Algae façade as green building method: application of algae as a method to meet the green building regulation

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Abstract. The Local Government of Bandung city has stipulated a Green Building regulation through the Peraturan Walikota Number 1023/2016. Signed by the mayor in October 2016, Bandung became the first city in Indonesia that put green building as mandatory requirement in the building permit (IMB) process. Green Building regulation is intended to have more efficient consumption of energy and water, improved indoor air quality, management of liquid and solid waste etc. This objective is attained through various design method in building envelope, ventilation and air conditioning system, lighting, indoor transportation system, and electrical system. To minimize energy consumption of buildings that have large openings, sun shading device is often utilized together with low-E glass panes. For buildings in hot humid tropical climate, this method reduces indoor air temperature and thus requires less energy for air conditioning. Indoor air quality is often done by monitoring the carbon dioxide levels. Application of algae as part of building system façade has recently been introduced as replacement of large glass surface in the building façade. Algae are not yet included in the green building regulation because it is relatively new. The research will investigate, with the help of the modelling process and extensive literature, how effective is the implementation of algae in building façade to reduce energy consumption and improve its indoor air quality. This paper is written based on the design of ITB Innovation Park as an ongoing architectural design-based research how the algae-integrated building façade affects the energy consumption.

Keywords: algae, building system façade, green building regulation, ITB Innovation Park

1. Introduction

The Local Government of Bandung city has stipulated a Green Building regulation through the Peraturan Walikota Number 1023/2016. Signed by the mayor in October 2016, Bandung became the first city in Indonesia that put green building as mandatory requirement in the building permit (IMB) process. At provincial level, the government of DKI Jakarta has their green building regulation earlier in their Peraturan Gubernur Number 38/2012. More cities will follow the example of Jakarta and Bandung, because green building regulation has become a national policy in the ministry of public works and housing Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat No. 02/PRT/M/2015. The expansion of regulatory framework indicates the growing importance of green building application in Indonesian large urban areas. This is in line with the findings that building sector is a major energy consumer. Research indicated that carbon-dioxide emissions from the building sector (when embodied energy is considered) exceed those of the industry and transport sectors [1].

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Introducing and implementing green building regulation in Indonesian cities is not a simple task. There are green building standards and regulations in other countries that can be adopted or used as reference for Indonesia. However, those standards are set according to the local climate that might be far different from the hot humid tropical climate in Indonesia. The economic level of the countries must be taken into consideration as well, because some measures of green building method may be too costly for Indonesian cities. Hence the green building regulation in Jakarta or Bandung might have been limited to control certain aspects of the building only for its ease of implementation by local government and building owners. There is still a chance that new or more advanced method of green building with appropriate technology to be implemented in this situation, provided that the method has been studied beforehand.

Green Building regulation is intended to have more efficient consumption of energy and water, improved indoor air quality, better management of liquid and solid waste etc. These objectives are attained through various design methods in building envelope, ventilation and air conditioning system, lighting, indoor transportation system, and electrical system. To minimize energy consumption of buildings that have large openings, sun shading device is often utilized so that indoor temperature rise due to reduction of solar heat gain through radiation. Another popular measure to reduce heat gain in buildings with large opening is by using low-E glass panes. For buildings in hot humid tropical climate, this method reduces indoor air temperature and thus requires less energy for air conditioning.

Indoor air quality is often done by monitoring the oxygen and carbon dioxide levels, among others in the building. Innovation in improving the air quality by installing a photo bioreactor or algae bioreactor has been experimented. Such bioreactor absorbs CO2 from the indoor air and releases more oxygen during photosynthesis process because algae are photoautotroph organisms. Algae photo bioreactor has been installed at the BIQ house in Hamburg, Germany and the GSA federal building in Los Angeles among others.

Figure 1. The BIQ House: first algae-powered building in the world. [2]

Figure 2. GSA federal building in Los Angeles. [3]

The application of algae bioreactor as sun screening device in building façade has not been studied extensively in terms of its solar heat transmittance or luminance. An architectural design-based research on the use and role of algae as part of the building façade system is currently being undertaken at the School of Architecture, Planning and Policy Development in Insitut Teknologi Bandung. Based on that research, this paper is intended to provide a description of possible alternative technology in the form of an algae bioreactor and the argumentation for its implementation to meet the green building regulation in Bandung city.

2. Methods

This paper is written based on a study conducted as part of an ongoing research project on building façade systems. The research project investigates the possibility of using an algae bioreactor as part of a building façade. The case study of the research project is a new Innovation Park building of ITB that is currently in the preliminary design phase. The new building is located in Jl. Ganesha across the ITB main campus. It sits on a site with its narrow side on the North and relatively long side on East/West. Large areas of the building's façade are facing East and West, thus exposing the building to more sun radiation due to its large windows on these sides. The research investigates the possibility and the advantage and disadvantage of using algae bioreactor in the building façade.

Figure 3. The design of ITB Innovation Park on Jalan Ganesha: the four storey building in the center.

The study uses a three stages method. It begins with a critical review of the existing green building regulation in Bandung city. The review is done to recognize the objectives of the regulation, as well as some background information regarding pertinent research findings that are used as the base for the green building regulation in Bandung. The background information will help to understand why these standards need to be applied in Bandung. The next step is to identify the requirements to meet those objectives, particularly to determine which parts of the building regulation are relevant to the algae bioreactor façade experiment.

The third or final stage is performing an experiment as an effort to meet the regulation. The experiment is performed in two ways. One experiment is done through computational modelling, and the other experiment is performed with physical measurement in the laboratory. Analysis is done by comparing the performance of the designed façade using conventional design features and the façade with algae bioreactor. This is performed by calculating the energy requirement for cooling of the building in three alternatives: glass windows, window with sun shading device or horizontal screen, and window with algae bioreactor as screen. Energy requirement for building cooling is used as the parameter in this experiment because the objective of green building is clear enough, i.e., to reduce the consumption of resources such as electicity, water and air.

3. Background Study on Green Building Regulation in Bandung

The Bandung city green building regulation has main principles that the buildings establishment shall not burden the environment beyond its carrying capacity; and shall promote efficient use of natural resources for the purpose of building construction and operation (As stated in the Article 4 of the Bandung Green Building Regulation). The regulation applies to two categories of buildings: the first category is for all new buildings or building-addition with a total floor area over 5,000 sqm, and the second category is for new building under 5,000 sqm.

Most of the energy in buildings in Indonesia is consumed by the HVAC system, regardless of the type of building. Office building, retail center, hotel, hospital, apartment building and educational facilities (as presented in Fig 4) show indoor cooling as the main energy consumption. The diagram indicates that HVAC contributes about 37% to 54% of building total energy consumption. Artificial lighting contributes 20% to 39% of total energy consumption. Therefore, reducing energy consumption for HVAC and artificial lighting through passive and active design can effectively reduce the overall building energy consumption. [4] The study of Innovation Park building focuses on the reduction of energy consumption for HVAC and artificial lighting.

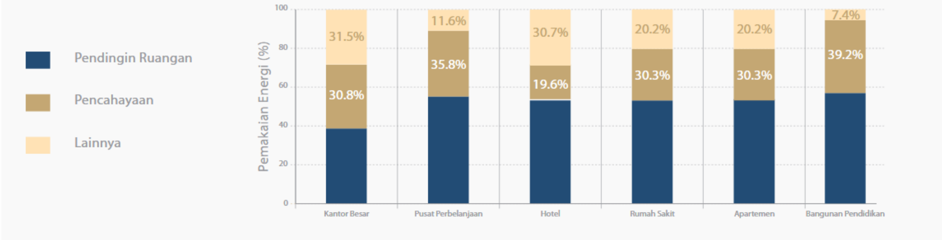

Figure 4. Details of energy consumption for various types of buildings. [5]

The Innovation Park building has a total floor area of approximately 2,000 sqm including its semi basement, so it falls into the category of new building under 5,000 sqm. The Mandatory Requirements for New Building construction with floor area less than 5,000 m² including basement is as following:

Article 39 [6]

The compulsory requirement of new green buildings for constructions with floor space of less than 5,000 m² (five thousand square meters) including the basement as referred to in Article 6 paragraph (5) letter b, including:

a. Energy efficiency;
b. Water efficiency;
c. Indoor air quality; and
d. Land management.

Article 40

Energy efficiency in building buildings as referred to in Article 39 letter a, covering:

a. System of building envelope;
b. Air conditioning system; and
c. Lighting system.

Article 41

1) The requirements of the green building building envelope system as referred to in Article 40 letter a, following the provisions referred to in Article 9.
2) Requirements of the green building building envelope system as referred to in paragraph (1) shall be required in buildings with functions other than residential houses.

In order to comply with Articles 39, 40 and 41 the Innovation Park building must have energy efficiency and indoor air quality by utilizing building envelope system, air conditioning and lighting because the building is used for non-residential purpose.

As shown in Figure 5, the external heat gain from the windows and walls of a typical office building in Bandung is about 63%, while the internal heat gain from equipment, lighting and occupancy is about 37%. This demonstrates enormous energy savings opportunities through carefully designed and precise building envelopes to reduce air cooling loads. [7] The Innovation Park building is mainly used as office, thus it is expected to have those values of external heat gain from window and walls.

Article 9

1) The requirements of green building building envelope system as referred to in Article 8 letter a, is intended to make the cooling load more efficient.
2) The system of building envelope referred to in paragraph (1), carried out by air conditioning system shall plan the building envelope by calculating the PMD / OTTV and PMA / RTTV values.
3) The PMD / OTTV value and PMA / RTTV value as referred to in paragraph (2), in buildings using air conditioning systems, shall be taken into account not exceeding 45 Watt / m2 (forty five watts per square meter).
4) The calculation of PMD / OTTV and PMA / RTTV as referred to in paragraph (3) shall use spreadsheet calculator or graph with solar radiation factor PMD / OTTV and PMA / RTTV areas provided by SKPD.
5) Provisions concerning the local solar radiation are listed in Attachment I which is an inseparable part of this Mayor Regulation.

4. Background Study on Green Building Regulation in Bandung

The design alternatives are tested and evaluated using computational modelling with Open Studio-Energy Plus/OS-EP software. Three design alternatives of building envelope system are evaluated using this method, whereas the alternative with algae bioreactor is physically tested in the laboratory. The three building envelope design alternatives are façade with conventional glass window panes, façade with horizontal shading device, and façade with brise-soleil. Weather data for Bandung is not available in the Open Studio-Energy Plus software, hence we used Singapore weather data as the basis for the simulation because it is the closest location.

For the simulation, several thermal zones are applied in the building, which has been designated according to its function. The use of air conditioning in this experiment is required to measure the amount of total energy (in kBtu) in the building with OS-EP software. For this experiment, thermal zone 3 was tested. Thermal zone 3 accommodates the main facilities such as co-working spaces, rental offices, and multi purposes/exhibition hall.

As the benchmark for the other façade design alternatives, the original design with glass panes windows is tested. Figure 6 displays the simplified model that was used for the computational modelling. The OpenStudio-Energy Plus result is shown in Table 1.

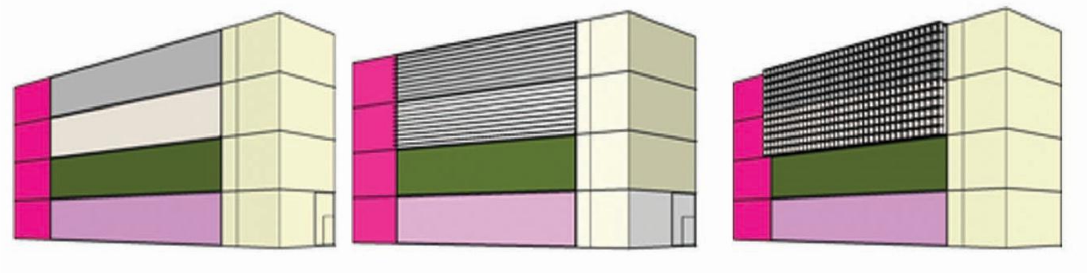

Figure 5. Simplified model of façade configurations (left to right): original design with glass panes windows, alternative with horizontal shading device, alternative with brise-soleil.

Table 1. Building Summary Original configuration window with glass pane.

Information	Value	Units
Net Site Energy	1,300,945	kBtu
Total Building Area	17,443	ft^2
EUI (Based on Net Site Energy and Total Building Area)	74.58	$kBtu/ft^2$

The second façade design alternative uses shading device in the form of fixed horizontal shutters in front of the glass window. Simplification of the building design for computational modelling was performed in order to enable quicker calculation of the main openings in the façade, while retaining the overall building shape and dimensions. Figure 7 below shows the model of façade configuration with horizontal shading device.

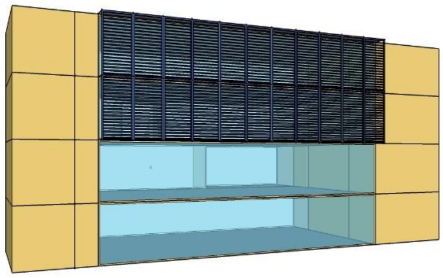

Figure 6. Model of façade configuration with fixed horizontal shutter shading device.

The OpenStudio result for the second façade design alternative is shown in Table 2 below

Table 2. Building Summary window configuration with horizontal shading device.

Information	Value	Units
Net Site Energy	1,281,051	kBtu
Total Building Area	17,443	ft^2
EUI (Based on Net Site Energy and Total Building Area)	73.44	$kBtu/ft^2$

The third façade design alternative uses brise-soleil, comprised of lightweight concrete with waffle pattern (square shaped holes) that is mounted in front of the glass window openings

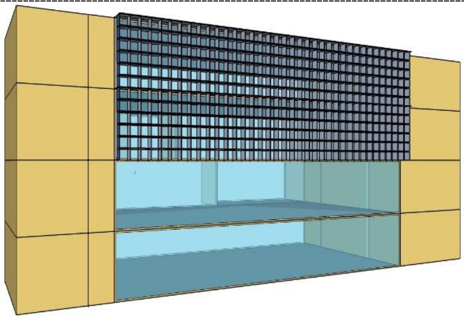

Figure 7. Model of façade with brise-soleil.

The OpenStudio-Energy Plus result for the third façade design alternative is shown in Table 3

Table 3. Building Summary window configuration with brise-soleil.

Information	Value	Units
Net Site Energy	1,278,700	kBtu
Total Building Area	17,443	ft^2
EUI (Based on Net Site Energy and Total Building Area)	73.31	$kBtu/ft^2$

The result of the experiment with computational modelling shows that energy consumption for indoor cooling of the Innovation Park building will be reduced 1.53% from 1,300,945 kBtu to 1,281,051 kBtu if we install horizontal shading device as compared to the glass windows in the original design. This confirms the suggestion in the green building regulation to apply shading device as a measure to reduce building energy consumption. However, changing the façade screening from the horizontal shading device to brise-soleil only reduces further the energy consumption by 0.18% from 1,281,051 kBtu to 1,278,700 kBtu.

5. Algae Bioreactor Experiment

The second experiment of measuring the heat properties of the algae bioreactor has not been performed in the research. Physical model construction is still undergoing and the bioreactor will be ready by end of July 2017. Measurement of light and heat transmittance through the reactor – that uses green algae – can be performed later in the ITB laboratory.

The model of façade as a sample in the experiment of algae bioreactor is made of thin glass block as a prototype of Algae building facade. A wooden box is attached behind the glass block. Measurement of the air temperature and the intensity of the incoming sunlight will be performed inside the wooden box that can be regarded as a representation of the indoor space of the building.

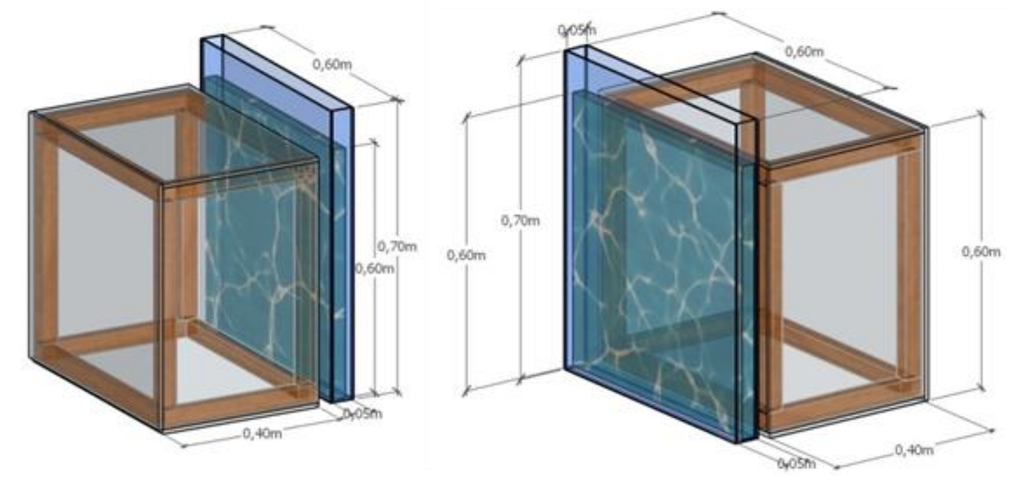

Figure 8. Model of façade with algae bioreactor.

Preparation of the bioreactor testing equipment was conducted through several trials. The first uses a 5mm thin glass (Figure 9 left) but it could not hold the weight of the water, so it had to be rebuild from a thicker glass that has 8mm thickness (Figure 9 center). The black box has no leaking or structural problem in this stage (Figure 9 right)

Figure 9. Construction process of algae bioreactor.

The Bioreactor is moved to the roof top of the Inter-University Center to determine the best placement position for the bioreactor test apparatus (Figure 10)

Figure 10. Placement of algae bioreactor on roof top.

Apparently after reconsideration, the Experiment tool can still be optimized before testing. The optimization is planned to be done with more air bubble pump modification and algae preparation, so the tool is temporarily taken to the Aquatic Ecosystem Analysis Lab., School of Life Sciences and Technology ITB.

After 10 days, the algae have also been grown and ready to be put into the photo bioreactor at the time as we mount it on the rooftop of the Inter-University Center. However, there are still some tools to acquire for the photo bioreactor, which are:

1) A larger aerator because the one installed is not sufficiently powerful
2) Rock aerator (3 pieces) with a diameter of 8cm
3) Clear silicone glue
4) Black paint for wooden stand (figure 11).

Figure 11. Temporary placement of algae bioreactor in the Aquatic Ecosystem Analysis Laboratory.

6. Concluding Remarks

The experiment has confirmed the Green Building Regulation’s suggestion to apply sun shading or screening device in building façade, particularly the façade in East and West orientation. The ITB Innovation Park building has larger East/West façade than its North/South façade, hence implementation of shading device is important for this office building.

The experiment of algae bioreactor as alternative for sun shading device is not yet completed at the time this paper was written, due to some setback during the preparation of the experiment device. The result of this algae bioreactor experiment can be compared to result of the computational modelling. According to the expert in Microbial Biotechnology Research Group ITB, another advantage of the bioreactor is the conversion of CO2 into O2 during its process that can be utilized to improve the air quality in the building. This is done by blowing the air from inside of the building into the bottom of the bioreactor. The O2 rich will come out of the top of the bioreactor air. Indoor air quality is one of the requirements stated in the Bandung's Green Building Regulation Article 39.

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