A review of energy use in a sustainable city model

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Abstract. Energy has an important role in human life so it must be considered in its use. Its use is found in all sectors, namely transportation, industry and buildings. If energy usage is uncontrolled, the main problem that occurs is global warming which will damage the environment. Therefore, development planning in all sectors applies the concept of sustainable energy efficiency, especially for buildings and urban development. The efficient use of energy can minimize environmental damage and improve prosperity so that the results obtained in an environment are maximized. The Urban Modelling Interface is used as a simulation tool to find out energy use from the environment and cities. This paper provides not only a review of the literature on energy operations in sustainable development through the use of systems of heating, ventilation, and air conditioning but also an evaluation related to factors that influence energy use and its standards in Indonesia. This research is expected to make a contribution related to the use of energy in city development.

1. Introduction
The implementation of the development planning of several cities in Indonesia has a distinctive challenge, so it raises a new level. The planning with a sustainable concept in Indonesia begins to be widely applied to long, medium, and short-time planning and is supported by the issuance of Presidential Regulation No. 59 of 2017 on the Implementation of Sustainable Development Goals [1]. This policy is based on Law of the Republic of Indonesia No. 17 of 2007 on long-term national planning for 2005-2025 which in the development implementation is carried out to meet current requirements without reducing the next generations’ ability to fulfil their requirements [2]. This effort is supported by all elements of government and society on a small to large scale. The largest scale is the city scale; the middle scale is the neighborhood scale (a sub-district and village); and the smallest scale is a building [3]. One of the development goals on an urban scale is to reduce the use of non-renewable resources, maximize the use of renewable resources and optimize the absorption of local and global waste [4]. The buildings in cities are responsible for the use of primary energy up to 70% [5], [6]. At all times, the energy consumption for transportation and industry is 27% and 25% respectively. The largest consumption is used for buildings by 48%, 40% for operational energy in buildings and 8% in the construction process [6]. The use of minimal energy has a good impact on the environment and surroundings [7]. The use of energy in Yogyakarta is dominated by the household sector as electrical energy. Energy use continues to increase in line with population growth [8]. This is due to the increasing number of residents from various cities and the heterogeneity of population living in Yogyakarta. This
situation indicates that the city has the potential to suit the needs of the migrant community [9]. One of the strategic areas of concern is the urban area around Tugu Yogyakarta. Based on the regulation of the Special Region of Yogyakarta No. 3 of 2018 concerning the Regional Medium Term Development Plan (RPJMD) of the Special Region Of Yogyakarta from 2017 to 2022, the government of Yogyakarta strives not only to provide adequate settlement infrastructure and facilities but also to develop residential land towards the top and the side [10]. This study aims to identify sustainable downtown models and factors that support energy use simulations through the Urban Modelling Interface (UMI) software in Yogyakarta.

2. Methods
This research is the initial stage in the thesis preparation stage. The method used in this research phase is included in the quantitative category through the study of literature originating from various sources such as journals, reports and books. Literature review in the early stages of research is used so that researchers can get clues and in detail can describe the related topics discussed [11]. The focus of the literature review is the model for sustainable urban development related to energy use through the Urban Modeling Interface (UMI) software.

3. Result and Discussion
3.1. City
A city as a residence of the population is characterized by the existence of buildings that support activities in fulfilling life and well-being [12], [13]. Mulyandari (2011), defines a city as a place where the population is dense, the houses are in groups, and the residents' livelihoods are not agriculture or plantations. Aspects that are very closely related to cities in the field of architecture are aspects of the urban frame with five factors, namely massing, land use, circulation, infrastructure, and public facilities and services. Another aspect is urban fabric consisting of building programs, building treatments, and building land using prototypes [15].

In the process of urban design, designing is defined as an action so that urban spaces can be structured to create order, beauty, and scale in harmony [14], [16]. Urban patterns are formed from arranged buildings and the availability of open space. The theory used is the figure ground theory by Trancik (1986). Figure in the form of building mass blocks depicted in black textures functions as a container for human activity, so it provides a presence of masses and objects on a road or site that tends to be private domain. Ground is the term for all spaces outside the building mass with white textures in the picture and can be open space (roads, urban space, open space), plaza, poche, garden, and so on. The design with the approach of the theory of figure ground can identify not only a texture and patterns of urban spatial structure but also problems of mass order or space in urban areas [16], [17]. There are 3 types of building block or solid typologies, namely single block, side defining block, and terrain block. The space or void has 4 typologies, which are linear closed systems, central closed systems, central open systems and linear open systems.

![Figure 1. Three Elements in Building or Solid Mass Blocks](image-url)
3.1.1. Urban Design Guide

The aspects to be considered in the urban design are land use, the intensity of land use, structuring of buildings, circulation systems and connecting lines, open space and green governance systems, environmental quality management systems, and infrastructure systems and environmental utilities (Balai Penerapan Teknologi Konstruksi, 2018).

1. Land use
   The principle used in structuring is the diversity of land uses that are mutually supporting, integrated, and then balanced taking into account the allotment of micro land (%) so as to form the desired pattern.

2. Land use intensity
   Determination of the maximum floor area of a building against land or its designation by considering the magnitude of the building base coefficient (KDB), the building floor coefficient (KLB), the green base coefficient (KDH), and the coefficient of basement site (KTB). The factors that determine KDB are the location of the building and the function of the building. The factors determining KLB are the location of the building, the type of building, and population density. The determining factor for KDH is the ratio between the total open space outside the building which is intended as landscaping or greening. The factors that determine KTB are the magnitude of the KDB and KDH, and the position of the building commensurate line (GSB) against the road commensurate line (GSJ).

3. Building layout
   Regional arrangement of buildings divides the area into several functions, namely residential functions (single dwelling, series, stacking), businesses (offices, hotels, industry), and other functions (social, cultural, and worship). The part in the structuring of the building pays attention to the arrangement of environmental blocks (topography, function composition, service scale, scale of plot) and arrangement of plot or plot of land (hierarchy of roads, functions, service scale, scale of plot). Both of these settings refer to the shape and size of the block, group and block configuration, open space, and green layout. The building arrangement refers to the building grouping, the location, and orientation of the building, the figure of the building mass, the architectural expansion of the building and is determined by the interwoven building layout of the area, the topography of the area, the determination of the land use intensity, the deepening of the designation of the building's function and building character. Another arrangement is the height of the building which is regulated by taking into account the composition of the elevation of the building above the ground surface area as well as the height of the building floor which is related to the maximum height of the building that is allowed for the comfort and safety of the room user.

4. Circulation system and connecting lines
   Physically circulation and connecting lines refer to the dimensions of circulation and accessibility standards; aesthetics, image, and character of the region; physical quality; and completeness of environmental support facilities. In the environment, circulation and connecting
lines refer to the value of the area, integration of regional blocks and supporting facilities, ecological sustainability of the area. Components that affect circulation and connecting lines are road and movement network systems, public and private vehicle circulation systems, and pedestrian and bicycle circulation systems.

5. Open space system and green layout
Components in structuring open space are public open space systems, private open space systems, and private open space systems accessible to the public.

6. Governance of environmental quality
Components in structuring environmental quality are the identity of an area, the structure of the area, and the meaning of the area. Identity is applied by referring to the image of the city, ie path, edge, node, district, and landmark.

7. Environmental infrastructure and utility systems
In environmental infrastructure and utilities, systems include evacuation rescue network systems, fire safety network systems, telephone networks, drainage networks, clean water and wastewater networks, solid waste networks, and gas and electricity networks.

Table 1. Urban Design Guide

| Aspect                   | Variable                                                                 | Indicator                                                                 |
|--------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Land use intensity       | Determination of the maximum floor area of a building against land or footprint | • Basic building coefficient (KDB)                                       |
|                          |                                                                           | • Building floor coefficient (KLB)                                        |
|                          |                                                                           | • Green basic coefficient (KDH)                                            |
|                          |                                                                           | • Basement site coefficient (KTB)                                          |
| Building layout          | Regional arrangement of buildings divides the area into several functions | • Residential functions (single dwelling, series, stacking)               |
|                          |                                                                           | • Business functions (office, hotel, industry)                            |
|                          |                                                                           | • Other functions (social, cultural, and worship).                        |
| Block environment settings|                                                                           | • Topography                                                              |
|                          |                                                                           | • Function composition                                                    |
|                          |                                                                           | • Service scale                                                           |
|                          |                                                                           | • Land plots                                                              |
|                          |                                                                           | • Block shape and size                                                    |
|                          |                                                                           | • Group and block configurations                                           |
|                          |                                                                           | • Open space and green layout                                             |
| Land or plot arrangement |                                                                           | • Hierarchy of roads                                                      |
|                          |                                                                           | • Function                                                                |
|                          |                                                                           | • Scale of service                                                        |
|                          |                                                                           | • The amount of land                                                       |
|                          |                                                                           | • The shape and size of the block                                          |
|                          |                                                                           | • Block groups and configurations                                          |
|                          |                                                                           | • Open space and green layout                                             |
| Building Arrangement     |                                                                           | • Building grouping                                                       |
|                          |                                                                           | • Location and orientation of the building                                |
|                          |                                                                           | • The figure of the building mass                                          |
|                          |                                                                           | • Architectural exposures                                                 |
|                          |                                                                           | • Interwoven building layout of the surrounding area                      |
|                          |                                                                           | • Topographical condition of the region                                   |
|                          |                                                                           | • Determination of intensity                                              |
|                          |                                                                           | • Land use                                                                |
| Aspect                                      | Variable                                                                 | Indicator                                                                                                                                 |
|--------------------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Building height settings                   |                                                                           | • function and character of the building                                                                                               |
| Circulation system and connecting lines    | Physically circulation and connecting lines refer to the dimensions of    | • The composition of the elevation of buildings on the ground plane                                                                   |
|                                            | the dimensions of circulation and accessibility standards; aesthetics,    | • The height of the building floor is related to the maximum height of the building that is allowed for the comfort and safety of the room user |
|                                            | image, and character of the region; physical quality; and completeness of |                                                                                                                                     |
|                                            | environmental support facilities                                           |                                                                                                                                     |
|                                            | In the environment, circulation and connecting lines refer to the value    |                                                                                                                                     |
|                                            | of the area, integration of regional blocks and supporting facilities,    |                                                                                                                                     |
|                                            | ecological sustainability of the area.                                    |                                                                                                                                     |
| Open space system and green layout         | Physically and non-physically                                            | • Road and movement network system                                                                                                      |
|                                            |                                                                           | • Public and private vehicle circulation systems                                                                                      |
|                                            |                                                                           | • Local public informal vehicle circulation system                                                                                     |
|                                            |                                                                           | • Transit movement system                                                                                                              |
|                                            |                                                                           | • Parking system planning service / service line system                                                                               |
|                                            |                                                                           | • Pedestrian and bicycle circulation system                                                                                             |
|                                            |                                                                           | • Integrated pedestrian linkage network system                                                                                         |
|                                            | Environmentally                                                          | • The balance of the planning area with its surroundings                                                                              |
|                                            |                                                                           | • Balance with environmental carrying capacity                                                                                        |
|                                            |                                                                           | • Ecological sustainability of the area                                                                                            |
|                                            |                                                                           | • Regional Empowerment                                                           |
| Environmental quality management           | The concept of environmental identity                                     | • Path                                                                               |
|                                            |                                                                           | • Edge                                                                               |
|                                            |                                                                           | • Node                                                                               |
|                                            |                                                                           | • District                                                                           |
|                                            |                                                                           | • Landmark                                                                           |
| Concept of environmental orientation       |                                                                          |                                                                                                                                     |
| Street face                                |                                                                          |                                                                                                                                     |
| Environmental infrastructure and utilities systems |                                                           | • Clean water and waste water network systems                                      |
|                                            |                                                                          | • Drainage network system                                                           |
|                                            |                                                                          | • evacuation rescue network system                                                   |
|                                            |                                                                          | • fire safety network system                                                        |
|                                            |                                                                          | • Telephone network system                                                          |
|                                            |                                                                          | • Waste network system                                                               |
|                                            |                                                                          | • Gas and electricity network system                                                |

3.2. **Urban Energy**
Energy use at the city level is related to the influence of city shape, city density, transportation infrastructure, and consumption patterns. The main difference between buildings and urban scale is the boundary of analysis but the assessment of energy use at the urban scale uses a method similar to the building scale [19]. Energy in the field of architecture embraces all aspects of a building from planning, implementation, to destruction [20]. The use of energy has resulted in global warming and if the use is uncontrolled, it will result in a large fee bill. Everyday humans spend more than 80% of their time in buildings, which directly affect energy use [21]. The amount of non-renewable energy use in buildings is 92% consisting of 7% nuclear, 22% coal, 24% gas, and 39% petroleum [6].

Figure 3. The Energy Use in Buildings

Energy in buildings is divided into two types, related to the construction and operation of a building during its life cycle [22]. Energy consumption during the building operation phase depends on various related factors such as climate and location; level of demand, supply and source of energy; function and use of buildings; building design; building materials; income levels; and the behavior of its inhabitants [23]. Energy use in the residential sector is influenced by income, cost, building characteristics, location, and weather [24]. Meanwhile, in the commercial sector, usage is more influenced by economic growth, population, and type of economic activity. However, energy consumption is also influenced by the same factors as climate, availability of resources and technology, as well as equipment efficiency (cooling, artificial lighting, and other electrical equipment) [24]. The aspects that are highly considered in the use of energy according to Satwiko (2005) are the location of buildings, land, mass (orientation, height, number and shape), use of space, building elements, lighting systems, ventilation systems, structures and utilities [20].

Energy use in buildings is influenced by several aspects such as climate, the quality of the environment around the building, the direction of the building, building materials and building plans [25]. Facade surface orientation, building shape and height of the distance of one floor and another affect energy use [26]. According to Ahmed & Alipour, the calculation of operational energy in buildings takes into account the geographical location of buildings, the physical properties of buildings, window-wall ratios (WWR), mass geometry, material usage, orientation, and operating hours of use in buildings [27]. Operational energy in buildings is defined as the use of energy in heating, cooling, lighting, and operation of building equipment [28].
Lechner explained that the design of buildings can be done through approaches in terms of heating, cooling, and lighting with three stages. At the basic building design stage, what an architect can do is to pay attention to location, site design, landscaping, form, orientation, color, insulation, exterior shading, construction materials, and air tightness for the heat retention approach. The approach to heat rejection is taken through window orientation, size, glazing type, insulation, shading. And the approach to heat avoidance is by means of efficient lighting and efficient appliances [6]. The purpose of energy use is to maintain a comfortable room environment through building operating systems such as heating, cooling, lighting, and ventilation [22]. From the discussion related to factors affecting energy operations in buildings, it can be summarized as follows:

Table 2. The Factor Affecting Operational Energy of a Building

| The factor affecting operational energy of buildings | [23] | [24] | [20] | [25] | [26] | [27] | [28] | [6] |
|----------------------------------------------------|------|------|------|------|------|------|------|------|
| Air tightness                                       |      |      |      |      |      |      |      | √    |
| Costs (income and usage)                            |      | √    |      |      |      |      |      |      |
| Color of building façade                           |      |      |      |      |      |      |      | √    |
| Construction materials                              | √    | √    | √    | √    |      |      |      |      |
| Equipment efficiency (coolers, artificial lighting, and other electrical equipment) |      |      |      | √    |      |      |      |      |
| Building elements (orientation, height, number and shape) | √    | √    | √    | √    | √    |      |      |      |
| Exterior shading                                    |      |      |      |      |      |      |      | √    |
| Glazing type                                       |      |      |      |      |      |      |      | √    |
| Climate                                            | √    | √    |      |      |      |      |      |      |
| Insulation                                         |      |      |      |      |      |      |      | √    |
| Building operating hours                           |      |      |      |      |      |      |      | √    |
| type of economic activity                          |      |      |      |      |      |      |      | √    |
| Building characteristics                           |      |      |      |      |      |      |      |      |
| Availability of resources and technology            |      |      |      |      |      |      |      | √    |
The factor affecting operational energy of buildings

Table 3. The energy consumption intensity in ASEAN

| Building Type          | Energy consumption intensity (kWh/m²/year) |
|------------------------|-------------------------------------------|
| Hospital               | 380                                       |
| Hotel or Apartment     | 300                                       |
| Shopping Center        | 330                                       |
| Office or commercial   | 240                                       |

3.2.1. The intensity of energy use

The ratio of energy input to estimates or the count of the amount of energy needed to cover various requirements related to the use of building standards serves as a measure of energy efficiency (Chaturvedi et al., 2018). Energy use standards in Indonesia are known as Energy Consumption Intensity (IKE) in the use of electricity. The result of the ASEAN-USAID report (1992) through a previous study in 1987 is that the target size of IKE in ASEAN countries is as follows [29].

| Building Type          | Energy consumption intensity (kWh/m²/year) |
|------------------------|-------------------------------------------|
| Hospital               | 380                                       |
| Hotel or Apartment     | 300                                       |
| Shopping Center        | 330                                       |
| Office or commercial   | 240                                       |

3.3. Urban Modelling Interface (UMI)

Modeling on the city scale uses computational methods with a variety of software to facilitate users in planning related to energy use. Various types of software in Urban Building Energy Modeling can use more than 20 types of software including CityBES, MIT UBEM Tool, UMI, Virtual EPB, CitySim, SEMANCO, SimStadt, Energy Atlas, Urban Footprint, and others [5]. Modeling Interface (UMI) is a...
development program from the MIT Sustainable Design Lab in 2013 [30]. UMI software is intended for architects and urban planners based on the design of environmental performance modeling of the environment and cities. Rhinoceros can do simulations related to operational energy, life cycle, walkability, and daylighting. Other reference devices in UMI used are EnergyPlus, Radiance / Daysim, Diva, and Grasshopper and Python scripts [26], [30]. In general, UMI is part of other software [26], [30]. The purpose of the UMI program is to be able to provide access to its users and be able to facilitate design on the scale of the environment, roads and buildings [30]. To start modeling an area, it is necessary to ensure that the work unit is in meters and make sure UMI is integrated with Rhinoceros [26]. The advantage of using this program is that the modeling of the area can be done appropriately and the data generated can be adjusted to the needs of its users [31]. UMI can analyze energy in buildings in urban areas together and research has been done in Boston in 92,000 buildings [5], [30].

4. Conclusions

From this article, it was concluded that the patterns in cities are formed from a combination of several elements. These elements are the structured buildings and the availability of open space, so the blocks of building mass and space appear outside the building masses that are arranged harmoniously and beautifully, and have the right scale. More detailed regulations on aspects of land use, land use intensity, building arrangement, circulation system and connecting lines, open space and green governance systems, environmental quality management systems, and infrastructure systems and environmental utilities are needed to optimize the area. Operational buildings use energy in meeting the needs of its users. Energy use in buildings can be minimized by paying attention to aspects of building elements (orientation, height, amount, and shape), location, construction materials, and climate. Energy use in scale is obtained from the cumulative use of energy in buildings contained in the city. Urban Modeling Interface (UMI) software can help design urban planning. UMI can simulate the use of energy in buildings that can be adjusted to the needs of the wearer.

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References

[1] Pemerintah Indonesia, Peraturan Presiden Republik Indonesia No.59 Tahun 2017 tentang Pelaksanaan Pencapaian Tujuan Pembangunan Berkelanjutan. Jakarta: Sekretariat Negara, 2017.
[2] Pemerintah Indonesia, Undang-Undang Republik Indonesia Nomor 17 Tahun 2007 tentang Rencana Pembangunan Jangka Panjang Nasional Tahun 2005 – 2025. Jakarta: Sekretariat Negara, 2007.
[3] Y. M. Ardiani, Sustainable Architecture: Arsitektur Berkelanjutan. Jakarta: Erlangga, 2015.
[4] A. Kusumawanto dan Z. B. Astuti, Arsitektur Hijau Dalam Inovasi Kota, Kedua. Yogyakarta: Gadjah Mada University Press, 2014.
[5] T. Hong, Y. Chen, X. Luo, N. Luo, dan S. H. Lee, “Ten questions on urban building energy modeling,” Build. Environ., vol. 168, hal. 106508, 2019.
[6] N. Lechner, Heating, cooling, lighting; Sustainable design methods for architects, Fourth. Canada: John Wiley & Sons, Inc., 2015.
[7] L. Hijriyah, “Model Perumahan Real Estate Berkelanjutan melalui Simulasi Urban Modelling Interface di Kabupaten Sleman, Yogyakarta,” Yogyakarta, 2018.
[8] Y. Badruzzaman, “Roadmap Energy di Provinsi Daerah Istimewa Yogyakarta,” Ijet, vol. 2, no. 1, hal. 18–30, 2013.
[9] Sumintarsih dan A. Adrianto, Dinamika Kampung Kota Prawirotamah dalam Perspektif Sejarah dan Budaya. Yogyakarta: Balai Pelestarian Nilai Budaya (BPNB) Daerah Istimewa Yogyakarta,
2014.

[10] Pemerintah Daerah Istimewa Yogyakarta, *Peraturan Daerah D.I. Yogyakarta Tentang Pembangunan Jangka Menengah Daerah (RPJMD) Daerah Istimewa Yogyakarta Tahun 2017-2022*. Yogyakarta: Sekretaris Daerah D.I Yogyakarta, 2018.

[11] J. W. Creswell, *Research Design: Pendekatan Kualitatif, Kuantitatif, dan Mixed. Edisi Ketiga*. Yogyakarta: Pustaka Pelajar, 2017.

[12] M. C. Branch, *PERENCANAAN KOTA KOMPREHENSIF; Pengantar dan Penjelasan*, Pertama. Yogyakarta: Gadjah Mada University Press, 1995.

[13] S. Kostof, *The City Shaped: Urban Patterns and Meanings Through History*. Boston: Thames and Hudson, 1991.

[14] H. Mulyandari, *Pengantar Arsitektur Kota*. Yogyakarta: Penerbit Andi, 2011.

[15] F. X. B. Pangarso, *Arsitektur Kota*. Yogyakarta: Kanisius, 2019.

[16] R. Trancik, *Finding Lost Space :Theories Of Urban Design*. New York: Van Nostrand Reinhold Co, 1986.

[17] M. Zahnd, *Perancang kota secara terpadu: teori perancangan kota dan penerapannya*, Edisi kedua. Semarang: Kanisius, 2006.

[18] Balai Penerapan Teknologi Konstruksi, *Panduan Rancang Kota*. Direktorat Jenderal Bina Konstruksi Kementerian Pekerjaan Umum Dan Perumahan Rakyat, 2018.

[19] A. Phungkam, *Modeling urban energy flows at macro and district levels – towards a sustainable urban metabolism*. 2015.

[20] P. Satwiko, *Arsitektur Sadar Energi*. Yogyakarta: Penerbit Andi, 2005.

[21] D. Strong dan V. Burrows, *A Whole-System Approach to High-Performance Green Buildings*. Boston: Artech House, 2017.

[22] K. A. . Al-Sallal, “Energy and carbon emissions of buildings,” in *Low Energy Low Carbon; Architecture Recent Advances & Future Directions*, K. A. . Al-Sallal, Ed. New York: Taylor & Francis, 2016.

[23] A. K. Chaturvedi, S. Jain, D. Gupta, dan M. Singh, *Advances in Energy-Efficient Buildings for New and Old Buildings*. New York: Taylor & Francis Group, 2018.

[24] A. R. Perace, Y. H. Ahn, dan HammiGlobal, *Sustainable Buildings and Infrastructure: Paths to the Future*, Second. New York: Taylor & Francis Group, 2018.

[25] T. Handayani, “Efisiensi energi dalam rancangan bangunan,” *Spektrum Sipil*, vol. 1, no. 2, hal. 102–108, 2010.

[26] MIT Sustainable Design Lab, *umidocs Documentation*, 2.3a4. 2019.

[27] K. G. Ahmed dan S. M. H. Alipour, “Urban form compaction and energy use intensity in new social housing neighborhoods in the UAE,” *Sustain.*, vol. 11, no. 14, hal. 1–24, 2019.

[28] N. Abbassabadi dan J. K. Mehdi Ashayeri, “Urban energy use modeling methods and tools: A review and an outlook,” *Build. Environ.*, vol. 161, no. March, hal. 106270, 2019.

[29] ASEAN-USAID, *Buildings Energy Conservation Project*, vol. I. Berkeley: ASEAN-USAID, 1992.

[30] C. Reinhart, T. Dogan, A. Jakubiec, T. Rakha, dan A. Sang, “UMI - AN URBAN SIMULATION ENVIRONMENT FOR BUILDING ENERGY USE, DAYLIGHTING AND WALKABILITY Christoph F Reinhart, Timur Dogan, J Alstan Jakubiec, Tarek Rakha and Andrew Sang Massachusetts Institute of Technology Department of Architecture,” *13th Conf. Int. Build. Perform. Simul. Assoc. Chambéry*, Fr. August 26-28 - 476, hal. 476–483, 2013.

[31] D. Mahendra, *Model Kawasan Perkantoran Terpadu Pemerintahan Kabupaten Boyolali yang Ramah Lingkungan dengan Simulasi Floor Area Ratio UMI*, Thesis. Yogyakarta: Universitas Gadjah Mada, 2018.