Developing Reference Building for Campus Type Buildings in Universitas Gadjah Mada

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Abstract. The building sector has been the highest consumer in the total energy consumption in Indonesia, in which the building sector shared 39% of the national energy consumption. A university is a campus that consists of the landscapes and buildings with many kinds of academic and social activities that creates a type of energy consumption profile. This paper aims to demonstrate the importance of having a complete and reliable audit data of a university to develop reference building for campuses. The reference building serves as a building benchmark model for energy consumption, for 20 faculties in Universitas Gadjah Mada (UGM) with more than 200 buildings. The energy consumption model of the buildings is developed using the CLTD/SCL/CLF calculation method. Data of the building geometry, building envelope, and building profile are using data collected from a green campus assessment tools (GreenmetricUI) by walkthrough audit. The research compared the energy profile obtained from the audit data and the model calculated. It is shown that the energy profile model from the CLTD/SCL/CLF method is generally higher than the reported energy consumptions from electricity bills. It can be concluded that the main success in developing a reference building is by having a reliable audit data and a complete record of the electricity bills to validate the model. Once the energy profile obtained from the CLTD/SCL/CLF modeling is available, the data can be used for modelling reference building using energy model software.

1. Introduction

The building sector is predicted to be the highest consumer in global energy consumption. In Indonesia, the building sector shared 39% of national energy consumption [1]. A building might have a large amount of energy consumption due to inefficiency in the equipment installed, occupant behavior, and building design. Optimizing the building performance by having a responsive building envelope that utilizes weather potential for its passive design is the best approach to reduce energy consumption. Heat transfer between the building envelope and the weather condition of the surrounding environment is the primary key. In Indonesia however, to build a building typology of the most optimum building envelope design, such complex building data is difficult to be found [2] [3].

A university, being a complex structure of building with a high diversity of education programs, produces a lot of different energy consumption profiles. Understanding the building consumption at a university level is a necessity. This intricacy can provide lots of data on energy usage, such as the energy profile, energy load, etc. In this case, this abundant data could be developed into a reference building, which is required for modeling urban energy consumption. Hence, developing a reference building requires modeling of several structures with the same typology. Most of the buildings that consume a
lot of energy in a university complex are learning centers, laboratories, and dormitories, which in Indonesia are affected mostly by the air conditioning system. In the case study of Universitas Gadjah Mada (UGM) is one of the biggest and oldest universities in Indonesia. UGM has 230 study programs with 39,000 students and most of the buildings are relying on AC units are not yet centralized, since buildings come with a variety of floor levels [4].

In the circumstances where air conditioning systems are the most energy usage, calculation of the cooling load based on the building's total heat gain becomes an essential factor in energy conservation of the building. Meanwhile, reference building is defined as a collection of information to represent the individual building data set. This categorization could be developed by considering the four data sets, including building geometry, building a system, building a profile, and building envelope [5] [6]. The cooling load calculation proposed in this research utilizes all these data sets. However, it only predicts the energy consumption needed by the building to achieve indoor thermal comfort. Hence, the air conditioning system will be able to operate efficiently by considering its external heat gain and internal heat gain but does not directly predict the total energy profile of a building. Other information needed to develop reference buildings is related to the building system. It includes the HVAC system, lighting system, water supply system, plug loads, transportation systems, fire alarm and security system, waste management equipment, and other building utilities. Each in detail should be accounted for in the total electricity or energy usage calculation.

This study utilizes a method to calculate the cooling load, which is the CLTD/SCL/CLF method. Section 3 provides a detail discussion of this method. It is considered as the beginning step in developing reference building in UGM using GreenMetricUI data with a bottom-up perspective [7]. GreenMetricUI is a global university ranking which assesses the sustainability aspects of campus developed by Universitas Indonesia. In 2018, UGM participated in the ranking assessment and placed on the 6th position in Indonesia and 91st on global ranking. The GreenMetric data that valued the sustainability aspects of UGM are required to develop a method for making UGM campus building typology.

2. Reference Building and Campus Energy Model
The campus energy model requires the buildings' characteristics that create the campus complex. Reference building is a set of data that contains information about building features [6]. The components are building historical data, geometry, utilities and building systems, thermal characteristics, and occupation pattern. A previous study shows how the reference building was developed for low-income residential housing using limited data and focused on the use of building geometry [8]. Cluster analysis was done to find similarities and relationships among the buildings based on the variables that are available within the data set. The data set is then applied to all the buildings being observed. The ability of the reference building that was developed using the building geometry data, to represent the building energy performances was proofed through simulation.

A different research for creating reference buildings also used the cluster analysis method with five research steps [9]. There are; (1) observing the area being studied in general to get the information of the building function, windows to wall ratio (WWR) values and year of construction, (2) characterizing of the building geometry using GIS, (3) characterizing the building shapes, (4) conducting cluster analysis and (5) conducting energy performance analysis based on computer simulation. The 3D model was then developed based on the GIS data, and the buildings were categorized into several groups depending on their shapes. Related variables are then analyzed to see the interaction followed by cluster analysis to obtain the representative structure for each cluster. The final result of the clustering is then compared with the energy performance analysis using computer simulation. The result shows that by using the 3D drawings of a building, one can develop a reference building for a residential building with better quality. It enables to estimate the energy consumption and evaluate the effectiveness of changing the building's shape for energy conservation purpose.

The development of reference buildings on a scale of a country had been done in India [10]. The reference building was developed through four steps. Started by identifying the building type, identifying the building parameters, calculating samples and gathering data, and then defining the
building parameters based on the numerical and categorical variables. Building typology was identified by grouping buildings that have similarities in the occupational type and building shape. The categorization is an office building, educational building, hospital, and residential building. Building parameters identified are those used in the energy performance analysis, which includes activity, shape, material, and equipment.

In the scale of urban space, other researches had developed an urban energy model for cities; one is for San Francisco, United States [11]. The data set of the reference building in this reference is more straightforward than the other researches discussed above. There were 4 data set that was used and merged into one data. Data are collected from the Department of technology (building footprint), Department of planning (land use), Department of environment (data energy disclosure), and data collected by auditors. A Geographical Information System (GIS) integrated the data with a result of a complete, accessible database for further data development of other urban areas or different building types.

3. CLTD/SCL/CLF
The Indonesia National Standard (SNI) 03-6572-2001 of guideline for ventilation system design and air conditioning in buildings defines the cooling load as the heat rate flow that needs to be removed from the room to obtain the air temperature and relative humidity for the desired room condition. There are two categories of cooling load which are external and internal. The external cooling load consists of heat gain from solar radiation through transparent materials, heat gain from heat transfer through the building envelope (roof and façade), heat gain from solar conduction through transparent walls, heat gain from heat transfer through partition, ceiling and floor, heat gain from outdoor air infiltration and heat gain from ventilated air. Included as internal cooling loads are heat gain from occupants or people, heat gain from the lighting system, heat gain from equipment, and heater.

Parameters of the Cooling Load Temperature Difference (CLTD), Solar Cooling Load (SCL) factor, and internal Cooling Load Factor (CLF) define the CLTD/SCL/CLF method. It is a method developed by ASHRAE to simplify cooling load calculation using the transfer function method for computer-based estimation. The factors taken into account in the calculation are simplified, obtained from the tabulation result using the transfer function method. In the CLTD/SCL/CLD method, the cooling load is the total heat gain obtained from heat conduction through the building envelope, heat transfer through room partition, heat gain from people, lighting and building equipment, and also heat gain (due to infiltration and ventilation). The values of the cooling load can be calculated using the equations that are listed in Table 1.

4. Method and Result

4.1. Method
There are two types of approaches that can be used for area energy modeling, which are a top-down and bottom-up approach (see Figure 1). In which stage is the single building characteristic data will be used during the energy modeling process, is what defines the type of procedure. The top-down approach uses the estimated total energy consumption and other related variables to characterize the entire buildings within the region. Started by modeling the energy consumption for the whole area and then it for a narrower space, and finally, the energy consumption model of a single building. The bottom-up approach works oppositely but limited to model only the energy consumption of a particular building type, decided at the beginning of the modeling process [12].
Table 1. Equations of the heat gain to calculate the total cooling load.

| Cooling Load Components                          | Heat Gain (in Watts) | Variables |
|-------------------------------------------------|----------------------|-----------|
| Solar radiation through glass                    | \( Q = A (SC) (SCL) \) | \( A = \) glass surface area (m²)
|                                                 |                      | \( SC = \) Shading Coefficient
|                                                 |                      | \( SCL = \) Solar Cooling Load factor
| Conduction through building envelope             | \( Q = U A (CLTD) \) | \( U = \) Conductivity coefficient for walls, glass and roof (W/m²·K)
|                                                 |                      | \( A = \) wall, window and roof area (m²)
|                                                 |                      | \( CLTD = \) outdoor and indoor temperature differences for cooling load calculation (°C)
| Heat transfer through Indoor partition           | \( Q = U A (T_b - T_{rc}) \) | \( U = \) overall heat transfer coefficient (W/m²·K)
|                                                 |                      | \( A = \) partition area (m²)
|                                                 |                      | \( T_b = \) Temperature differences of adjacent rooms
|                                                 |                      | \( T_{rc} = \) Designed temperature
| Sensible and Latent Heat from People/occupants   | \( Q = N (qSensible)(CLF) \) | \( N = \) Number of occupants
|                                                 | \( Q = N (qLatent) \) | \( qSensible = \) sensible heat gain
|                                                 |                      | \( qLatent = \) latent heat gain
|                                                 |                      | \( CLF = \) cooling load factor based on hours of occupancy
| Artificial Lighting                             | \( Q = W . Ful . Fsa . (CLF) \) | \( W = \) Required power
|                                                 |                      | \( Ful = \) utilization factor
|                                                 |                      | \( Fsa = \) special use factor
|                                                 |                      | \( CLF = \) cooling load factor based on hours of occupancy
| Sensible and Latent Heat from Equipment          | \( Q = qSensible . Ful . Fra . (CLF) \) | \( qSensible = \) sensible heat gain
|                                                 | \( Q = qLatent . Ful \) | \( qLatent = \) latent heat gain
|                                                 |                      | \( Ful = \) utilization factor
|                                                 |                      | \( Fra = \) radiation factor
|                                                 |                      | \( CLF = \) cooling load factor based on hours of occupancy
| Infiltration and ventilation                    | \( Q = (1.20) . I . (H_b - H_i) \) | \( I = \) ventilation and infiltration in liter per second
|                                                 |                      | \( H_b = \) outdoor air enthalpy (kJ/kg)
|                                                 |                      | \( H_i = \) indoor air enthalpy (kJ/kg)

This paper proposes a method for developing energy building reference as a building benchmark model at Universitas Gadjah Mada (UGM) using a bottom-up perspective. Some software was utilized for the different purposes in each research phase. Data was documented, sorted, and tabulated for the cooling load calculation in Microsoft Excel, which included the calculations using all the equations listed in Table 1. Geometry data of the selected buildings in UGM were modeled using Google SketchUp to meet with some of the existing drawings of the buildings that are available in the Google SketchUp 3D warehouse. Following the modeling process of the campus, data were embedded into the campus model in sets of databases. Therefore, GIS is the best method for this purpose, and the software used was ArcGIS. Not less important is the weather data that defines some of the input variables in the cooling load calculation. The free software Climate Consultant was used to generate the climate data obtained from the Meteonorm software database, to provide further required information regarding the weather data.
The first part is data collection and processing. There are six sources of data used, which are GreenMetricUI, SNI, ASHRAE, OpenStreetMap, Google SketchUp 3D Warehouse, and Meteonorm. The data were categorized as building profile and system data, building geometry data, and weather data. A world ranking system for the green university, known as GreenmetricUI, is available, and UGM has participated since 2018 [9]. Results from the assessment in 2018 have provided data regarding several building profiles and systems. Data were collected by walkthrough audits, collecting electricity bills, and focus group discussion (FGD) with the building managers and head of university operational units. Other data that are needed to build a complete data typology for the energy model were collected from the SNI and ASHRAE documents. Indonesia National Standards (SNI) used were the SNI-03-6572:2001, which provides a guideline on the ventilation system and air conditioning design for buildings, and the SNI 6389:2011 regarding energy conservation of buildings. ASHRAE Fundamental Handbook 1997 Chapter 27 and Chapter 28 about cooling load calculation, was also used in this research.

The geometry data of the buildings, however, are not entirely available. The campus model was completed by using 3D drawings from the OpenStreetMap and Google SketchUp 3D warehouse. Meteonorm is a database software that provides reliable weather data from more than 8350 weather stations all around the world and 1900 of them located in Asia. Weather data from surrounding weather stations to create weather data for areas that do not have a local weather station through interpolation. This research uses the Yogyakarta city weather data collected from Meteonorm. Table 2 presents all data sets used for the urban energy model.

The second part is to integrate all the data sets into single input data for the energy profile model using the CLTD/SCL/CLF method [13]. The model output evaluates how precise the input dataset is and also for the guidance to give recommendations on how to build the reference building for campuses. It shows the importance of developing a complete and accurate database of the building profile, building system, building geometry, and building envelope properties with all its interaction to the surrounding environment having the presence of other elements (adjacent buildings, vegetation, topography profile, and weather condition).
Table 2. Dataset used and the relevant information taken

| Dataset                                | Source            | Aggregation level | Relevant information                                      |
|----------------------------------------|-------------------|-------------------|-----------------------------------------------------------|
| Building system and profile            | GreenMetric       | Building faculty  | Total energy consumption, renewable energy, equipment utilized, occupancy level |
| Building geometry and building envelope| GIS (Open street map) | Building          | Building geometry, floor area, building height            |
| Building profile                       | Meteonorm         | City              | Climate data                                              |
| Building system, profile, and envelope | Indonesian standard (SNI) | -                | Typical material, typical schedule, typical energy data |

Energy Use Intensity (EUI) is a parameter that can be used to measure building energy performance. In Indonesia, the EUI is replaced by what is known as 'Intensitas Konsumsi Energi (IKE),' which is the total energy consumption of a building divided by the supplied floor area (W/m²). A standard IKE for university buildings is not yet available. The closest standard would be IKE for office buildings such as the IKE value obtained by Green Building Council Indonesia (GBCI) of a maximum of 250 kWh/m²-year for office buildings [14]. Using the electricity bills from GreenmetricUI data, IKE of 12 schools in UGM was generated. These IKE values were then compared with the IKE obtained from the cooling load calculation. Cooling load only affects one component of the building electricity. It is the amount of energy required to remove heat from the building using an air conditioning system to achieve thermal comfort and visual comfort. Meanwhile, the total energy of the building is contributed by lighting usage, appliances, building transportation systems, etc. Therefore, the results should show the IKE provided from the actual electricity bills being much larger than the IKE obtained from the cooling load calculation.

4.2. Result and Discussion

The complete research approach is provided in Figure 2, with each step described in the previous section. The electricity consumption data is the cumulative consumption of all the buildings that exist in a particular school area. It is used since there is no information about electricity consumption for each building. Medical School complex has the highest IKE of 466,02 kWh/m²-year with an average IKE of 94,05 kWh/m²-year for all the 12 schools. Two complex buildings exceed the standard IKE for office buildings in Indonesia. Hence, no further information on what cause this matter. An energy monitoring system can be an alternative solution to monitor the energy consumption of a building continuously and not relying only on the electricity bills.

The results from the model developed with the CLTD/SCL/CLF method compared with the audit data and electricity bills collected for GreenMetricUI assessment are presented. The results in Figure 3 show that the IKE from the cooling load calculation using building models is generally higher than the IKE obtained from the actual electricity billing collected. Theoretically, this should not be the case since the cooling load only predicts the amount of electricity usage for the air conditioning system. It should be no more than 60% of the entire electricity use of an office building. The result indicates that the profile energy of buildings in UGM should not only rely on the electricity bills. It also suggests that the information regarding the building structures and daily usage is not valid. Although the difference in the energy use intensity is high, the total energy consumption slightly shows the same trend.
Two primary analyses could be taken as a conclusion based on this result. Firstly, the walk-in audit method could not be verified. Hence the data accuracy cannot be validated. Secondly, the CLTD/SCL/CLF method demands an idealized condition, which means that the calculated energy consumption data generally derived as a peak day. However, this preliminary practice could show where the most impacting data set should be taken as the primary concern to develop a reference building. Based on previous studies and evaluation of the data collected, there are four categories in the database where data are required. The first data set that is needed for developing a reference building is the building geometry, which consists of information of the floor area, floor levels, and ceiling heights. The building envelope data is the second dataset required, which in the case of cooling load calculation contributes the most for estimating the overall thermal transfer values (OTTV) of a building. It consists of data regarding the envelope area, window to wall ratio (WWR), and materials of the wall, roof, and windows. Data of the building system is the third category, which includes the HVAC system and its performances and also lighting system. The last dataset is the building usage profile, which are operational hours, orientation, room capacities, and annual electricity bills.
5. Conclusion

Developing a reference building for campuses should heavily consider the reliability of the data set utilized, which consists of the building geometry, building system, building energy profile (using validated electricity bills), and building envelope data. However, the precision of the data collected, particularly from the GreenMetricUI data, is hardly validated. The data required depend on how the data were recorded in each university. With CLTD/SCL/CLF method, the available data can be extracted as data input for the campus energy model. Again, this method proposed is the most preliminary approach to develop a reference building since the cooling load is only one component of the electricity consumption. It is the amount of energy required to remove heat from the building using the air conditioning system to achieve thermal comfort and visual comfort. Meanwhile, the total energy of the building is contributed from lighting usage, appliances, building transportation systems, etc.

The reference data used for this model can be further developed as the university's reference building. The data are supposed to be renewed periodically every five years as the campus itself is continuously going under construction of new buildings. Further research is required to validate the reference building with a more accurate model and more precise data.

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