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Optimization Study of Parametric Thermal Bimetal Material Module for Green Building in Tropical Humid Climate

Case Study: Kampung Juminahan, Yogyakarta, Indonesia

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Abstract

The largest energy consumption that we use is the consumption of electrical energy in terms of meeting the lighting needs and building air conditioning requirements (World Energy Consumption, 2016). According to the Ministry of Energy and Mineral Resources (2017), Indonesia's largest energy use in commercial buildings is for flight systems (63%), lighting systems (20%), vertical transportation (7%) electronic devices (10%). The use of energy in the fulfillment of excessive needs result in worsening conditions on earth. Data can be a reflection of how the condition of the earth that we live at this time. Energy savings should be made to reduce the damage already occurring on this earth such as electricity usage savings, optimization of use of materials, the use of motor vehicles that cause air pollution, and others.

The way that can be used to reduce artificial energy use is to utilize the existing passive building design such as the use of solar energy that can be maximized during the day, so that the use of electrical energy for lamps and artificial air conditioning. reduced. In addition, it can also be considered the optimal use of wind direction and speed that can suppress the use of Air Conditioner (AC) in excess.

Building envelope with bimetal thermal material module application is part of kinetic architecture via biomimicry approach. Kinetic architecture is a concept where buildings are designed to allow parts of buildings to move without compromising the unity of the structural system. Approaches that can be applied in green building design is by optimizing bimetal material module that utilizes the thermal coefficient of a material. With this approach, building envelopes are improvised so that they can adapt to the existing environment. This research take location of case study in Kampung Juminahan, Yogyakarta, Indonesia which has characters of comunal housing.

Keywords

Thermal bimetal; Thermal responsive design; green building

1. Introduction

The way that can be used to reduce the use of artificial energy is by utilizing the existing passive building design such as the use of solar energy that can be maximized its use during the day, so the use of electrical energy for lamps and artificial air conditioning is reduced. In addition, it can be considered also the optimal use of wind direction and speed that can suppress the use of Air Conditioner (AC) in excess.

Building envelope with the application of bimetal thermal material module which is part of Kinetic Architecture.

Kinetic architecture is a concept whereby buildings are designed to allow parts of buildings or building structures to move without compromising the unity of the structural system. The approach can be applied in green building design one of them by optimizing the module on bimetal material that utilizes thermal coefficient of a material. With this approach, the building envelope is improvised so that it can adapt to the existing environment.

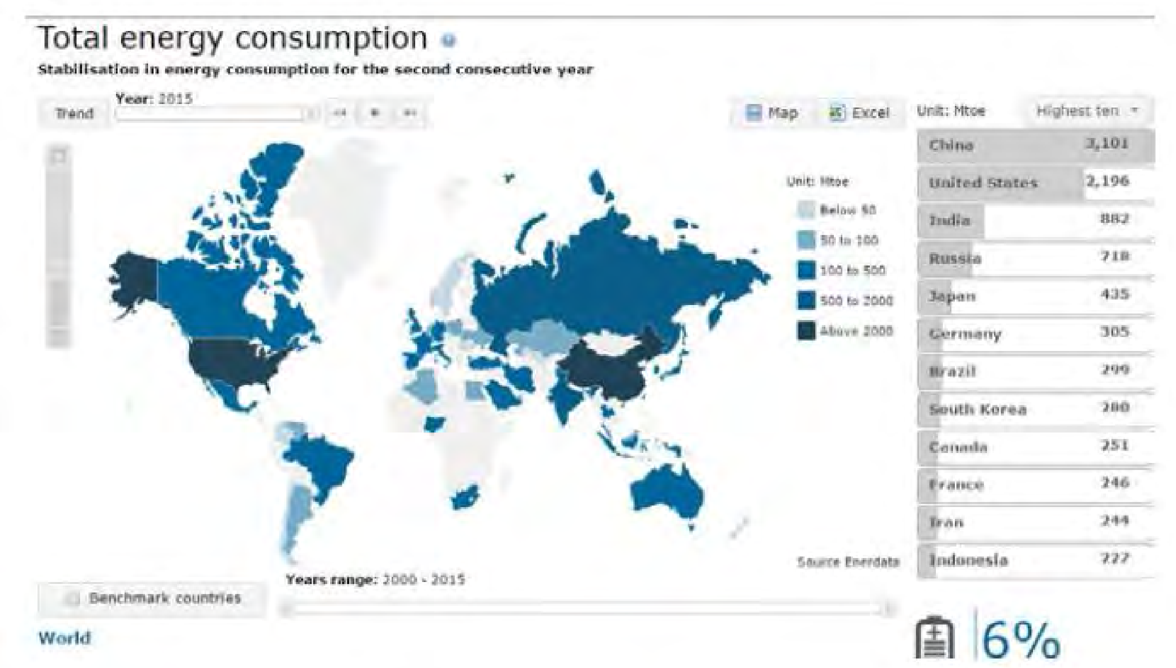


Figure 1. World Total Energy Consumption Data 2015 which shows that Indonesia ranks 10th. With 3% of energy use addition each year. (Source: https://yearbook.enerdata.net/)

Nomenclature
A The Kinetic Architecture is a term used in the early scientific literature of 1962 and is used by materials scientists to define how the process mimics the basic functions of biological forms and systems to produce sustainable solutions.

2. Objectives and Problem Statements

Based on the above background, the issues discussed that can be formulated that is:
– How is the bimetal thermal material module system applicable to green building envelopes in tropical climates.
– What parameters affect the bimetal thermal material module system contained in green building envelopes in tropical climates.
This research is expected to give benefits that is:
– Academic Benefits
This research is very closely related to some substance of lecture about lighting and thermal regulation, so it is expected to expand the insight of lecturers and students of the substance.
– Benefits in Implementation or Practice
The results of this study can provide alternative green building solutions for the tropical climate through the application of bimetal thermal material module in an effort to save energy. This research will produce the product of Variant Model of Bimetal Thermal Material Module which has been tested with energy-saving software.

3. Research Constraints

To obtain data according to the study, some boundaries are defined as follows:
1. The energy saving aspect in this research is focused on the building envelope element only.
2. Designed building envelope focuses on building envelope using concept approach of bimetal thermal material module application.
3. Simulation using software related thermal testing, lighting and optimization of energy parameters as a whole to study the effect of using building envelope with bimetal thermal material module approach.
4. Modeling of building envelope as a tool of illustration and simulation tool.

4. Kinetic Architecture and Applications of Bimetal Thermal Module

The Kinetic Architecture is a term used in the early scientific literature of 1962 and is used by materials scientists to define how the process mimics the basic functions of biological forms and systems to produce sustainable solutions. The Kinetic Architecture Approach adapts to the environment, it supports sustainability in architecture. How to approach the Kinetic Architecture is by imitating the natural form to understand the natural process of principles in behavior and form. (Mohd Shahril Bin Ab Sahak, Biomimetic in Architectural Sustainable Approach journal)
Weinstock (2006) has explained in detail that the principle of adaptation in inspired design gives meaning to biological systems that can respond and adapt to environmental stresses with high complexity and produce nonlinear responses. The main principle in adaptation is only minor variations in the design by repeating consistently over time. (Mohd Shahril Bin Ab Sahak Biomimetic in Architectural Sustainable Approach).
Speaking of green building concept means talking about buildings that apply the principles of environmental responsibility and efficient use of resources throughout the development process. From the planning, design, construction, to the operation phase and utilization, keeping in mind the economic, function, durability, safety and comfort aspects.
While energy-saving design is one of the values of the concept of green buildings that are concentrated on the design of a building. Ecologically responsible design and careful attention to the efficient use of resources. It can shape the architecture that accommodates the thermal and visual needs of the natural, the selection of materials that support comfort, to the use of smart technology that helps the planned system to save resources.
Adhering to the principle of eco-friendly and resource-saving makes energy-saving designs contextual according to the location of an architectural work. So the science of energy-saving design does not contain an absolute design list of a building. More like the formulation of the theory and the provisions on which the design decisions are based. There are three main factors that need to be considered in designing energy-efficient buildings, among others:
1. Climate
This type of local climate affects the thermal and visual conditions of an environment. With regard to temperature, air flow and humidity, as well as solar thermal radiation and light intensity, it is hoped that design decisions will be able to bring a comfortable, healthy and efficient atmosphere in the use of resources.
2. Environmental Quality
The environment around the building would have a major impact on life on a farm. The quality of air, soil and water becomes the thing that will then be in direct contact with the building and its users. So energy-saving design planning should pay attention to this.
3. Wind's Direction
Not enough to review the climatic conditions only, the direction of the wind which then affect the direct direction of heat and air sources is often a thing that escaped attention. Causing a suitable building for the region's climate designation may not be energy efficient when in the wrong direction.
The existence of the three factors of influence for each building, resulting in a very diverse design problem for an energy-efficient building context. Completion of each climate issue, environmental quality and overall direction of

the wind can be observed:
1. Space Orientation and Aperture
The direction of the building and the room and its openings have a great effect on the amount of light and air. Adjusting to the state of the land can help optimize the utilization of natural light and air. That way, the use of lighting systems and artificial air regulator can be reduced. Another thing is about the location of the openings themselves. The position at the top and bottom of the building can increase the effect of cross ventilation, which makes the air feel more maximal. The use of openings facing each other or menyiku also will establish good cross ventilation in space.
2. The Bulding Mass
Still associated with the thermal conditions, the spatial mass arrangement affects the airflow passing through each chamber. A complex building plan with multiple barriers will block air through the space. Look again at the state of the environment, need what kind of space conditions to achieve comfort.
3. Materials
Not only the shapes, materials use will affect the condition of space. Color selection is also included. As we know, incoming heat can be through three ways, namely conduction, kenveksi and radiation. Materials with low conductivity and light colors will be good insulators.
4. Smart Technology
Energy-saving design does not mean it should be a back building like a cave. Rely on all natural resources and put aside the needs of modern humans. Many misconceptions about the use of technology. A kinetic tool is always evil to the environment, energy required, emissions generated and costs incurred. Yet as a result of the use of energy it could be more profitable for energy saving. Water conservation machine for example. It takes electrical energy possible to move, but it can be how much water can be used again. Which then impacts on how much electricity ultimately saves on the need for no water from the city pump.

5. Research Method

Method of data processing is done by literature review. The data that have been obtained in accordance with the group of research substance in the form of precedents and journals that have been there will then be processed to get the essence of the study. The data will be grouped according to the group of research substance in the table which is then reviewed based on substance, method, and conclusion.
The method used to analyze the data is by calculation to prove the form of the most effective and efficient module both in terms of shape and use of materials.
At this stage, two forms of thermo bimetal module from prototyping research ever undertaken by Doris Kim Sung compared to their effectiveness in the use of materials using software help.
The use of the software used in the experimental method of Rhinoceros 5.0 is a 3D modeling program based on NURBS (Non Uniform Rational B-Spline). With the support of the Grasshopper build 0.8 plugin, it can help in applying the actual responsive facial module with the results of the suitability and accuracy of the module model components so there is no need to make actual models real. Then the calculation on the model is done related to the surface area of the facade module that must be wasted on its application to the building that has been made. The building is a cubical building with a large surface area and adjustable height.
Simulation with the plus and Ecotect energy software is also done in analyzing data with the model that represents the shape of the building and the building envelope.

6. Building Sheath

The building envelope is a building element that envelops buildings, ie transparent or non-transparent walls and roofs where most of the thermal energy moves through them (Regulation of the Provincial Governor of the Special Capital Province of Jakarta No. 38 of 2012 on Green Building Building Article 1)

The building envelope is a complex membrane where energy exchange is affected by the material. It can be designed to operate "as part of a holistic and morphological building metabolism, and will connect to other parts of the building, including sensors, actuators and command cables from building management systems" (M. Wigginton and J. Harris .2009). (Dewidar, K.M., Living Skins: A New Concept of Self Active Building Envelope Regulating Systems)

The main purpose of the building envelope is to protect people from outside the environment. The facade system is usually static, the facade is designed to respond to many scenarios and perform functions that can conflict with each other: lighting vs. energy efficiency, ventilation to views and energy generation. With faculty movers and making them dynamic, they can better adapt to conditions, deliver to improve occupant comfort, and achieve a more sustainable design. The facade can now feel the environment and make their own modifications to achieve the intended purpose. (Karen Kensek and Ryan Hansanuwat in his journal entitled Environment Control Systems for Sustainable Design: A Methodology for Testing, Simulating and Comparing Kinetic Facade Systems.)

7. Parametric Definition of Thermal Bimetal Module

The use of bimetal materials is used in building envelopes in order to respond to energy from the surrounding environment. Bimetallic materials use two types of metal plates, namely aluminum and steel. Both metals have the highest and lowest thermal expansion coefficients, the highest aluminum, and the lowest iron or steel. With the use of bimetal materials, the building envelope can adapt to meet the needs of comfort both thermal and air conditioning for building users.

Here is a building-inspired envelope of lotus flowers and uses bimetallic materials with two aluminum and steel plates. The module used in the casing is the development of the shape of the hexagon formation.

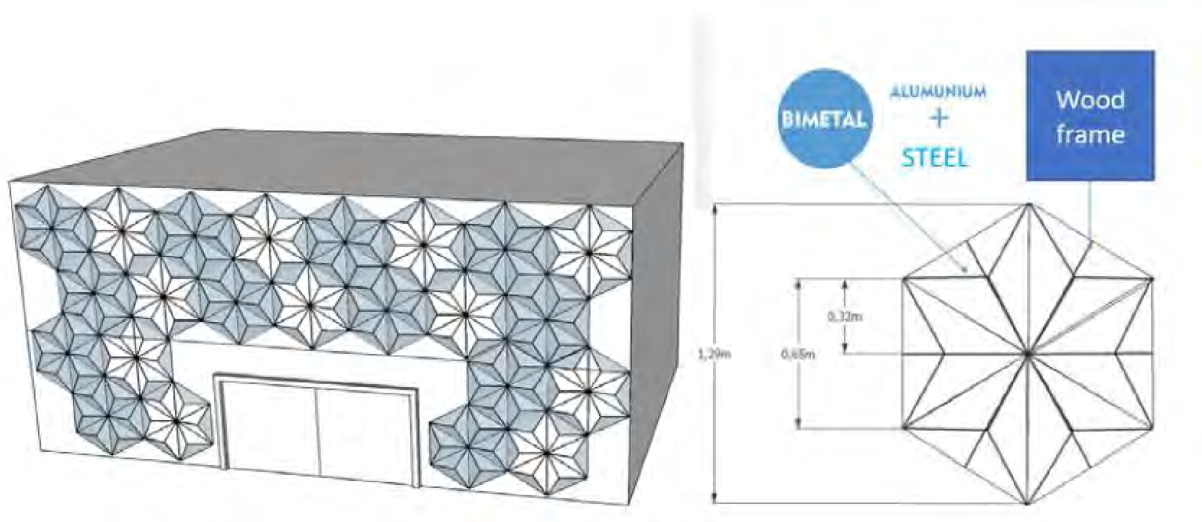


Figure 2. Parametric Module of Thermal Bimetal

There are various basic forms that can be used as a building envelope module approach. Modular forms such as triangles, quadrangles, and hexagons, are quite effective modules, because the relationships between modules can meet each other perfectly, without any empty parts including square, triangle, or hexagon.

In figure 3 we can see a formula analysis to find out which modules are more effective and efficient. If r = radius or center point distance to angle, then the number of angles determines the cross-sectional area. So the hexagon has the largest cross-sectional area when compared with the quadrilateral and triangle, because it has the most number of radius.

Analysis of the efficiency of material use on the three module is done by using comparison. Suppose there are a number of materials to make a module cover with a circumference of 12 units. Thus, the hexagon has the largest area with the same circumference, then it's considered as the most efficient to optimize the existing ingredients.

Application of biomimetic to respond to environmental energy in the form of sunlight is also applied to buildings. The building element in the form of wall in the artshop section using the approach. It produces a wall with openings corresponding to the intensity of sun exposure on the surface of the wall, so that the openings have different magnitudes. The more surface exposed to the sun the smaller the openings, and vice versa if the intensity of exposure to the sun a little more openings will be. Here is the wall scripting.

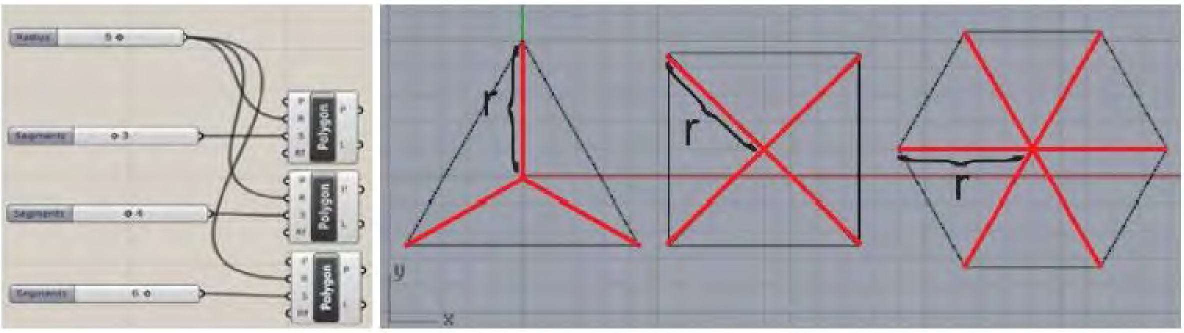
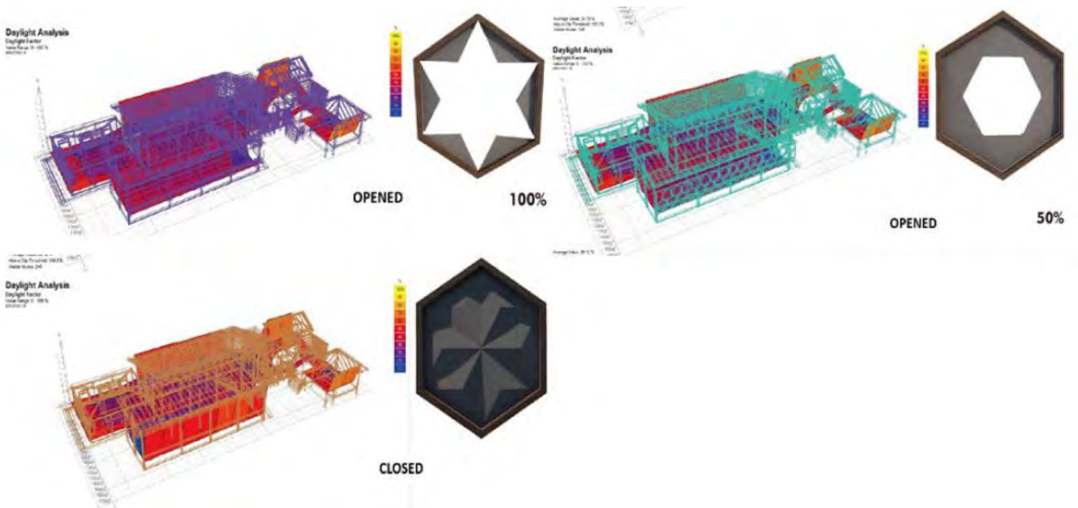


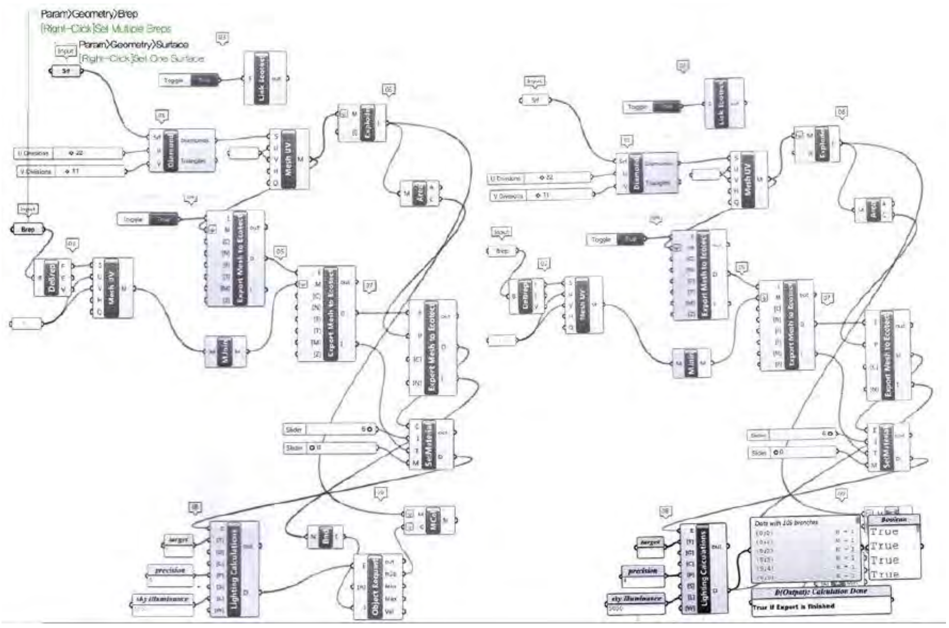
Figure 3. Parametric Optimization on module

Figure 4. Parametric Wall Scripting

To know the airflow on the design which is equipped with biomimetic sheath, then tested with Flow Design software. Here are the results of testing with Flow Design. Wind speed data obtained from BMKG Yogyakarta wind speed 18m / s and blow from the east. On the envelope with the open position of the wind can enter into the building, so the air flow more smoothly and the space in the building is cooler. Here is a comparison table of the number of lux day lighting that goes into buildings with different shroud conditions. Lux minimal used for 300 lux in cloudy sky conditions, and lux maximum of 5000 lux on the condition of the clear sky.



Scheme 1: Comparison of module application



8. Conclusions

The use of building envelope can affect energy consumption in a building. Consumption of energy such as lighting, and air conditioning, can be reduced amount of use. The biomimicry approach for designing is a step back to nature, because the nature-inspired adaptation behavior provides a good feed back to nature. Shape with rectangular repetition is quite effective as a module, because the cover between the segments can be complementary, without any parts to be wasted. From the addition of Biomimicry Parametric Thermal Bimetal Module, the building could drop Overall Thermal Transfer Value (OTTV) as much as 14,19 points, from 38 to 23,81 points, which leads to drop of energy consumption for cooling as much as 19% a year. These will lead to energy efficiency level that is the major requirement for Green Building.

HEAT CONDUCTION THROUGH WALLS																
NO	ELEVATION	URAIAN	Tinggi	Lebar	FAÇADE AREA (A) m²	SOLAR ABSORPTION FACTOR (α)	Tinggi	Lebar	Repetisi	LUAS JENDELA AREA (m²)	WINDOW TO WALL RATIO (WWR)	(1-WWR)	U-VALUE W/m²k (Uw)	Tdeq	0TTVi	A * OTTV
Lantai Dasar																
	Utara	Dinding 1+Kaca 1	60,65	36	2.183	0,10	4,00	36,00	13,00	1.872	0,86	0,14	2.380	10	0,34	741
	Selatan	Dinding 1+Kaca 1	60,65	36	2.183	0,10	4,00	36,00	13,00	1.872	0,86	0,14	2.380	10	0,34	741
	Barat	Dinding 1+Kaca 1	60,65	40,431	2.452	0,10	2,00	31,37	13,00	816	0,33	0,67	2.380	10	1,59	3.895
	Timur	Dinding 1+Kaca 1	60,65	40,431	2.452	0,10	2,00	31,37	13,00	816	0,33	0,67	2.380	10	1,59	3.895
		total area			9.271					5.375	0,51				2	9.271
HEAT CONDUCTION THROUGH WINDOWS																
NO		URAIAN			FAÇADE AREA (A) m²					LUAS JENDELA m²	WINDOW TO WALL RATIO (WWR)		U-VALUE W/m²k (Uf)	ΔT	0TTV	A * OTTV
Lantai Dasar																
	Utara	Dinding 1+Kaca 1	60,65	36	2.183	0,20	3,00	20,00	13,00	780	0,36	0,64	3.950	5	7,06	15.405
	Selatan	Dinding 1+Kaca 1	60,65	36	2.183	0,20	3,00	36,00	13,00	1.404	0,64	0,36	3.950	5	12,70	27.729
	Barat	Dinding 1+Kaca 1	60,65	40,431	2.452	0,20	2,00	12,37	13,00	322	0,13	0,87	3.950	5	2,59	6.352
	Timur	Dinding 1+Kaca 1	60,65	40,431	2.452	0,20	2,00	31,37	13,00	816	0,33	0,67	3.950	5	6,57	16.108
		total area			9.271					3.321	0,37				29	65.594
SOLAR HEAT GAIN THROUGH WINDOWS																
NO		ELEVATION			FAÇADE AREA (A) m²					LUAS JENDELA m²	WINDOW TO WALL RATIO (WWR)	SOLAR FACTOR (SF) (W/m2	U-VALUE W/m²k (Uf)	SHADING COEF.	0TTV	A * OTTV
Lantai Dasar																
	Utara	Dinding 1+Kaca 1	60,65	36	2.183		4,00	20,00	13,00	1.040	0,48	130,00	3.950	0,30	18,58	40.560
	Selatan	Dinding 1+Kaca 1	60,65	36	2.183		4,00	36,00	13,00	1.872	0,86	97,00	3.950	0,30	24,95	54.475
	Barat	Dinding 1+Kaca 1	60,65	40,431	2.452		2,00	12,37	13,00	322	0,13	243,00	3.950	0,30	9,56	23.446
	Timur	Dinding 1+Kaca 1	60,65	40,431	2.452		2,00	31,37	13,00	816	0,33	112,00	3.950	0,30	11,18	27.405
		total area			9.271					4.049	0,33				64	145.886
SUMMARY OTTV																
															OTTV Wall	1,00
OTTV total = (A1*OTTV1 + A2*OTTV2 +...+ Ai*OTTVi)															OTTV GLASS	7,08
(A1+A2+...+Ai)															OTTV SOLAR	15,74
															OTTV Total	23,81

Figure 5. Overall Thermal Transfer Value (OTTV) after application of the module.

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