SINERGI Vol. 23, No. 2, June 2019: 79-98
Accredited **SINTA 2** by KEMENRISTEKDIKTI, Decree No: 10/E/KPT/2019
http://publikasi.mercubuana.ac.id/index.php/sinergi
http://doi.org/10.22441/sinergi.2019.2.001

BUILDING ENVELOPE COMPONENT TO CONTROL THERMAL INDOOR ENVIRONMENT IN SUSTAINABLE BUILDING: A REVIEW

Abraham Seno Bachrun[1,2], Ting Zhen Ming[1], Anastasia Cinthya[3]
[1]School of Civil Engineering and Architecture, Wuhan University of Technology, Wuhan, P.R. China
[2]Department of Architecture, Universitas Mercu Buana, Jakarta, Indonesia
[3]Department of Interior Design, Universitas Tarumanagara, Jakarta, Indonesia
E-mail: abraham.seno@mercubuana.ac.id, tzming@whut.edu.cn, anastasiag@fsrd.untar.ac.id

Abstract -- *The engineering of building envelope aims is to achieve building energy efficiency which uses shading device to increase the shaded area. Also, to reduce heat gain by the building from solar radiation, this will reduce the energy load on the building. This paper aim to focuses on the deepening of technology of building envelope elements, and how the building envelope can control the thermal comfort as part of the indoor environment in a building that carries sustainability architecture. In conclusion, finally, reveal that the principles of passive design on building envelope have a great influence on the comfort level in the building. It is not possible to create a design that meets the thermal comfort requirements by emphasizing the design of building envelopes. The goal to be achieved in sustainable design is to minimize the use of the current design that takes much energy (almost14% world energy consumption) to address the issue of energy crisis lately.*

Keywords: *Building Envelope, Sustainable Building, Thermal Indoor Environment*

Received: May 2, 2019 *Revised: May 29, 2019* *Accepted: June 2, 2019*

INTRODUCTION

Sustainable architecture has much meaning from all sides. Some of these are the words quoted by James Steele's: "Sustainable Architecture is the movement that meets today's architectural needs, without jeopardizing the ability of future generations. The need differs from one society to another, from one region to another (Steele, 1997). The community itself determines the best thing.

From the development of the concept of energy which discussed in some research, the role of building envelope in performing the task of energy management is significant. Many papers focus the discussion on the building envelope, by varying the material, orientation direction, and color of the arrangement of the construction. It is only to obtain the effectiveness in the use of energy and thermal comfort in the indoor environment (Sadineni, Madala, & Boehm, 2011). The more surface area of the building will result in more energy cycles. The building envelope is an essential factor, too as part of the hardware to control (Wetter, 2011). In this globalization is not only technology that is overgrowing, but human needs are also growing more and more. Excessive exploitation and wasted use of energy are increasingly being done for fulfilling the needs of nature will cause more damage, and making the environment unhealthier (Zhai, 2006).

Nowadays, the whole world is beginning to recognize in reducing exploitation activities and the efficient use of energy (Pérez-Lombard, Ortiz, & Pout, 2008). Globally, buildings consume more than 40% of the world's total energy consumption (Pérez-Lombard, Ortiz, & Pout, 2008). In a building, energy is consumed for lighting, electronic equipment, and air conditioning or HVAC system. The total energy consumption of some of these components determines the cost of electricity in which HVAC becomes the most significant component in consuming energy. Therefore, energy efficiency efforts in buildings should focus more on efforts to conserve cooling energy or the factors that influence it (Yu et al., 2011).

As described from data on the pie chart in Fig. 1, now has been done various ways to control the use of energy, especially in buildings (Pérez-Lombard, Ortiz, & Pout, 2008). One of the control measures undertaken is to create standard energy usage in buildings. Before construction, the use of energy to be used in buildings was first evaluated.

This is done so that when the building is used there is no waste of energy (Bribián, Capilla, & Usón, 2011). This standard is used as essential criteria in building construction. Buildings will not be allowed to build if the calculated energy usage is still more significant than the maximum allowed standard value in each country.

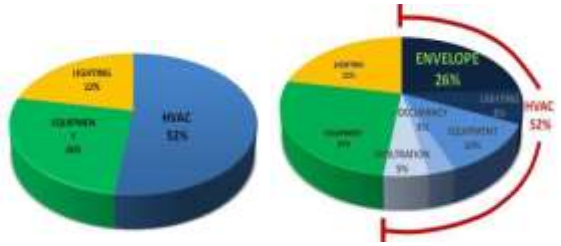


Figure 1. Partial Building Energy Consumption (Lave et al., 2006)

As we know, environmental policy in every country is different (Wong & Fan, 2013). Along with the development of science and technology, energy becomes an integral part of the architecture (Olivieri et al., 2014). Building dependence on energy can we see from the use of elevators (vertical transportation system) in tall buildings, the use of electrical energy for lighting, as well as other utility needs such as air conditioning machines (Yang, Yan, & Lam, 2014). Thus, the architecture required to provide physical comfort, including comfort, space, thermal, sound and lighting, and energy-saving (Manzano-Agugliaro et al., 2015).

The building envelope consists of non-translucent component (e.g., wall) and a fenestration system or a translucent component (e.g., windows) that separates the interior of the building from the exterior environment (Rosso et al., 2017). The building envelope provides protection against unwanted external environment influences from climate condition such as heat, radiation, wind, rain, noise, pollution, etc. The building envelope has a vital role in reducing energy consumption for heating, cooling, and lighting. In medium and high rise buildings, the wall area is much larger than the roof area. Therefore, the design of the vertical building envelope, especially windows, should be done carefully to avoid the inclusion of heat into the building in excess (Nimpuno, 2017; Wang et al., 2014).

The building envelope, as the most prominent architectural element in a building, has a significant influence on the level of energy consumption in buildings (Mirrahimi et al., 2016). The design of the building envelope will affect the buildings' energy load with the engineering of building envelope with better thermal performance and will minimize external heat gain. The engineering of building envelope aims is to achieve building energy efficiency, which uses a shading device to increase the shaded area. Also, to reduce heat gain by the building from solar radiation, this will reduce the energy load on the building.

According to Olgyay (2015), the level of productivity and human health is strongly influenced by local climatic conditions (Olgyay, 2015). If climatic conditions are by human physical needs, then the level of productivity can reach the maximum point. Similarly, the level of health will reach optimal if climatic conditions also support achievement. The wall is part of the greatest variation in its presence. The wall, in this case, is including all the parts that constitute the constituent elements of the wall.

Proper use of building material should consider the comfort of the inner building, with thermal comfort near the optimally comfortable temperature of 22.8˚C-25.8˚C with 70% humidity (for the wet, humid area). According to Lippsmeir (1994) the comfort limits for equatorial conditions are in the range of 22.5˚C-29˚C air temperature with 20 - 50% air humidity (Carera & Prianto, 2016; Syah & Nugroho, 2013). It is further explained that the value of convenience should be considered with the possibility of a combination of radiation heat, air temperature, humidity, and air velocity. This sufficient temperature is obtained by experiments that include the results of measurements of air temperature, humidity, and wind speed.

Based on the above research background, it is interesting to do deepening descriptively. This paper aim to focuses on the deepening of technology of building envelope elements, and how the building envelope can control the thermal comfort as part of the indoor environment in a building that carries sustainability architecture.

LITERATURE OVERVIEW AND DISCUSSION

Sustainability Architecture

Sustainable architecture and design (often called green construction and building) are "the practice of planning, construction, and operating buildings using environmentally responsible processes and efficient resources." Sustainable architecture limits its environmental impact by conserving energy (it is recommended to produce its energy) And water as much as possible and made of recycled or renewable materials to achieve maximum resource efficiency (Sunstein & Reisch, 2014). In other words, the energy and water used should be as small as possible, but all building performance and occupants are not diminished. Sustainable architecture work includes a variety of roles, including Architecture and design, construction, supply Green building materials, maintenance, and more.

Architectures (building) have the potential to be used - or save - large amounts of energy, water, and materials used, and to produce or minimize waste. Also, they can teach us about history, art, and anthropology related to the building and its environment. As a result, sustainable architecture and design are important for sustainability not just because green practices can reduce the environmental footprint of the building, but also because sustainable buildings can be used to teach those who live, work or learn about environmental and cultural sustainability (Mika, 2014).

Many passive architectural strategies have been developed over time. Various elements and strategies have been developed along with the times and technology. Examples of such strategies include design elements, construction, to building management such as room arrangement or the size and orientation of windows in a building, and the orientation of the facade and the highway or the ratio between the height of the building and the width of the road for urban planning (Song et al., 2015).

A significant amount of energy is ejected out of the building through water, air, and compost. Energy recycling technologies from building sites can effectively recover energy from waste heat from used buildings and air and transfer that energy into fresh, fresh water or fresh air (Cabeza et al., 2014).

The design of passive solar buildings enables buildings to utilize solar energy efficiently without the use of active solar technical mechanisms such as photovoltaic cells or solar thermal panels (Chen, Yang, & Lu, 2015).

Even some types of it can be combined with the design of the building itself. A passive solar building design incorporates materials with a high thermal mass that effectively withstand heat and great insulation that works to prevent heat release. Low energy designs also require the use of solar shading, using awnings, blinds or shutters, to relieve the heat of the summer sun and reduce the need for artificial refrigeration. Also, low-energy sustainable buildings typically have shallow building skin surface area to volume ratio to minimize heat loss (GhaffarianHoseini et al., 2013).

Sustainable architecture is also often found in traditional architecture. The condition gives evidence that past people have been thinking about how buildings can withstand the climate. The situation is something that we can imitate by acculturating with the technology that developed lately (Nazem, 2015). So that can create harmony between the past with technology. Then architecture can survive without forgetting the history of a culture

Sustainable development is essential to be applied in this modern era (Chen, Yang, & Lu, 2015; GhaffarianHoseini et al., 2013). The purposes of sustainable development are:

a. Environmental Sustainability

Is the development that retains natural resources to last longer because it allows architecture to adapt with ecosystems itself, which is associated with the age of the vital potential of natural resources and the ecological environment of humans, such as climate, biodiversity, and industry. The natural damage caused by the exploitation of natural resources has reached the level of global destruction, so slowly but surely, the earth will lose its potential to support human life, from the exploitation of nature.

b. Social Sustainability

Architecture improves social sustainability by providing opportunities for building balance and connectivity. Socially sustainable architecture fosters the balance between the individual and the collective and between the present and the future; Also, the relationship between the individual within the building and between the inhabitants and the surrounding community is something that is done by the sustainable architecture in terms of social sustainability.

c. Economic Sustainability

A sustainable economic ideology is a concept that reflects the economic system itself, can be applied and applied in demonstrating efficiency and fairness in the distribution of earth resources, especially in the development of architecture. Economic sustainability refers to preserving all natural resources when we consume them so that future generations can enjoy them as well. Industrial systems are inherently extractive, exploitative, and ultimately dependent on a limited supply of non-renewable resources. The industrial system will eventually degrade and deplete the resources with which its productivity depends, and therefore, unsustainable.

Sustainable architecture is a consequence of the International commitment on sustainable development because architecture is closely related and focuses its attention on human factors by focusing on the main pillar of the concept of sustainable development, i.e., aspects of the built environment with the development of its environment, in addition to the pillars of economic and social development (Lozano et al., 2015).

Architectural sustainability process covers the entire life cycle of a building, starting from the process of development, utilization, preservation, and demolition of buildings. The vision of sustainable architecture is not only driven to reduce greenhouse gas emissions (greenhouses effect), also contains the intention to emphasize the importance of quality side over quantity in terms of functional aspects, environment, health, comfort, aesthetics and added value (Kalan & Oliveira, 2015).

From this side, awareness of the human factor is put forward compared to other factors (Sameh, 2014). The condition is happened because the paradigm that has also changed and experienced the development that initially as the paradigm of economic growth then shifted to the welfare paradigm. The implementation of sustainable architectures are (Lozano et al., 2015):

a. Energy efficiency.

Energy needs to be given special attention by Architects, especially electrical energy because electricity is closely related to the field of Architecture (Maldonado, 1998). One of the causes of the strangeness is the design that less enters the sunlight into the building (Acosta, Campano, & Molina, 2016).

- Utilize sunlight for maximum daylight during the day to reduce the use of electrical energy. However, still crucial to anticipating for solar radiation.
- Utilizing natural ventilation instead of artificial air conditioning (passive versus active design)
- Use ventilation and openings, crosslinking, and other innovative ways. Utilizing rainwater in innovative ways to accommodate and treat rainwater for domestic use.
- The concept of efficient energy use such as natural lighting and delivery is a specific concept for tropical climates.

In addition to reducing the cost of infrastructure and domestic costs, building efficiency also has the most significant impact on reducing emissions due to climate change (Burlacu & Racanel, 2014). Improvements in building efficiency often have low or no marginal costs or provide a return on investment in the form of energy cost savings as fast as six months to a year.

b. The efficiency of building site:

- Using as necessary the existing site, not all the site should be used as buildings, or covered with buildings because thus the existing site does not have enough green space and parks.
- The green potential of plants in the site can be replaced or maximized by various innovations, such as roofing over buildings (roof gardens), hanging gardens (by hanging plant pots around the building), hedges or which can be filled with plants, walls with garden Walls, and so forth.
- Appreciate the presence of existing plant on the site, by not easily cutting down trees, so that existing plants can be part to share with the building.
- Open design with open spaces to the park (by pre-planned flexibility) can be an innovation to integrate outside and inside buildings, providing greater space flexibility.
- In architectural planning, consider the things that can be benchmarks in using a variety of potential of a site

c. The use of new technologies and materials:

- Utilizing renewable energy potentials such as the wind, solar, and water energy to generate domestic electrical energy for households and other buildings independently.
- Utilizing new materials through new inventions that globally can open the opportunity to use renewable materials that are quickly produced, cheap and open to innovation, such as bamboo material

d. Waste management:

- Create a system of domestic sewage treatment such as dirty water (black water, gray water) that is self-sufficient and does not burden the city's water flow system.
- Innovative ways, such as making a decomposition system of organic waste to break down naturally in the field, making ordinary objects into domestic waste or waste from materials that can be recycled or can easily decompose naturally.

Building Energy Savings Potential

As stated above, the building envelope can have a substantial impact on total energy consumption as it can significantly affect cooling loads, primarily due to the control of the acquisition of heat radiation through windows, and the utilization of natural lighting. A combination of passive design strategies has the potential for energy savings of about 31% in office buildings, as shown in Fig. 2.

The combination can be accomplished through the design of building envelopes that include shading. The extent of Window to Wall Ratio (WWR) window ratios, the selection of glass with low shading coefficient and the utilization of natural light for indoor illumination (Košir, Gostiša & Kristl, 2016).

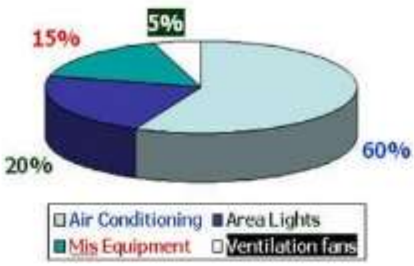


Figure 2. Typical Energy Consumption Pattern in Buildings: Typical Energy Saving Approach in Buildings (Hardik, 2015)

In more detail, the results of simulation studies showing potential energy savings through passive designs including reduced window area, external shading use, and use of glass with better shading coefficient (low SC values) can be seen in Table 1 (Hanif et al., 2014).

As can be seen in Table 1, a passive design strategy that combines the use of external shade, reduced window area and glass usage with low Shading Coefficient grades can produce about 25% energy savings (Hanif et al., 2014).

Table 1. Building Energy Saving Potential for Various Building Type (IFC, 2011)

Passive Design Strategy	Office	Retail	Hotel	Hospital	Apartment	School
Shading	10.1%	4.6%	10.2%	8.8%	5.3%	1.9%
WWR	8.0%	3.9%	8.7%	7.5%	2.3%	0.0%
Glazing	7.3%	3.2%	8.5%	8.0%	6.5%	4.2%
Daylight	4.9%	NA	NA	NA	NA	3.5%
Reflectivity	0.5%	0.3%	0.6%	0.3%	2.3%	2.6%
Wall Insulation	0.3%	0.2%	1.0%	0.5%	3.2%	-0.9%
TOTAL	31.1%	12.2%	29.0%	25.1%	19.6%	11.3%

Because the intensity of solar radiation differs for each orientation, control of external heat recovery through the window design system (fenestration system) can also be achieved through proper building orientation. The results of this study emphasize the critical role of architects in the development of a design that is not only attractive but also energy efficient (Buyya, Beloglazov, & Abawajy, 2010).

Fundamental Building Heat Transfer

Understanding the fundamental heat flows from conduction, convection, and radiation is key to creating energy efficiency in buildings (Soares et al., 2013). The principle of fundamental building heat transfer is depicted in Fig. 3.

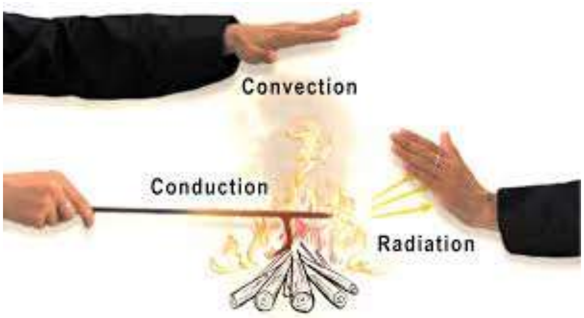


Figure 3. The Fundamental of Heat Transfer: Conduction, Convection, & Radiation (Workshop, 2014)

Moisture flows are also important because moisture holds energy as "latent heat."

a. Overall Thermal Transfer Value

The Overall Thermal Transfer Value (OTTV) is based on the assumption that buildings are in a completely closed system of building envelopes. Also, OTTV calculations do not take into account the following factors (Chow & Philip, 2000):

- Internal shade devices, such as curtains
- Solar or shadow reflections from adjacent buildings.
- Acquisition of heat from Roof calculated separately through the calculation of RTTV (Roof Thermal Transfer Value) and not required by this arrangement

OTTV is the measure of external heat recovery transmitted through the unit area of the building envelope (W/m2). Transmission of solar radiation through windows is generally much more significant than through walls (Chan & Chow, 2014). Therefore, the planning and design of windows should be done carefully to avoid overheating of heat through orientation setting, window opening area, determination of shading coefficient and use of external shade.

The OTTV concept includes three basic elements of heat transfer through the outer envelope of the building (Vijayalaxmi, 2010): heat conduction through a translucent wall, solar radiation through glass, and heat conduction through glass. The equation can calculate the total thermal displacement (OTTV) value for each area of the outer wall of a building with a certain orientation:

$$OTTV_i = \alpha\,[U_w \times (1-WWR)] \times TD_{ek} + (SC \times WWR \times SF) + (U_f \times WWR \times \Delta T) \quad (1)$$

Where

$OTTV_i$	=	Thermal displacement value on the outer wall having a particular direction or orientation (Watt/m²)
α	=	The absorbance of solar radiation
U_w	=	The thermal transmittance of the non-translucent wall (Watt/m².ºK)
WWR	=	Wall Window Ratio, The ratio of the width of the window to the area of the entire outer wall at the specified orientation
TD_{ek}	=	The equivalent temperature difference (⁰K)
SC	=	Coefficient of shading from the fenestration system
SF	=	Solar radiation factor (Watt /m²)
U_f	=	Thermal transmittance of penetration (Watt/m².⁰K)
∆T	=	planning temperatures difference between the outside and the inside (counting as 5˚K)

To calculate OTTV throughout the outer wall, the OTTV calculation results in all outer planes are summed using the following formula:

$$\mathbf{OTTV} = \frac{\sum_{i=1}^{n}(\mathbf{A_{0i}}\mathbf{x}\mathbf{OTTV_i})}{\sum_{i=1}^{n}\mathbf{A_{0i}}} \quad (2)$$

Where

A_{0i}	=	Wall area on the outer wall i (m²). This area includes all the walls of opaque walls and the surface area of the window contained on the wall
$OTTV_i$	=	Thermal displacement value on the wall i as the result of calculation using equation

The second alternative is the "graphical method," as shown in Fig. 4, which shows the combined values of SHGC, OTTV, and WWR for various orientations of building envelope. With this graphical method, the WWR values of a window with a certain SHGC can be easily determined to satisfy the OTTV rule ≤45 W/m2 (Huda et al., 2013). This graph is applicable for the construction of brick walls with a U-value of 0.039 W / m2-K and a single glass window pane of 8 mm without external shade. Since the heat transmission through the wall is not significant, this method can also be applied to other wall construction with similar U-Value. This graphical method is beneficial in the early stages of design development to find out easily and quickly whether the design concept of building envelope developed already meets the applicable OTTV requirements.

b. Heat Transfer Through Building Envelope

In buildings dominated by external cooling loads, energy consumption for HVAC systems is primarily determined by heat transfer through building envelope components including (Zhao & Magoulès, 2012):

- Heat transfer through windows,
- Heat transfer through walls,
- Heat transfer through the roof,
- Infiltration rate and exfiltration through cracks, windows, and door openings.

Several design principles can be applied to reduce heat recovery through building envelopes (Granadeiro et al., 2013):

- Designing the shape and orientation of buildings to minimize exposure to the building envelope of solar and eastern sun radiation.
- Reduced heat transmission through windows by reducing window area, providing an appropriately designed external shield and selecting glass material with low SHGC or SC values.
- Reduced heat transmission through walls by using adequate insulation.
- Reduced heat transmission through the roof with higher reflectivity, emissivity and insulation values.
- Reduce infiltration and excitation by sealing the building tightly and controlling door and window openings.

Heat transfer through the building envelope can be categorized as radiation, conduction, and convection through walls and windows. Gorantla (2016) observed that for typical construction and building envelope materials, heat transfer through windows is approximately 40-130 times higher than heat transfer through walls (Kirankumar, Saboor, & Setty, 2016).

Even for the best SHGC glass available on the market, heat transfer through windows is still much higher than brick walls. Therefore, the control of heat transfer through the window to reduce the cooling load is an essential factor for the success of the overall passive design strategy. Other forms of heat transfer, which can increase the cooling load are infiltration and exfiltration through cracks of building envelope and window and door openings.

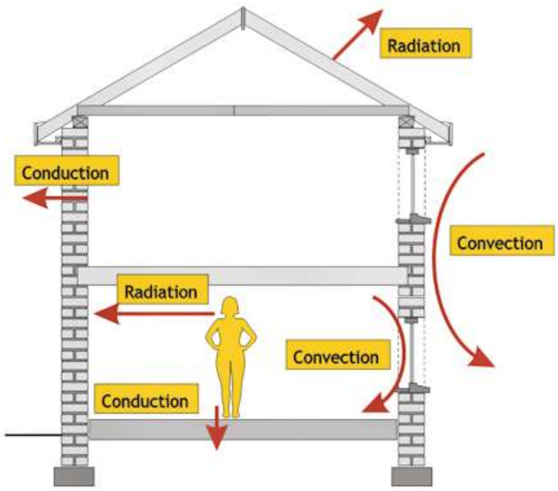


Figure 4. Building Heat Transfer (NN, 2009)

Building Shape and Orientation

"Massing" is part of the design that determines the overall shape and size of the building. Is the building tall or short? Long or thin? Will it have a significant or more solid piece? Most successful use of common shapes and building sizes to minimize the energy load as much as possible and maximize the passive design of buildings where using free energy from sunlight and wind (Ballarini, Corgnati, & Corrado, 2014).

In addition to reducing energy use and enabling passive design strategies, successful size and orientation can take advantage of site conditions, such as rainwater harvesting, and can help the building contribute to the health and vitality of the surrounding ecological, social and economic communities (Abanda & Byers, 2016). For example, it can be grouped and oriented to connect its social space with street life, or avoid shading around wildlands, or can drive pedestrian traffic from ecologically sensitive areas.

For many types of buildings in the world, the mass phase is one of the most critical factors in the aspects of passive heating, cooling, and lighting. However, often this is not considered until after it is done. It is essential to start considering the passive design strategy at the idea stage, so that the sun-exposed surface area at different times, the height of the building, and the width of the building can all be optimized and unthinkable for the comfort of passive occupant buildings (Rodriguez-Ubinas et al., 2014).

In the example, as shown in Fig. 5, "Option 2" has the same area as "Option 1" but uses less than half the energy, because its mass is better.

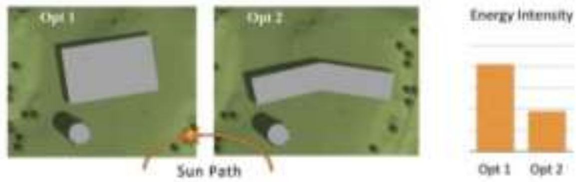


Figure 5. Building Mass Variation & It is Energy Consumption (Workshop, 2014)

The building mass decisions depend on the specific location of the project (site) and the target occupant of the building (Scheuer, Keoleian, & Reppe, 2003). Simulation of BIM tools can provide engineering and designers with an initial conceptual energy analysis to test various mass options. They can also affect building materials, acoustics, rainwater harvesting, and other performance factors (Nguyen, Reiter & Rigo, 2014). The right massing depends on the building program. Sparsely populated buildings with little activity or equipment, like many homes, produce less heat from internal loads. In cold climates, they benefit from a compact floor plan, which is useful in avoiding heat loss outside the building (Gorse et al., 2015). It minimizes the ratio of surface area to volume, decreases heat loss to the wind and serial cooling. On the other hand, densely populated buildings with high activity and energy-intensive equipment generate much heat, causing a high internal cooling load (Gand et al., 2015). Thus, even in colder climates, it may be advantageous for such buildings to have thinner planes, to get better cooling without any cost.

Sophisticated enrichment could be further away from this building's bulk to optimize heat or cooling gain (Ahn et al., 2014). Example:

- The roof can be tilted for optimal solar heating.
- Discloses and overhangs can shade parts of buildings with other parts of the same building.
- The aerodynamic curve can reduce heat loss due to infiltration.
- The interior buffer zone can be placed on the west side of the building to protect the residential and work areas from the hot afternoon sun (e.g., ladders, toilets, and entrance corridors.)

Whether building masses are simple or complex, simulation of building energy modeling should be done as a basis for the mass selection as shown in Fig. 6.

Orientation is just the aspect of the wind facing the shape of the building. Is it directly facing south or 80˚ north-northeast? Along with the mass, building orientation can be the most crucial step in providing the building with passive thermal and visual comfort.

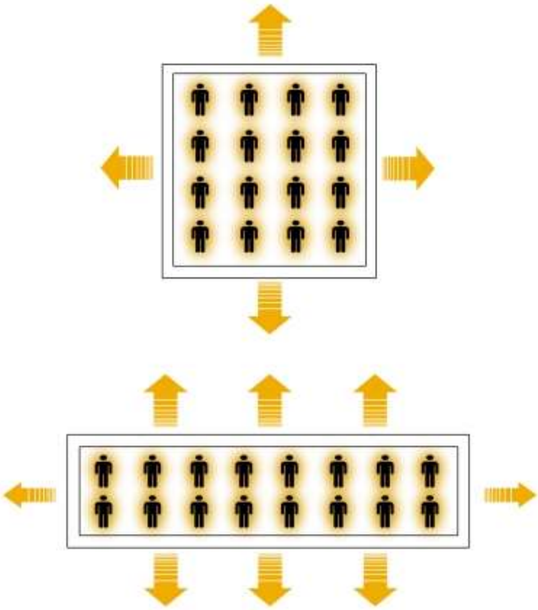


Figure 6. Thinner buildings lose more of their internal heat to the outside (Workshop, 2014)

Orientation must be decided along with curing in the initial design process since both cannot be utterly optimized without the other (Wong & Fan, 2013). Even the process has to be thought of since the idea (holistic design). Orientation is merely a form of a compass facing a building. The orientation should be optimized early on, along with the mass, and can be the most crucial step for passive design.

To avoid overheating of excessive solar radiation, the main surface of the building's envelope with windows is as far as possible oriented to the north and south (Valladares-Rendóna, Schmid & Lo, 2016). The condition allows the window to get natural light from the dome of the sky while still minimizing the heat gain from solar radiation directly. Service spaces and stairs with massive walls can be placed on the West and East side so that they can function as thermal buffer zones (Jan et al., 2014).

The comparison of solar thermal radiation exposure represented by the OTTV values for different shapes and building orientations is presented in Fig. 9. The OTTV values are for simple rectangular buildings with continuous windows (SHGC 0.4) and the same floor area.

Window Area

The proportion of window width has a significant influence on the cooling load as it determines the total heat gain that goes into the building (Hee et al., 2015). The condition happens because the glass window can admit that the heat into the building is much higher than the massive wall. Therefore, the higher ratio of window to wall (WWR) area usually causes higher cooling load (Lee et al., 2013).

The reduced window area is one of the most effective solutions to reduce cooling load and overall building energy consumption. Because window construction is usually more expensive than wall construction, reducing WWR can also lower the cost of construction. Simulation study results on typical buildings show that reducing the window area by half can reduce energy consumption by 10% (Hee et al., 2015) as listed in Table 2.

Table 2. Impact of WWR on Energy Saving (%) for Different Building Types (0% savings is the base case)

WWR	Office	Retail	Hotel	Hospital	Apartment	School
69%	-	-	-	-	-	-
53%	3.7%	2.0%	4.6%	3.9%	-	-
40%	8.0%	3.9%	8.7%	7.5%	-	-1.8%
34%	9.5%	4.9%	10.6%	9.1%	2.3%	-
20%	13.2%	7.1%	14.5%	12.6%	6.8%	5.4%

The thermal comfort of building occupants is another crucial driver for the residential and commercial sectors and one of the most significant drivers for change. Improved thermal comfort can be used as a selling point for technologies. When considering building technology solutions that result in greater thermal comfort, it is important to also focus on solutions that will reduce energy use rather than increase it (Kwong, Adam, & Sahari, 2014). New technologies and methods to consider include composite thermal comfort models that are easy to use and being able to understand human perception and personalized comfort better.

Glazing

Based on their thermal properties, glass materials have different characteristics, depending on the nature of solar transmittance, solar absorption, solar reflectance, and visible transmittance. The thermal transmission characteristics of the glass material are measured from U-values, for conduction, and Solar Heat Gain Coefficient (SHGC) or Shading Coefficient

(SC) for radiation. In this case, the value of SHGC = 0.86 SC (Lee et al., 2013).

Representation of U-values, Visible Transmittance (VT) and SHGC for a variety of locally produced glass materials are presented in Table 3. Better glass material with a low SHGC value of 0.2 is available globally. However, at this time, the application is still very limited due to the high cost. Alternatively, offline coatings that can be applied by local industries are also available (Ji et al., 2013). This relatively inexpensive additional layer can lower the SHGC value by up to 0.2.

Table 3. U-value, Light Transmission and SHGC Value from Typical Glass Material (IFC, 2011)

SINGLE GLAZING 8mm	U-Value	Visual Transmission %	SC	SHGC
Clear	4.94	89	0.95	0.82
Color	5.18	55	0.51 – 0.57	0.44 – 0.49
Reflective	5.18	42 – 48	0.42 – 0.53	0.36 – 0.46
Low	4.54	35 – 67	0.40 – 0.69	0.34 – 0.59

For a climate with a relatively small temperature difference between the inner and outer space, refining the SHGC value will be more effective than increasing the U-Value. In other words, having double glazing to reduce the heat gain of conduction through a window is usually inefficient. For example, reducing SHGC from 0.67 to 0.38 would reduce total energy consumption by 8% (Carlos & Corvacho 2015). While adding clear glass to form double glass with the same SHGC and decreasing the U-Value from 5.8 to 3.4 will only reduce the total energy consumption by about 1%.To show clearly the significant SHGC impact on total energy consumption, the simulation study results for various building types are summarized in Table 4.

Table 4. Impact of SHGC on Energy Saving (%) for Typical Buildings (U value 5.8W/m2/k, visual transmission 0.57) (IFC, 2011)

SHGC	Office	Retail	Hotel	Hospital	Apartment	School
0.6	0.0%	0.0%	0.0%	0.0%	0.0%	-
0.5	5.7%	2.4%	5.1%	5.7%	3.7%	3.2%
0.4	8.4%	3.7%	8.5%	8.2%	6.1%	5.1%
0.3	11.0%	5.1%	11.9%	10.8%	8.4%	6.7%
0.2	14.4%	6.6%	15.4%	13.3%	10.6%	7.5%

Shading Device

a. Internal Shading Device

The internal shade (curtain) retains solar radiation after passing through the glass window and prevents the occurrence of direct solar radiation concerning the occupants and the deeper interior (Gago et al., 2015). However, internal shading is not as effective as external shade in reducing cooling loads. Bright colors from internal shading with reflective layers are more effective than dark colors because more heat is reflected out through the window glass. Fenestration system thermal performance is depicted in Fig. 7.

Internal shading, in general, can be set fully to meet the individual needs of the occupants and is available in various designs and colors so that it can be combined with other interior design elements. In terms of design, the internal shade can be distinguished as roller shades, horizontal blinds, vertical blinds, and curtains. Amongst all that, the horizontal curtain performs better by reflecting sunlight to the ceiling to improve the performance of natural lighting to the interior that is far away from the window (Aksamija & Green, 2014).

Figure 7. Fenestration System Thermal Performance (Al-Tamimi, Fadzil, & Harun, 2011)

b. External Shading Device

The external shade is more effective, reducing solar thermal gain than the internal shade because it can block solar radiation before it reaches the building envelope. The external shade needs to be carefully designed not only to reduce the cooling load but also to create an aesthetic architecture while taking into account the natural lighting performance (Huang, Niu, & Chung, 2103).

The geometry of the shading device should be designed according to the path of the sun movement, which led to the design of different shapes and sizes for different orientations. In general, horizontal shading devices are more suitable for windows with south and north orientation, where the angle of sunlight arrives relatively high. Example of the vertical and horizontal shading is shown in Fig. 8.

Figure 8. Example of the Vertical Fins Application (top left) (Boyles et al., 2009), The horizontal Shading (top right) Wangsadinata & Suprayitno, 2008)

The effect of external shading devices on the potential energy savings for different types of buildings has been studied using computer simulations (Freewan, 2014) as the base case is a shadeless window for offices, retail, hotels, and hospitals; And 300 mm horizontal shading for apartments and schools. Also, the underlying case of WWR for apartments and schools is 40% and 35% respectively, while for other types of buildings is 69% (Sari & Suryabrata, 2014).

Differences in essential case characteristics for different types of buildings are by the existing building characteristics in the major city of a developing country. Therefore, energy savings through the use of external shading devices for apartments and schools is smaller because of the smaller window area in both types of buildings. The effectiveness of the horizontal shielding device is not determined by the shade, but by the vertical shadow angle (VSA) (Nielsen, 2005). There are many ways to get the same VSA, for example, by using a single horizontal overhang, pergola, multiple horizontal overhangs with smaller depth sizes, as shown in Fig. 9.

As illustrated in Fig. 10, the simulation results of external shielding devices are very effective at reducing cooling loads from windows, where about 14% energy savings can be obtained through the use of egg crate (Tzempelikos & Athienitis, 2007). The effectiveness of the shade varies depending on WWR, orientation, and selection of glass materials. In general, higher energy savings through shade can be achieved for high-rise buildings with WWR and SHGC. Therefore, the design of a fenestration system or window should be done comprehensively to cover all possible strategies to get the best results.

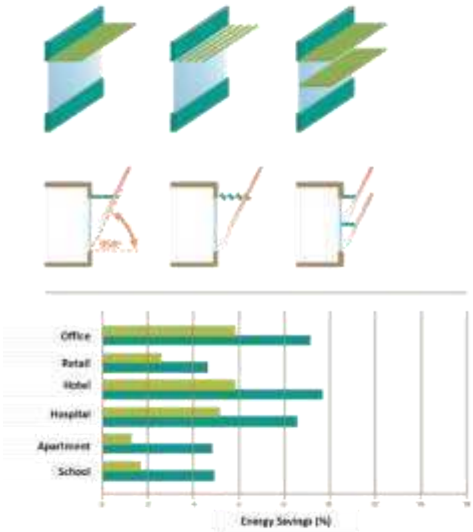


Figure 9. Generic External Shade Type: Overhang and Potential Energy Saving (IFC, 2011)

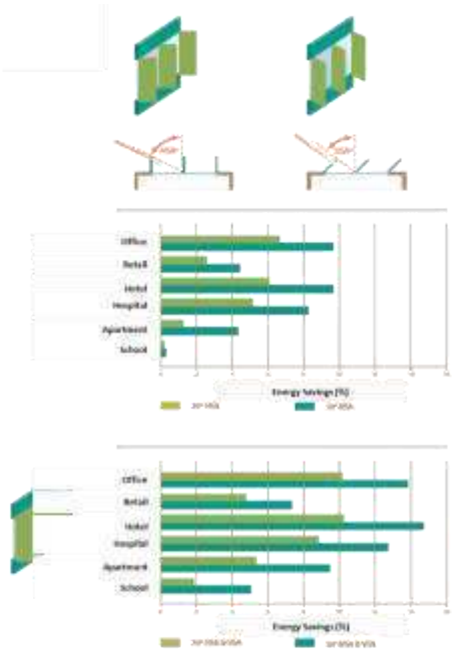


Figure 10. Generic External Shade Type: Vertical Fins (top) and Eggcrate (bottom) and Potential Energy Saving (IFC, 2011)

Light Shelf

Light Shelf is a horizontal element that divides the window into two parts. Upper window for natural lighting and lower window for vision In addition to functioning as a lower window shade, the reflector of light also serves to reflect sunlight coming from the top of the window to help penetrate natural light into the room away from the window. The glass above the reflector needs to have a higher VT (Visible Transmittance), while the glass beneath the reflector can have a lower SGHC and VT. This will optimize light penetration without causing excessive heat. To obtain better natural lighting distribution, the reflector's top surface, as well as the ceiling, should have a high reflectance. Example of heat transmission reduction with horizontal shade is shown in Fig. 11.

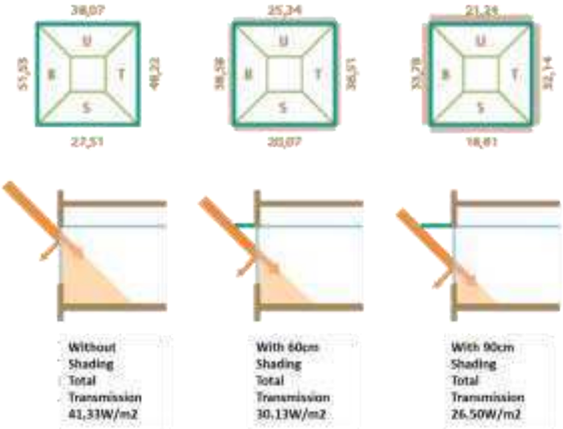


Figure 11. Heat Transmission Reduction with Horizontal Shade

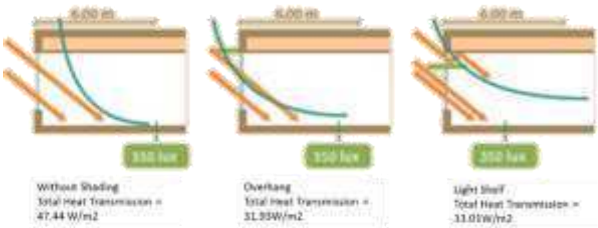


Figure 12. Example of Light Shelf Performance (Suryabrata, 2013)

Fig. 12 shows the performance of a light reflector that can distribute natural lighting more evenly and deeper by reflecting light from the ceiling of the room (Lim & Ahmad, 2015). Ceilings near lighter windows can also reduce the glare sensation due to reduced contrast between interior surfaces (ceilings) and the outside environment.

Wall

The building wall generally consists of several layers of material with different thickness and thermal properties. The combined value of conductance (k) and resistance R-value of each material layer determine the overall thermal properties of the wall, which can be represented by the U-Value (Ficco et al., 2015).

The lower the U-value, the better because of, the lower thermal transfer. The application of massive sheaths with lower U-values is better than the curtain wall. The massive envelope not only significantly reduces heat transmission and cooling loads but also decreases the Mean Radiant Temperature (MRT) in space (Tan, Wong & Jusuf, 2014). MRT is the average surface temperature of the material surrounding a room (e.g., wall, floor, ceiling, table, etc.). The lower the value of MRT, the better. Along with the air temperature, MRT affects the thermal comfort level in the form of "operative temperature" (Operative Temperature), which is the average value of air temperature and MRT.

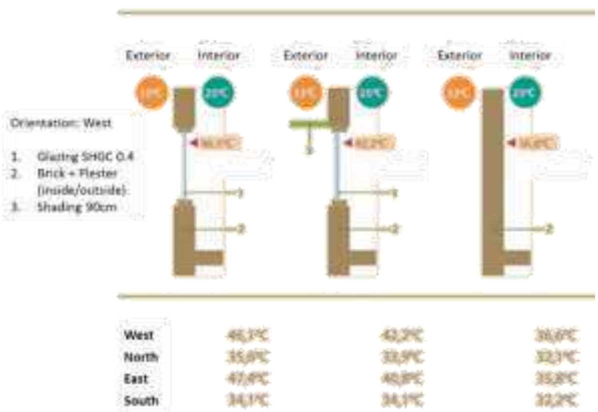


Figure 13. Surface Temperature Comparison for Glass Materials and Brick Walls

As shown in Fig. 13, the inner surface of the glass can reach a much higher temperature than the surface temperature of the brick wall. Therefore, even though the air temperature in a room is in a comfort zone (e.g., 25˚C), the resulting operative temperature may be higher (e.g., 28˚C) if the building envelope is dominated by glass windows (Mirrahimi et al., 2016). In other words, although air temperature measurements show 25˚C, people will feel like 28˚C. In this case, the air temperature should be set lower (e.g., 22-23˚C) to achieve a standard thermal comfort level.

Another typical building envelope construction is curtain wall with glass panel and massive lightweight panel (e.g., aluminum composite panel) (Stazi et al., 2014). In terms of its thermal characteristics, curtain walls are particularly susceptible to heat transfer, and therefore the addition of an insulating layer is essential to improve the thermal performance of the building's envelope.

Roof

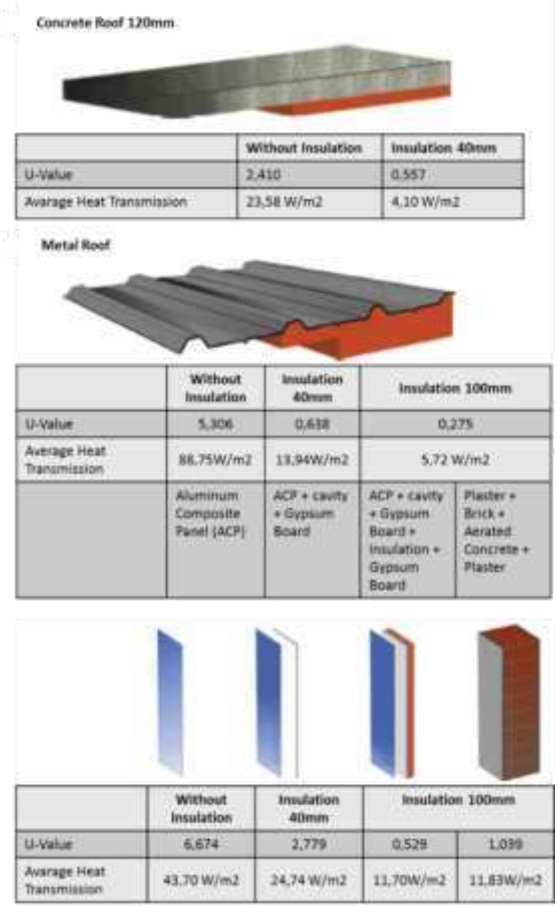
In single or low-storey buildings with large roof areas, the roof can be a significant source of heat recovery of a building. To minimize the increase of heat through the roof, materials with high reflectivity and emissivity should be selected (Dabaieh et al., 2015). Since roofing materials typically have high U-values (high heat transmission), the addition of insulating layers can significantly reduce cooling loads. Having a roof with reflectivity and high emissivity will also reduce the urban heat island phenomenon.

Fig. 14 shows the results of a simulation study revealing the significant impact of using insulating layers on concrete and metal roofs to reduce heat transmission. Keep in mind that the roof (horizontal surface) receives much higher solar radiation than the wall (vertical surface) (Zhao et al., 2016). Therefore, roof construction with better thermal performance (lower U-value) should be used, because of its effectiveness in reducing air cooling loads.

As illustrated in Fig. 14, adding 40 mm insulating layers under the concrete roof reduces heat transmission significantly from 23.58 W / m2 to just 4.10 W / m2. The insulation layer has a much more significant effect for metal roof sheets, where heat transmission is reduced from 88.75 W / m2 to 13.94 W / m2 (Ozel, 2014). Similarly, the addition of an insulating layer to the curtain wall construction on the Aluminum composite panel with a gypsum panel will reduce the heat transmission by more than 50%.

Infiltration

Infiltration is the leak of external air into the building by accident. This can happen through cracks that occur on walls, roofs, or doors and windows. This can also happen through open doors and windows. This air leakage can be exacerbated by wind, negative air pressure from buildings, etc. Infiltration can increase the energy consumption of cooling loads because the incoming air must be cooled and moisture reduced (Ng, Persily & Emmerich, 2015). If the interior of the building is pressurized positively, the interior air can start to leak out. This is known as exfiltration.



	Without Insulation	Insulation 40mm
U-Value	2,410	0.557
Avarage Heat Transmission	23,58 W/m2	4,10 W/m2

	Without Insulation	Insulation 40mm	Insulation 100mm	
U-Value	5,306	0,638	0,275	
Average Heat Transmission	88.75W/m2	13,94W/m2	5,72 W/m2	
	Aluminum Composite Panel (ACP)	ACP + cavity + Gypsum Board	ACP + cavity + Gypsum Board + Insulation + Gypsum Board	Plaster + Brick + Aerated Concrete + Plaster

	Without Insulation	Insulation 40mm	Insulation 100mm	
U-Value	6,674	2,779	0,529	1,039
Avarage Heat Transmission	43,70 W/m2	24,74 W/m2	11,70W/m2	11,83W/m2

Figure 14. Example of Heat Building Material and Heat Transmission (W/m2)

Thermal Indoor Environment

The thermal environment is also a part of ergonomic design. Temperature and suitable and comfortable room are very important for us to feel comfortable, especially when working or doing activities. Temperatures or temperatures that are suitable and comfortable are ranged between 20-22˚C in winter and 20-24˚C in summer. The degree of respect and tolerance of humans to the thermal environment depends on several factors, namely physical condition, age, sex, body fat, and alcohol consumption.

Thermal Comfort

Creating a comfortable thermal environment is one of the essential parameters to be considered in designing a building (Dewsbury & Nolan, 2015). Thermal environments are considered together with other factors, such as air quality, lighting, and noise levels when we evaluate the environment of our activities. If we do not pay attention to the comfort of our place of activity, then the impact will lead to decreased productivity.

Thermal comfort, as defined by ISO Standard (International Standard Organization) 7730, is a complicated relationship between air temperature, air humidity, and airflow velocity, coupled with the type of clothing and activity and metabolic rate of the inhabitants that present an expression of feeling of satisfaction with the condition Air in an environment (Yang, Yan, & Lam, 2014). Comfort conditions are also interpreted as thermal neutrality, which means that one feels neither too cold nor too hot.

Thermal Discomfort

Although a person has a thermal neutrality sensation, certain parts of the body may be exposed to conditions that result in thermal discomfort (Carlucci et al., 2015). This local thermal discomfort cannot be removed by increasing or decreasing the temperature of the enclosure. This is necessary to eliminate localized heating or cooling causes. In general, local thermal insecurities can be grouped in one of the following four titles, as shown in Fig. 15:

1. Local convective cooling caused by a draft
2. Cooling or heating of body parts by radiation. This is known as a radiation asymmetry problem.
3. Cold feet and warm heads at the same time, caused by large vertical air temperature differences.
4. Hot or cold feet, due to uncomfortable floor temperature.

Only when the local thermal and general thermal convenience parameters have been investigated can the quality of the thermal environment be assessed.

Factors Affecting in Thermal Comfort

The most commonly used indicator is air temperature, this parameter is easy to use, and many people can feel it. However, although this air temperature is an essential parameter in the assessment, it will not be accurate to obtain data if only one of these parameters is only to determine thermal comfort. Air temperature should always be considered with other environmental parameters as well as personal factors (Bonte, Thellier, & Lartigue, 2014). The six factors that affect thermal comfort include environmental and personal factors:

- Environment Factors

a. Air Temperature
b. Radiant Temperature
c. Air Velocity
d. Humidity

- Personal Factors

a. Cloth Isulation (Clo)
b. Metabolism (Met)

Figure 15. Local Thermal Discomfort (NN, 1997)

Air Temperature

Air temperature measured by a thermometer is an essential element of weather. This weather element changes according to place and time. The place is open; the temperature is different from the place, as well as in different grass areas with a barren or paved road and so forth. Air temperature measurements only obtain one average value from the atmosphere. To get the average temperature can be calculated by adding the maximum temperature (Tmax) with minimum temperature (Tmin) then divided by two (Perini & Magliocco, 2014).

Radiant Temperature

Thermal radiation is the heat radiation of objects that generate heat. Heat radiation will occur if there is a heat source in an environment. Radiation temperatures have a significant influence over the air temperature associated with loss and addition of heat to the environment (Tan, Wong & Jusuf, 2014). Our skin absorbs a lot of radiation energy almost the same as the black body, although the use of clothing may reduce this. For example, radiation heat sources are the sun, fire, electronic appliance, kitchen burning, oven, and so forth.

Air Velocity

Explanation of the speed of air movement across people in an environment. Wind movement can help cool it if it is colder than the environment.

Airflow velocity is also an essential factor in thermal comfort because people are sensitive to it. Air movement in hot or humid conditions can increase heat loss through convection without changes in air temperature (Maimaitiyiming et al., 2014). Limited air movement in cold environments can be felt as airflow. If the air temperature is lower than the skin temperature, this will affect increasing the heat loss of convection. Physical activity can also improve air movement.

Air Humidity

If the water is heated and will evaporate into the environment. Air humidity is the ratio between the actual amount of water vapor in the air with the maximum amount of water vapor in the air at the same temperature. Air humidity between 40% and 70% does not significantly affect thermal comfort (Amara et al., 2015). In some rooms, air humidity is usually maintained between 40-70%. However, in rooms not conditioned by air, or where external climatic conditions affect thermal comfort in air humidity may increase by more than 70% on rather hot days and hot days. Indoor air humidity can vary, and also depends on whether there is a drying process in which the steam is removed.

The environment with high air humidity has a lot of water vapor in the air, which prevents the evaporation of sweat from the skin. In tropical environments, air humidity is essential because the evaporation of sweat is less when the air humidity is high (above 80%) (Olgyay, 2015). Sweat evaporation is a way of keeping heat losses in humans. When it cannot penetrate the clothes, the moisture in the clothes increases as a cause of sweat because sweat cannot evaporate.

Indoor Environment Strategy

In all climates to obtain thermal comfort using the passive method is to reduce the existing control equipment. In cold or winter climates, passive solar heating, good insulation and control of air infiltration to reduce heating equipment. In hot climates of massive buildings, good evaporation, and shade cooling can be used to improve comfort (Wang et al., 2015).

Other exceptions are in temperate and high humidity. A building designed with the passive cooling method is a highly applicable one. This method is done by maximizing cross ventilation which will make the use of air conditioning is not applied. If the building will be air conditioning installed then the design to be applied is very different.

The result is that the building must be closed, covered and blocked. Therefore, in every decision making either passive or active control should be considered whether to use cross ventilation or using air conditioning (Sun et al., 2013) - procedures for warm and wet climates by comparing psychrometric charts with air movement in potential zones. If the climate line is full closing zone, we can say enter in the passive design. If not, then there are two alternatives whether the required air conditioning or with a closed building or convenience constraints can be met.

The discussions based on the above theories are related to several things. The role of technology and the combination of building elements to reduce building energy use. The combination of building envelope elements and building roofs will create an unusual architectural combination. Building control environments, both passively and actively, or hybrids will be able to increase the comfort of building users. In some cases, the use of passive strategies saves more energy. Use of technology that utilizes sunlight to the fullest, without reducing the comfort of building users. The solar energy is abundant, but it can increase new problems from the building's thermal side

All strategies in the building environment carried out must consider the surrounding environment, locality, and the architecture of the building itself. The most important thing is using low energy.

Several steps are needed to implement the energy conservation agenda in architecture. From an engineering point of view, the simple way is to use criteria and technical standards to reduce energy waste. The next stage is from the institutional side, facilitating a pattern of fundamental patterns of energy use in the artificial environment by improving the quality of building design, transportation systems and production of consumer products in a wider spectrum, for example through regional and urban planning to minimize macro energy use. Moreover, the most challenging stage is to cultivate conservation ethics in each of them to use energy wisely and hold a commitment to do it. Pragmatic design of energy-saving architecture can be applied if designers understand climate behavior where the building is established and apply knowledge of natural or artificial lighting awareness in the right place. Thus energy-efficient architecture is a container that can play a more significant role to improve the quality of energy, environmental quality, and quality of human life through the quality of energy-conscious design.

The building envelope is an element that separates indoor and outdoor environments; they are subject to environmental effects from temperature, humidity, air movement, rain, snow, solar radiation, and various other natural factors.

It is crucial to carry out maintenance of building envelopes to ensure the quality of the environment/work/industry and to avoid premature failure of building structures. One of the problems of building envelope maintenance that is often encountered is water runoff damage, especially in areas with high rainfall. The envelope of the building also needs to be designed and protected from two effects of wind storms: debris due to fluctuating winds and pressure. This is an important consideration in areas prone to hurricanes/hurricanes/typhoons. A review of the effects of wind storms on building envelopes concluded that the penetration of high-rise buildings was most affected due to hurricanes. Some building codes and standards regarding wind debris and the effects of fluctuating pressures on building envelopes are also discussed in this review. Generally, the considerable effort can be made to examine, classify, and document distress symptoms rather than the errors themselves.

CONCLUSION

This paper aim to focuses on the deepening of technology of building envelope elements, and how the building envelope can control the thermal comfort as part of the indoor environment in a building that carries sustainability architecture. Descriptively revealed in advance about the sustainable aspect of the architecture itself. Then discussed the physical aspects of buildings associated with building skin. The paper also describes each element related to the building's skin and its effect on the thermal indoor environment. The convenience of the building is closely related to the surrounding natural or environmental conditions and the conditioning or arrangement of the space within the building. Problems faced in the application of the comfort aspects of the building depends on the object of the building faced.

For buildings that require perfect quality of occupancy, then these requirements must be adopted and applied. This application will be more efficient when associated with energy-saving issues in the building in question.

The principles of passive design on building envelope have a significant influence on the comfort level in the building. It is not possible to create a design that meets the thermal comfort requirements by emphasizing the design of building envelopes. The goal to be achieved in sustainable design is to minimize the use of the current design that takes a lot of energy to address the issue of energy crisis lately.

Improvements to building envelope elements are generally referred to as passive energy efficiency strategies. Passive energy efficiency strategies are susceptible to meteorological factors and, therefore, require a broader understanding of climate factors by a designer. For example, thermal mass applications as a method of saving energy are more effective in places where the atmospheric air temperature difference between day and night is high. Building computer code energy modeling plays an important role in choosing the best energy efficiency options for a particular location. To ensure the correct operation of the designed envelope, building a building envelope is very important. Periodic energy audits of envelopes and building maintenance are important for achieving the best energy performance and long life for building envelopes.

Currently, while some advancements in envelope component technology are easy and cost-effective to adopt, others are still in the research and development stage for future implementation. Several studies have been conducted to find the economic feasibility of various building energy efficiency strategies. The energy efficiency approach sometimes does not require additional capital investment. For example, a holistic energy efficient building design approach can reduce the size of a mechanical system to compensate for the additional costs of energy efficiency features. Government incentives and price cuts in many parts of the world promote market penetration and social awareness of this technology.

The disadvantage of this paper is that it does not discuss building envelop technology in terms of technology in depth. A further study is needed to discuss this issue more deeply. In the future, it is necessary to discuss the use of building envelopes against the use of technology that utilizes solar energy such as the solar chimney.

ACKNOWLEDGMENT

This paper is prepared under the guidance from Tingzhen Ming, Ph.D., Professor for the 2nd semester's assignment, Doctoral Program, Department of Built Environment and Energy Engineering, School of Civil Engineering and Architecture, Wuhan University of Technology.

REFERENCES

Abanda, F. & Byers, L. (2016). An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling). *Energy, 97,* 517-527. http://doi.org/10.1016/j.energy.2015.12.135

Acosta, I., Campano, M.A. & Molina, J.F. (2016). Window design in architecture: Analysis of energy savings for lighting and visual comfort in residential spaces. *Applied Energy, 168,* 493-506. http://doi.org/10.1016/j.apenergy.2016.02.005

Ahn, B.-L., et al. (2014). Effect of LED lighting on the cooling and heating loads in office buildings. *Applied Energy, 113*, 1484-1489. http://doi.org/10.1016/j.apenergy.2013.08.050

Aksamija, A. & Green, D. (2014). Visibility of Research in Design Practice Current and Future Trends. In *ARCC Conference Repository*.

Al-Tamimi, N.A.M., Fadzil, S.F.S. & Harun, W.M.W. (2011). The effects of orientation, ventilation, and varied WWR on the thermal performance of residential rooms in the tropics. *Journal of Sustainable development, 4*(2), 142-149. http://doi.org/10.5539/jsd.v4n2p142

Amara, F., et al. (2015). Comparison and simulation of building thermal models for effective energy management. *Smart Grid and renewable energy, 6*, 95-112. http://doi.org/10.4236/sgre.2015.64009

Ballarini, I., Corgnati, S.P. & Corrado, V. (2014). Use of reference buildings to assess the energy saving potentials of the residential building stock: The experience of TABULA project. *Energy Policy, 68,* 273-284. http://doi.org/10.1016/j.enpol.2014.01.027

Bonte, M., Thellier, F. & Lartigue, B. (2014). Impact of occupant's actions on energy building performance and thermal sensation. *Energy and Buildings, 76*, 219-227. http://doi.org/10.1016/j.enbuild.2014.02.068

Boyles, M., et al. (2009). Virtual Simulation for Lighting & Design Education. In IEEE Virtual Reality Conference, Lafayette, LA, USA. (pp.275-276). http://doi.org/10.1109/VR.2009.4811052

Bribián, I.Z., Capilla, A.V., & Usón, A.A. (2011). Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. *Building and Environment*, *46*(5), 1133-1140. http://doi.org/10.1016/j.buildenv.2010.12.002

Burlacu, A. & C. Racanel. (2014). Reducing Cost of Infrastructure Works Using New Technologies. In *Proceedings of the International Conference on Road and Rail Infrastructure CETRA*. Spilt Dalmatia, Croatia.

Buyya, R., Beloglazov, A., & Abawajy, J. (2010). *Energy-efficient management of data center resources for cloud computing: a vision, architectural elements, and open challenges*. preprint arXiv:1006.0308.

Cabeza, L.F. et al. (2014). Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. *Renewable and Sustainable Energy Reviews, 29,* 394-416. http://doi.org/10.1016/j.rser.2013.08.037

Carera, A. & E. Prianto. (2016). Karakter Kenyamanan Termal pada bangunan Ibadah di Kawasan kota Lama, Semarang. Prosiding SNST 2016, Semarang, Indonesia. (pp. 15-19).

Carlos, J.S. & Corvacho, H. (2015). Evaluation of the performance indices of a ventilated double window through experimental and analytical procedures: SHGC-values. *Energy and Buildings, 86*: 886-897. http://doi.org/10.1016/j.enbuild.2014.11.002

Carlucci, S., et al. (2015). Multi-objective optimization of a nearly zero-energy building based on thermal and visual discomfort minimization using a non-dominated sorting genetic algorithm (NSGA-II). *Energy and Buildings, 104,* 378-394. http://doi.org/10.1016/j.enbuild.2015.06.064

Chan, A.L.S. & Chow, T.T (2014). Calculation of overall thermal transfer value (OTTV) for commercial buildings constructed with naturally ventilated double skin façade in subtropical Hong Kong. *Energy and Buildings, 69,* 14-21.

Chen, X., Yang, H. & Lu, L. (2015). A comprehensive review on passive design approaches in green building rating tools. *Renewable and Sustainable Energy Reviews, 50,* 1425-1436. http://doi.org/10.1016/j.rser.2015.06.003

Chow, W. & Philip, C. (2000). Controlling building energy use by overall thermal transfer value (OTTV). *Energy, 25*(5), 463-478. http://doi.org/10.1016/S0360-5442(99)00079-1

Dabaieh, M., et al. (2015). Reducing cooling demands in a hot dry climate: A simulation study for non-insulated passive cool roof thermal performance in residential buildings. *Energy and Buildings, 89*, 142-152. http://doi.org/10.1016/j.enbuild.2014.12.034

Dewsbury, M. & Nolan, G. (2015). *Thermal performance for timber-framed residential construction: building comfortable and energy-efficient timber houses*. Wood Solutions, Australia.

Ficco, G., et al. (2015). U-value in situ measurement for energy diagnosis of existing buildings. *Energy and Buildings, 104,* 108-121. http://doi.org/10.1016/j.enbuild.2015.06.071

Freewan, A.A. (2014). Impact of external shading devices on thermal and daylighting performance of offices in hot climate regions.

Solar Energy, 102, 14-30. http://doi.org/10.1016/j.solener.2014.01.009

Gago, E., et al. (2015). Natural light controls and guides in buildings. Energy saving for electrical lighting, reduction of cooling load. *Renewable and Sustainable Energy Reviews, 41*: 1-13.

Gang, W., et al. (2015). Impacts of cooling load calculation uncertainties on the design optimization of building cooling systems. *Energy and Buildings, 94,* 1-9. http://doi.org/10.1016/j.enbuild.2015.02.032

GhaffarianHoseini, A., et al. (2013). Sustainable energy performances of green buildings: A review of current theories, implementations and challenges. *Renewable and Sustainable Energy Reviews, 25,* 1-17. http://doi.org/10.1016/j.rser.2013.01.010

Gorse, C., et al. (2015). Understanding Building Performance: Implications of heat loss and air permeability on building control. *Journal of Zero Carbon Building, 4*, 36-49.

Granadeiro, V., et al. (2013). Building envelope shape design in early stages of the design process: Integrating architectural design systems and energy simulation. *Automation in Construction, 32*, 196-209. http://doi.org/10.1016/j.autcon.2012.12.003

Hanif, M., et al. (2014). Potential energy savings by radiative cooling system for a building in tropical climate. *Renewable and sustainable energy reviews, 32,* 642-650. http://doi.org/10.1016/j.rser.2014.01.053

Hardik, H. (2015). *Energy efficiency by cool roofs*. Available in: https://www.slideshare.net/hardik6373/energy-efficiency-by-cool-roofs

Hee, W., et al. (2015). The role of window glazing on daylighting and energy saving in buildings. *Renewable and Sustainable Energy Reviews, 42,* 323-343. http://doi.org/10.1016/j.rser.2014.09.020

Huang, Y., Niu, J.-l., & Chung, T.-M. (2103). Study on performance of energy-efficient retrofitting measures on commercial building external walls in cooling-dominant cities. *Applied energy, 103*, 97-108. http://doi.org/10.1016/j.epenergy.2012.09.003

Huda, M., et al. (2013). Analysis of Important Factors Evaluation Criteria for Green Building. *The International Journal of Engineering and Science (IJES), 2,* 41-47.

I.F.C. (2011). *Jakarta Building Energy Efficiency Baseline and Saving Potential: Sensitivity Analysis*.

Jan, A., et al. (2014). *Investigation of the Use of Solar Thermal Buffer Zone in Buildings*, In book: Progress in Exergy, Energy, and the Environment. Springer. (pp. 841-848)

Ji, L., et al. (2013). Analysis on energy-saving potential of transparent insulating glass coating. Build. Sci., *29*, 7-8.

Kalan, A. & Oliveira, E. (2015). The Sustainable Architecture of Bazaars and its Relation with Social, Cultural and Economic Components (Case Study: The Historic Bazaar of Tabriz). *International Journal of Architecture and Urban Development, 5*(4), 5-12.

Kirankumar, G., Saboor, S., & Setty, A.B.T. (2016). Simulation of Various Wall and Window Glass Material for Energy Efficient Building Design. *Key Engineering Materials*. 692, 9-16. http://doi.org/10.4028/www.scientific.net/KEM.692.9

Košir, M., Gostiša, T. & Kristl, Ž. (2016). Search for an Optimised Building Envelope Configuration During Early Design Phase with Regard to the Heating and Cooling Energy Consumption. *CESB16-Central Europe towards Sustainable Building*. Prague, Czech. (pp. 805-812).

Kwong, Q.J., Adam, N.M. & Sahari, B. (2014). Thermal comfort assessment and potential for energy efficiency enhancement in modern tropical buildings: A review. *Energy and Buildings*, *68*(Part A), 547-557. http://doi.org/10.1016/j.enbuild.2013.09.034

Lave, L.B. et al. (2006). Energy Efficiency in Residential and Commercial Buildings. In *Panel on Energy Efficiency Technologies*. Washington, DC, US.

Lee, J., et al. (2013). Optimization of building window system in Asian regions by analyzing solar heat gain and daylighting elements. *Renewable energy, 50,* 522-531. http://doi.org/10.1016/j.renene.2012.07/029

Lim, Y.-W. & Ahmad, M.H. (2015). The effects of direct sunlight on light shelf performance under tropical sky. *Indoor and Built Environment, 24*(6), 788-802. http://doi.org/10.1177/1420326X14536066

Lozano, R., et al., (2015). A review of commitment and implementation of sustainable development in higher education: results from a worldwide survey. *Journal of Cleaner Production, 108*(A), 1-18. http://doi.org/10.1016/j.clepro.2014.09.048

Maimaitiyiming, M., et al. (2014). Effects of green space spatial pattern on land surface temperature: Implications for sustainable urban planning and climate change adaptation. *ISPRS Journal of Photogrammetry and Remote Sensing, 89*, 59-66. http://doi.org/10.1016/j.isprsjprs.2013.12.010

Maldonado, E. (1998). Environmentally Friendly Cities. In *Proceedings of Plea 1998, Passive*

and Low Energy Architecture. Lisbon, Portugal.
Manzano-Agugliaro, F., et al. (2015). Review of bioclimatic architecture strategies for achieving thermal comfort. *Renewable and Sustainable Energy Reviews*, *49*, 736-755. http://doi.org/10.1016/j.rser.2015.04.095
Mika, P. (2014). The capabilities of using concrete in sustainable architecture. In *International Multidisciplinary Scientific Conferences on Social Sciences & Arts*, Bulgaria. (pp. 1015-1022) http://doi.org/10.5593/sgemsocial2014/B41/S15.123
Mirrahimi, S., et al. (2016). The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot–humid climate. *Renewable and Sustainable Energy Reviews*, *53*, 1508-1519. http://doi.org/10.1016/j.rser.2015.09.055
Nazem, F. (2015). Sustainable Traditional Architecture and Urban Planning in Hot–Humid Climate of Iran. World Academy of Science, Engineering and Technology. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, 9*(11), 1484-1487.
Ng, L.C., Persily, A.K. & Emmerich, S.J. (2015). Improving infiltration modeling in commercial building energy models. *Energy and Buildings, 88*, 316-323. http://doi.org/10.1016/j.enbuild.2014.11.078
Nguyen, A.-T., Reiter, S. & Rigo, P. (2014). A review on simulation-based optimization methods applied to building performance analysis. *Applied Energy, 113*, 1043-1058. http://doi.org/10.1016/j.epenergy.2013.08.061
Nielsen, T.R. (2005). Simple tool to evaluate energy demand and indoor environment in the early stages of building design. *Solar Energy, 78*(1), 73-83. http://doi.org/10.1016/j.solener.2004.04.016
Nimpuno, W.B. (2017). Post-Occupansy Evaluation: The Application of the Universal Design in Hayrettin Paşa Square, Istanbul. *SINERGI, 21*(1), 39-46. http://doi.org/10.22441/sinergi.2017.1.006
NN. (1997). *Thermal Comfort*. Innova Airtech Instruments. Available at: http://www.blowtex-educair.it/downloads/thermal%20comfort.htm
NN. (2009). Insulation - Principles and Calculations. University of the West of England. Availabel in: https://fet.uwe.ac.uk/conweb/hi4web/Principles/section1.htm
Olgyay, V. (2015). Design with climate: bioclimatic approach to architectural regionalism. Princeton University Press, US.
Olivieri, L., et al. (2014). Integral energy performance characterization of semi-transparent photovoltaic elements for building integration under real operation conditions. *Energy and Buildings*, *68*(A), 280-291. http://doi.org/10.1016/j.enbuild.2013.09.035
Ozel, M. (2014). Effect of insulation location on dynamic heat-transfer characteristics of building external walls and optimization of insulation thickness. *Energy and Buildings, 72,* 288-295. http://doi.org/10.1016/j.enbuild.2013.11.015
Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. *Energy and buildings*, *40*(3), 394-398. http://doi.org/10.1016/j.enbuild.2007.03.007
Perini, K. & Magliocco, A. (2014). Effects of vegetation, urban density, building height, and atmospheric conditions on local temperatures and thermal comfort. *Urban Forestry & Urban Greening,* *13*(3), 495-506. http://doi.org/10.1016/j.ufug.2014.03.003
Ramos, T., et al. (2015). Spatial and temporal variations in indoor environmental conditions, human occupancy, and operational characteristics in a new hospital building. *PLoS One, 10*(3), e0118207. http://doi.org/10.1371/journal.pone.0118207
Ravindu, S., et al. (2015). Indoor environment quality of green buildings: case study of an LEED platinum certified factory in a warm humid tropical climate. *Building and Environment, 84*, 105-113. http://doi.org/10.1016/j.buildenv.2014.11.001
Rodriguez-Ubinas, E., et al. (2014). Passive design strategies and performance of Net Energy Plus Houses. *Energy and buildings, 83,* 10-22. http://doi.org/10.1016/j.enbuild.2014.03.074
Rosso, F., et al. (2017). Cool, Translucent Natural Envelope: Thermal-optics Characteristics Experimental Assessment and Thermal-energy and Day Lighting Analysis. *Energy Procedia*, 111, 578-587. http://doi.org/10.1016/j.egypro.2017.03.220
Sadineni, S.B., S. Madala, and R.F. Boehm. (2011). Passive building energy savings: A review of building envelope components. *Renewable and Sustainable Energy Reviews*, *15*(8), 3617-3631. http://doi.org/10.1016/j.rser.2011.07.014
Sameh, S.H. (2014). Promoting earth architecture as a sustainable construction technique in Egypt. *Journal of cleaner production, 65,* 362-373. http://doi.org/10.1016/j.clepro.2013.08.046

Sari, D.P. & Suryabrata, I.J.A.. (2014). *Potensi Strategi Night Ventilative Cooling Di Indonesia Dengan Simulasi Energyplus: Kasus Bangunan Hipotetik Perkantoran Berdasarkan Data Iklim Bogor*. Universitas Gadjah Mada, Yogyakarta.

Scheuer, C., Keoleian, G.A., & Reppe, P. (2003). Life cycle energy and environmental performance of a new university building: modeling challenges and design implications. *Energy and buildings, 35*(10), 1049-1064. http://doi.org/10.1016/S0378-7788(03)00066-5

Soares, N., et al. (2013). Review of passive PCM latent heat thermal energy storage systems towards buildings' energy efficiency. *Energy and buildings, 59,* 82-103. http://doi.org/10.1016/j.enbuild.2012.12.042

Song, Y., et al. (2015). Multi-criteria approach to passive space design in buildings: Impact of courtyard spaces on public buildings in cold climates. *Building and Environment*, *89*, 295-307. http://doi.org/10.1016/j.buildenv.2015.02.025

Stazi, F., et al. (2014). Energy, comfort and environmental assessment of different building envelope techniques in a Mediterranean climate with a hot dry summer. *Applied Energy, 134*, 176-196. http://doi.org/10.1016/j.apenergy.2014.08.023

Steele, J., (1997). Sustainable architecture: principles, paradigms, and case studies. McGraw-Hill, NY, US.

Sun, B., et al. (2013). Building energy management: Integrated control of active and passive heating, cooling, lighting, shading, and ventilation systems. *IEEE Transactions on automation science and engineering, 10*(3), 588-602. http://doi.org/10.1109/TASE.2012.2205567

Sunstein, C.R. & Reisch, L.A. (2014). Automatically green: Behavioral economics and environmental protection. *Harvard Enviromental Law Review, 38*(1), 1-27.

Suryabrata, I.J.A. (2013). *Pengaruh Integrasi Pencahayaan Alami Pada Sistem Pencahayaan Terhadap Efisiensi Energi Bangunan Tinggi*. Universitas Gadjah Mada, Yogyakarta, Indonesia.

Syah, F.F. and Nugroho, M.S.P. (2013). Kenyamanan Termal Gedung Setda Kudus. *Sinektika: Jurnal Arsitektur, 13*(2), 105-113.

Tan, C.L., Wong, N.H. & Jusuf, S.K. (2014). Effects of vertical greenery on mean radiant temperature in the tropical urban environment. *Landscape and Urban Planning, 127*, 52-64. http://doi.org/10.1016/j.landurbplan.2014.04.005

Tzempelikos, A. & Athienitis, A.K. (2007). The impact of shading design and control on building cooling and lighting demand. *Solar Energy, 81*(3), 369-382. http://doi.org/10.1016/j.solener.2006.06.015

Valladares-Rendóna, L., Schmid, G. & Lo, S.L. (2016). Review on energy savings by solar control techniques and optimal building orientation for the strategic placement of façade shading systems. *Energy and Buildings, 140,* 458-479. http://doi.org/10.1016/j.enbuild.2016.12.073

Vijayalaxmi, J. (2010). Concept of overall thermal transfer value (OTTV) in design of building envelope to achieve energy efficiency. *International Journal of Thermal & Environmental Engineering, 1*(2), 75-80. http://doi.org/10.5383/ijtee.01.02.003

Wang, L.-S., et al. (2014). A study of building envelope and thermal mass requirements for achieving thermal autonomy in an office building. *Energy and Buildings*, *78*, 79-88. http://doi.org/10.1016/j.enbuild.2014.04.015

Wang, Y., et al. (2015). Evaluation on classroom thermal comfort and energy performance of passive school building by optimizing HVAC control systems. *Building and Environment, 89*, 86-106. http://doi.org/10.1016/j.buildenv.2015.02.023

Wangsadinata, W. & Suprayitno, G. (2008). *Roosseno, jembatan dan menjembatani*. 2008: Yayasan Obor Indonesia.

Wetter, M. (2011). Co-simulation of building energy and control systems with the Building Controls Virtual Test Bed. *Journal of Building Performance Simulation*, *4*(3), 185-203. http://doi.org/10.1080/19401493.2010.518631

Wong, K.-d. & Fan, Q. (2013). Building information modelling (BIM) for sustainable building design. *Facilities*, *31*(3), 138-157. http://doi.org/10.1108/02632771311299412

Workshop, A.S. (2014). *Heat Energy Flows in Buildings*. Available in: http://auworkshop.autodesk.com/library/building-science/heat-energy-flows-buildings.

Yang, L., Yan, H., & Lam, J.C. (2014). Thermal comfort and building energy consumption implications–a review. *Applied Energy*, *115*, 164-173. http://doi.org/10.1016/j.apenergy.2013.10.062

Yu, Z., et al.. (2011). A systematic procedure to study the influence of occupant behavior on building energy consumption. *Energy and Buildings*, *43*(6), 1409-1417. http://doi.org/10.1016/j.enbuild.2011.02.002

Zhai, Z. (2006). Application of computational fluid dynamics in building design: aspects and trends. *Indoor and built environment*, *15*(4),

305-313. http://doi.org/10.1177/1420326X06067336
Zhao, B., et al. (2016). Impact of buildings on surface solar radiation over urban Beijing. *Atmospheric Chemistry and Physics, 16*(9), 5841-5852. http://doi.org/10.5195/acp-5841-2016
Zhao, H.-X. & Magoulès, F. (2012). A review on the prediction of building energy consumption. *Renewable and Sustainable Energy Reviews, 16*(6), 3586-3592. http://doi.org/10.1016/j.rser.2012.02.049