focused Renovation

- For "specific methods of improvement" of the menu of environment-focused renovation, the next chapter introduces cost/effect simulation results of typical cases. We hope these results become a helpful resource for school facility staff to consider environmental measures when renovating existing gymnasiums.

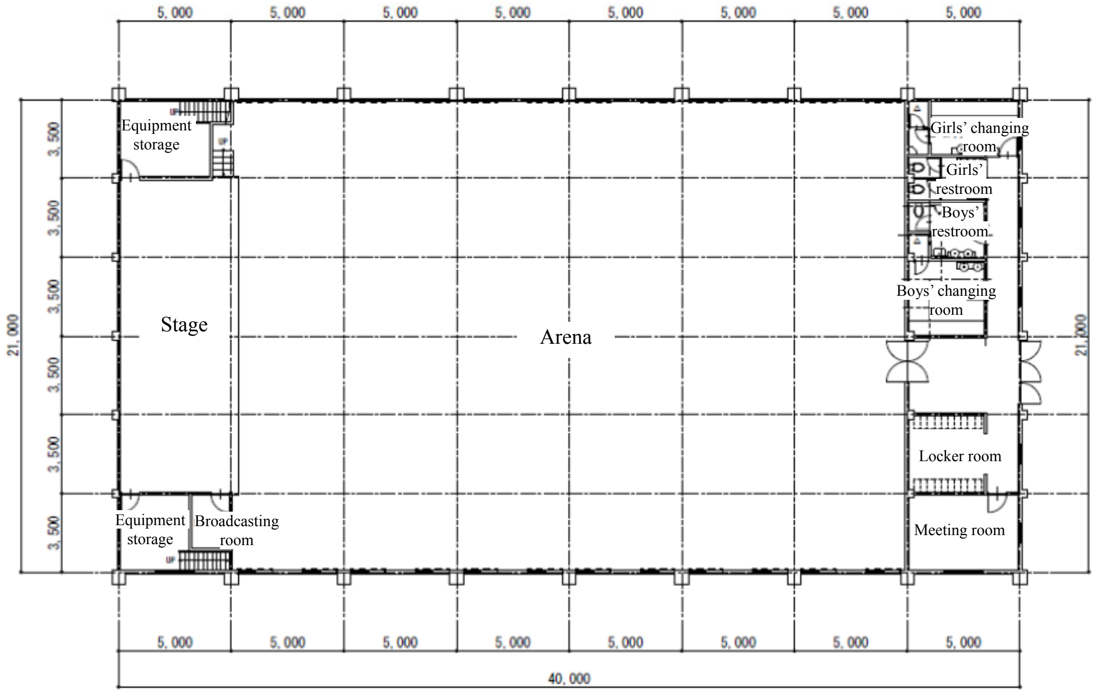
2 Conditions Relevent to Simulation

(1) Existing Gymnasium Model

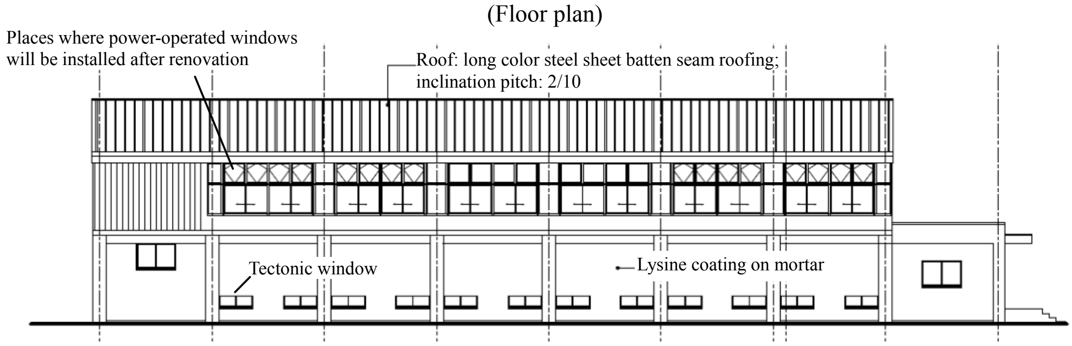
- Specifications of the model set for estimation are shown in Table 2. The area is that of typical public elementary/junior-high school gymnasiums. The model drawing is created based on Design Examples 1 (S type) and 2 (SR type) of the *Manual of Seismic Retrofitting of School Facilities—Steel Frame Indoor Sports Facility* (2003 edition)(Figure 3)
- It is presumed that the existing gymnasium is earthquake resistant.
  It is assumed that the interior/exterior and building equipment are past their durable years and are to be replaced.

Table 2 Specification of Existing Gymnasium Model

Structure	Lower gallery: RC; Upper gallery: S
Opening	On the east and west
Floor area	930m^2 (1st floor arena: 630m^2)
Insulation	None
Window sash	Single-pane glass
Roof	Batten seam roofing (without high solar reflectance coating)
Heating method	Kerosene fan heater (only in Regions I and II)
Set temperature for heating	15 degrees C (only in Regions I and II)
Lighting	Mercury lamp (400W/lamp) ---------- 24 lamps: Ensuring average floor illuminance of 300lx



(Floor plan)



(Elevation)

Figure 3 Drawings of Existing Gymnasium Model

(2) Method of Calculating Initial Cost

- Initial costs of renovation menus in Chapter 3 are estimations of the renovation work cost of each improvement method and do not include costs of related works.
- Initial costs of model plans for each region in Chapter 4 are estimations of the renovation work cost of the entire gymnasium and include related, temporary and removal works.
- Unit prices of the equipment/material used for estimation are those in Kanto or Tokyo. Prices may vary in other regions.
- Be advised that they are just reference values because the actual construction cost may vary depending on the design condition and other factors.

(3) Method of Calculating Running Cost

- Unit prices used for estimating the running cost of model plans for each region in Chapter 4 are those in Kanto or Tokyo. Prices may vary in other regions.
- The running cost of electricity use is estimated assuming a contract covering only the gymnasium. If the contract includes the school building, etc., the basic charge will be reduced.
- Be advised that they are just reference values because the actual running cost may change depending on the design condition, characteristics of the region, contract detail and other factors.

(4) The Region on Which the Model Plans Focus and Detailed Conditions

- Simulations of effects in menu of environment-focused renovation (Chapter 3) and simulations in model plans by region (Chapter 4) are calculated under the conditions in Tables 3 to 8.
- For model plans by region (Chapter 4) the country is divided into Regions I to VI under the Energy Conservation Standard and effects are calculated for each region. The Regions are shown in Figure 4.
- Simulations of Menus of environment-focused renovation in Chapter 3 are based on the conditions of Tokyo in Region IV.
- Simulations of Menus of environment-focused renovation are made only for the area of the arena.

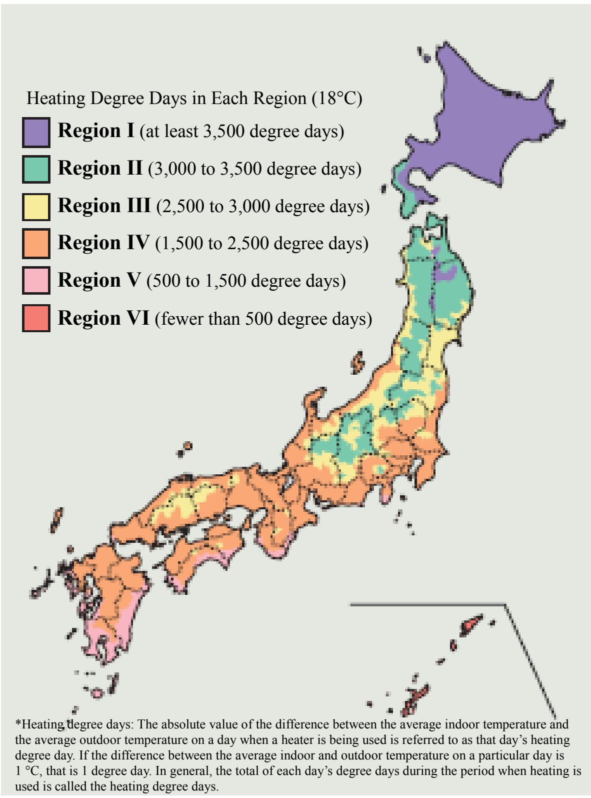


Figure 4 Regional Classifications Under Energy Conservation Standards
(Source) Japan Center for Climate Change Actions
Website: http: //www.jccca.org/

Table 3 Common Conditions (before/after renovation)

Item	Content
Calculator	DAIKUKAN[1]
Meteorological data	Expanded AMEDAS weather data: 1981-2000
Floor area	630m^2 (arena)
Period of use	203 weekdays (excluding long vacations; days off on Saturdays and Sundays)
Hour of use	Pattern 1: 8:00-15:00 (class) 18:00-21:00 (facilities are open to citizens) Pattern 2: 8:00-16:00 (class) 16:00-18:00 (club activities) 18:00-1:00 (facilities are open to citizens) *including time for preparation, etc. *Pattern 1 assumes elementary school while Pattern 2 assumes junior-high school
Lighting time	Pattern 1: 8:00-15:00 (50%) 18:00-21:00 (100%) Pattern 2: 8:00-16:00 (50%) 16:00-18:00 (100%) 18:00-21:00 (100%) *Gymnasium use rate on weekday throughout year in ( )
Heating time	Consecutive operation from 8:00 to 21:00 (Regions I and II)
Heat generation from human body	70 students (2 classes) Standing position: 0.75 times of 1.2met (child)
Internal heat generation	Twenty four 400W mercury lamps (15.8W/m^2) *Ensuring average floor illuminance of 300lx * Lighting equipment is not mercury lamps after renovation of model plan by region.
Setting of heating (only in Regions I and II)	15 degrees C Supply temperature: set at 50 degrees C[2] Number of outlets: set to maintain airflow speed under 7.0m/s[2]
Airtightness performance * Estimated based on the existing literature[3,4]	(Before the renovation) Window sash: equivalent leakage area 21.44cm^2/m^2 (*equivalent to Grade A-2) equivalent leakage area per roof/wall/floor area: 1.78cm^2/m^2 (*differential pressure: 1mmAq) (After the renovation) Window sash: Equivalent leakage area 5.36cm^2/m^2 (*Equivalent to Grade A-3) Equivalent leakage area per roof/wall/floor area: 0.45cm^2/m^2 (*differential pressure: 1mmAq)

Table 4 Assumed Period of Long Vacations

	Summer	Winter	Spring
Regions I and II	Jul. 24 – Aug. 17	Dec. 24 – Jan. 19	Mar. 25 – Apr. 7
Regions III to VI	Jul. 20 – Aug. 31	Dec. 24 – Jan. 8	Mar. 25 – Apr. 7

*Major cities of the regions are: Sapporo (Region I), Morioka (Region II), Fukushima (Region III), Tokyo (Region IV), Kagoshima (Region V) and Naha (Region VI)

Table 5 Heating Period (Regions with heating installation (Regions I and II))

Region I (Sapporo)	Oct. 15 to May 15
Region II (Morioka)	Nov. 1 to Mar. 31

1 Indoor heat load calculator considering vertical temperature distribution created by the Heat Road Calculation Panel, the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan

2 Kobayashi, et al, Study on Heating System of Gymnasiums, Collection of Papers NO.89, April 2003, The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan

3 Enai, Kubota and Aratani, Hokkaido ni okeru Taiikukan, Netsu Shinpoziumu, Heat Panel, Research Committee on Environmental Engineering, Architectural Institute of Japan the 17th Conference

4 Murakami and Yoshino,"Investigation of Air-Tightness of Houses," Transactions of the Architectural Institute of Japan, No.325, May 1983

Table 6 Site Conditions of Gymnasiums Before Renovation

Site	Constructional element	Thickness	Solar absorptivity
Roof	Steel plate Wood wool cement board	0.5mm 30mm	0.8
Wall	Mortar Concrete Plywood	30mm 150mm 5.5mm	0.7
Floor	Flooring material Plywood	15mm 18mm	—
Opening	Aluminum sash + single-pane glass		—

Table 7 Simulation Conditions of Menu of Environment-focused Renovation

Environment-focused Renovation Menu		Specification of the renovation
(1) Rooftop Insulation/ Shielding	a Thermal insulation covering	Insulation thickness: 20mm rigid urethane foam
	b Covering (vent layer installation)	Calculated with solar reflectance of 0.6
	c High solar reflectance coating	Calculated with solar reflectance of 0.2
(2) Insulation of Floor/ Wall Surfaces	a Underfloor thermal insulation (foundation thermal insulation)	Insulation thickness: 20mm sprayed rigid urethane foam
	b Dry exterior thermal insulation (thermal insulation covering)	Insulation thickness: 20mm rigid urethane foam
	c Wet exterior thermal insulation	Insulation thickness: 20mm rigid urethane foam
	d Spraying insulation material	Insulation thickness: 20mm sprayed rigid urethane foam
(3) Insulation in Openings	a Pair glass	U-value = 4.65W/(m^2K)
	b Low-e pair glass	U-value = 4.07W/(m^2K) solar heat gain coefficient: μ = 0.43
(6) Devices for Heating of a Large Space*1)	a Sucking in warmed air through floor	Roof/wall Insulation thickness: 40mm rigid urethane foam Floor Insulation thickness: 40mm sprayed rigid urethane foam
	b Blowing warmed air from floor	
	c Floor heating	
(7) Finishing with High Rate of Reflection	a Finishing with high rate of reflection	Wall/ceiling reflection rate: 0.7 Floor reflection rate: 0.25
(8) Securing Ventilation Utilizing Temperature Difference	a Ventilation utilizing temperature difference	Permanent opening of tectonic windows*2) and high openings (at the level of 6.0m) Flow rate coefficient of tectonic window: 0.65 Flow rate coefficient of high opening: 0.33 (only tectonic windows were open from 8:00 to 15:00 before the renovation)
(9) Use of Daylight	a Use of daylight	500mm×2000mm slit (top light) Transmittance: 0.5
		Transmittance: 0.5
(10) Solar Energy Generation	a Solar energy generation	Generation capacity: 4.0kW (one installation on the south side)
(11) Use of Heat Emitted by Sun	a Use of heat emitted by sun	System efficiency: 15%
(12) Roof Spray Cooling Using Rain Water	a Roof spray cooling using rain water	Spray amount: 1.5kg/m^2h
(13) Replacement with Energy Conserving Lighting Equipment	a Replacement with energy conserving lighting equipment	Power consumption of equipment Mercury lamp: 440W Ceramic metal halide lamp: 260W Electrodeless discharge lamp: 260W LED: 135W
(14) Zoning of Lighting Equipment	a Changing switching system of lighting equipment (zoning control)	Calculation of control according to the brightness: divide the space into eight zones. If the illuminance of any point directly beneath lighting equipment is below 300lx, light all lighting equipment of the zone. Turn off the lights when it is 300lx or higher. Number of lighting equipment units: 3/zone (24 in total) It is assumed that, when the direct illuminance at the window is over 20,000lx, (blackout) curtains are drawn and neither skylight nor direct light enter the gymnasium.

*1) Meteorological data of Sapporo is used for (6) Devices for heating of a large space. Meteorological data of Tokyo is used for other items.
*2) See Figure 3 for the location of tectonic windows

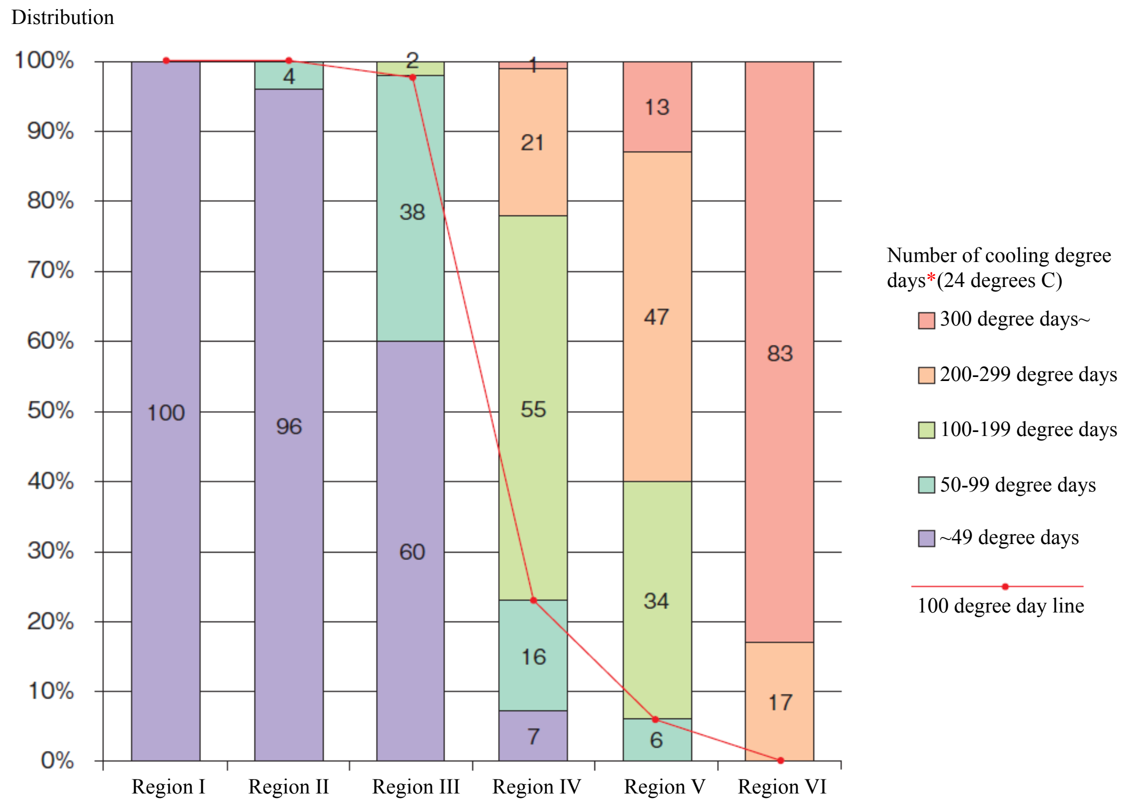
Table 8 **Simulation Conditions of Model Plans by Region**

CO_2 emissions of heating (Regions I and II) and temperature in winter (Region III) and summer (Regions IV to VI)	Insulation performance before renovation: see Table 6 Insulation performance after renovation: see List of environment-focused renovations for each Region*1) *Other conditions are in Tables 3 to 5	
CO_2 emissions from lighting	Lighting condition	Before renovation: all lamps are lighted After renovation: Zone control Divide the space into eight zones. If the illuminance of any point directly beneath lighting equipment is below 300lx, light all lighting equipment of the zone. Turn off the lights when it is 300lx or higher.
	Reflection rate	Ceiling: 0.35; Wall: 0.25; Floor: 0.25 Ceiling: reflection rate of typical grey; Wall/floor: reflection rate of typical brown
	Opening/ drawing of curtains	It is assumed that, when the direct illuminance at the window is over 20,000lx, (blackout) curtains are drawn and neither skylight nor direct light enter the gymnasium.

*1) Insulation thickness is based on the insulation thickness of the wall in the simplified point method of *the Standards of Judgment for Construction Clients, etc. and Owners of Specified Buildings*

3 Basic Concept of Model Plans for Each Region

- Implement measures with high CO_2 reduction effect based on the CO_2 emission characteristics of gymnasiums. In cold regions, for example, take measures to reduce heating energy first, but take measures to reduce use of power for lighting first in other regions.
- Secure appropriate thermal environment year-round as long as possible.
- Consider the climate and geographical conditions of the Region. For example, improve the thermal environment in winter in cold Regions and improve the thermal environment in summer in other Regions. The city distribution by cooling degree days in Regions I to VI of the Energy Conservation Standard is shown in Figure 5 for reference. The big difference between Region III and IV at the line of 100 degree days shows the greater need to improve the summer thermal environment in Regions IV to VI.
- Reduce the environmental burden by introducing high efficiency lighting and other equipment while improving building performance through thermal insulation and incorporating use of natural energy including wind.
- Choose renovation contents within the budget.



* Cooling degree days: The absolute value of the difference between the average indoor temperature and the average outdoor temperature on a day when cooling equipment is being used is referred to as that day's cooling degree day. If the difference between the average indoor and outdoor temperature on a particular day is 1 °C, that is 1 degree day. In general, the total of each day's degree days during the period when cooling equipment is used is called the cooling degree days.
The figure shows that, for example, in Region I there is no city with expanded AMEDAS weather data for cooling degree days exceeding 50. Cooling degree days of any city in the region are below 50. In Region VI, cooling degree days are over 300 in 83% of the cities with data, while cooling degree days of the remaining 17% are within the range of 200 to 299.

Figure 5 City Distributions by Cooling Degree Days in Each Region of the Energy Conservation Standard (Analyzed based on the expanded AMEDAS weather data 1981-2000)

4 Points to Keep in Mind when Using Model Plans for Each Region

- In the CO_2 emission simulation, reduction rates are estimated assuming use only during the set time period. Be advised that the use outside the set time period will change the simulation result.
- When considering environment-focused renovation for individual cases, it is necessary to check the conditions with consideration of the geographical conditions and climate of the region based on the actual conditions of the school.
- When considering environment-focused renovation for individual cases, it is necessary to formulate a plan with attention to regulations by ordinance of the local government (limitation of total floor area/height, etc.)
- To grasp energy use and CO_2 emissions of individual gymnasiums, it is necessary to know the actual usage of the facilities and equipment.
- When making close examination of renovation effects, it is necessary to conduct higher precision simulation with detailed input conditions based on the operation by the school. The simulation may require a separate budget in addition to design fees.

Chapter 3 Environment-focused Renovation Menu

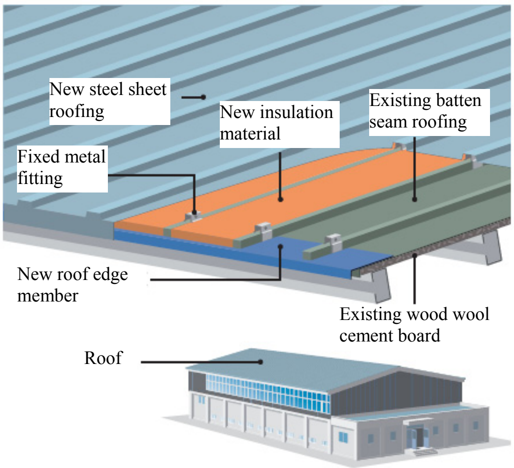
1 Improving Insulation Performance (Improving Airtightness Performance)

(1) Rooftop Insulation/Shielding

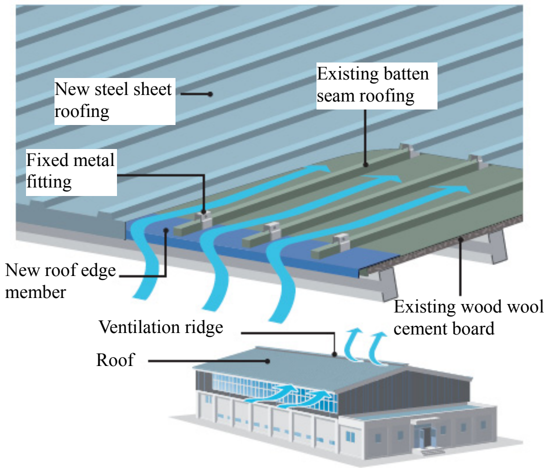
Outline of the improvement method

Example of the improvement method

a Thermal insulation covering



b Covering (vent layer installation)



Features and necessary points

a Thermal insulation covering

● **Features**

- Insulation work of roof by covering (laying insulation material on existing batten seam roofing and covering it with steel plates)
- Temperature fluctuation on the roof surface due to receiving solar radiation heat is reduced by laying insulation material.
- Insulation materials can be installed on the existing roof, which also prevents corrosion of and rain water damage to the existing roof materials.
- There will be no waste that might be generated by tearing down an existing roof.

● **Necessary points**

- Pay due attention because increased load on the building may require reinforcement in some cases.

b Covering (vent layer installation)

● **Features**

- Double roofs by covering method secures ventilation (creating a vent layer on the existing batten seam roof and covering using steel plates)
- The existing roof can be covered with steel plates, which also prevents corrosion of and rain water damage to the existing roof materials.
- There will be no waste that might be generated by tearing down an existing roof.

● **Necessary points**

- Pay due attention because increased load on the building may require reinforcement in some cases.
- Because the method improves heat shielding but not insulation performance, improvement in the thermal environment in winter is not expected.

Cost/Effect

Initial cost

a: Insulation material installation: 8,000 to 10,000 yen/m^2 (roof area)

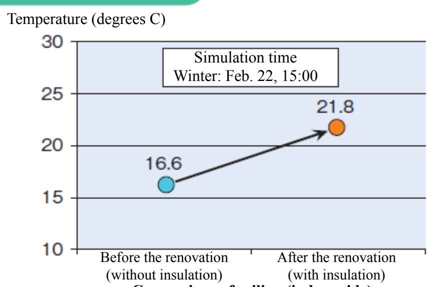
- Specification: installed over the existing roof material
- Including construction cost

b: 5,000 yen to 8,000 yen/m^2 (roof area)

- Specification: installed on the existing roof material
- Including construction cost

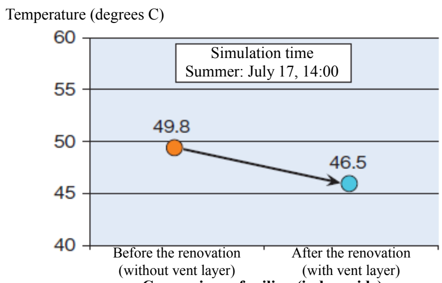
Evaluation of effects

Simulation result



Comparison of ceiling (indoor side) surface temperature (in winter)

* Because the ceiling surface temperature is higher than before the renovation when the room temperature is low in winter, the sensible temperature caused by radiation heat is higher.



Comparison of ceiling (indoor side) surface temperature (in summer)

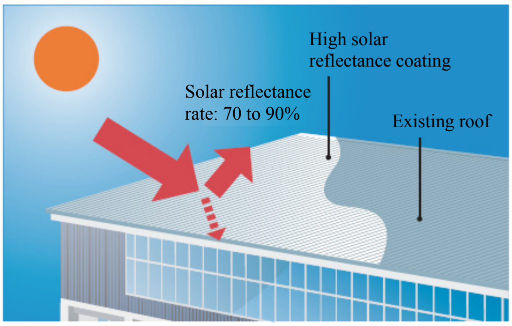
* Because the ceiling surface temperature is lower than before the renovation when the room temperature is high in summer, the sensible temperature caused by radiation heat is lower.

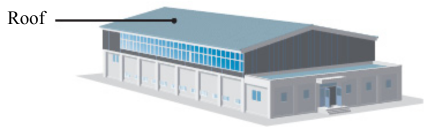
(1) Rooftop Insulation/Shielding

Outline of the improvement method

Example of the improvement method

c High solar reflectance roof coating





Features and necessary points

● **Features**

- Washing existing roof and applying high solar reflectance paint
- Heat shielding effect is improved without major renovation work.

● **Necessary points**

- Because the method improves heat shielding but not insulation performance, improvement in the thermal environment in winter is not expected.
- It is necessary to consider the impact of reflected light on the neighborhood.

Cost/Effect

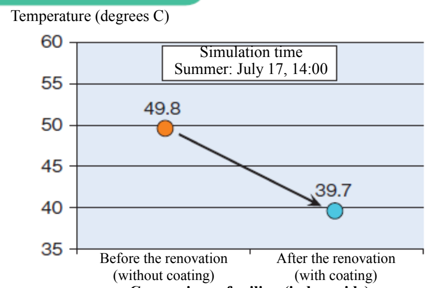
Initial cost

3,000 yen to 6,000 yen/m^2 (of roof area)

- Specification: Washing existing roof and applying high solar reflectance paint
- Excluding washing cost

Evaluation of effects

Simulation result



Comparison of ceiling (indoor side) surface temperature (in summer)

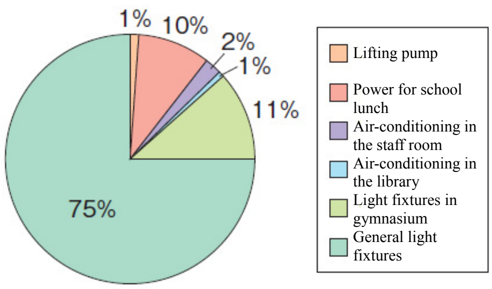
* Because the ceiling surface temperature is lower than before the renovation when the room temperature is high in summer, the sensible temperature caused by radiation heat is lower.

TOPIC

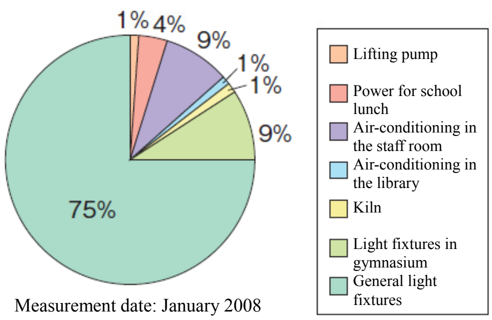
[Electrical energy consumption structure at schools]

- Energy used in gymnasiums accounts for about 10% of all energy consumption in schools.
- Examples below are both in Region IV. The electrical energy consumption structure is different in other Regions.

Example of municipal elementary schools in Kanagawa Prefectural (without cooling in classrooms)

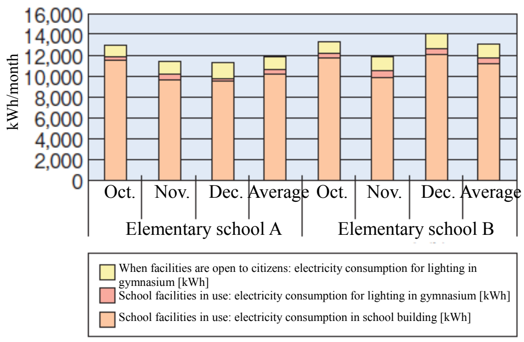


Measurement date: July 2007



Measurement date: January 2008

Example of municipal elementary schools in Chiba Prefecture



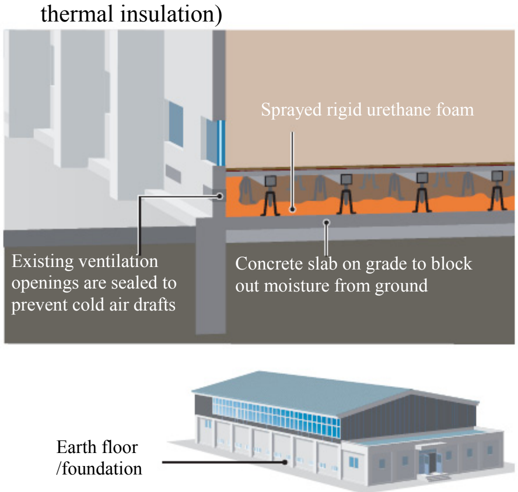
Source: Data created by Project Leader Komine

(2) Insulation of Floor/ Wall Surfaces

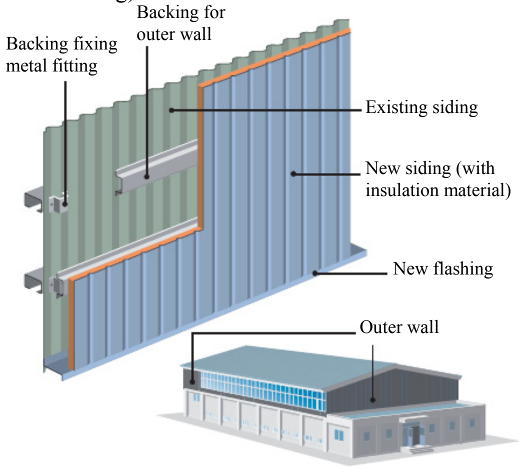
Outline of the improvement method

Example of the improvement method

a Underfloor thermal insulation (foundation thermal insulation)



a Dry exterior thermal insulation (thermal insulation covering)



Features and necessary points

Underfloor thermal insulation

● **Features**

- Improving insulation performance of floor by spraying insulation material on earth floor
- Improving insulation performance by spraying insulation material when removing floor materials and wooden floor posts in improvement work of aged facilities (including squeaking floors)

● **Necessary points**

- If the existing gymnasium has underfloor ventilation openings, it is necessary to seal them.
- When sealing ventilation openings, it is necessary to check whether damp proofing has been made such as concrete slab on grade.

Dry exterior thermal insulation

● **Features**

- Insulation materials installed on the existing outer wall protect the building from outdoor air and sunlight as well as having the effect of slowing aging degradation of the building.
- No waste that might be generated by demolishing the existing siding.

● **Necessary points**

- Pay due attention because increased load on the building may require reinforcement in some cases.
- If there is equipment such as piping on the outer wall, it is necessary to remove and renew it.

Cost/Effect

Initial cost

1,500yen/m² (of floor base)

- Specification: Spraying urethane foam
- Including construction cost
- Excluding damp proofing and ventilation opening work

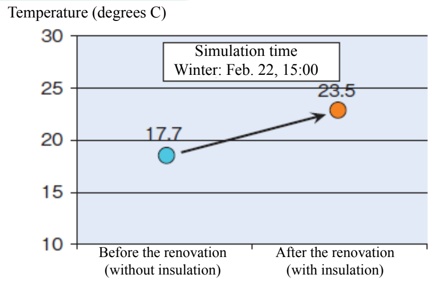
*Assumed that the construction work is done at the same time with floor replacement

Dry method: 14,000 to 20,000 yen/m² (of wall area)

- Specification: construction on existing outer wall
- Including construction cost

Evaluation of effects

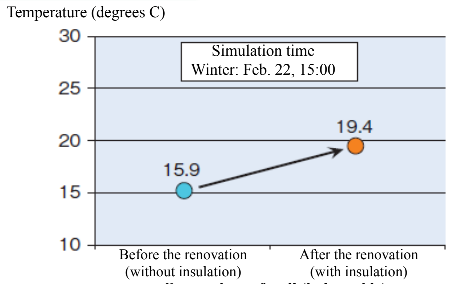
Simulation result



Comparison of floor surface temperature (in winter)

* Because the floor surface temperature is higher than before the renovation, chilling from the floor is reduced.

Simulation result



Comparison of wall (indoor side) surface temperature (in winter)

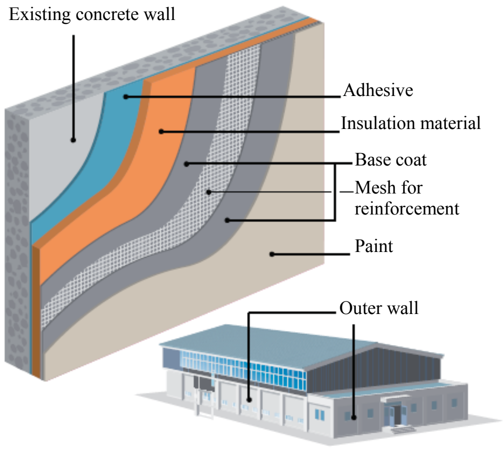
* Because the wall surface temperature is higher than before the renovation when the room temperature is low in winter, the sensible temperature caused by radiation heat is higher.

(2) Insulation of Floor/ Wall Surfaces

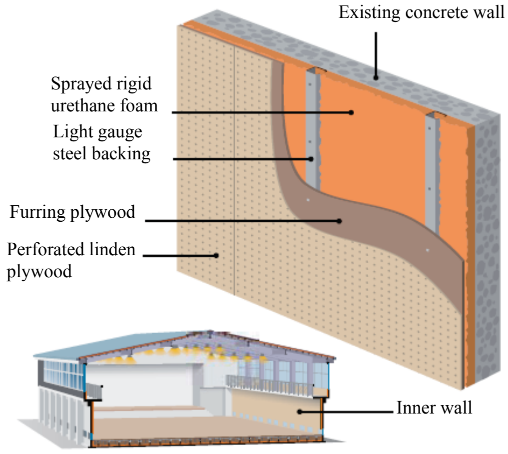
Outline of the improvement method

Example of the improvement method

c Wet exterior thermal insulation



d Spraying insulation material



Features and necessary points

c Wet exterior thermal insulation

● **Features**

- Insulation materials installed on the existing outer wall protect the building from outdoor air and sunlight as well as having the effect of slowing aging degradation of the building.
- The temperature on the indoor side of the concrete wall rises in winter, which prevents internal condensation

● **Necessary points**

- If there is equipment such as piping on the outer wall, it is necessary to remove and renew it.

d Spraying insulation material

● **Features**

- Spraying insulation materials on the inside of the concrete outer wall.
- Containing gas with very low thermal conductivity, urethane foam outperforms other insulation materials.
- It can be sprayed seamlessly even on places where applying and injecting are difficult.

● **Necessary points**

- It is necessary to finish by applying perforated linden plywood, etc. over the sprayed insulation material.

Cost/Effect

Initial cost

Exterior thermal insulation 15,000 yen/m^2 (of wall)

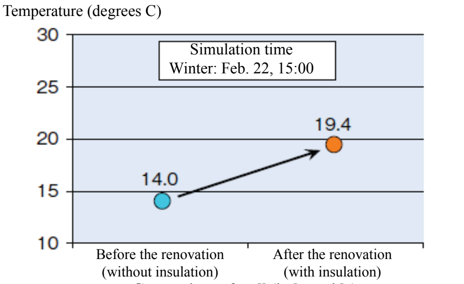
- Specification: polystyrene foam spraying finish
- Excluding the cost to remove the existing wall finishing material

Spraying insulation material: 5,000 yen/m^2 (of wall area)

- Specification: urethane foam spraying, perforated linden plywood boarding(GL method), painting
- Excluding the cost to remove existing wall finish materials

Evaluation of effects

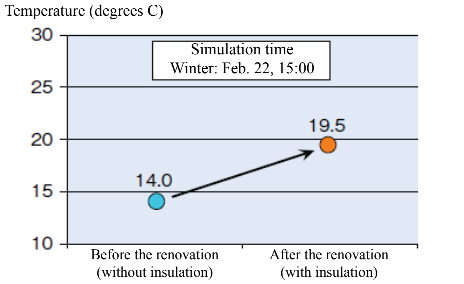
Simulation result



Comparison of wall (indoor side) surface temperature (in winter)

* Because the wall surface temperature is higher than before the renovation when the room temperature is low in winter, the sensible temperature caused by radiation heat is higher.

Simulation result



Comparison of wall (indoor side) surface temperature (in winter)

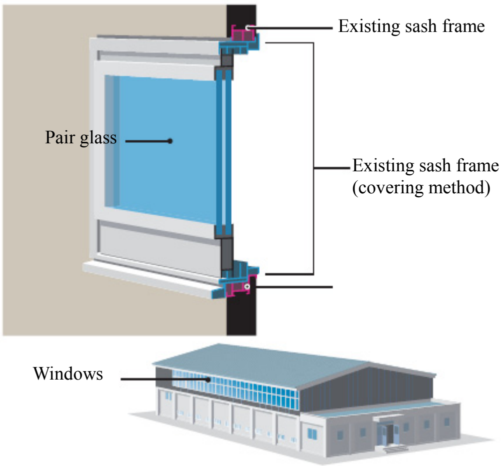
* Because the wall surface temperature is higher than before the renovation when the room temperature is low in winter, the sensible temperature caused by radiation heat is higher.

(3) Insulation in Openings

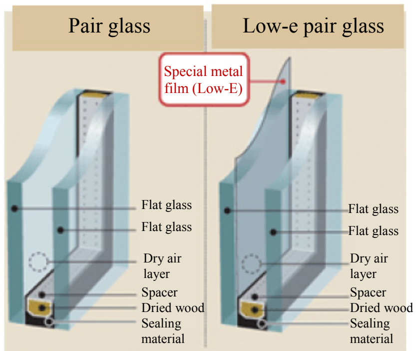
Outline of the improvement method

Example of the improvement method

a Pair glass



b Low-e pair glass



Difference between pair glass and Low-e pair glass

Source: Flat Glass Association of Japan Website

*Special metal film is multilayer film of silver and oxidative metal that protects the silver (from the Flat Glass Manufacturers Association of Japan Website)

Features and necessary points

a Pair glass

● **Features**

- Replacing thermally weak single-pane glass with pair glass with lower heat transmission
- Improving airtightness by the covering method in which a new sash frame for pair glass is installed over the existing sash frame
- Pair glass lowers thermal conduction by containing dry air between two panes of glass
- Pair glass has excellent thermal insulation properties that can prevent condensation

● **Necessary points**

- In the covering method that retains the existing sash frame, the internal width and height of the new sash frame are smaller than those of the old one.

b Low-e pair glass

● **Features**

- Replacing with low-e pair glass with special metal film coating on its surface to reduce intrusion of solar radiation heat and ultraviolet radiation into the room
- Improving air-conditioning efficiency by keeping out solar radiation heat in summer

● **Necessary points**

- It is necessary to consider the impact of reflected light from glass on the neighborhood.
- It makes the room darker compared with using ordinary glass.
- Because dirt is easily noticeable, cleaning is required every two or three months.

Cost/Effect

Initial cost

a Pair glass

Pair glass: 70,000 yen/m^2 (of window area)

- Specification: installation with covering method
- Including construction cost
- Excluding curing, secondary material, etc.

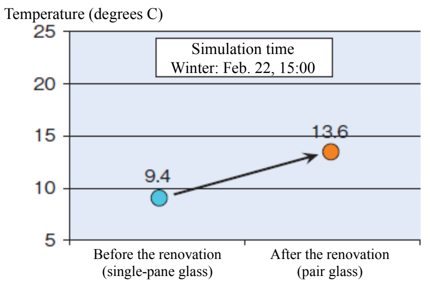
b Low-e pair glass

Low-e pair glass 90,000 yen/m^2 (of window area)

- Specification: installation with covering method
- Including construction cost
- Excluding curing, secondary material, etc.

Evaluation of effects

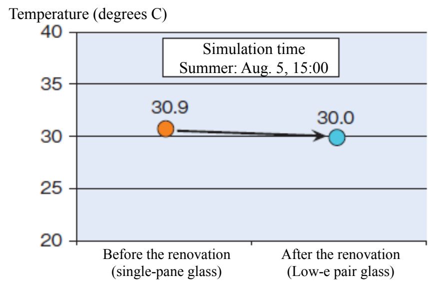
Simulation result



Comparison of glass (indoor side) surface temperature

* Pair glass conducts less outside cold to inside in winter

Simulation result



Comparison of glass (indoor side) surface temperature

* Solar heat gain from outside is reduced in summer.

2 Shading from Sunshine / Preventing Reflection

(4) Outside Shade (Louver Type)

Outline of the improvement method

Example of the improvement method

a Louver

Louver
(when installing at double sliding windows)

Features and necessary points

● **Features**

- Louvers are attached on the outside of windows to prevent direct solar radiation coming into the room. The method has a high insolation shielding effect.
- Installation on the opening on the south side is effective while installation on the eastern/western side is not so effective.
- Because solar radiation is shielded while windows are open, ventilation is secured and heat does not remain in the room.

● **Necessary points**

- If the window is a rescue entrance for firefighters, be cautious that the installation would not interfere with the entrance.
- The installation may not be possible for outswinging windows such as Power-operated window.
- It takes more labor to clean.

Cost/Effect

Initial cost

Louver: 500,000 to 600,000 yen/window surface unit
(using 5m-wide louver)

- Specification: aluminum louver and auxiliary struts
- Excluding construction cost

Evaluation of effects

- Solar radiation shielding is effective to keep a room cool in summer.
  Solar radiation entering a room varies depending on the direction of the window.
  If the window is on the south side, the sun is high and horizontal shades such as louvers are effective.
- Shielding solar radiation outside of the window produces more effect to reduce heat gain than shielding inside the room.

(5) Wall Vegetation

a Wall vegetation

Wall vegetation (Climbing type)
Source: Wall Greening Guidline, Tokyo Metropolitan Government

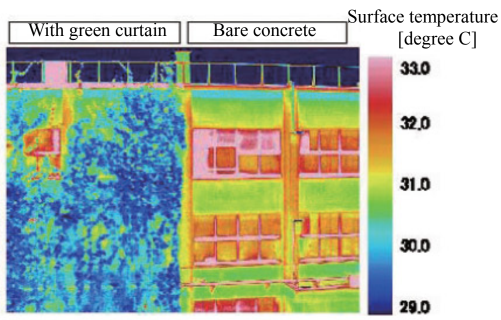
● **Features**

- Covering outer wall surface of building with plants to reduce the heat of solar radiation entering from the wall surface
- Planting methods include climbing, hanging and panel types.

● **Necessary points**

- Because direct contact of plants with the wall surface may cause cracking, water leak, etc., install latticework, wire, etc.
- It requires close consideration on conditions such as watering, compost, pest control, wind damage and climate conditions.
- Because the moisture holding capacity of a horizontal surface is weak and rain water is not enough for water supply, water supply system (such as control timer) is necessary.

Wall vegetation: 50,000 to 100,000 yen/m^2 of greening area



Comparison of outer wall temperature

Source: The Project on the Eco-friendly Renovation of School Buildings and Environmental Education – Feasibility Study, Ministry of the Environment

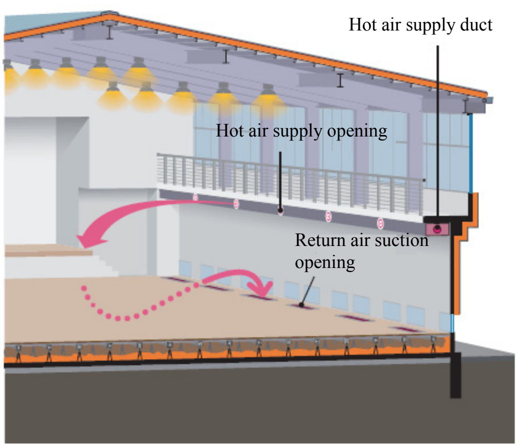
3 Appropriate Indoor Temperature

(6) Heating of a Large Space

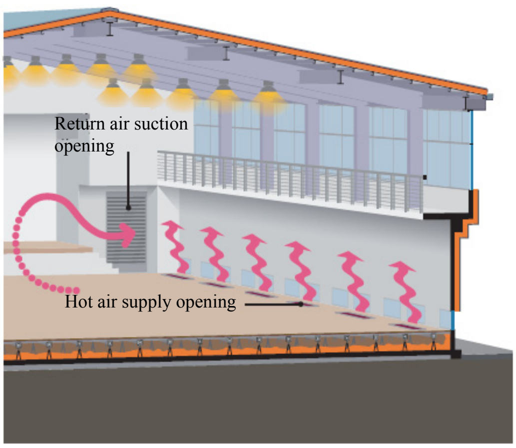
Outline of the improvement method

Example of the improvement method

a Sucking in warmed air through floor



b Blowing warmed air from floor



Features and necessary points

a Sucking in warmed air through floor

● **Features**

- Channeling hot air to the floor surface as much as possible and suctioning through the floor weaken the natural convection of the supplied hot air toward the ceiling.
- Unlike with the case of higher sucking, you can make the temperature of the space higher than 2m from the floor level near the set temperature and reduce waste of heating energy.
- Using the underfloor as a sucking chamber warms the floor surface with return air, which may produce a floor heating effect.

● **Necessary points**

- It is necessary to clean the suction opening on the floor.

b Blowing warmed air from floor

● **Features**

- Because hot air supplied from the floor with a slow air-flow rate moves slowly toward the ceiling, the temperature difference between high and low parts of the space is reduced.
- The space can be heated at the set temperature up to near the ceiling space excluding the vicinity of the floor with the effect of reducing waste of heating energy.

● **Necessary points**

- It is necessary to clean the supply opening on the floor

Cost/Effect

Initial cost

a

Heating system: about 6 million yen/gymnasium

- Specification: including heat source equipment, ducts and sucking
- Including construction cost

b

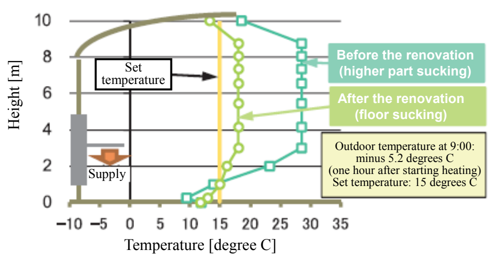
Heating system: about 6 million yen/gymnasium

- Specification: including heat source equipment, ducts and sucking
- Including construction cost

Evaluation of effects

a

Simulation result

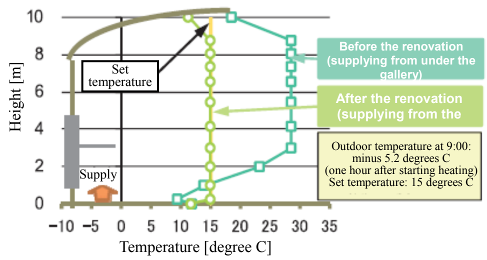


Horizontal temperature distribution in gymnasium

* Floor sucking maintains the set temperature up to the higher space of the gymnasium, making the room temperature relatively even.

b

Simulation result



Horizontal temperature distribution in gymnasium

* The set temperature is maintained from floor surface up to a higher position. The room temperature is even.

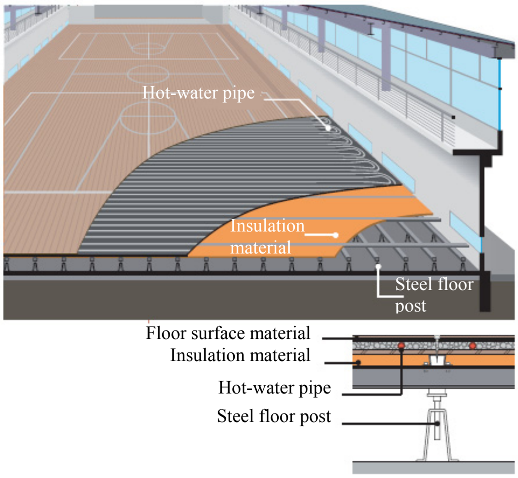
4 Equalizing Indoor Illumination

(6) Heating of a Large Space

Outline of the improvement method

Example of the improvement method

c Floor heating



Features and necessary points

● **Features**

- Heating a large space from under the floor using radiation heat and natural convection
- The floor itself is warm.
- No artificial convection caused by heating
- Little vertical temperature difference

● **Necessary points**

- Because drafts greatly reduces the heating efficiency, it is necessary to improve the airtightness.
- Because hot water heating requires a boiler, it is necessary to consider where to install a boiler.
- Because it takes time for floor heating to warm a space, it is necessary to start heating earlier than the start of activity and switch off earlier than the end of activity.

Cost/Effect

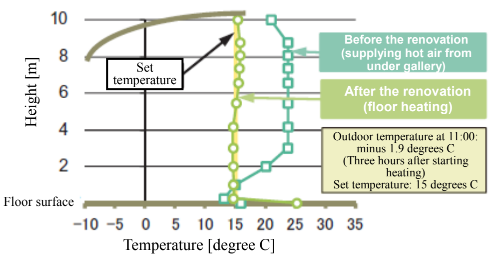
Initial cost

Floor heating system: about 27 million yen/gymnasium (hot water heating)

- Specification: hot water floor heating including heat source equipment, floor material, header and piping work cost
- Including construction cost

Evaluation of effects

Simulation result

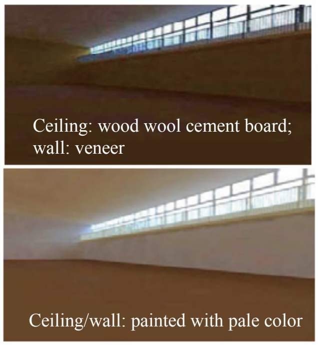


Vertical temperature distribution in gymnasium

* The floor itself is warm. The set temperature is maintained up to higher positions and the room temperature is even without artificial convection.

(7) Finishing with High Rate of Reflection

a Finishing with high rate of reflection



Material (color)	Rate of reflection
White	80～85%
Pale color	30～70%
Deep color	15～40%

Interior materials of darker color make the rate of reflection lower. The room is felt darker because they absorb light.

Difference in perceived brightness depending on the ceiling/wall finishing material (image)

● **Features**

- Using brighter finishing materials on room walls increases the light reflection rate and makes the room brighter.

● **Necessary points**

- Dirt is easily noticeable on white.
- Painting of ceiling requires an environment that enables work in high places
- If white balls are used in a ball game, etc., it might be difficult to see them against a white wall and ceiling.

Ceiling: plasterboard replacement, 600,000 yen /gymnasium

- Excluding the cost to remove existing ceiling finish, scaffolding, etc.

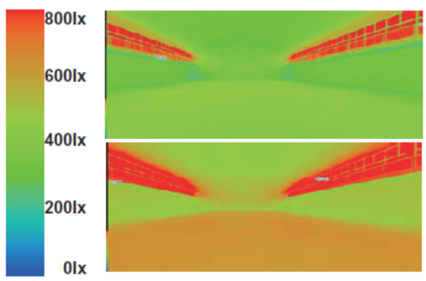
Ceiling: repainting, 1 million yen/gymnasium

- Excluding repair of existing ceiling finish, scaffolding, etc.

Ceiling: repainting, from one million yen /gymnasium

- Excluding the cost to remove existing wall finish, joist, scaffolding, etc.

Simulation result



Above: when "darker" materials that absorb light are used on ceiling/wall
Below: when "brighter" materials that reflect light are used on ceiling/wall

Comparison of room illuminance (under the same lighting condition)

5 Use of Natural Ventilation

(8) Securing Ventilation Utilizing Temperature Difference

Outline of the improvement method

Example of the improvement method

a Ventilation utilizing temperature difference

Power-operated window
(simultaneous opening/closing of windows using one motor)

Features and necessary points

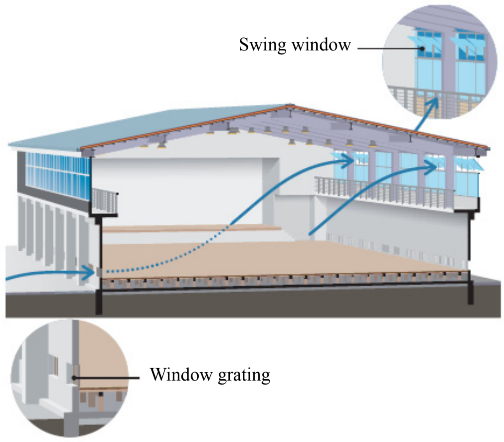
● **Features**

- They can let out hot air in the gymnasium when the outdoor temperature is high in summer and intermediate periods.
- Install upper windows at the level as high as possible.
- If they are installed horizontally side by side, all windows can be operated using one motor.
- This is a simple system with fewer malfunctions compared with operators such as a wire system.
- It can be linked to a rain sensor.

● **Necessary points**

- Because the system protrudes inward, it is necessary to be careful about the position of curtains and blinds so that they do not get hung up on a protrusion.
- Secure places for maintenance of motors and moving parts of the windows that may suffer failure.

a Ventilation utilizing temperature difference



● **Features**

- They can let out hot air in the gymnasium when the outdoor temperature is high in summer and intermediate periods.
- Install upper windows at the highest level possible.
- It is effective to install swing windows also for tectonic windows, or to install gratings for them.

● **Necessary points**

- Because the equipment to close windows (at the time of strong wind or rain) is electrically driven, power source and control instrumentation work is necessary.
- It is necessary to be careful about the position of curtains and blinds so that they do not get hung up on windows.
- Secure places for maintenance of motors and moving parts of the windows that may suffer failure.

Cost/Effect

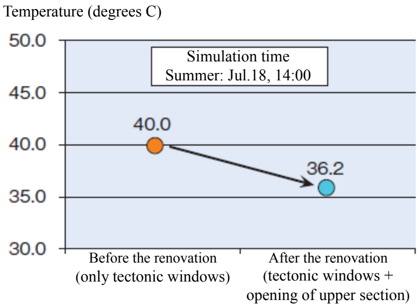
Initial cost

Power-operated window: about three million yen/gymnasium (two 40m-long horizontal window units)
*One 40m-long horizontal window unit: 1.5 million yen

- Specification: opening and closing of two 40m-long horizontal window units are controlled by a motor
- A rain sensor is optional (about 500,000 yen)

Evaluation of effects

Simulation result



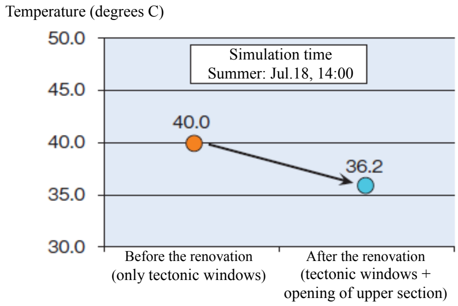
Room temperature at the height 1m above the floor (in summer)

* In addition to lowering the room temperature, the system lowers the sensible temperature through wind.

Swing window: about 7 million yen/gymnasium

- Specification: 10 horizontal twin windows, control sensors and control panels
- Excluding piping, wiring and electric works

Simulation result



Room temperature at the height 1m above the floor (in summer)

* In addition to lowering the room temperature, the system lowers the sensible temperature through wind.

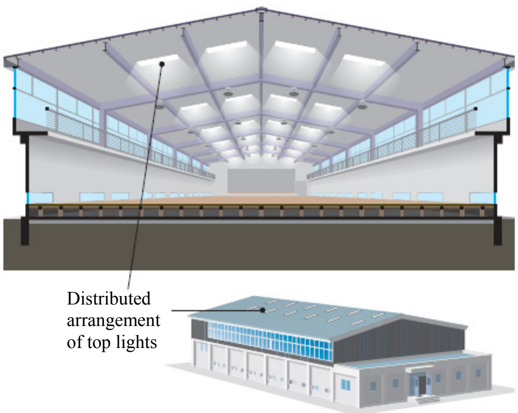
6 Use of Natural Light

(9) Use of Daylight

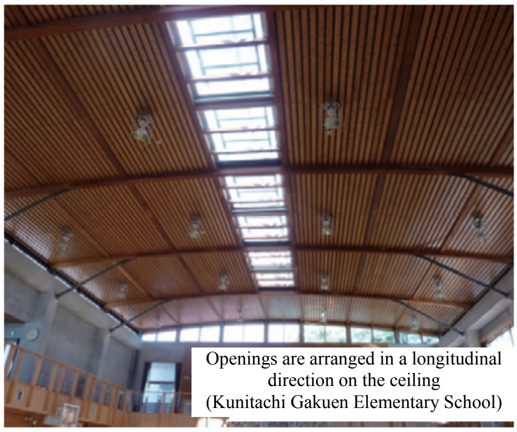
Outline of the improvement method

Example of the improvement method

a Use of daylight



a Use of daylight



Use of daylight through openings

Features and necessary points

● **Features**

- Distributed arrangement of top lights on the roof to let in sunlight and reduce the use of artificial lighting as much as possible
- If the top lights are designed to open and close to function also as a smoke ventilation system, they can be used as high openings for ventilation utilizing temperature difference.

● **Features**

- Arranging large top lights in a longitudinal direction concentrated on the center line of the ceiling
- Because daylight reaches the center part where little daylight reaches through side windows, daytime use of artificial lighting can be reduced.

■ Necessary points when installing lighting windows (daylight use) on ceiling

1. Avoid letting in direct sunlight to prevent dazzle and reduce solar radiation heat.
2. If the gymnasium is used for events that need darkness, it is necessary to install black-out curtains, etc.
3. It is necessary to provide enough strength to light shielding devices such as louvers to resist the impact of balls, etc.
4. It is necessary to consider how to clean the surface of top lights in high places.
5. Pay attention to the details of design so that balls, etc. do not get caught in the fittings around lighting windows.

Cost/Effect

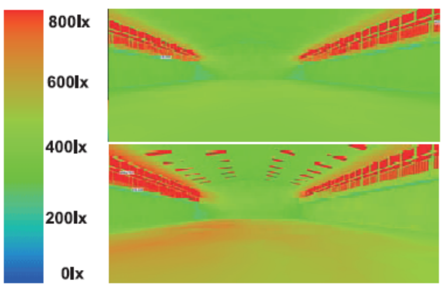
Initial cost

Varies depending on the design conditions, etc.

Varies depending on the design conditions, etc.

Evaluation of effects

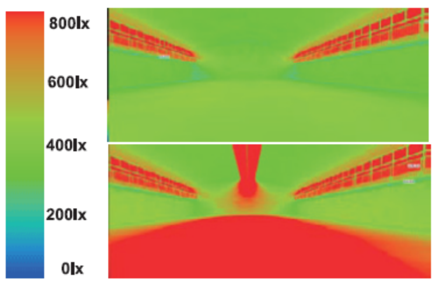
Simulation result



Above: with typical two-side opening for gymnasium
Below: with slits at even intervals on the ceiling

Comparison of indoor illuminance

Simulation result



Above: with typical two-side openings for gymnasium
Below: with large openings on the ceiling

Comparison of indoor illuminance

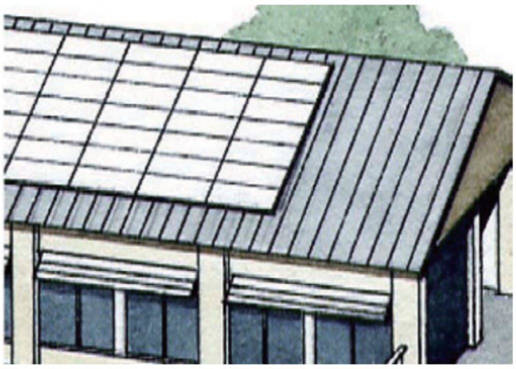
7 Utilizing as a Source of Energy

(10) Solar Energy Generation

Outline of the improvement method

Example of the improvement method

a Solar energy generation



Photovoltaic installation on roof surface (pitched roof)

Features and necessary points

● **Features**

・Installing solar cells on roof surface and using generated power
・A solar energy generation system with a self-sustained operation function can be used in the time of disaster as well.

● **Necessary points**

・It is necessary to consider the climate and other conditions of the region because output may be small due to a low rate of sunshine depending on the region.
・Installation on a south-facing roof is ideal.
・It is necessary to examine the load of the equipment and consider the weathering at the mounting parts

Cost/Effect

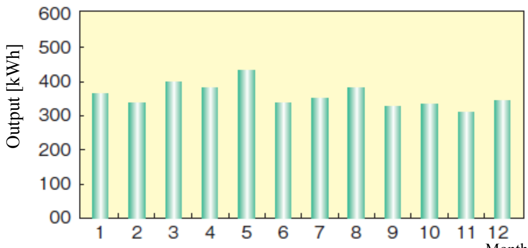
Initial cost

Installing solar energy equipment: 0.9 to 1.1 million yen/kW in average for 10 to 30kW (actual price at the field test by NEDO in 2006: rooftop installation)

・Specification: excluding related works such as water proofing renovation

Evaluation of effects

Simulation result

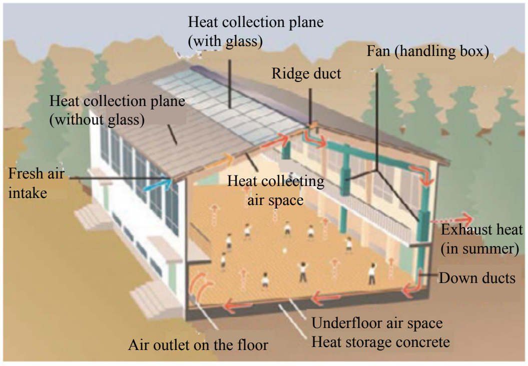


Output of solar energy generation

・Generation capacity: 4.0kW (one installation on a south-facing roof)
・Assuming that it is unaffected by surrounding buildings (no shadow)
・Tokyo area (output may vary in other regions due to different amount of solar insolation)

(11) Solar Thermal Application

a Solar thermal application



Pneumatic floor heating system using solar thermal application (air flow in winter)

● **Features**

・The system sucks in air from the edges of the eaves and heats the air on a glass heat collection plane installed on the roof to use for heating.
・Warmed air is sent under the floor through down ducts using a fan, warms the floor and blows into the gymnasium.
・The system enables 24-hour ventilation and heating of the floor surface and inside of the gymnasium.
・In summer, the system emits solar radiation heat from the roof surface by pumping hot air through ridges to improve the thermal environment in the gymnasium.

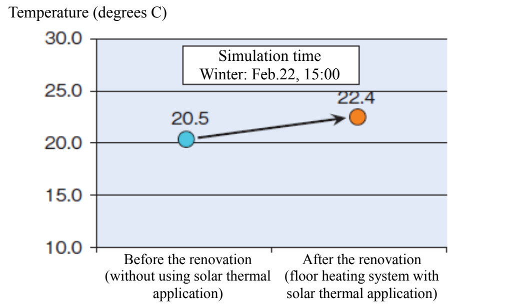
● **Necessary points**

・When installing double roofs, it is necessary to check the structural safety of the existing gymnasium.

Solar thermal equipment work: about 16 million yen/gymnasium (Actual price of installation in an existing gymnasium of about 500m^2)

・Specification: installing a second roof on the existing roof
・Heat collecting area is 63.5m^2 in this example

Simulation result



Comparison of temperature 1m above the floor (in winter)

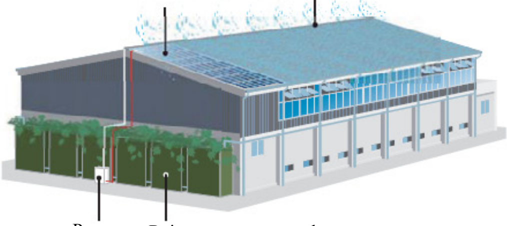
* The system enables energy conservation with solar thermal application while producing heating effects.

(12) Roof Spray Cooling Using Rain Water

Outline of the improvement method

Example of the improvement method

a Roof spray cooling using rain water



Features and necessary points

● **Features**

- Sprinklers for spraying all over the roof and tanks to store rainwater are installed.
- Cooling of the entire roof through evaporation of sprayed rainwater lowers the surface temperature of the roof on the indoor side. Reduced radiation heat from the roof surface improves the thermal environment in the gymnasium.
- It can be designed to use rainwater also for the flushing of toilets in the gymnasium and watering of plants.

● **Necessary points**

- It is necessary to consider the installation place of rainwater tanks and the power of pumps, etc.
- It is necessary to disinfect rainwater because it is sprayed on the roof.

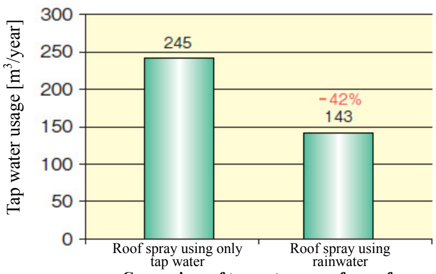
Cost/Effect

Initial cost

Watering system: from 1 million yen
Rainwater tank: from 100,000 yen (1000-liter tank)
- Specification: water supply, exterior piping
- Excluding installation work

Evaluation of effects

Simulation result

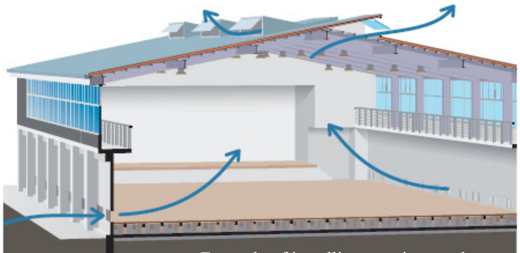


Comparison of tap water usage for roof spraying with and without using rainwater

*Spraying on fine/cloudy weekdays from July to September (excluding summer vacation)
(Precipitation data: Expanded AMEDAS weather data 1981-2000, Tokyo)

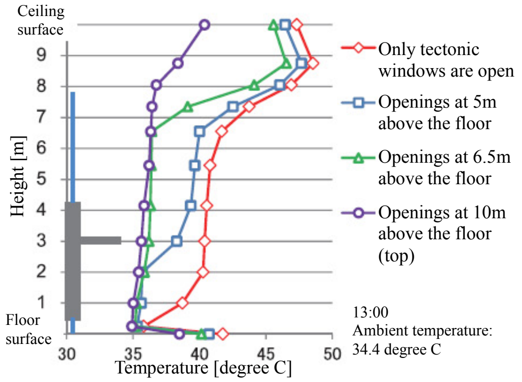
TOPIC

[Difference of room temperature depending on the height of the ventilation window]
—Simulation result—

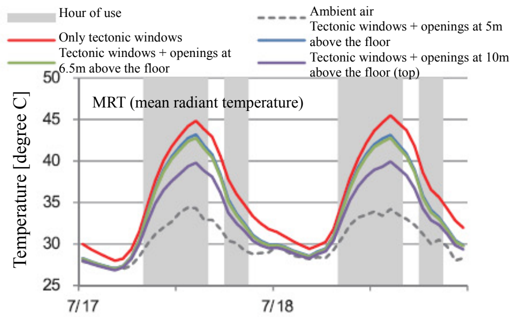


Example of installing openings at the top

- The simulation result shows the effectiveness of installing ventilation windows as high as possible.
- For a large space such as a gymnasium, it is important not only to lower the temperature in the lower space but also to alleviate heat storage in the upper space. From the upper graph (below) you can see the temperature of the large space is relatively even when the ventilation windows are installed higher.
- From the lower graph (below) you can see that radiation heat from the ceiling / wall surfaces and the sensible temperature are lower when the ventilation windows are installed higher.



Wall temperature with ventilation windows installed at different heights (Tokyo, July 17)
—Wall temperature on vertical cross-section—



Mean radiant temperature with ventilation windows installed at different heights (Tokyo, July)
—Relation between elapsed time and MRT—

8 Efficient Use of Energy

(13) Replacement with Energy Conserving Lighting Equipment

Outline of the improvement method

Example of the improvement method

a Replacement with energy conserving lighting equipment

Ceramic metal halide lamp

Electrodeless discharge lamp

LED Lamp

Features and necessary points

● **Features**

(Ceramic metal halide lamp)
- Ballast for mercury lamp can be used.
- Reduction rate is about 40% from typical mercury lamp.
- Service life is 18,000 hours.

(Electrodeless discharge lamp)
- Its long service life eliminates the need of replacement and an elevating machine for replacement.
- Because it lights up instantly, it is feasible to switch it off during breaks, etc.
- Service life is 60,000 hours.

(LED Lamp)
- Because it lights up instantly, it is feasible to switch it off during breaks, etc.
- Service life is 60,000 hours.

● **Necessary points**

(Ceramic metal halide lamp)
- It takes five minutes for the lamp to light up.
- It takes 10 to 15 minutes for the lamp to light up after switching off.

(Electrodeless discharge lamp)
- Because it is necessary to replace the entire lighting equipment, an environment that enables high-place work is required.

(LED Lamp)
- Because it is necessary to replace the entire lighting equipment, an environment that enables high-place work is required.
- At the present stage, performance greatly varies depending on the manufacturer.

Cost/Effect

Initial cost

Ceramic metal halide lamp: 4,000 yen/lamp
- Excluding wiring and installation costs

Electrodeless discharge lamp: 60,000 yen/lamp
- Excluding wiring and installation costs

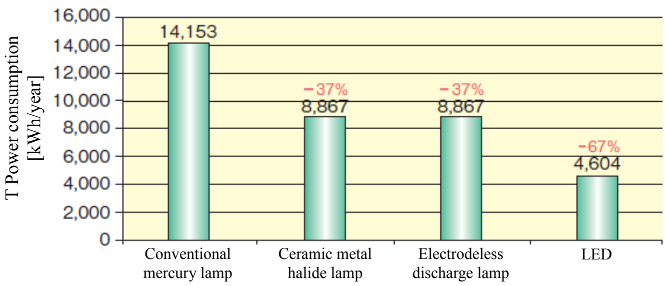
*Offered by only a small number of manufacturers

LED Lamp 40,000 yen/lamp
- Excluding wiring and installation costs

*Offered by only a small number of manufacturers

Evaluation of effects

Simulation result



Comparison of power consumption of lighting equipment

* Estimation condition hour of use: 203 days × 7 hours =1,421 hours (24 lighting equipment units)

9　Appropriate Operational Management

(14)　Zoning of Lighting Equipment

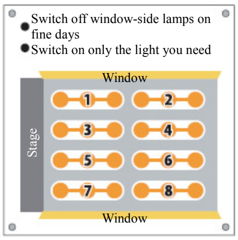
(15)　Consecutive Use

Outline of the improvement method

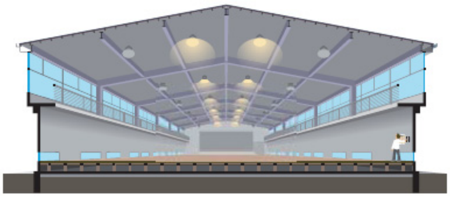
Example of the improvement method

(14)

a　Changing switching system of lighting equipment (zoning control)



An example of switch panel display



(15)

a　Consecutive use

	Mon.	Tue.	Wed.	Thu.	Fri.
1		5–2	1–2•4–1	5–2	1–1•3–1
2	2–2•5–1	1–1•3–1	6–1	3–2•4–2	5–1
3	1–2•3–2	2–1•4–2	2–2•4–2	2–2	1–2•4–1
4	1–1•3–1	3–2•4–1	6–2	5–1	6–1
5	6–1	2–1		6–2	2–1•5–2
6		6–2			

Example of modifying of time slots for gymnasium use

・Ensure common understanding on what learning activities in the gymnasium require lighting and what activities do not.
・It is necessary to ensure common understanding among teachers about timetable modification. For example, if the activity of 2nd grade Class 1 in the 5th period on Tuesday does not need lighting, activity that does not require lighting may be chosen for 6th grade Class 1 in the following 6th period.

Source: *What We Can Do for the Global Environment*, Ministry of Education, Culture, Sports, Science and Technology

Features and necessary points

(14)

● **Features**

・Divide the wiring systems of lighting switches to allow switching of individual lines of lamps (blocks) parallel to the window side. The lines may be further divided into smaller blocks for more detailed control.
・Be careful to switch off lamps in the zone where a sufficient illuminance level is secured during the daytime of fine days.

● **Necessary points**

・Ensure smooth management by color coding, for example.
・Equipment without instantaneous lighting function requires switching on and off in advance.

(15)

● **Features**

・Lighting equipment with high power consumption is used in gymnasiums.
・It takes several minutes for mercury lamps to come up to full brightness when they are switched on.
・It takes time for heating equipment to work and turn up the room temperature.
・Heating equipment, in particular, uses a large amount of power when rising (in a situation where heating equipment requires electrical power)
・Consecutive use can reduce power consumption.

● **Necessary points**

・It is necessary to plan a realistic curriculum.

Cost/Effect

Initial cost

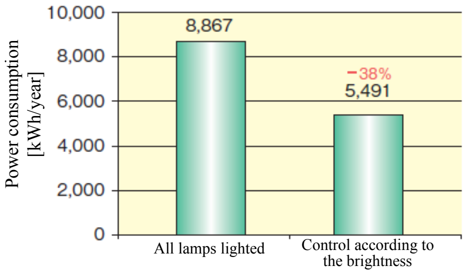
(14) Varies depending on the design conditions, etc.

(15) Only modifications in management

Evaluation of effects

(14)

Simulation result

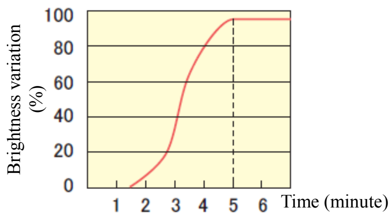


Comparison of power consumption with and without zone control

*Calculation condition: 260W-lamps are used
hour of use: 203 days × 7 hours = 1,421 hours (24 lighting equipment units)

(15)

Simulation result



Charecteristics of mercury lamp (lighting in gymnasium)

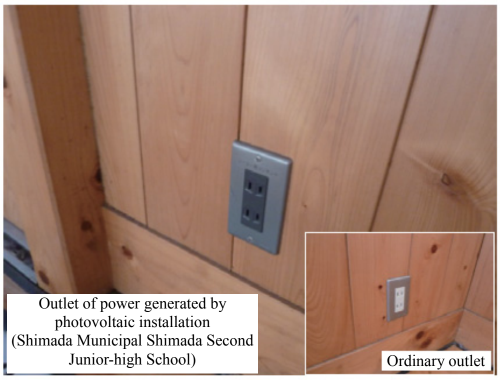
Source: *What We Can Do for the Global Environment*, Ministry of Education, Culture, Sports, Science and Technology

・Consecutive use of a gymnasium by modifying timetables can reduce energy consumption while ensuring an appropriate room temperature and illuminance when starting class.
・It takes time for heating equipment to reach the set temperature after starting operation and it consumes five to six times more power at the beginning compared with during stable operation.

10 Ideas for Learning About Environmental Problems

(16) Implementing into Environmental Education

Outline of the improvement method

	a Realizing the usefulness of generated power	b Displaying explanation of eco facilities
Example of the improvement method	 Outlet of power generated by photovoltaic installation (Shimada Municipal Shimada Second Junior-high School) / Ordinary outlet Installing outlet for power generated by photovoltaic installation	 Displaying explanation of eco facility equipment (Kobe Municipal Tamon Higashi Junior High School) A plate for explanation of eco facility equipment
Features and necessary points	● **Features** ・Students can realize the blessings of nature by using power generated by photovoltaic installation through the outlet. ・Power is available even in the time of disaster. ● **Necessary points** ・To use power generated by photovoltaic installation during power outage, it is necessary to install a solar energy generation system with a self-sustained operation function.	● **Features** ・Displaying the outline of the eco facility helps understanding of the menu of environment-focused renovation adopted in the facility ・Teachers and students can see the content of the adopted menu of environment-focused renovation even several years after the renovation. ● **Necessary points** ・Select a place easily seen by students. ・It is necessary to make it clear what equipment is explained.

Cost/Effect

	a	b
Initial cost	Varies depending on the design conditions, etc.	Panel cost: up to 20,000 yen (depending on the size) ・Specification: hardened polystyrene ・Excluding installation cost
Evaluation of effects	・Designing eco facilities to make the mechanism and effects visible can help students realize and understand them. ・Using school facilities for environmental education can help students become familiarized with the idea of eco school, increase interest and deepen understanding.	・Designing eco facilities where the mechanism and effects are visible can help students realize and understand them. ・Using school facilities for environmental education can help students become familiarized with the idea of eco school, increase interest and deepen understanding.

Chapter 4 Model Plans for Each Region

1 Common Element

(1) Outline of the Plan

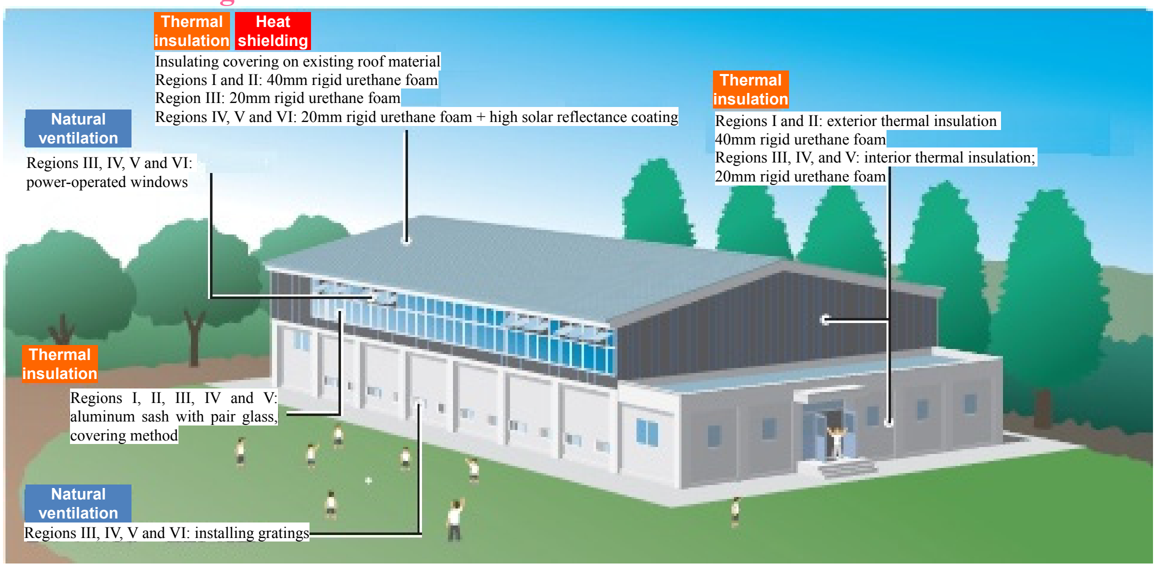
Outline of existing gymnasium model

Structure	Lower gallery: RC; Upper gallery: S
Opening	On the east and west (the longitudinal direction of the gymnasium is north-south axis
Floor area	930m^2 (1st floor arena: 630m^2)
Insulation	None
Window sash	Single-Pane Glass
Roof specification	batten seam roofing (without high solar reflectance coating)
Lighting	24 mercury lamps (400W/lamp); ensuring average floor illuminance of 300lx
Heating method*	kerosene fan heater
Set temperature for heating*	15 degrees C

*Heating equipment is installed only in Regions I and II based on the Energy Conservation Standard

Exterior appearance of a gymnasium after environment-focused renovation

Common for Regions I to VI



CO_2 emission coefficient used for the simulations

The following CO_2 emission coefficient is used for the simulations (to ensure conformity with *Promoting Environment-focused Renovations of School Buildings - Results of a Simulation of Environmental Measures in Model Plans (National)* published in November 2010.)

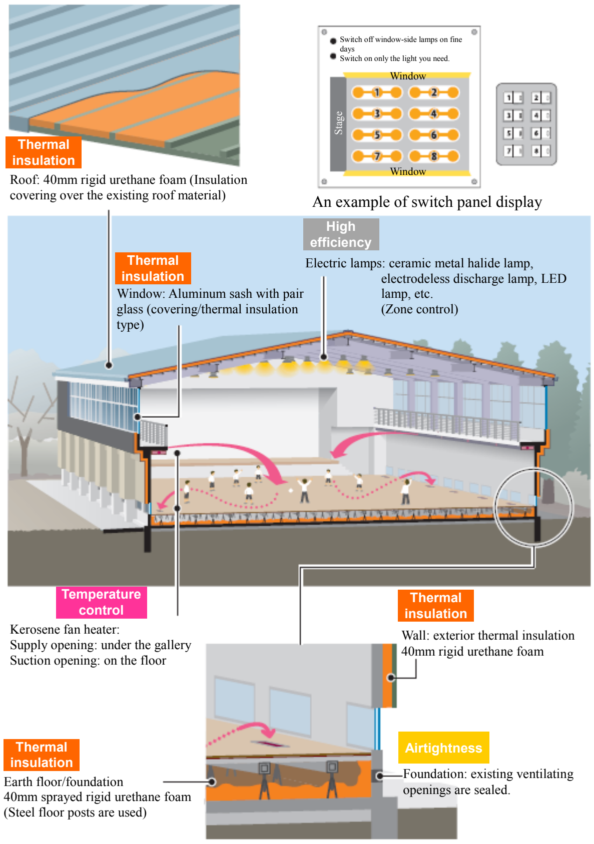
- For electricity, the actual emission coefficient (unit: kg-CO_2/kWh) of 2008 is used as made public by electric power suppliers pursuant to the greenhouse gas emissions calculation and reporting system based on the Act on Promotion of Global Warming Countermeasures (Act No. 117 of October 9, 1998).
  [Region 1 (Sapporo)] Hokkaido Electric Power Co., Inc., 0.588
  [Regions II (Morioka) and III (Fukushima)] Tohoku Electric Power Co., Inc., 0.469
  [Region IV (Tokyo)] Tokyo Electric Power Co., Inc., 0.418
  [Region V (Kagoshima)] Kyushu Electric Power Co., Inc., 0.374
  [Region VI (Naha)] Okinawa Electric Power Co., Inc., 0.946

- For kerosene, the value given in "the manual for calculating and reporting greenhouse gas emissions" (the Ministry of the Environment) is used.
  [All Regions] 2.49 kg-CO_2/L

2 Outline of Plans for Each Region and Evaluation Results

(1) Region I

Outline of the Plan



List of menus of environment-focused renovation

Item	Site	Before the renovation	After the renovation: Content	After the renovation: Method
Thermal insulation/airtightness	Roof	Without insulation	40mm rigid urethane foam	Covering over the existing roof material; installing insulation materials between existing battens
	Outer wall	Without insulation	Exterior thermal insulation 40mm rigid urethane foam	Installing insulation materials over existing mortar
	Floor (foundation)	Without insulation	40mm sprayed rigid urethane foam	Removing floor materials and wooden floor posts, spraying urethane on earth floor, installing steel floor posts and flooring. Ventilating openings are sealed.
	Sash	Aluminum sash with single-pane glass	Aluminum sash with pair glass	Covering method (thermal insulation type)
Natural ventilation		–	–	–
Heating		Kerosene fan heater (under gallery supply)	Kerosene fan heater (under gallery supply + floor sucking)	Changing in boiler/ducts; changing the location of suction opening
Lighting		24 mercury lamps (400W)	Ceramic metal halide lamp, electrodeless discharge lamp or LED lamp + Zone control	Replacing lighting equipment; Adjusting circuits

Simulation result

(1) Reduction of CO_2 emissions

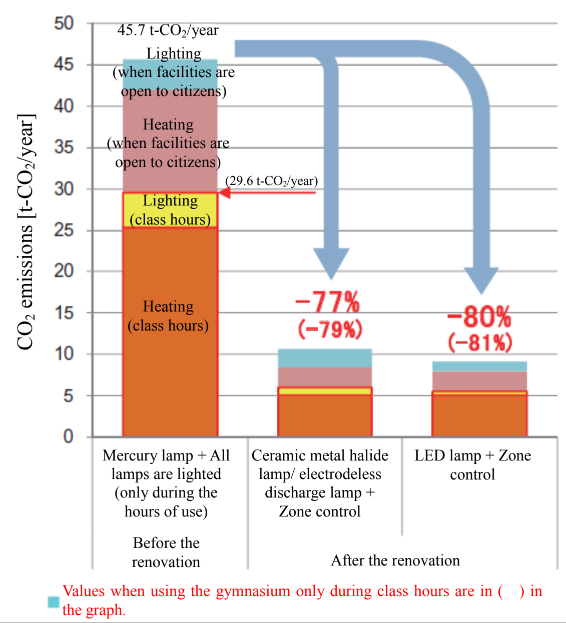
- **Annual CO_2 emissions**

(i) Environment-focused renovation can reduce CO_2 emissions by about 77-80%.
*The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school.

(ii) Measures to improve thermal insulation and airtightness performance are effective in Region I because loss of heating energy is significant in winter due to the large space and low airtightness performance.

(iii) The reduction rates in the graph are values assuming the use of heating and artificial lighting equipment during class hours and when facilities are open to citizens. The rates are lower by 1-2% if they are used only during class hours.

(iv) If heating equipment is not in the existing gymnasium and newly installed in the renovation work, CO_2 emissions will increase by about 1.4 to 2.9 tons annually even if more efficient lighting equipment is used.



Annual CO_2 emissions (Region I)*

*Above is the result of simulation assuming use in an elementary school. For simulation result of a junior-high school (including club activities), see Reference 2.

- **Annual CO_2 emissions from heating**

(i) The plan can reduce emissions from 25.4t to 5.1t for use during class hours, and from 12.5t to 2.4t for hours when facilities are open to citizens; the reduction rate is 79.9-80.8%.
(ii) This is a plan to reduce the heating load of a large space by improving the insulation and airtightness of the roof, outer wall, floor and sash.

- **Annual CO_2 emissions from lighting**

(i) The plan can reduce emissions from 4.2t to 0.5-1.0t for use during class hours, and from 3.6t to 1.2-2.2t for hours when facilities are open to citizens.
(ii) Reduction rates for use during class hours are 76.2% for using metal halide lamps and 88.1% for using LED lamps; reduction rates for hours when the facilities are open to citizens are 38.9% for using metal halide lamps and 66.7% for using LED lamps.
(iii) This is a plan to ensure energy conservation by zone control in addition to replacement with high-efficiency equipment.

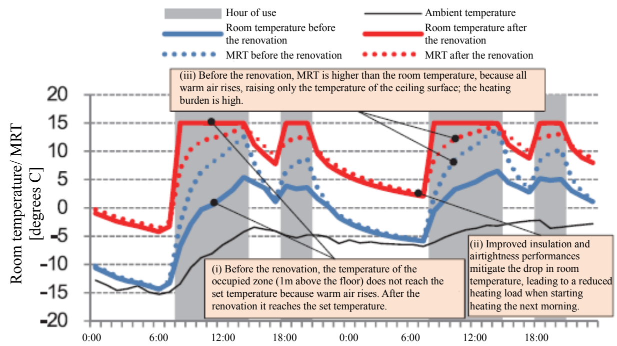
Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	Contribution to the reduction (%)	LED lamp + Zone control	Contribution to the reduction (%)
Heating (class hours)	25.4	5.1 (－79.9%)	58.0	5.1 (－79.9%)	55.6
Lighting (class hours)	4.2	1.0 (－76.2%)	9.1	0.5 (－88.1%)	10.1
Subtotal (only class hours)	29.6	6.1 (－79.4%)	－	5.6 (－81.1%)	－
Heating (when facilities are open to citizens)	12.5	2.4 (－80.8%)	28.9	2.4 (－80.8%)	27.7
Lighting (when facilities are open to citizens)	3.6	2.2 (－38.9%)	4.0	1.2 (－66.7%)	6.6
Total	45.7	10.7(－76.6%)	100.0	9.2 (－79.9%)	100.0

*Values in ( ) are reduction ratio by use compared with the CO_2 emissions before the renovation.

(2) Improvement of indoor thermal environment

(i) Winter: Improved insulation and airtightness performance can maintain a set temperature at 15 degrees C at the height zone where activities take place.
(ii) Winter: Improved insulation and airtightness performance mitigates the drop in room temperature, leading to a reduced heating load when starting use the next day.
(iii) Winter: Before the renovation, MRT is higher than the room temperature, which indicates that the ceiling surface is more heated than the indoor space. After the environment-focused renovation, the room temperature is higher, indicating that the entire room is relatively evenly heated.
(iv) Because there is no major problem with the thermal environment in gymnasiums in summer in Region I, no improvement measure is taken.



*MRT is surface temperature of indoor ceiling, wall, etc.
February 20 to 21
Temporal change of room temperature (1m above the floor) in winter (Region I)

(3) Reducing running cost through environment-focused renovation

(i) The environment-focused renovation can reduce energy costs by about 68% in the case of a separate power contract for the gymnasium, and by 78% excluding the basic rate (when using ceramic metal halide lamps and/or electrodeless discharge lamp).
(ii) Because oil for heating accounts for 63-71% of energy cost excluding basic rate of electricity in cold regions, the most part of reduction is made in heating.
(iii) The table to the right is the result of trial calculation under a certain assumption to provide a rough guide. The actual energy cost needs to be calculated based on the contract content and fee structure applicable to the school.

Estimation of annual energy costs before and after the renovation

Use	Before the renovation	After the renovation	
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	LED lamp + Zone control
Oil (heating/class)	¥723,000	¥126,000	¥126,000
Oil (Heating: when facilities are open to citizens)	¥355,000	¥59,000	¥59,000
General electricity (heating blast fan/ class hours)	¥67,000	¥26,000	¥26,000
General electricity (heating blast fan / when facilities are open to citizens)	¥34,000	¥12,000	¥12,000
General electricity (lighting/class)	¥91,000	¥21,000	¥11,000
General electricity (lighting: when facilities are open to citizens)	¥78,000	¥49,000	¥25,000
Subtotal	¥1,348,000	¥293,000	¥259,000
Comparison (%)	100	22 (－78)	19 (－81)
General electricity (basic rate)	¥472,000	¥295,000	¥236,000
Total	¥1,820,000	¥588,000	¥495,000
Comparison (%)	100	32 (－68)	27 (－73)

(4) Initial cost of the environment-focused renovation

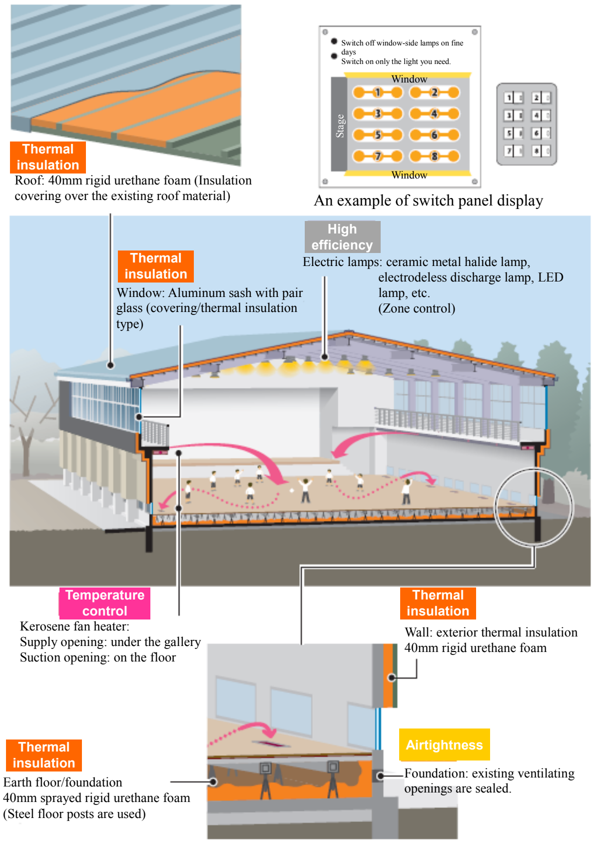
(i) Construction cost of the environment-focused renovation is about 85,000 yen/m^2.
(ii) Out of the cost of the environment-focused renovation, about 43,000 yen/m^2 is for measures to address aging degradation. The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school. The increase required for environmental measures is about 42,000 yen /m^2.
(iii) The direct construction cost for improvement of thermal insulation (including related works such as floor replacement) accounts for about 61% of the costs of the environment-focused renovation.

Rough estimation of construction cost per unit floor area (including tax)
(yen/m^2)

Major renovation work			Environment-focused renovation	Measures to address aging degradation (included in the amount to the left)
Construction work	Exterior	Roofing work	11,800	9,000
		Outer wall work	11,600	2,000
	Interior	Sash/door	12,500	0
		Floor	14,500	12,900
		Wall	1,300	1,300
		Other	400	400
	Temporary/demolish		9,100	8,200
Electric work	Lighting		1,200	0
Machinery work	Heating		6,200	0
Common expense			16,200	8,800
Total			84,800	42,600

(2) Region II

Outline of the Plan



List of menus of environment-focused renovation

Item	Site	Before the renovation	After the renovation: Content	After the renovation: Method
Thermal insulation/airtightness	Roof	Without insulation	40mm rigid urethane foam	Covering over the existing roof material; installing insulation materials between existing battens
	Outer wall	Without insulation	Exterior thermal insulation 40mm rigid urethane foam	Installing insulation materials over existing mortar
	Floor (foundation)	Without insulation	40mm sprayed rigid urethane foam	Removing floor materials and wooden floor posts, spraying urethane on earth floor, installing steel floor posts and flooring. Ventilating openings are sealed.
	Sash	Aluminum sash with single-pane glass	Aluminum sash with pair glass	Covering method (thermal insulation type)
Natural ventilation		–	–	–
Heating		Kerosene fan heater (under gallery supply)	Kerosene fan heater (under gallery supply + floor sucking)	Changing in boiler/ducts; changing the location of suction opening
Lighting		24 mercury lamps (400W)	Ceramic metal halide lamp, electrodeless discharge lamp or LED lamp + Zone control	Replacing lighting equipment; Adjusting circuits

Simulation result

(1) Reduction of CO_2 emissions

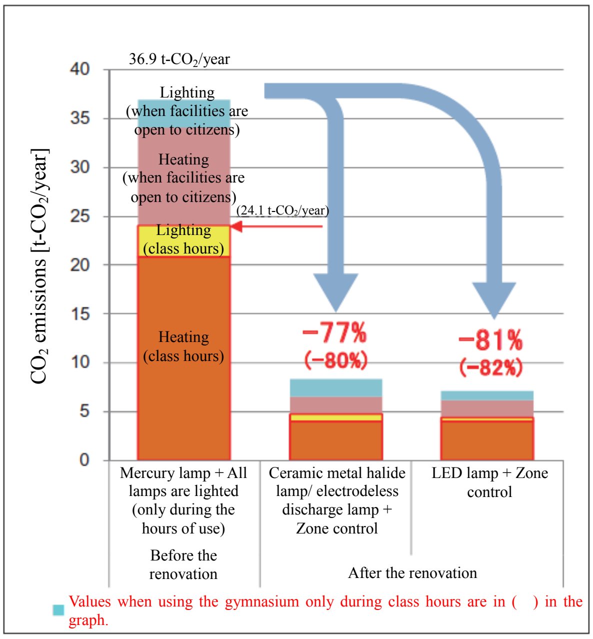
- **Annual CO_2 emissions**

(i) The environment-focused renovation can reduce CO_2 emissions by about 77-81%.
*The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school.

(ii) Measures to improve thermal insulation and airtightness performance are effective in Region II because loss of heating energy is significant in winter due to the large space and low airtightness performance.

(iii) The reduction rates in the graph are values assuming the use of heating and artificial lighting equipment during class hours and when facilities are open to citizens. The rates are lower by 1-3% if they are used only during class hours.

(iv) If heating equipment is not in the existing gymnasium and newly installed in the renovation work, CO_2 emissions will increase by about 1.0 to 2.3 tons annually even if more efficient lighting equipment is used.



Annual CO_2 emissions (Region II)*

*Above is the result of simulation assuming use in an elementary school. For simulation result of a junior-high school (including club activities), see Reference 2.

- **Annual CO_2 emissions from heating**

(i) The plan can reduce emissions from 20.8t to 4.0t for use during class hours, and 10.0t to 1.8t for hours when facilities are open to citizens; the reduction rate is 80.8-82.0%.

(ii) This is a plan to reduce the heating load of a large space by improving the insulation and airtightness of the roof, outer wall, floor and sash.

- **Annual CO_2 emissions from lighting**

(i) The plan can reduce emissions from 3.3t to 0.4-0.8t for use during class hours, and from 2.8t to 0.9-1.8t for hours when facilities are open to citizens.

(ii) Reduction rates for use during class hours are 75.8% for using metal halide lamps and 87.9% for using LED lamps; reduction rates for hours when the facilities are open to citizens are 35.7% for using metal halide lamps and 67.9% for using LED lamps.

(iii) This is a plan to ensure energy conservation by zone control in addition to replacement with high-efficiency equipment.

Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	Contribution to the reduction (%)	LED lamp + Zone control	Contribution to the reduction (%)
Heating (class hours)	20.8	4.0 (−80.8%)	58.9	4.0 (−80.8%)	56.4
Lighting (class hours)	3.3	0.8 (−75.8%)	8.8	0.4 (−87.9%)	9.7
Subtotal (only class hours)	24.1	4.8 (−80.1%)	−	4.4 (−81.7%)	−
Heating (when facilities are open to citizens)	10.0	1.8 (−82.0%)	28.8	1.8 (−82.0%)	27.5
Lighting (when facilities are open to citizens)	2.8	1.8 (−35.7%)	3.5	0.9 (−67.9%)	6.4
Total	36.9	8.4 (−77.2%)	100.0	7.1 (−80.8%)	100.0

*Values in ( ) are reduction ratio by use compared with the CO_2 emissions before the renovation.

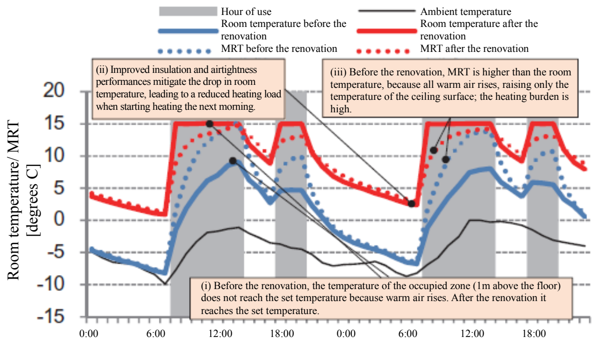
(2) Improvement of indoor thermal environment

(i) Winter: Improved insulation and airtightness performance can maintain a set temperature at 15 degrees C at the height zone where activities take place.

(ii) Winter: Improved insulation and airtightness performance mitigates the drop in room temperature, leading to a reduced heating load when starting use the next day.

(iii) Winter: Before the renovation, MRT is higher than the room temperature, which indicates that the ceiling surface is more heated than the indoor space. After the environment-focused renovation, the room temperature is higher, indicating that the entire room is relatively evenly heated.

(iv) Because there is no major problem with the thermal environment in gymnasiums in summer in Region II, no improvement measure is taken.



*MRT is surface temperature of indoor ceiling, wall, etc.

January 30-31

Temporal change of room temperature (1m above the floor) in winter (Region II)

(3) Reducing running cost through environment-focused renovation

(i) Environment-focused renovation can reduce energy cost by about 66% in the case of a separate power contract for the gymnasium, and by 78% excluding the basic rate (when using ceramic metal halide lamps and/or electrodeless discharge lamp).

(ii) Because oil for heating accounts for 59-68% of energy costs excluding the basic rate of electricity in cold regions, the greatest part of reduction is in heating.

(iii) The table to the right is the result of trial calculation under a certain assumption to provide a rough guide. The actual energy cost needs to be calculated based on the contract content and fee structure applicable to the school.

Estimation of annual energy cost before and after the renovation

Use	Before the renovation	After the renovation	
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	LED lamp + Zone control
Oil (heating/class)	¥608,000	¥103,000	¥103,000
Oil (Heating: when facilities are open to citizens)	¥292,000	¥46,000	¥46,000
General electricity (heating blast fan/ class hours)	¥55,000	¥23,000	¥23,000
General electricity (heating blast fan / when facilities are open to citizens)	¥26,000	¥10,000	¥10,000
General electricity (lighting/class)	¥91,000	¥22,000	¥11,000
General electricity (lighting: when facilities are open to citizens)	¥78,000	¥49,000	¥25,000
Subtotal	¥1,150,000	¥253,000	¥218,000
Comparison (%)	100	22 (−78)	19 (−81)
General electricity (basic rate)	¥472,000	¥295,000	¥236,000
Total	¥1,622,000	¥548,000	¥454,000
Comparison (%)	100	34 (−66)	28 (−72)

(4) Initial cost of the environment-focused renovation

(i) Construction cost of the environment-focused renovation is about 85,000 yen/m^2.

(ii) Out of the cost of the environment-focused renovation, about 43,000 yen/m^2 is for measures to address aging degradation. The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school. The increase required for environmental measures is about 42,000 yen /m^2.

(iii) The direct construction cost for improvement of thermal insulation (including related works such as floor replacement) accounts for about 61% of the costs of the environment-focused renovation.

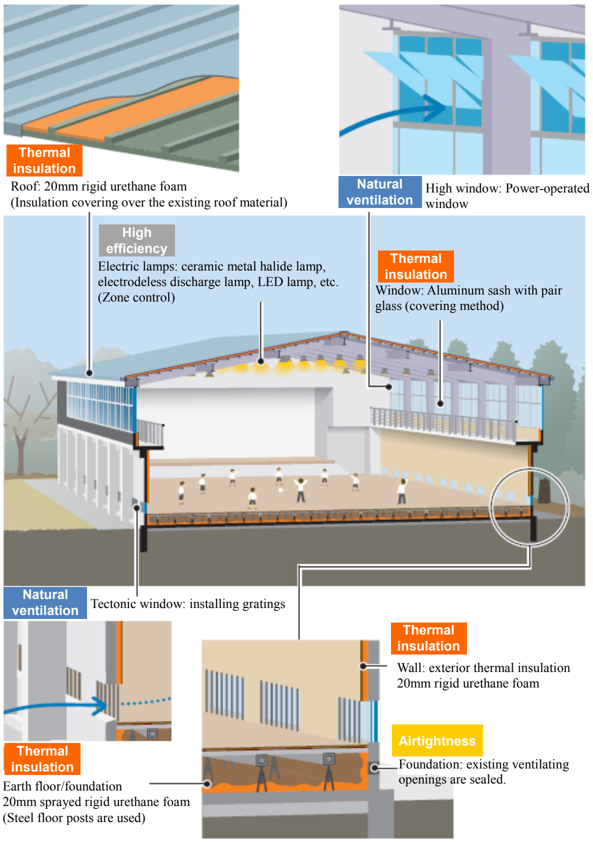
Rough estimation of construction cost per unit floor area (including tax)

(yen/m^2)

Major renovation work			Environment-focused renovation	Measures to address aging degradation (included in the amount to the left)
Construction work	Exterior	Roofing work	11,800	9,000
		Outer wall work	11,600	2,000
	Interior	Sash/door	12,500	0
		Floor	14,500	12,900
		Wall	1,300	1,300
		Other	400	400
	Temporary/demolish		9,100	8,200
Electric work	Lighting		1,200	0
Machinery work	Heating		6,200	0
Common expense			16,200	8,800
Total			84,800	42,600

(3) Region III

Outline of the Plan



List of menus of environment-focused renovation

Item	Site	Before the renovation	After the renovation	
			Content	Method
Thermal insulation/airtightness	Roof	Without insulation	20mm rigid urethane foam	Covering over the existing roof material; installing insulation materials between existing battens
	Outer wall	Without insulation	20mm rigid urethane foam	Spraying rigid urethane and finishing with linden plywood, etc.
	Floor (foundation)	Without insulation	20mm sprayed rigid urethane foam	Removing floor materials and wooden floor posts, spraying urethane on earth floor, installing steel floor posts and flooring. Ventilating openings are sealed.
	Sash	Aluminum sash with single-pane glass	Aluminum sash with pair glass	Covering method
Natural ventilation		Tectonic window	Installing power-operated windows Installing gratings to tectonic windows	Installed in part of sashes in gallery
Heating		–	–	–
Lighting		24 mercury lamps (400W)	Ceramic metal halide lamp, electrodeless discharge lamp or LED lamp + Zone control	Replacing lighting equipment; Adjusting circuits

Simulation result

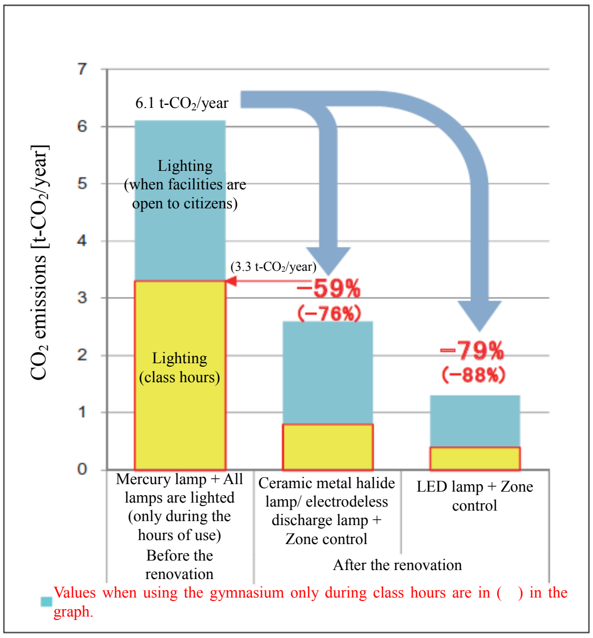
(1) Reduction of CO_2 emissions

● **Annual CO_2 emissions**

(i) The environment-focused renovation can reduce CO_2 emissions by about 59-79%.
*The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school.

(ii) Because heating equipment is not introduced in Region III, CO_2 emissions are reduced by replacing lighting equipment with high-efficiency equipment.

(iii) The reduction rates in the graph are values assuming the use of artificial lighting during class hours and when the facilities are open to citizens. The rates are lower by 7-9% if they are used only during class hours.



Annual CO_2 emissions (Region III)*

*Above is the result of simulation assuming use in an elementary school. For simulation result of a junior-high school (including club activities), see Reference 2.

● Annual CO_2 emissions from lighting

(i) The plan can reduce emissions from 3.3t to 0.4-0.8t for use during class hours, and from 2.8t to 0.9-1.8t for hours when facilities are open to citizens.

(ii) Reduction rates for use during class hours are 75.8% for using metal halide lamps and 87.9% for using LED lamps; reduction rates for hours when the facilities are open to citizens are 35.7% for using metal halide lamps and 67.9% for using LED lamps.

(iii) This is a plan to ensure energy conservation by zone control in addition to replacement with high-efficiency equipment.

Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	Contribution to the reduction (%)	LED lamp + Zone control	Contribution to the reduction (%)
Lighting (class hours)	3.3	0.8 (－75.8%)	71.4	0.4 (－87.9%)	60.4
Lighting (when facilities are open to citizens)	2.8	1.8 (－35.7%)	28.6	0.9 (－67.9%)	39.6
Total	6.1	2.6 (－57.4%)	100.0	1.3 (－78.7%)	100.0

*Values in ( ) are reduction ratio by use compared with the CO_2 emissions before the renovation.

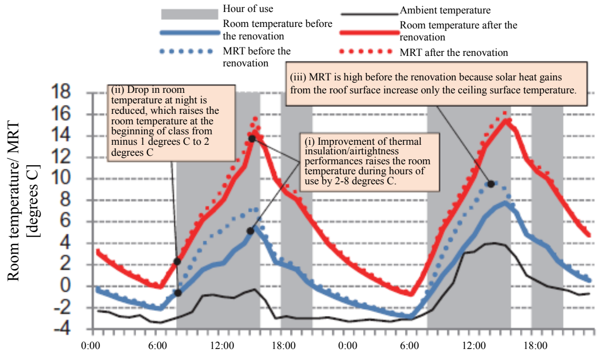
(2) Improvement of indoor thermal environment

(i) Winter: Improved insulation and airtightness performance raises the room temperature at the level where activities take place by 2-8 degrees C compared with before the renovation.

(ii) Winter: Improved insulation and airtightness performance mitigates the drop in room temperature, maintaining the higher room temperature until starting use the next day.

(iii) Winter: Before the renovation, only the ceiling surface was warmed by solar heat gain as indicated by the divergence between MRT and the room temperature. After the renovation, the room temperature and MRT are almost same indicating evenness of room temperature.

(iv) Because there is no major problem with the thermal environment in the gymnasium in summer in Region III, no improvement measure is taken.



*MRT is surface temperature of indoor ceiling, wall, etc.

January 30-31

Temporal change of room temperature (1m above the floor) in winter (Region III)

(3) Reducing running cost through environment-focused renovation

(i) The environment-focused renovation can reduce energy costs by about 41% in the case of a separate power contract for the gymnasium, and by 59% excluding the basic rate (when using ceramic metal halide lamps and/or electrodeless discharge lamp).

(ii) Because school facilities are open to citizens at night, the electricity bill of lighting for hours when the facility is open to citizens is higher than that during class hours (if the facilities are open to citizens every weekdays.)

(iii) The table to the right is the result of trial calculation under a certain assumption to provide a rough guide. The actual energy cost needs to be calculated based on the contract content and fee structure applicable to the school.

Estimation of annual energy cost before and after the renovation

Use	Before the renovation	After the renovation	
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	LED lamp + Zone control
General electricity (lighting/class)	¥91,000	¥21,000	¥11,000
General electricity (lighting: when facilities are open to citizens)	¥78,000	¥49,000	¥25,000
Subtotal	¥169,000	¥70,000	¥36,000
Comparison (%)	100	41 (－59)	21 (－79)
General electricity (basic rate)	¥314,000	¥216,000	¥157,000
Total	¥483,000	¥286,000	¥193,000
Comparison (%)	100	59 (－41)	40 (－60)

(4) Initial cost of the environment-focused renovation

(i) Construction cost of the environment-focused renovation is about 78,000 yen/m^2.

(ii) Out of the cost of the environment-focused renovation, about 45,000 yen/m^2 is for measures to address aging degradation. The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school. The increase required for environmental measures is about 33,000 yen /m^2.

(iii) The direct construction cost for improvement of thermal insulation (including related works such as floor replacement) accounts for about 66% of the costs of the environment-focused renovation.

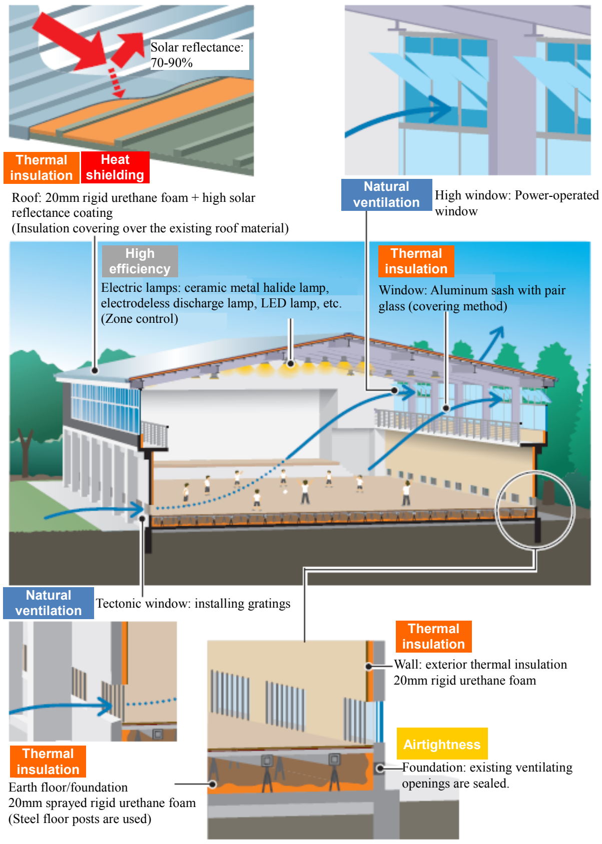
Rough estimation of construction cost per unit floor area (including tax)

(yen/m^2)

Major renovation work			Environment-focused renovation	Measures to address aging degradation (included in the amount to the left)
Construction work	Exterior	Roofing work	10,800	9,000
		Outer wall work	2,000	2,000
	Interior	Sash/door	19,900	0
		Floor	14,300	12,900
		Wall	4,000	2,900
		Other	400	400
	Temporary/demolish		9,700	8,200
Electric work	Lighting		1,200	0
Common expense			15,300	9,100
Total			77,600	44,500

(4) Region IV

Outline of the Plan



List of menus of environment-focused renovation

Item	Site	Before the renovation	After the renovation: Content	After the renovation: Method
Thermal insulation/airtightness	Roof	Without insulation	20mm rigid urethane foam + high solar reflectance coating	Covering over the existing roof material; installing insulation materials between existing battens
	Outer wall	Without insulation	20mm rigid urethane foam	Spraying rigid urethane and finishing with linden plywood, etc.
	Floor (foundation)	Without insulation	20mm sprayed rigid urethane foam	Removing floor materials and wooden floor posts, spraying urethane on earth floor, installing steel floor posts and flooring. Ventilating openings are sealed.
	Sash	Aluminum sash with single-pane glass	Aluminum sash with pair glass	Covering method
Natural ventilation		Tectonic window	Installing power-operated windows Installing gratings to tectonic windows	Installed in part of sashes in gallery
Heating		–	–	–
Lighting		24 mercury lamps (400W)	Ceramic metal halide lamp, electrodeless discharge lamp or LED lamp + Zone control	Replacing lighting equipment; Adjusting circuits

Simulation result

(1) Reduction of CO_2 emissions

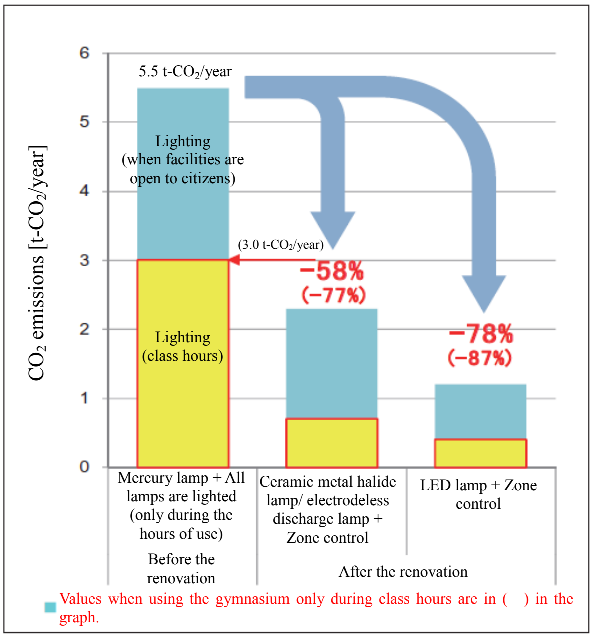
- **Annual CO_2 emissions**

(i) Environment-focused renovation can reduce CO_2 emissions by about 58-78%.

*The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school.

(ii) Because air-conditioning equipment is not introduced in Region IV, CO_2 emissions are reduced by replacing lighting equipment with high-efficiency equipment and introducing zone control.

(iii) The reduction rates in the graph are values assuming the use of artificial lighting equipment during class hours and when the facilities are open to citizens. The rates are lower by 9-19% if they are used only during class hours.



Annual CO_2 emissions (Region IV)*

*Above is the result of simulation assuming use in an elementary school. For simulation result of a junior-high school (including club activities), see Reference 2.

● Annual CO_2 emissions from lighting

(i) The plan can reduce emissions from 3.0t to 0.4-0.7t for use during class hours, and from 2.5t to 0.8-1.6t for hours when the facilities are open to citizens.

(ii) Reduction rates for use during class hours are 76.7% for using metal halide lamps and 86.7% for using LED lamps; reduction rates for hours when the facilities are open to citizens are 36.0% for using metal halide lamps and 68.0% for using LED lamps.

(iii) This is a plan to ensure energy conservation by zone control in addition to replacement with high-efficiency equipment.

Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	Contribution to the reduction (%)	LED lamp + Zone control	Contribution to the reduction (%)
Lighting (class hours)	3.0	0.7 (－76.7%)	71.9	0.4 (－86.7%)	60.5
Lighting (when facilities are open to citizens)	2.5	1.6 (－36.0%)	28.1	0.8 (－68.0%)	39.5
Total	5.5	2.3 (－58.2%)	100.0	1.2 (－78.2%)	100.0

*Values in ( ) are reduction ratio by use compared with the CO_2 emissions before the renovation.

(2) Improvement of indoor thermal environment

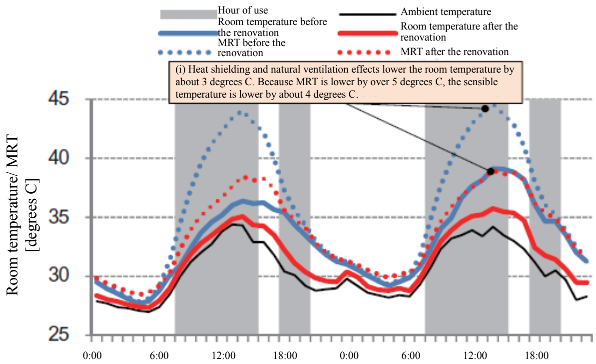
*Reference 3 shows evaluation of indoor comfort in summer

(i) Summer: Improvement of the thermal insulation/heat shielding performance of the roof and the effect of natural ventilation lowers the temperature by up to 3 degrees C. Because radiation heat from the ceiling and wall surfaces is mitigated, the sensible temperature is lower by about 4 degrees C.

(ii) Summer: For gymnasiums without air-conditioning equipment, it is best to make the room temperature close to the ambient temperature, but it is important to further lower the sensible temperature. For this purpose, it is important to reduce heat gain from radiation by lowering the ceiling/wall surface temperature.

(iii) Winter: Improvement of thermal insulation and airtightness performance raises the room temperature compared with before the renovation.

(iv) Winter: Improved insulation and airtightness performance mitigates the drop in room temperature, maintaining the higher room temperature until starting heating the next day.



*MRT is surface temperature of indoor ceiling, wall, etc.

July 17-18

Temporal change of room temperature (1m above the floor) in summer (Region IV)

(3) Reducing running cost through environment-focused renovation

(i) The environment-focused renovation can reduce energy costs by about 41% in the case of a separate power contract for the gymnasium, and by 59% excluding the basic rate (when using ceramic metal halide lamps and/or electrodeless discharge lamp).

(ii) Because school facilities are open to citizens at night, the electricity bill of lighting for hours when the facility is open to citizens is higher than that during class hours (if the facilities are open to citizens every weekdays.)

(iii) The table to the right is the result of trial calculation under a certain assumption to provide a rough guide. The actual energy cost needs to be calculated based on the contract content and fee structure applicable to the school.

Estimation of annual energy cost before and after the renovation

Use	Before the renovation	After the renovation	
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	LED lamp + Zone control
General electricity (lighting/class)	¥91,000	¥21,000	¥11,000
General electricity (lighting: when facilities are open to citizens)	¥78,000	¥49,000	¥25,000
Subtotal	¥169,000	¥70,000	¥36,000
Comparison (%)	100	41 (－59)	21 (－79)
General electricity (basic rate)	¥314,000	¥216,000	¥157,000
Total	¥483,000	¥286,000	¥193,000
Comparison (%)	100	59 (－41)	40 (－60)

(4) Initial cost of the environment-focused renovation

(i) Construction cost of the environment-focused renovation is about 79,000 yen/m^2.

(ii) Out of the cost of the environment-focused renovation, about 45,000 yen/m^2 is for measures to address aging degradation. The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school. The increase required for environmental measures is about 34,000 yen /m^2.

(iii) The direct construction costs for improvement of thermal insulation/heat shielding (including related works such as floor replacement) account for about 66% of the costs of the environment-focused renovation.

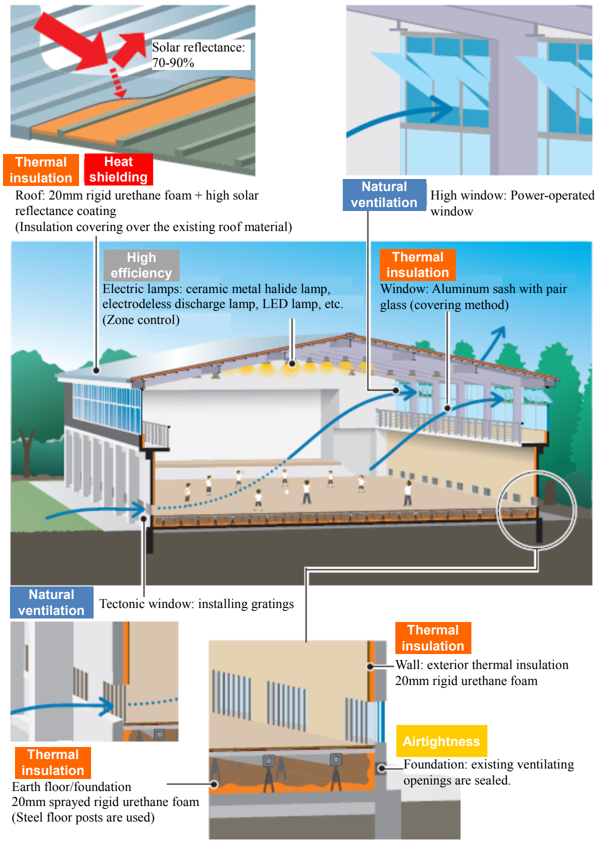
Rough estimation of construction cost per unit floor area (including tax)

(yen/m^2)

Major renovation work			Environment-focused renovation	Measures to address aging degradation (included in the amount to the left)
Construction work	Exterior	Roofing work	11,600	9,000
		Outer wall work	2,000	2,000
	Interior	Sash/door	19,900	0
		Floor	14,300	12,900
		Wall	4,000	2,900
		Other	400	400
	Temporary/demolish		9,700	8,200
Electric work	Lighting		1,200	0
Common expense			15,500	9,100
Total			78,600	44,500

(5) Region V

Outline of the Plan



List of menus of environment-focused renovation

Item	Site	Before the renovation	After the renovation: Content	After the renovation: Method
Thermal insulation/airtightness	Roof	Without insulation	20mm rigid urethane foam + high solar reflectance coating	Covering over the existing roof material; installing insulation materials between existing battens
	Outer wall	Without insulation	–	–
	Floor (foundation)	Without insulation	–	–
	Sash	Aluminum sash with single-pane glass	–	–
Natural ventilation		Tectonic window	Installing power-operated windows Installing gratings to tectonic windows	Installed in part of sashes in gallery
Heating		–	–	–
Lighting		24 mercury lamps (400W)	Ceramic metal halide lamp, electrodeless discharge lamp or LED lamp + Zone control	Replacing lighting equipment; Adjusting circuits

Simulation result

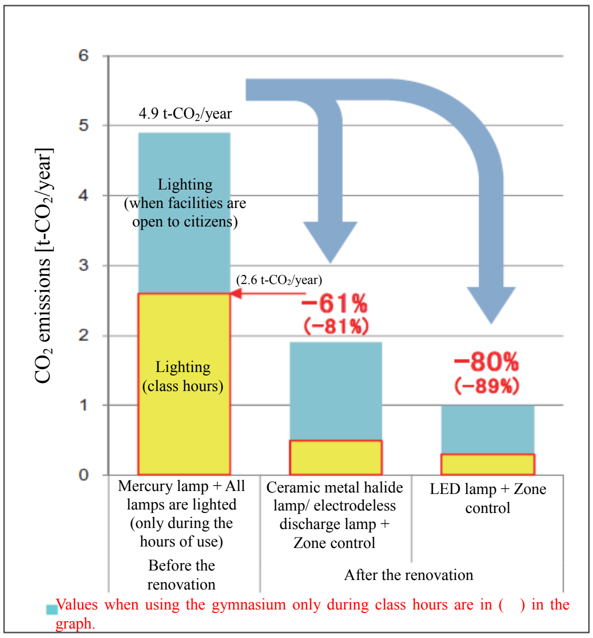
(1) Reduction of CO_2 emissions

● **Annual CO_2 emissions**

(i) Environment-focused renovation can reduce CO_2 emissions by about 61-80%.
*The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school.

(ii) Because air-conditioning equipment is not introduced in Region V, CO_2 emissions are reduced by replacing lighting equipment with high-efficiency equipment and introducing zone control.

(iii) The reduction rates in the graph are values assuming the use of heating and artificial lighting equipment during class hours and when the facilities are open to citizens. The rates are lower by 9-20% if they are used only during class hours.



Annual CO_2 emissions (Region V)*

*Above is the result of simulation assuming use in an elementary school. For simulation result of a junior-high school (including club activities), see Reference 2.

● Annual CO_2 emissions from lighting

(i) Renovation can reduce emissions from 2.6t to 0.3-0.5t for use during class hours, and from 2.3t to 0.7-1.4t for hours when the facilities are open to citizens.

(ii) Reduction rates for use during class hours are 80.8% for using metal halide lamps and 88.5% for using LED lamps; reduction rates for hours when the facilities are open to citizens are 39.1% for using metal halide lamps and 69.6% for using LED lamps.

(iii) This is a plan to ensure energy conservation by zone control in addition to replacement with high-efficiency equipment.

Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	Contribution to the reduction (%)	LED lamp + Zone control	Contribution to the reduction (%)
Lighting (class hours)	2.6	0.5 (－80.8%)	70.0	0.3 (－88.5%)	59.0
Lighting (when facilities are open to citizens)	2.3	1.4 (－39.1%)	30.0	0.7 (－69.6%)	41.0
Total	4.9	1.9 (－61.2%)	100.0	1.0 (－79.6%)	100.0

*Values in (　) are reduction ratio by use compared with the CO_2 emissions before the renovation.

(2) Improvement of indoor thermal environment

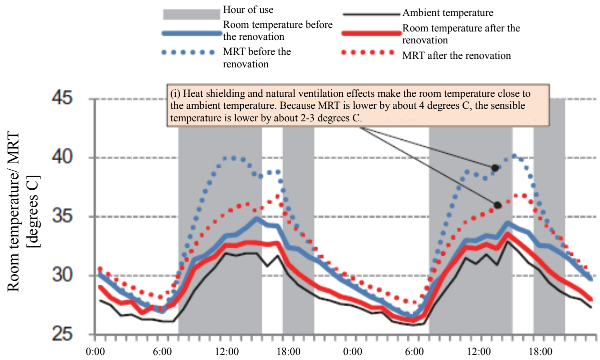
*Reference 3 shows evaluation of indoor comfort in summer

(i) Summer: Improvement of the thermal insulation/heat shielding performance of the roof and the effect of natural ventilation make the room temperature close to the ambient temperature. Because radiation heat from the ceiling and wall surfaces is mitigated, the sensible temperature is lower by about 2-3 degrees C.

(ii) Summer: For gymnasiums without air-conditioning equipment, it is best to make the room temperature close to the ambient temperature, but it is important to further lower the sensible temperature. For this purpose, it is important to reduce heat gain from radiation by lowering the ceiling/wall surface temperature.

(iii) Winter: Improvement of thermal insulation and airtightness performance raises the room temperature compared with before the renovation.

(iv) Winter: Improved insulation and airtightness performance mitigates the drop in room temperature, maintaining the higher room temperature until starting heating the next day.



*MRT is surface temperature of indoor ceiling, wall, etc.

September 4-5

Temporal change of room temperature (1m above the floor) in summer (Region V)

(3) Reducing running cost through environment-focused renovation

(i) The environment-focused renovation can reduce energy costs by about 41% in the case of a separate power contract for the gymnasium, and by 60% when excluding the basic rate (using ceramic metal halide lamps and/or electrodeless discharge lamp).

(ii) Because school facilities are open to citizens at night, the electricity bill of lighting for hours when the facility is open to citizens is higher than that during class hours (if the facilities are open to citizens every weekdays.)

(iii) The table to the right is the result of trial calculation under a certain assumption to provide a rough guide. The actual energy cost needs to be calculated based on the contract content and fee structure applicable to the school.

Estimation of annual energy cost before and after the renovation

Use	Before the renovation	After the renovation	
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	LED lamp + Zone control
General electricity (lighting/class)	¥91,000	¥18,000	¥10,000
General electricity (lighting: when facilities are open to citizens)	¥78,000	¥49,000	¥25,000
Subtotal	¥169,000	¥67,000	¥35,000
Comparison (%)	100	40 (－60)	21 (－79)
General electricity (basic rate)	¥314,000	¥216,000	¥157,000
Total	¥483,000	¥283,000	¥192,000
Comparison (%)	100	59 (－41)	40 (－60)

(4) Initial cost of the environment-focused renovation

(i) Construction cost of the environment-focused renovation is about 79,000 yen/m^2.

(ii) Out of the cost of the environment-focused renovation, about 45,000 yen/m^2 is for measures to address aging degradation. The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school. The increase required for environmental measures is about 34,000 yen /m^2.

(iii) The direct construction costs for improvement of thermal insulation/heat shielding (including related works such as floor replacement) account for about 66% of the costs of the environment-focused renovation.

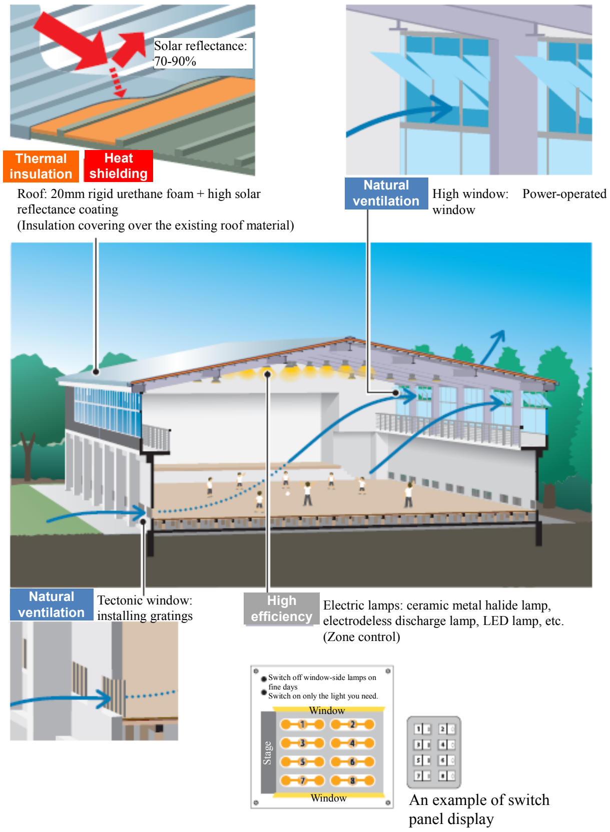
Rough estimation of construction cost per unit floor area (including tax)

(yen/m^2)

Major renovation work			Environment-focused renovation	Measures to address aging degradation (included in the amount to the left)
Construction work	Exterior	Roofing work	11,600	9,000
		Outer wall work	2,000	2,000
	Interior	Sash/door	19,900	0
		Floor	14,300	12,900
		Wall	4,000	2,900
		Other	400	400
	Temporary/demolish		9,700	8,200
Electric work	Lighting		1,200	0
Common expense			15,500	9,100
Total			78,600	44,500

(6) Region VI

Outline of the Plan



List of menus of environment-focused renovation

Item	Site	Before the renovation	After the renovation	
			Content	Method
Thermal insulation/airtightness	Roof	Without insulation	20mm rigid urethane foam + high solar reflectance coating	Covering over the existing roof material; installing insulation materials between existing battens
	Outer wall	Without insulation	–	–
	Floor (foundation)	Without insulation	–	–
	Sash	Aluminum sash with single-pane glass	–	–
Natural ventilation		Tectonic window	Installing power-operated windows Installing gratings to tectonic windows	Installed in part of sashes in gallery
Heating		–	–	–
Lighting		24 mercury lamps (400W)	Ceramic metal halide lamp, electrodeless discharge lamp or LED lamp + Zone control	Replacing lighting equipment; Adjusting circuits

Simulation result

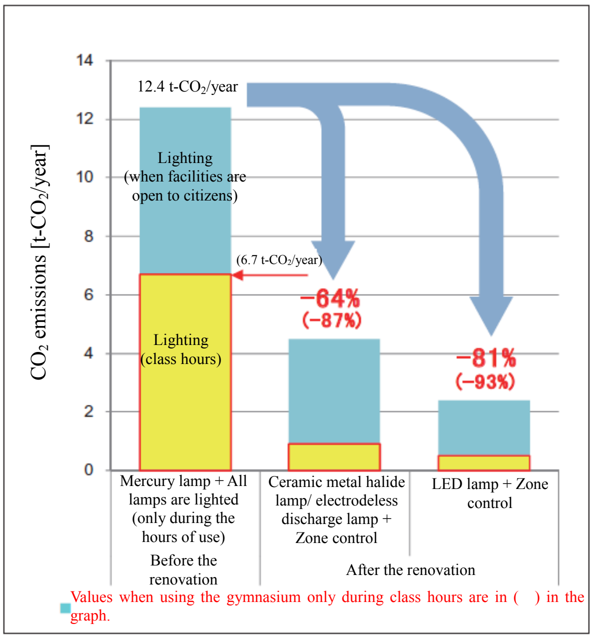
(1) Reduction of CO_2 emissions

- **Annual CO_2 emissions**

(i) Environment-focused renovation can reduce CO_2 emissions by about 64-81%.
*The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school.

(ii) Because air-conditioning equipment is not introduced in Region VI, CO_2 emissions are reduced by replacing lighting equipment with high-efficiency equipment and introducing zone control.

(iii) The reduction rates in the graph are values assuming the use of heating and lighting equipment during class hours and when the facilities are open to citizens. The rates are lower by 12-23% if they are used only during class hours.



Annual CO_2 emissions (Region VI)*

*Above is the result of simulation assuming use in an elementary school. For simulation result of a junior-high school (including club activities), see Reference 2.

- **Annual CO_2 emissions from lighting**

(i) Renovation can reduce emissions from 6.7t to 0.5-0.9t for use during class hours, and from 5.7t to 1.9-3.6t for hours when the facilities are open to citizens.

(ii) Reduction rates for use during class hours are 86.6% for using metal halide lamps and 92.5% for using LED lamps; reduction rates for hours when the facilities are open to citizens are 36.8% for using metal halide lamps and 66.7% for using LED lamps.

(iii) This is a plan to ensure energy conservation by zone control in addition to replacement with high-efficiency equipment.

Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	Contribution to the reduction (%)	LED lamp + Zone control	Contribution to the reduction (%)
Lighting (class hours)	6.7	0.9 (−86.6%)	73.4	0.5 (−92.5%)	62.0
Lighting (when facilities are open to citizens)	5.7	3.6 (−36.8%)	26.6	1.9 (−66.7%)	38.0
Total	12.4	4.5 (−63.7%)	100.0	2.4 (−80.6%)	100.0

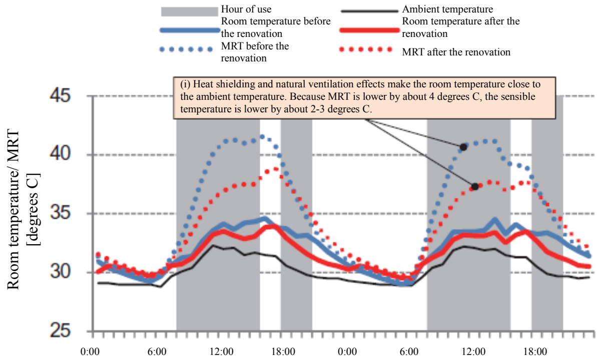
*Values in ( ) are reduction ratio by use compared with the CO_2 emissions before the renovation.

(2) Improvement of indoor thermal environment

*Reference 3 shows evaluation of indoor comfort in summer

(i) Summer: Improvement of the thermal insulation/heat shielding performance of the roof and the effect of natural ventilation make the room temperature close to the ambient temperature. Because radiation heat from the ceiling and wall surfaces is mitigated, the sensible temperature is lower by about 2-3 degrees C.

(ii) Summer: For gymnasiums without air-conditioning equipment, it is best to make the room temperature close to the ambient temperature, but it is important to further lower the sensible temperature. For this purpose, it is important to reduce heat gain from radiation by lowering the ceiling/wall surface temperature.



*MRT is surface temperature of indoor ceiling, wall, etc.

July 17-18

Temporal change of room temperature (1m above the floor) in summer (Region VI)

(3) Reducing running cost through environment-focused renovation

(i) The environment-focused renovation can reduce energy costs by about 42% in the case of a separate power contract for the gymnasium, and by 63% excluding the basic rate (when using ceramic metal halide lamps and/or electrodeless discharge lamp).

(ii) Because school facilities are open to citizens at night, the electricity bill of lighting for hours when the facility is open to citizens is higher than that during class hours (if the facilities are open to citizens every weekdays.)

(iii) The table to the right is the result of trial calculation under a certain assumption to provide a rough guide. The actual energy cost needs to be calculated based on the contract content and fee structure applicable to the school.

Estimation of annual energy cost before and after the renovation

Use	Before the renovation	After the renovation	
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamp/ Electrodeless discharge lamp + Zone control	LED lamp + Zone control
General electricity (lighting/class)	¥91,000	¥13,000	¥7,000
General electricity (lighting: when facilities are open to citizens)	¥78,000	¥49,000	¥25,000
Subtotal	¥169,000	¥62,000	¥32,000
Comparison (%)	100	37 (−63)	19 (−81)
General electricity (basic rate)	¥314,000	¥216,000	¥157,000
Total	¥483,000	¥278,000	¥189,000
Comparison (%)	100	58 (−42)	39 (−61)

(4) Initial cost of the environment-focused renovation

(i) Construction cost of the environment-focused renovation is about 63,000 yen/m^2.

(ii) Out of the cost of the environment-focused renovation, about 43,000 yen/m^2 is for measures to address aging degradation. The rate of reduction of CO_2 emissions in a gymnasium is very high but they account for only several percent of CO_2 emissions from the entire school. The increase required for environmental measures is about 20,000 yen /m^2.

(iii) The direct construction cost for improvement of thermal insulation (including related works such as floor replacement) accounts for about 63% of the cost of the environment-focused renovation.

Rough estimation of construction cost per unit floor area (including tax)

(yen/m^2)

Major renovation work			Environment-focused renovation	Measures to address aging degradation (included in the amount to the left)
Construction work	Exterior	Roofing work	11,600	9,000
		Outer wall work	2,000	2,000
	Interior	Sash/door	11,500	0
		Floor	12,900	12,900
		Wall	1,300	1,300
		Other	400	400
	Temporary/demolish		9,100	8,200
Electric work	Lighting		1,200	0
Common expense			12,600	8,800
Total			62,600	42,600

Reference

Reference 1　Breakdown of Renovation Cost (Initial Cost)

1. Direct construction cost

[yen]

		Regions I and II		Region III		Regions IV and V		Region VI	
		Environment-focused renovation	Of which Measures to address aging degradation	Environment-focused renovation	Of which Measures to address aging degradation	Environment-focused renovation	Of which Measures to address aging degradation	Environment-focused renovation	Of which Measures to address aging degradation
Construction costs	Dismantlement	4,900,000	4,000,000	5,400,000	4,000,000	5,400,000	4,000,000	4,900,000	4,000,000
	Arena floor	3,900,000	3,900,000	3,900,000	3,900,000	3,900,000	3,900,000	3,900,000	3,900,000
	Door/sash removal	400,000	0	400,000	0	400,000	0	400,000	0
	Finish removal	500,000	0	1,000,000	0	1,000,000	0	500,000	0
	Other	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Renovation work	52,100,000	27,500,000	51,400,000	29,000,000	52,200,000	29,000,000	40,600,000	27,500,000
	1. Temporal								
	Temporal	3,600,000	3,600,000	3,600,000	3,600,000	3,600,000	3,600,000	3,600,000	3,600,000
	2. Exterior								
	Roof insulation	2,600,000	0	1,600,000	0	2,400,000	0	2,400,000	0
	Roof (other than insulation)	8,400,000	8,400,000	8,400,000	8,400,000	8,400,000	8,400,000	8,400,000	8,400,000
	Outer wall insulation	8,900,000	0	0	0	0	0	0	0
	Outer wall (other than insulation)	1,900,000	1,900,000	1,900,000	1,900,000	1,900,000	1,900,000	1,900,000	1,900,000
	3. Interior								
	Sash	11,100,000	0	18,000,000	0	18,000,000	0	10,700,000	0
	Door	500,000	0	500,000	0	500,000	0	0	0
	Floor insulation	1,500,000	0	1,300,000	0	1,300,000	0	0	0
	Floor (other than insulation)	12,000,000	12,000,000	12,000,000	12,000,000	12,000,000	12,000,000	12,000,000	12,000,000
	Wall insulation	0	0	1,000,000	0	1,000,000	0	0	0
	Wall (other than insulation)	1,200,000	1,200,000	2,700,000	2,700,000	2,700,000	2,700,000	1,200,000	1,200,000
	Other finish	400,000	400,000	400,000	400,000	400,000	400,000	400,000	400,000
	Intermediate total	57,000,000	31,500,000	56,800,000	33,000,000	57,600,000	33,000,000	45,500,000	31,500,000
Equipment work cost	1. Lighting	1,100,000	0	1,100,000	0	1,100,000	0	1,100,000	0
	2. Heating	5,800,000	0	0	0	0	0	0	0
	Intermediate total	6,900,000	0	1,100,000	0	1,100,000	0	1,100,000	0
Total		63,900,000	31,500,000	57,900,000	33,000,000	58,700,000	33,000,000	46,600,000	31,500,000

2. Common expense

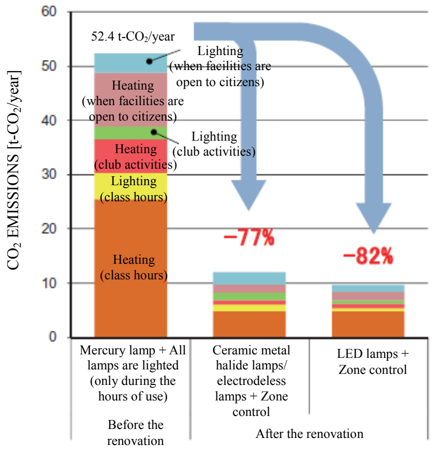
		Regions I and II		Region III		Regions IV and V		Region VI	
		Environment-focused renovation	Of which Measures to address aging degradation	Environment-focused renovation	Of which Measures to address aging degradation	Environment-focused renovation	Of which Measures to address aging degradation	Environment-focused renovation	Of which Measures to address aging degradation
Construction costs	Common temporal work costs	2,000,000	1,100,000	2,000,000	1,100,000	2,000,000	1,100,000	1,600,000	1,100,000
	Site office expenses	5,500,000	3,400,000	5,500,000	3,500,000	5,600,000	3,500,000	4,600,000	3,400,000
	General administrative expense	6,500,000	3,700,000	6,500,000	3,900,000	6,600,000	3,900,000	5,300,000	3,700,000
	Intermediate total	14,000,000	8,200,000	14,000,000	8,500,000	14,200,000	8,500,000	11,500,000	8,200,000
Equipment work costs	Lighting overhead (15%)	200,000	0	200,000	0	200,000	0	200,000	0
	Heating overhead (15%)	900,000	0	0	0	0	0	0	0
	Intermediate total	1,100,000	0	200,000	0	200,000	0	200,000	0
Total		15,100,000	8,200,000	14,200,000	8,500,000	14,400,000	8,500,000	11,700,000	8,200,000

Reference 2 Simulation Results of Model Plans for Each Region (Complement)

[Annual reduction of CO_2 emissions of junior-high school (with club activities)]

Graphs and subdivision table of annual CO_2 emissions

Region I

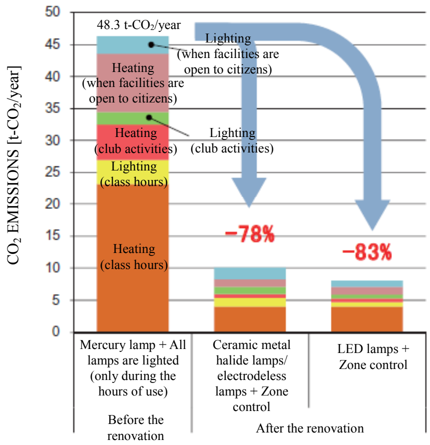


Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamps/ electrodeless lamps + Zone control	Contribution to the reduction (%)	LED lamps + Zone control	Contribution to the reduction (%)
Heating (class hours)	25.5	4.8 (−81.2%)	51.2	4.8 (−81.2%)	48.4
Lighting(class hours)	4.8	1.3 (−72.9%)	8.7	0.6 (−87.5%)	9.8
Heating (club activities)	6.2	0.8 (−87.1%)	13.4	0.8 (−87.1%)	12.6
Lighting (club activities)	2.4	1.4 (−41.7%)	2.5	0.7 (−70.8%)	4.0
Heating (when facilities are open to citizens)	9.9	1.5 (−84.8%)	20.8	1.5 (−84.8%)	19.6
Lighting (when facilities are open to citizens)	3.6	2.2 (−38.9%)	3.4	1.2 (−66.7%)	5.6
Total	52.4	12.0 (−77.1%)	100	9.6 (−81.7%)	100

*Values in ( ) are reduction rates of CO_2 emissions by use compared with before the renovation.

Region II

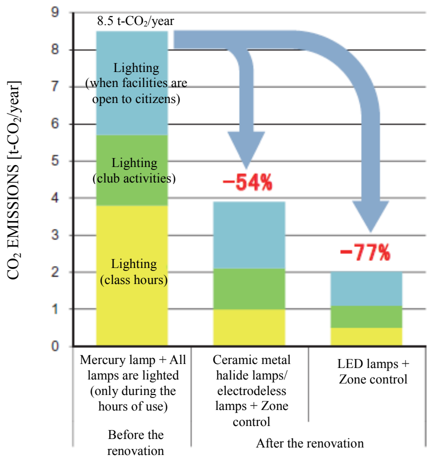


Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamps/ electrodeless lamps + Zone control	Contribution to the reduction (%)	LED lamps + Zone control	Contribution to the reduction (%)
Heating (class hours)	23.2	4.0 (−82.8%)	53.1	4.0 (−82.8%)	50.1
Lighting(class hours)	3.8	1.4 (−63.2%)	6.6	0.7 (−81.6%)	8.1
Heating (club activities)	5.5	0.6 (−89.1%)	13.5	0.6 (−89.1%)	12.8
Lighting (club activities)	1.9	1.1 (−42.1%)	2.2	0.6 (−68.4%)	3.4
Heating (when facilities are open to citizens)	9.1	1.2 (−86.8%)	21.8	1.2 (−86.8%)	20.6
Lighting (when facilities are open to citizens)	2.8	1.8 (−35.7%)	2.8	0.9 (−67.9%)	5.0
Total	46.3	10.1 (−78.2%)	100	8.0 (−82.7%)	100

*Values in ( ) are reduction rates of CO_2 emissions by use compared with before the renovation.

Region III

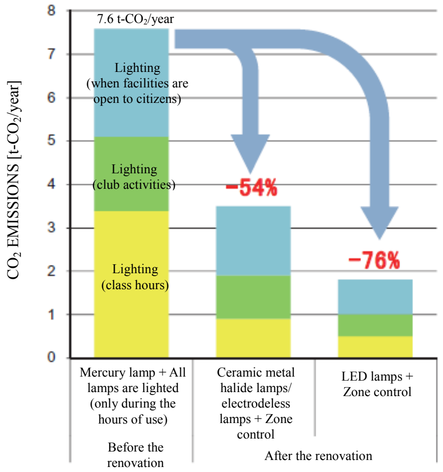


Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamps/ electrodeless lamps + Zone control	Contribution to the reduction (%)	LED lamps + Zone control	Contribution to the reduction (%)
Lighting(class hours)	3.8	1.0 (−73.7%)	60.9	0.5 (−86.8%)	50.8
Lighting (club activities)	1.9	1.1 (−42.1%)	17.4	0.6 (−68.4%)	20.0
Lighting (when facilities are open to citizens)	2.8	1.8 (−35.7%)	21.7	0.9 (−67.9%)	29.2
Total	8.5	3.9 (−54.1%)	100.0	2.0 (−76.5%)	100.0

*Values in ( ) are reduction rates of CO_2 emissions by use compared with before the renovation.

Region IV

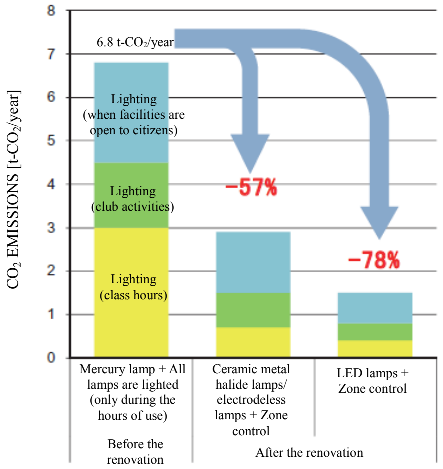


Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamps/ electrodeless lamps + Zone control	Contribution to the reduction (%)	LED lamps + Zone control	Contribution to the reduction (%)
Lighting(class hours)	3.4	0.9 (−73.5%)	61.0	0.5 (−85.3%)	50.0
Lighting (club activities)	1.7	1.0 (−41.2%)	17.1	0.5 (−70.6%)	20.7
Lighting (when facilities are open to citizens)	2.5	1.6 (−36.0%)	21.9	0.8 (−68.0%)	29.3
Total	7.6	3.5 (−53.9%)	100.0	1.8 (−76.3%)	100.0

*Values in ( ) are reduction rates of CO_2 emissions by use compared with before the renovation.

Region V

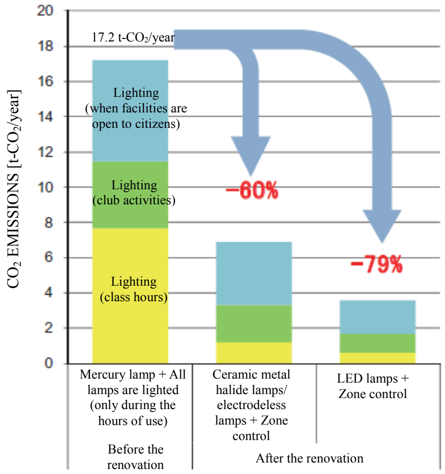


Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamps/ electrodeless lamps + Zone control	Contribution to the reduction (%)	LED lamps + Zone control	Contribution to the reduction (%)
Lighting(class hours)	3.0	0.7 (−76.7%)	59.0	0.4 (−86.7%)	49.0
Lighting (club activities)	1.5	0.8 (−46.7%)	17.9	0.4 (−73.3%)	20.8
Lighting (when facilities are open to citizens)	2.3	1.4 (−39.1%)	23.1	0.7 (−69.6%)	30.2
Total	6.8	2.9 (−57.4%)	100.0	1.5 (−77.9%)	100.0

*Values in ( ) are reduction rates of CO_2 emissions by use compared with before the renovation.

Region VI



Annual CO_2 emissions [t-CO_2/year]

Use	Before the renovation	After the renovation			
	Mercury lamp + All lamps are lighted (only during the hours of use)	Ceramic metal halide lamps/ electrodeless lamps + Zone control	Contribution to the reduction (%)	LED lamps + Zone control	Contribution to the reduction (%)
Lighting(class hours)	7.7	1.2 (−84.4%)	63.1	0.6 (−92.2%)	52.2
Lighting (club activities)	3.8	2.1 (−44.7%)	16.5	1.1 (−71.1%)	19.9
Lighting (when facilities are open to citizens)	5.7	3.6 (−36.8%)	20.4	1.9 (−66.7%)	27.9
Total	17.2	6.9 (−59.9%)	100.0	3.6 (−79.1%)	100.0

*Values in ( ) are reduction rates of CO_2 emissions by use compared with before the renovation.

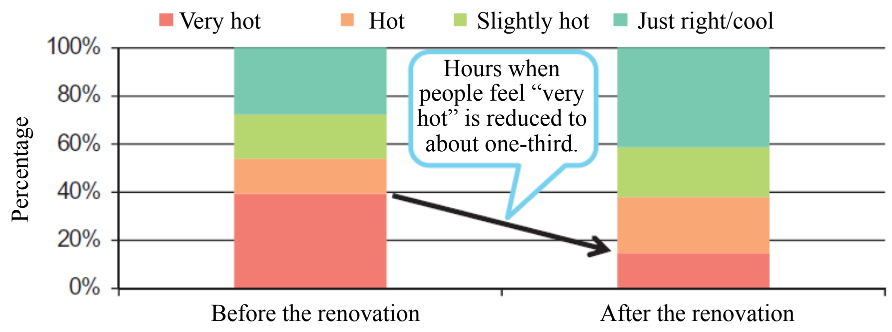
Reference 3 Evaluation of Summer Indoor Comfort in Regions IV to VI

We calculated PMV* of Regions IV to VI and evaluated the level of "hot" and "cold (cool)" feeling.
The graphs below show PMV distribution in summer. They show that natural ventilation (ventilation using temperature difference) improves the indoor environment in all Regions.

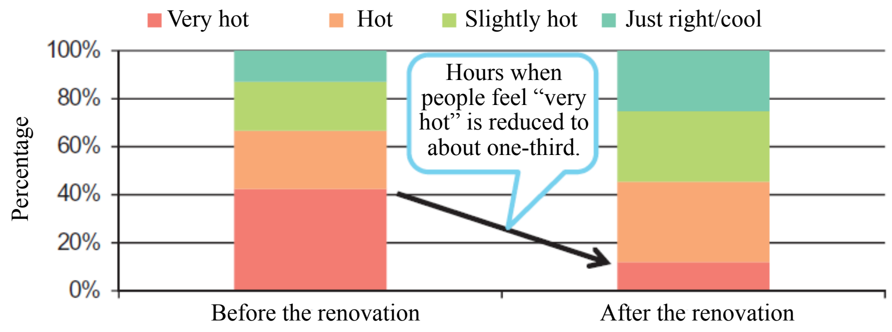
*PMV is an indicator to evaluate comfort. The table to the right shows correspondence between PMV values and warm-cold sense (feeling of warmth/cold).
PMV is calculated from air temperature, mean radiant temperature, humidity, air current, amount of clothing and metabolic heat produced by activity.

PMV value	Warm-cold sense
+3	Very hot
+2	Hot
+1	Slightly hot
0	Neutral(comfortable)
-1	Slightly cold
-2	Cold
-3	Very cold

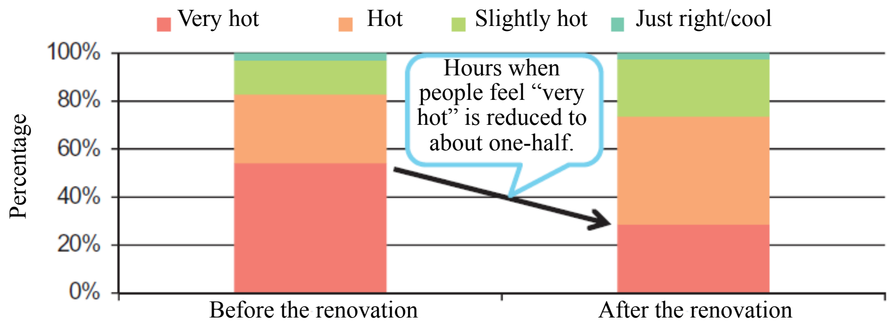
Region IV



Region V



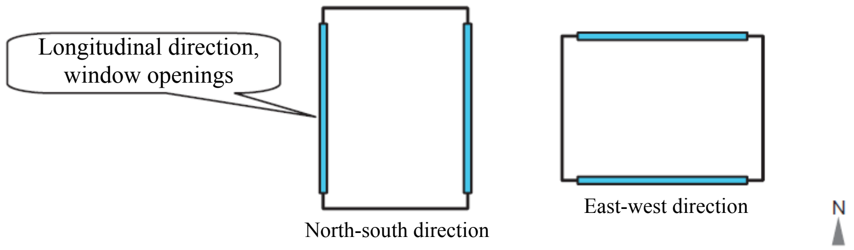
Region VI



Reference 4 Impact of the Direction of Gymnasium on Simulation Result

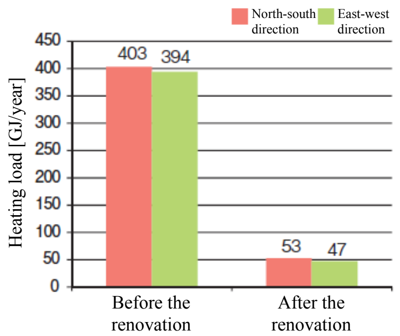
Direction of Gymnasium

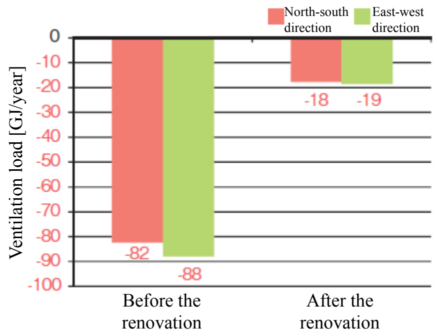
In the report, simulations were conducted assuming that the gymnasium lies in the north-south direction as illustrated by the drawing below. Additional simulations were conducted to examine possible differences by changing the direction of the gymnasium to east-west.



Heating load and ventilation load in cold region (Region II)

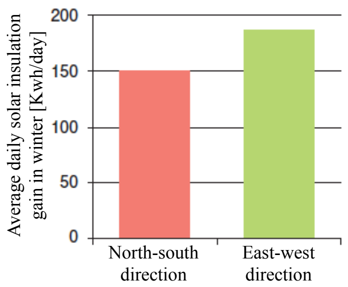
There is little difference in values both in heating and ventilation loads.

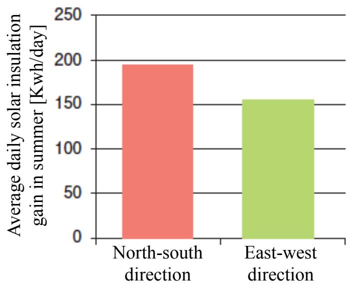




Solar radiation gain in warm region (Region IV)

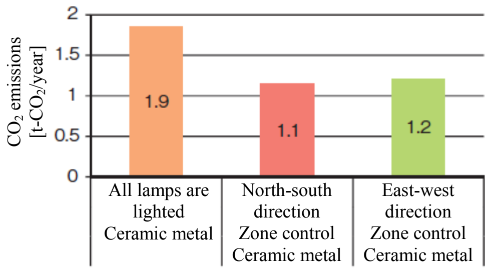
The solar radiation gain of the east-west gymnasium is slightly higher in winter while that of the north-south gymnasium is slightly higher in summer. Considering the weight of the cold in winter and that of the heat in summer, the indoor environment is slightly better in existing gymnasiums of east-west direction.





Annual CO_2 emissions from lighting

The results of CO_2 emissions from lighting show little difference.



Reference 5 About the Study Organization (Working Group Regulations)

Fundamental Study of School Facility Environments

October 24, 2007
Final revision on March 17, 2011
Decision by the Director General of
the National Institute for Educational Policy Research

1. Aims

In recent years, environmental problems on a global scale have been raised as a common issue for the whole world, and the development of school facilities that take the reduction of the environmental burden and coexistence with nature into consideration is required. Moreover, since 2008 when the commitment period of the Kyoto Protocol started, so the government and other bodies are strengthening initiatives aimed at reducing greenhouse gas emissions.

Based on this kind of situation, as well as grasping the current situation with regard to energy consumption in school facilities, the research group will carry out a study of policies for promoting environmental measures in existing school buildings and contribute to educational facility measures associated with the future development of school facilities.

2. Focus of the Study

(1) Grasping the actual energy consumption situation in school facilities
(2) Formulating model plans for environmental measures focused on existing school buildings
(3) Develop tools for calculation of CO_2 emissions from school facilities
(4) Other relevant matters

3. Implementation Method

With the cooperation of the academics listed in the annex to this document, research will be conducted into the areas listed in item 2. above. In addition, the research group will be able to seek the cooperation of other interested parties, as required.

4. Implementation period

The study will be carried out between 24 October 2007 and 31 March 2012.

(Annex)

Fundamental Study of School Facility Environments: Cooperating Parties

(Japanese alphabetical order, ○: Project Leader)

(Commissioners)
Osamu Koizumi, Manager, Project Coordination Headquarters, Nihon Sekkei, Inc.
○ Hiromi Komine, Professor, Department of Architecture and Civil Engineering, Chiba Institute of Technology
Jun Sakaguchi, Professor, Department of International Studies and Regional Development, University of Niigata Prefecture
Nobuyasu Terashima, Manager, ARCOM R&D Architects Department, Chodai, Co., Ltd.
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(Survey specialist member)
Yuhei Kobayashi, Architecture & Civil Engineering Laboratory, School of Engineering, Chiba Institute of Technology

(Observers: Department of Facilities Planning and Administration, Minister's Secretariat, Ministry of Education, Culture, Sports, Science and Technology (MEXT))
Seiichiro Yamamoto, Deputy Director, Facilities Planning Division (until March 31 2011)
Yoshiyuki Kotani, Deputy Director, Facilities Planning Division (from April 1, 2011)
Tomoyasu Shimada, Advisor Section Chief, Facilities Planning Division (from April 1, 2010)
Kazuyuki Todogawa, Deputy Director, Local Facilities Aid Division (Until March 31, 2011)
Hideki Takami, Deputy Director, Local Facilities Aid Division (From April 1, 2011)
Atsuya Morii, Technical Section Chief, Local Facilities Aid Division

(Cooperation with Simulations and illustrations)
Satoh Energy Research Co,. Ltd.

In addition, the following staff members at the National Institute for Educational Policy Research were involved in the compilation of the report.

Koichi Shinpo, Director, Educational Facilities Research Center (Until January 5, 2012)
Fukuei Saito, Director, Educational Facilities Research Center (From January 6, 2012)
Masahiro Kobayashi, Senior Researcher, Educational Facilities Research Center
Atsushi Fujii, Specialist, Educational Facilities Research Center

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- "*Wall Greening Guideline*" Tokyo Metropolitan Government

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