Feasibility of Algae Photobioreactor as Façade in the Office Building in Indonesia

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Abstract. Algae has a high potential as a renewable energy resource. Recent studies about algae photobioreactor application in the building façade seem promising and the first algae building has been constructed in Hamburg, Germany. However, the application of algae photobioreactor in the hot and humid climate is still limited. This paper will discuss the feasibility of algae photobioreactor as façade in the office building by evaluating the model from Sketchup software. This is a real project of a new office building, named ITB Innovation Park at Institut Teknologi Bandung campus, Jalan Ganesha no. 15. The algae photobioreactor is planned to be installed in the west façade as shading devices and renewable energy resources. It is assumed that the acrylic moulding would work better to reduce leakage issues and the possibility of killing the algae.

1. Introduction
Greenhouse emission from the building can be decreased by increasing the energy efficiency by using passive design architecture according to the climate and applying renewable energy technology to supply electricity of the building and reduce the energy demands. Application of renewable energy such as photovoltaic panels and solar thermal in the building has been widely conducted by the researchers across the world. However, the application of another source of renewable energy such as biomass from the microorganism is still limited.
As can be seen in figure 1, a pilot project of the “house with Bio-IQ” or BIQ house in Hamburg, Germany is the first building that uses an approximately 200 sqm algae photobioreactor in its façade which produced net annual energy of about 4,500 kWh of electricity. This algae building consists of 15 apartments where the algae photobioreactor in the southeast and southwest façades are also utilized to generate heat to the apartments and produce biomass. There are 129 photobioreactors (PBRs) modules in this building, with 70 cm wide, 270 cm high and 8 cm thick which arranged in groups and mounted on a steel frame [1].
A study by Kim in 2013 revealed that algae facades system has the potential to be used in the future as sustainable façade alternatives and it is possible to generate energy. Structural analysis and thermal performance analysis using computer simulation were conducted, as well as create the prototype of the panel (see Figure 2). The researcher suggested that investigate the long-term performance and durability must be performed [2].
The thesis of Bogias in 2014 explored the cultivation of algae biomass in smaller scales by creating the prototypes of secondary skin façade (see Figure 3), to test the possible material that can be used for algae photobioreactor. Although harvesting algae in a built environment have some benefits such as producing oxygen, manage wastewater, or produce a valuable product, it comes with challenges. There are three design principles of the algae photobioreactor: spatial impact, practicality, and environmental impact. These design principles are beneficial to define the requirements of a photobioreactor in a building-specific context and to evaluate how the design of the algae textile could accommodate these challenges [3].

A theoretical study was also conducted by Pruvost et al. in France to investigate the photobioreactor technology in an integrated building façade. It was revealed that to decrease operational costs, CO₂ supply, and thermal regulation were the most significant aspects [4]. Proksch in 2013 concluded that integration of algae cultivation and architecture expand a new perspective of sustainable design by associating carbon-neutral energy production with ecological recycling of environmental pollutants.
Algae cultivation could enhance the environmental footprint as well as carbon dioxide’s emission of power plants, industrial operation, and large urban infrastructures. In the smallest scale, it can also improve building performance if it used in the facade [5]. Elrayies in 2018 has explained the promising applications of photobioreactor in the built environment. In this paper, the essential aspects of microalgae as a renewable energy source, the possible types, the composition, mechanisms, and the implications of algae photobioreactor façades in terms of energy and environmental performance has been reviewed. The challenges and prospects of this technology are also discussed. It is clear that there are specific technical requirements that need to be considered and solved for all the inputs (carbon dioxide, water, nutrients, and microalgae) and outputs (heat, algal biomass, and oxygen) of the algae photobioreactor in the building façade [6]. Feasibility study of Algae Building Technology in Sydney was conducted by Wilkinson et al. in 2016 to investigate the technological, economic, environmental, social, and regulatory drivers and challenges to algae building technology. A series of semi-structured interviews with the substantial group of highly experienced and well-educated professional stakeholders in the Australian built environment sectors such as architects, engineers, director, project manager, sustainability manager, and the government. Their opinions and perceptions on the prospects of living algae in the building systems were mostly concerned about the technical factors such as climate suitability, mechanical systems and maintenance, leakage and contamination potential, and amount of algae production. There is a big consideration on the economic factors such as the high costs of development, research, production, and manufacture. Environmental factors were strong drivers because of the algae could improve the built environment quality. Social factors which include the opinion of the aesthetics of the algae photobioreactor. Most of the respondent agree that the panel is attractive although a few of them thought the opposite about the green color of the algae. For the regulatory issues, the guidelines need to be produced and provided to help the stakeholder to ensure that the algae façade have taken thorough due diligence [7]. An experiment by Martokusumo et al in 2017, reported that a simplified prototype of algae photobioreactor under hot humid climate region could decrease the indoor temperature when the outdoor temperature is higher (afternoon time) and indoor temperature will increase when the temperature outside is colder (night time). It is also revealed that the oxygen produced by the algae could be supplied to the building for air purifier [8].

Figure 4. Experiment of algae photobioreactor in Indonesia
The objectives of this study are to examine the feasibility of algae photobioreactor in the building in Indonesia, by discussing the potential and challenge including technical issues of algae photobioreactor in the project of ITB Innovation Park building located in Bandung City, West Java, Indonesia.

2. Methods
This paper is the continuation of the study about algae photobioreactor in the building which is conducted by Martokusumo et al. in 2017. The algae photobioreactor will be placed in the west façade of ITB Innovation Park building (see Figure 5) in Jalan Ganeca Bandung, just across the Institut Teknologi Bandung campus. It was planned that the algae-photobioreactor’s design will follow the BIQ house in Hamburg, Germany. However, to make it less complicated, the team has discussed with the Algae expert in Institut Teknologi Bandung, that the panels in the façade are only a place for algae Chlorella being exposed to the sunlight and help the photosynthesize process.

Figure 5. Design plan for the use of algae photobioreactor on building facades.
The process of giving algae the nutrition and carbon-dioxide will be placed in the basement of the building. The room in the basement will have a large rectangular pond with approximately volume of 2,000 litres to produce algae, a preparation area to make the medium for algae, to store the stock culture, and to prepare inoculum to refresh the culture. The algae in the pond will then be pumped to the photobioreactor panels in the third and fourth floor west façade through the pipe, and when the algae fill up the panels, it will flow to the pond in the basement. The circulation will proceed continuously in the closed loop, unless the algae is ready to be harvested and all the panels as well as the pool need to be cleaned up.

A rectangular pond made with curved corners to avoid dead algae at the corners when the pool is stirred. The algae room will also be maintained in a temperature of 20 °C. As can be seen in the figure 6, the material of the pond is acrylic to penetrate lighting from the surrounding. The pond is connected by four types of pipes, which are: culture medium pipe to the algae photobioreactor, oxygen pipe produced from the pond that will be transferred to the building, nutrient pipe to supply algae growth, and pipe to harvest biomass and for cleaning process.

![Figure 6. Algae circulation from the algae room before it was pumped to the algae photobioreactor.](image)

### 3. Discussion and Conclusion

From previous studies, algae photobioreactor is potentially beneficial to be applied in a building. However, there has not been much further research into the technical aspects and constraints, especially if the algae photobioreactor would be placed in the hot and humid climate such as Indonesia. The initial design of IIP building will have 56 panels algae photobioreactor with total volume of 1,500 litres. Each photobioreactor panel dimension (include frames) is 600 mm x 1,800 mm, with a 20 mm gap between the glass as a room for the algae. The proposed material of the algae photobioreactor is a 6 mm tempered glass and mounted on a steel frame.

An alternative also has been made to compare which design will work better to be placed in the building façade. After having discussion with a custom-made façade consultant, there is an idea to make the algae photobioreactor using acrylic pipes that are sold in the market or moulding the acrylic according to the desired shape.

There are several aspects to consider of how this algae photobioreactor would be applied in the building façade, i.e.: material availability and price, manufacture and constructability, function, and maintenance. As a first step, the 3D model using Sketchup software was made to visualize the idea of algae photobioreactor using steel frame with glass (see Figure 7) and an acrylic moulding and pipes (see Figure 8).
In the design of steel frame and glass, algae will flow through the pipe at the top, fill the entire panel, and then it will flow again towards the pond in the algae room in the basement through the pipe at the bottom of the frame. Because of the narrow gap between the glass, the pipes dimension would be smaller. The steel frame is also potentially having a leak from the holes to insert the pipes as well as the connection between glass and steel frame. Furthermore, the shape of the frame could potentially kill the algae since it would stack up in the corner of the glass. However, this design will work better in reducing the direct sunlight into the building.

With the acrylic moulding and pipes, possibility of algae dies will be reduced because the algae will flow directly through all the pipes. The leakage can also be anticipated because the connection between the pipes has been moulded. However, a supporting structure will be needed such as perforated metal sheet to support the weight of the pipes.

Based on the Sketchup model, the design of Algae Photobioreactor was evaluated to determine which design is better and would work well (see Table 1).

### Table 1. Comparison of Algae Photobioreactor Design.

| Algae photobioreactor       | Advantages                               | Disadvantages                                      |
|-----------------------------|------------------------------------------|---------------------------------------------------|
| **Steel Frame and Glass**   | - The design is simple and can be functioned better as shading device | - The gap between glass is too narrow (20mm) so the manufacturing would be difficult |
|                             | - High possibility of algae dies when stack up in the corner | - The weight of the steel frame, glass, and algae would be heavy |
|                             | - Difficult for maintenance (cleaning)   |                                                   |
| **Acrylic Moulding and Pipes** | - Design can be adjusted                | - Expensive to mould the acrylic                   |
|                             | - Low possibility of leaking              | - Need supporting structure                         |
|                             | - Reduce the possibility of algae dies    | - High possibility of scratches                      |

From this study, it can be concluded that acrylic moulding is more preferable because the design can be adjusted and has low risk of leak. However, further studies by making the prototype and simulation...
in the computer to calculate the thermal performance of algae photobioreactor are still on progress and will be published later.

4. References

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