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Energy Saving Measures and Simulation in the Library Building of University of Surabaya

Elieser Tarigan
Department of Electrical Engineering, Center for Renewable Energy Studies, PSET, University of Surabaya
Jl. Raya Kalirungkut, Surabaya 60292, Indonesia
elieser@staff.ubaya.ac.id

Abstract

The rapid rate use of fossil fuels globally results in many environmental problems. The adoption of energy efficient technology has the potential to substantially reduce the amount of energy used in buildings. This paper discuses the energy saving measures and simulation for a six-floor library building, University of Surabaya, Indonesia. Simulation was carried out using the Excellence in Design for Greater Efficiency (EDGE) simulation software. The results of simulation showed that 53% of energy efficiency can be reached, without lowering of the building comfort, by applying of four measures at the same time are daylight photoelectric sensors for internal spaces (OFE29), radiant cooling and heating system (OFE16), higher thermal performance glass (OFE8), and external shading devices (OFE4). The implementation of the four measures would result in reduction of 758 ton of CO_2/year with a payback period of 2.2 years.

Keywords: Energy efficiency, energy building, energy saving, library building, energy simulation

Abstrak

Pemanfaatan energy fosil dalam jumlah yang besar secara global menimbulkan permasalahan berkaitan dengan lingkungan. Usaha untuk mengimplementasikan teknologi dalam penghematan energi sangat signifikan dalam penerapannya pada bangunan. Tulisan ini mendiskusikan parameter-parameter penghematan energi serta mensimulasikannya pada sebuah bangunan perpustakaan Universitas Surabaya yang terdiri dari 6 lantai. Simulasi dilakukan menggunakan sofware EDGE. Hasil simulasi menunjukkan bahwa kombinasi 4 parameter penghematan energi dapat memberikan penghematan energi hingga 53%. Parameter tersebut adalah daylight photoelectric sensors for internal spaces (OFE29), radiant cooling and heating system (OFE16), higher thermal performance glass (OFE8), dan external shading devices (OFE4). Implementasi keempat parameter tersebut akan mengurangi emisi karbodiokasida 758 ton per tahun dengan payback period sekitar 2,2 tahun.

Kata kunci: *Efisiensi energi, energi pada bangunan, hemat energi, bangunan perpustakaan, simulasi energi*

I. Introduction

Energy has been the main global issue, along with population, food, and environment issues [1]. Energy use by human populations has increased at a rapid rate, in particular by extraction and combustion of fossil fuels. This, however, results in many environmental problems at local, regional and global scales [2]-[7]. Studies from a number of countries have shown that the adoption of energy efficient technology has the potential to substantially reduce the amount of energy used in commercial and industrial buildings [2][8][9]. There have been few quantitative attempts to identify energy saving measures. Nevertheless, it is clear that the potential to implement energy saving measures exists [3][8][10]. Studies indicate that the energy efficiency plan contemplates short-term tangible/intangible actions, and considers the investment and payback period of the tangible measures. Reductions in energy consumption are expected if the energy efficiency plan would be implemented [11].

The University of Surabaya (Ubaya) is one of the private universities, especially in the eastern region of Indonesia. The management of the University of Surabaya has a very high concern for sustainability issues. The university was founded

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around 1965. The university occupies three different locations in East Java Province. Two campuses area located at different area in Surabaya City (Campus 1 and Campus 2) and another one (Campus 3) is located in Trawas, Mojokerto. The latest campus is so-called integrated outdoor campus (IOC). The academic activities are mainly held in Campus 2. Currently, there are 29 permanent buildings situated on campus 2. The buildings are being used for various different academically purposes such classrooms, offices, library, laboratories, canteens, etc. The total area of land of the campus is about 88,020 m^2 with about 1,535 m of a circumference. The total area occupied by buildings is about 12,280 m^2 or 14% of the land area. The library building situated in Campus 2 is the main object in this study.

This study aims to simulate the energy savings in the central library building of University of Surabaya which consist of a six-floor library building. The simulation work is conducted to find the most feasible way of energy efficiency. The information and the results from this study are expected to be useful and applicable for scaling up to a wider scope of similar buildings as one way to promote and toward energy sustainability.

II. Materials and Method

A. *Building Description*

The object of this study is an existing six-floor library building at the University of Surabaya, Indonesia. The building consists of 6,372 m^2 in total. Figure 1 shows the front view of the building. The wall of the building is constructed from common brick and plaster. The floor is from tiles of 20 cm x 20 cm ceramic. About 30% of façade and all sides of the exterior wall are closed windows glass of single layer with aluminum frame.

Inside of the building is divided into several partitions for different purposes, such as bookshelves, reading rooms, computer rooms, offices, bathrooms, etc. Figure 2 show typical situation inside of the building. The building uses a centralized cooling system which is turned on during working hours 07.00-19.00 WIB. For lighting, all of the lamps installed (FL lamp) are also turned on during working hours. Electricity is supplied by national building grid (PLN). This information, along with other real conditions and information of the buildings are used as the base case of simulation.

Figure 1. Library building of University of Surabaya

The building uses a centralized cooling system which is turned on during working hours 07.00-19.00 WIB. For lighting, all of the lamps installed (FL also) are also turned on during working hours. Electricity will improve by national electricity grid, PLN. This information, along with other real conditions and information of the buildings are used as the base case of simulation. The dimension of the building (floor plan depth, main orientation, and other building data) as needed in the simulation input parameters are shown in Table 1. The front of the building is facing South West (SE). The orientation of the building will have a direct effect on energy consumption.

Table 1. Building data and orientation

Item Data	Building Data
Floor plan depth	5 m
Main orientation	SouthWest
Built-up area excluding car parking	6,372 m^2
Floors above grade	6
Floor to floor height	3.5 m
Open plan office	3,891 m^2
Privat office	610 m^2
Corridors	451 m^2
Conference rooms	387 m^2
Lobby	514 m^2
Bathrooms	196 m^2
M&E rooms, store	323 m^2
Occupancy density	10 m^2/person
Operational hours	10 hours/day
Working days	5 days/week
Holidays	12 days/year
Building length:	
North	0
South	0
DataEast	0
West	0
Northeast	100 m
Northwest	100 m
Southeast	100 m
Southwest	100 m

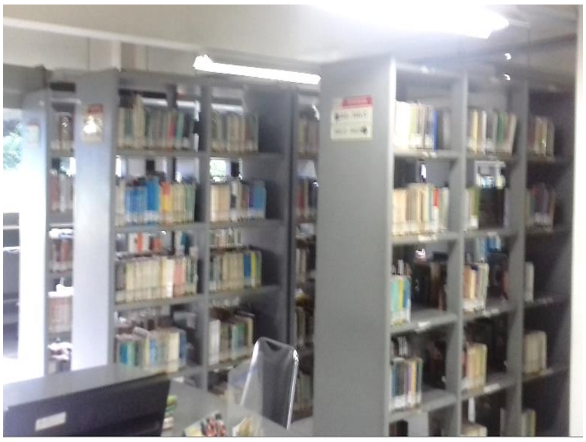

Figure 2. Book selves (inside view)

B. Software and Simulation

Energy simulation in this study is conducted using web-based simulation software namely EDGE (Excellence in Design for Greater Efficiency) provided by IFC of World Bank Group. The software is free to anyone who creates a user account [12] at the website: https://app. edgebuildings.com.

The software provides a measurable way to cut back on the resource intensity of new buildings, empowering stakeholders to determine the most cost-effective options for a building's resource-efficient design. There are three main measures feature in the software: energy measures, water measures, and material measures. The software calculates the utility savings and reduced carbon footprint building against a base case. The saving energy opportunities will be known by entering as much of the building's information as possible into the software, and choosing systems and solutions [13].

Table 2. Assumption parameters for simulated building

Parameter input	Assumption Value
Solar Reflectivity for Paint-Wall	30%
Solar Reflectivity for Paint-Roof	30 %
Roof U Value	1.28 W/m^2.K
Wall U Value	2.80 W/m^2.K
Glass-U Value	5.8 W/m^2.K
Glass SHGC	0.6 (factor)
Cooling system	ASHRAE 90.1.2007
AC system Efficiency	4.90 COP
Heating System Efficiency	1.00 COP
CO2 Emissions from Electricity generation	755 g/kWh

Table 3. Assumption parameters for simulated building

Month	Average Temp. (^{o}C)
January	28.5
February	28.5
March	29.0
April	29.0
May	28.5
June	28.5
July	28.5
August	28.0
September	29.0
October	30.0
November	30.5
December	29.0

In this work, however, the simulation was carried out with the focus on energy measures for the building. From four building categories in the software, the type of "Office Building" transfer as this type is considered the most suitable based the input parameters. For unknown value for some parameters of the simulated building, the default values (key assumption) from the software were used, as shown in Table 2.

The local weather condition will affect the energy saving strategies for the building. Weather parameters (monthly temperature) in Surabaya for simulation input, are shown in Table 3. The data was obtained from previous studies [14]. The annual rainfall in Surabaya is about 1159.8 mm, while the geographical position is 7^{o}19'24.40S and 112^{o}46'06.04W.

C. Energy Measures

There are 30 energy efficiency measures on the simulation for the type of buildings, denoted with OFE01-OFE30. The simulation work is conducted to find the most feasible represents to apply for the simulated buildings. The following is a short description of each of the measures, summarized from the program user manual [15]:

1) Reduced Window to Wall Ratio (OFE01): This measure is important for the roof with high albedo (solar reflectivity). The cooling load in air-conditioned spaces can be reduced by specifying a reflective finish for the roof. On the other hand, in non-air conditioned spaces, this will improve thermal comfort. The color is the key consideration of the material or finish.

2) Reflective Paint/Tiles for Roof Solar Reflectivity (OFE02): This measure is important for the roof with high albedo (solar reflectivity). The cooling load in air-conditioned spaces can be reduced by specifying a reflective finish for the measure. On the other hand, in non-air conditioned spaces, this will improve thermal comfort. The color is the key consideration of the material or finish.

3) Reflective Paint for External Walls Solar Reflectivity (OFE03): Description for this measure is similar to “Reflective Paint/Tiles for Roof Solar Reflectivity-OFE02” above for wall condition.

4) External Shading Devices (OFE04): This measure is applied to external shading devices of exterior building. External shading devices are commonly used to protect the glazing elements (windows) from direct solar radiation. The reason is that when solar radiation has penetrated the windows (glass), it will increase solar heat gain as well as glare.

5) Insulation of Roof Surfaces (OFE05): This measure associated with the U-value of materials. Employing of insulation will improve the U-value. In a warm climate, the insulation prevents heat transfer from the external environment to the internal space. While, in the cold climate, it prevent heat transfer from the internal space to the external environment. Therefore, a building with good insulation has lower energy requirements.

6) Insulation of External Walls (OFE06): Description for this measure is similar to “Insulation of Roof Surfaces-OFE05” above for external wall condition.

7) Low-E Coated Glass (OFE07): Employing a Low-E coating to glazing will reduce the transference of heat from one side to the other. A low-E coated glass decreases of its U-value (thermal resistance), as well as the Solar Heat Gain Coefficient (SHGC). The process is by reflecting thermal energy. The intention in warm climates is to reduce heat gain, on the other hand, in cold climates to reflect heat indoors.

8) Higher Thermal Performance Glass (OFE08): This measure is applied only to the double or triple multi-paned glass with a superior thermal performance. The type of glass also has a Low-E coating with related to heat transfer.

9) Natural Ventilation Offices, Corridors, Lobby (OFE09): Occupant comfort of a building can be improved by a well-designed natural ventilation. This way will reduce the cooling load, which is also reduced initial capital as well as the cost of maintenance. The measure can be applied by considering the ratio of room depth to ceiling height and the proportion of openings.

10) Ceiling Fans in All Office Rooms (OFE10): Ceiling fans are commonly applied for increasing of the movement of air which affects the human comfort. This measure is used for a building which ceiling fans are specified in all rooms for office.

11) Variable Refrigerant Volume (VRV) Cooling System (OFE11): The measure is applied to a building with a VRV cooling system. In many cases, the original building does not include the cooling system, which might raise the risk that the users will deal with any overheating and with inappropriate and poorly installation of a cooling system. The cooling load can be reduced by designing of an efficient cooling system installation.

12) Air Conditioning with Air Cooled Screw Chiller (OFE12): Description for this measure is similar to “Variable Refrigerant Volume (VRV) Cooling System (OFE11)” above for Air Conditioning with Air Cooled Screw Chiller.

13) Air Conditioning with Water Cooled Chiller (OFE13): This measure is for a building with Air Cooled Screw Chiller. Energy saving can be achieved with a higher value of Coefficient of Performance (COP).

14) Geothermal Ground Source Heat Pump (OFE14): This measure is for a building with geothermal heat pump. Geothermal is an alternative clean and renewable energy. Energy saving can be achieved with a higher value of Coefficient of Performance (COP).

15) Absorption Chiller Powered by Waste Heat (OFE15): This measure is for a building with a cooling system power is provided by capturing the waste heat for cooling cycle and the absorption chiller system. The COP is used in this measure to establish the efficiency. The cooling and/ or heating load can be reduced significantly by designing the installation of a mechanical refrigeration system using the waste heat generated in other processes.

16) Radiant Cooling and Heating System (OFE16): This measure is for a building where at least 50% of the cooling and heating output is from radiant cooling or heating system. Operational costs for energy system, in many cases, can be reduced by reducing fan energy associated with traditional forced air cooling/ heating systems. The radiant cooling and heating system can also improve comfortness through lower in wide temperature diversities, strong ventilation drafts, and the noise of a fan.

17) Recovery of Waste Heat from the Generator for Space Heating (OFE17): This measure is for a building where energy for space heating is obtained from wasted heat from power generation through burning diesel or gas. Capturing the heat wasted from power generators, which can provide heat for space heating, may substantially help of reduction of fossil fuel consumption and operating costs, as well as lower greenhouse gas emissions.

18) Variable Speed Drives on the Fans of Cooling Towers (OFE18): This measure is for a building where the HVAC system requires a cooling tower(s). Energy consumption can be reduced by specifying Variable Speed Drive (VSD) on the fans of cooling towers.

19) Variable Speed Drives in AHUs (OFE19): This measure is for a building using VSD fans in the Air Handling Units (AHUs) of the HVAC system. The purpose of the measure is to encourage the project team to specify a suitable VSD.

20) Variable Speed Drives Pumps (OFE20): This measure is for building with VSD pumps installed in the HVAC system. The purpose of the measure is to specify VSD pumps to reduce energy consumption, as well as utility cost.

21) Sensible Heat Recovery from Exhaust Air (OFE21): This measure is for a building where the heat from the exhaust air is re-used with sensible heat recovery installed in the ventilation system.

22) High Efficiency Condensing Boiler for Space Heating (OFE22): This measure is for a building where the boiler used for delivering space heating is a gas condensing boiler.

23) Air Economizers during Favorable Outdoor Conditions (OFE23): This measure is for building in which all the air handlers in the HVAC system use air economizers. In many cases, the outside air conditions are suitable to cool the building with a small mechanical cooling.

24) Energy Saving Light Bulbs Internal Spaces (OFE24): This measure is used for a building wherein all of internal the rooms: offices, circulation area, lobby, storage, restrooms, etc. are used one of the three types of bulbs: CFL, LED, or T5 type. This type of lamps reduces the building's energy use for lighting.

25) Energy Saving Light Bulbs External Spaces (OFE25): The description is similar to OFE24 above with condition for external spaces.

26) Lighting Controls for Corridors and Staircases (OFE26): Less energy consumption for lighting can be achieved by installing automatic controls in shared or public, and outdoor spaces where there is the possibility of lights being left on when not required. This measure is related to previous measures (particularly OFE24 and OFE25) that lighting controls can lower energy needed for lighting. Hence, a better efficient the light bulbs would give the less impact the automated controls. However, the lighting control should not be applied to an emergency or safety lighting systems.

27) Occupancy Sensors in Bathrooms, Conference Rooms, and Closed Cabins (OFE27): Occupancy sensors can be used to control all ambient lighting in closed office cabins, bathrooms, conference rooms etc. By this, less energy is consumed by the possibility of controlling lights being left on when not required is reduced.

28) Occupancy Sensors in Open Offices (OFE28): The description is similar to OFE27 above with condition in open offices.

29) Daylight photoelectric sensors for internal spaces (OFE29): Energy for lighting can be saved during day time by switching off electric lights when lighting needs can be met by natural light.

30) Solar Photovoltaic (OFE30): This measure for a building where solar photovoltaic panels are installed for supplying energy for the building. Electricity demand from the grid can be reduced by solar PV system which is a renewable source. In order to optimize the portion of energy from the PV system, the energy consumption should be firstly reduced to minimize electricity demand (e.g. by applying the possible previous measures). There are many different types of solar photovoltaic systems available and different technologies convert solar energy into electricity with varying levels of efficiency. Efficiency levels of up to around 20% can be achieved by some commercially available systems, but others are only capable of delivering as little as 5% efficiency. Design teams should, therefore, ensure that the specified system achieves the maximum efficiency possible for the available capital [14]. In addition, there are many aspects that we have to considered in order to optimize the use of renewable energy [16].

III. Results and Discussions

Based case condition of energy uses in the simulated building is as shown in Figure 3, a generated graph from the software. It is obviously seen that the "open plan office" segment, which represents the main rooms functioned for library activities, need a significant portion of energy. The base case condition of energy uses, then it is tempted to improve the saving energy by simulating with the 30 energy efficiency measures.

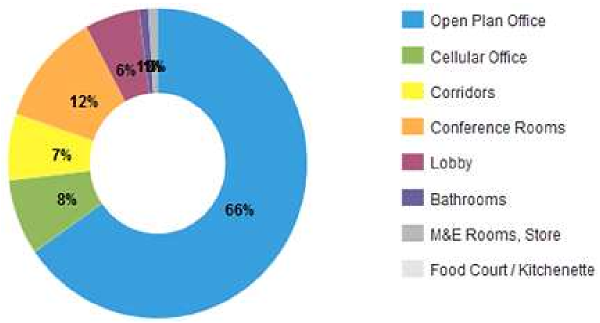

Figure 3. Base case for energy saving simulation

The main simulation result is summarized in tabulated form as shown in Table 4 and Table 5. It shows the codes, the referred energy saving measure, and the estimated energy saving by applying a particular measure. The result in the table shows the possibility of energy efficiency when the particular measure is applied solely. The combination of the application of several different measures at the same time, however, might not accumulate the number or level of saving percentage. This is due to the measures are in fact related each other. Therefore the important task in the simulation is to find the optimum energy saving from the combination of measures. The consideration should also include the cost, the easiness and building comfort when the measures are applied.

Of the 30 measures, there are about 9 measures individually would give the result of energy saving higher than 10%, however in terms of cost, easiness, building comfort and other considerations, not all of the measures are feasible to be applied in the building. For example, implementing of OFE09 (natural ventilation offices, corridors, lobby) solely would give energy saving up to 24.88%. While solely implementing of OFE10 (ceiling fans in all office rooms) would give energy saving up to 22.80 %. While the combination of OFE09 and OFE10 would give energy saving of about 28%. These implementations, however, will impact the less comfort of the building

The initial cost for PV system a is significantly high with a payback period of 14.5 years. In a real condition, however, on-site potential solar radiation need to be investigated, as output electricity from the PV will depends on the radiation. Prediction and calculation can be made using using least square support vector machine method [17].

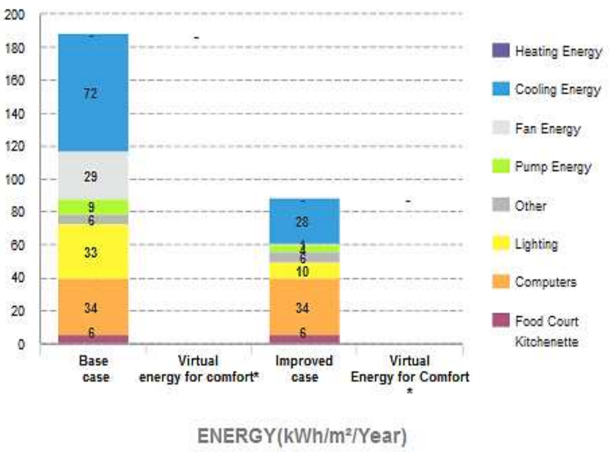

Figure 4. Base case and improved case of energy use

Table 4. Energy saving measures and simulation results

Measures codes	Energy saving measures	Energy saving (%)
OFE01	Reduced window to wall ratio	11.38
OFE02	Reflective paint/tiles for roof solar reflectivity	1.17
OFE03	Reflective paint for external walls solar reflectivity	1.30
OFE04	External shading devices	16.49
OFE05	Insulation of roof surfaces	2.30
OFE06	Insulation of external walls	3.60
OFE07	Lowe coated glass	8.16
OFE08	Higher thermal performance glass	17.42
OFE09	Natural ventilation offices, corridors, lobby	24.88
OFE10	Ceiling fans in all office rooms	22.80
OFE11	Variable refrigerant volume (VRV) cooling system	2.47
OFE12	Air conditioning with air cooled screw chiller	*-9.92*
OFE13	Air conditioning with water cooled chiller	5.40
OFE14	(Geothermal) ground source heat pump	-3.62
OFE15	Absorption chiller powered by waste heat	0.52
OFE16	Radiant cooling and heating system	16.89
OFE17	Recovery of waste heat from the generator for space heating	0
OFE18	Variable speed drives on the fans of cooling towers	0.69
OFE19	Variable speed drives in AHUs	0.18
OFE20	Variable speed drives pumps	0
OFE21	Sensible heat recovery from exhaust air	1.63
OFE22	High-efficiency condensing boiler for space heating	0
OFE23	Air economizers during favorable outdoor conditions	0
OFE24	Energy saving light bulbs internal spaces	10.69
OFE25	Energy saving light bulbs external spaces	0.75
OFE26	Lighting controls for corridors & staircases	0.09
OFE27	Occupancy sensors in bathrooms, conference rooms, and closed cabins	1.76
OFE28	Occupancy sensors in open offices	4.56
OFE29	Daylight photoelectric sensors for internal spaces	15.0
OFE30	Solar photovoltaic	24.87

Table 5. Embodied energy savings, operational CO_2 savings, and payback

Measures	Embodied energy savings (MJ/m^2)	Operational CO_2 savings (Ton/yr)	Payback in years
OFE01	308	336	0
OFE02	35	-7	N/A
OFE03	35	36	1.41
OFE04	35	446	N/A
OFE05	35	16	1.78
OFE06	35	107	0
OFE07	35	221	0
OFE08	35	469	3.84
OFE09	35	0	N/A
OFE10	35	437	0.28
OFE11	35	43	0
OFE12	35	-188	N/A
OFE13	35	101	0.14
OFE14	35	-69	N/A
OFE15	35	5	4.77
OFE16	35	242	0.29
OFE17	35	-4	N/A
OFE18	35	11	4.17
OFE19	35	-4	N/A
OFE20	35	-4	N/A
OFE21	35	17	2.06
OFE22	35	-4	N/A
OFE23	35	-4	N/A
OFE24	35	73	3.16
OFE25	35	4	12.4
OFE26	35	-2	N/A
OFE27	35	8	5.83
OFE28	35	31	2.32
OFE29	35	101	0.63
OFE30	35	358	14.5

Negative values of energy saving would be obtained by implementing OFE12 (air conditioning with air cooled screw chiller) and OFE14 (geothermal ground source heat pump). In the simulation, the suggested improved case for OFE12 has a COP that varies according to the peak cooling load of a project building and energy savings. A negative value of energy saving from implementing geothermal heat pump can be understood that the building is situated in a hot climate where heating for a building is not needed.

Simulation results show that by applying the combination of four measures: OFE4, OFE8, OFE16 and OFE 29 would result in the total energy efficiency of 52.6%. The measures refer respective to: external shading devices, higher thermal performance glass, radiant cooling, and heating system, and daylight photoelectric sensors for internal spaces. The comparison of base case and improve case of energy use is shown in Figure 4. The measures are not affected the energy comfort in the building. Applying these measures would give the operational CO_2 saving of 759 tCO_2/year. In term of costs, the payback period is about 2.2 years.

Using of renewable energy from solar photovoltaic, PV (OFE3) could save energy (fossil) about 25% of total energy by installing PV system with a capacity of 404 KWp. Such system will give the operational CO_2 saving of 358 tCO_2/year. Table V presents the summary of simulation results for the embodied energy savings, the operational CO_2 savings, and payback period for each individual measure.

IV. CONCLUSIONS

Energy saving in an existing building can be achieved by many ways. Simulation for a six-floor library building of the University of Surabaya shows that by applying the combination of four measures (from 30 energy saving measures in the simulation) would result in the total energy efficiency of 52.6%. The measures refer respectively to external shading devices, higher thermal performance glass, radiant cooling, and heating system, and daylight photoelectric sensors for internal spaces. The four measures are not affected the energy comfort in the building. Applying these measures would give the operational CO_2 saving of 759 tCO_2/year and the payback period is about 2.2 years.

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