

Development of an Embodied Energy Calculation based on Android™

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Abstract

World's carbon emission reduction needs an active participation from stakeholders in construction industries. Carbon emission as one of environmental indicators can be calculated based on energy consumed by an activity. This article examines Embodied Energy (EE) value of a low-cost house. EE value relates strongly to carbon emission of a material. Thus, it is substantial to know total EE value of a building in order to measure its environmental impact.

Android-based application in calculating EE value of a material is developed with the same principles to the previous computer-based program. The three main parts of the application are Material Unit Analysis (MUA) method, inventory of EE value of building materials, and a rule in conversion material's unit. This application uses Java language. The mobile application is aimed to be user-friendly. Assessment of the use of the application shows that 90% of the respondents say that the application's display is delightful, 80% say that the application is quite delicate for the phone, 85% comment that it is easy to use. However, there are technical issues for the application in Indonesia such as internet signal's stability and the capacity of internal storage of the phone.

Keywords: embodied energy, calculation, application, android

1. INTRODUCTION

Mitigation of environmental impact can be done in many approaches. One of them is through designing a low-energy building. Low-energy building is part of green building design, which can contribute positively to the environment [1]. One of environmental impact indicators is carbon emission of a construction project or a building. Carbon emission can be calculated by using total embodied energy value of a building [2].

Embodied Energy (EE) is energy consumed by all of the processes associated with the production of a building material is called the. Building lifecycle consists of pre-construction phase, construction phase, operation, maintenance, and demolition. EE value can be calculated for whole phase or for the each phase. EE value also can be counted for whole component or for specific materials only[3].

There are some methods to calculate the EE value, the most common method used is Lifecycle Assesment (LCA). However, this method has a broad scope, meanwhile EE calculation needs to be more detailed in the scope of the objected material used in a building as well as in a specific building or in a specific construction phase. This detailing aims to get more valid result[4].

Construction project in Indonesia is usually started with planning and estimating the construction work. This planning includes the work unit, the work volume, using Indonesian Construction Work Unit Cost Analysis (Bahasa Indonesia: Analisis Harga Satuan Pekerjaan-AHSP) as guidance. AHSP gives value for the work volume and its cost, which are essential for scheduling the project[5]. Construction management itself consists of three components: material, manpower, and equipment. Material is the unchanged variable of a construction work, so it can be used as basic of EE calculation of the work[3].

The study aims at identifying a method to calculate the total EE value of a low-cost housing. The common housing types in Indonesia are Type 21, Type 36, and Type 45. This calculation is aided by android-based application. The application is made to attract the interest of the housing construction's stakeholders, thus their environmental awareness could increase and they would consider minimizing environmental impact of their projects.

2. LITERATURE REVIEW

2.1 Material Unit Analysis (MUA) Method

In estimating the building’s cost, Indonesia usually uses Construction Work Unit Cost or *Analisa Harga Satuan pekerjaan* (AHSP). AHSP guideline is issued by the National Standardization Agency (BSN). It consists of work components of building, are; 1) coefficients, 2) unit, 3) description of work, 4) work volume.

In order to calculate the EE material, a method developed from AHSP is created. It is done by extracting the useful component of AHSP for EE calculation. The method is called Material Unit Analysis (MUA) as shown by Figure 1 below. From the MUA method, list of materials used in low-cost housing in Indonesia is obtained.

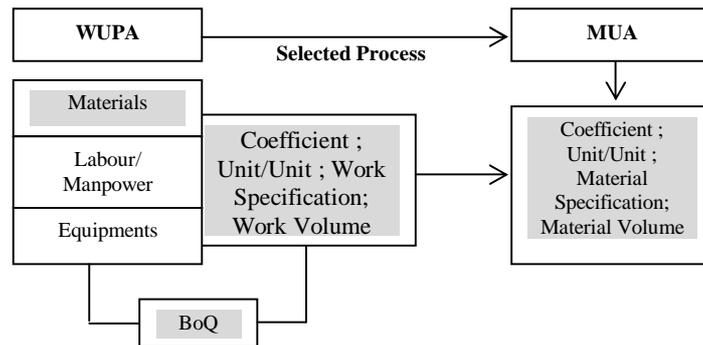


Figure 1 Material Unit Analysis Selection Process

Table 1 MUA resulting from analysis of AHSP of brick wall component per m²

Coefficient	Unit	Material Specification	Material Volume
70	unit	Brick	Suitable for each building unit
18,95	Kg	Portland Cement	
0.038	m ³	Sand	

Table 1 shows the example of list resulted from MUA analysis. The example is for brick wall, while the selection is continued for the whole building’s component. The analysis shows that a typical low-cost house in Indonesia uses 48 kinds of material.

It is important to convert all of the volume units used in each of the materials to a reference unit, since the units of the 48 materials are different. The reference unit used is the international unit of mass, which is kilogram (kg). For example, the unit for sand, m³, is converted to kg by multiplying it to density of the material.

2.2 Inventory of Material’s EE Value

From the list, the EE value of low-cost house’s materials needs to be determined. A valid inventory of EE value of building materials is required. This research uses Inventory of Carbon and Energy, from the University of Bath [6]. Sample of the result is shown by Table 2.

Table 2. Cross reference for mass material unit (kg) to EE material (MJ/kg) for wall component work per m²

Material Volume	Unit	Material Specification	EE Material (MJ/Kg), ICE, Bath	EE Material Result (MJ/KG)
210	Kg	Brick	3.00	630
18,95	Kg	Portland Cement	4.5	85.275
61	Kg	Sand	1.00	61

In case of an unprecedented material that is not recorded in the ICE, a manual measurement is done, until the all of the EE value of the 48 materials are defined. The data resulted from this data sorting is then filled in to the application, and be used as the basic of EE calculation in the application.

2.3 Android-based Application

Computer-based program is made to facilitate the EE calculation, so it becomes faster and easier to be used. Nowadays, the program is becoming easier and favorable to the people due to the advancement of smartphone.

Moreover, a simple EE calculation, which can be accessed anytime and anywhere by only using people's gadget, could be an alternative to elevate the participation of people in energy embodied of a building, and thus its environmental impact. Android, as one of the OS used in smartphone, makes it possible.

3. METHODOLOGY

This research is conducted using the following steps:

1. Literature review and collecting secondary data, used in defining the EE calculation method, the material used to collect data about the materials used in typical Indonesia's low-cost housing, and collecting data of EE value of building materials. This step is also utilised to review the android-based programs that can be used for this research.
2. Experiment, conducted to concept the android application, programming, testing, preparing the data back-up, debugging, and application trial and error until the application is ready to use.

4. RESULT AND DISCUSSION

4.1 The Development of Programming Language

The application should be interesting in display, simple, and easy to download. Creation of such an application is strongly related to programming language used. Flowchart of the application of the EE calculation is shown as follow.

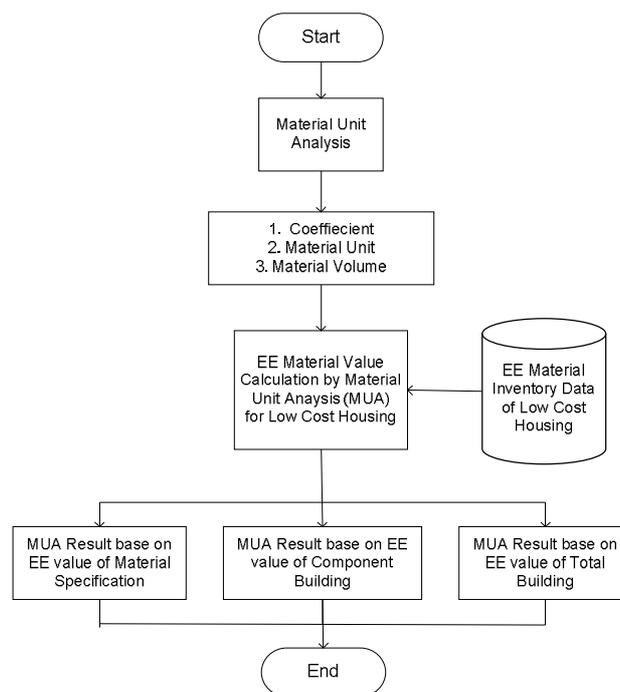


Figure 2 Flowchart of EE Calculation Application

Calculation resulted from the application can appear in three displays, such as:

1. material's specification and each EE value;
2. EE value for each building's components; and
3. total EE value of the building.

The application can be downloaded from the internet or from the android play store as Embodied Energy Calculation GBRC in green icon.

4.2 Application's Display

1. Main page

The first appearance of this application on the installed smartphone is in form of shortcut image. The application is named as EEC Software.

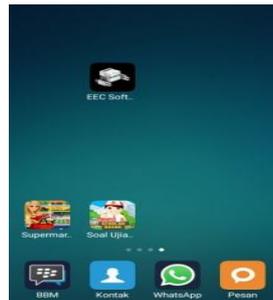


Figure 3 Icon of EE Calculation Application on smartphone display

The software's shortcut brings the user into the main page of the EEC software which contains an option for the user as shown by Figure 4.



Figure 4 Main Display of EE Material Calculation Application on Smartphone

2. Introduction page

This page contains a brief explanation about the software and its objectives. Also, it explains briefly about what embodied energy is and its relation to sustainability.

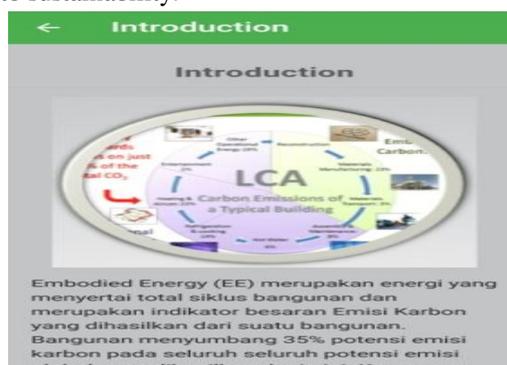


Figure 5 Introduction Section on Smartphone

3. Software page

This page contains the main functions of the application. There are four options available, "Inventory Data", "Input New EE Inventory", "EE Calculator, and "Unit Conversion". Inventory data includes a list of materials used in a low-cost housing as well as its EE value. As mentioned previously, most of the data is referred to ICE (2011).



Figure 6 Software Section on Smartphone

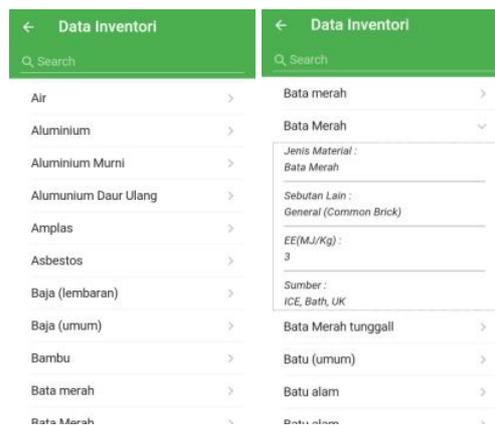


Figure 7 The display of the Inventory Data

The second option is Input New EE Inventory. If the users find materials that are not recorded in the Inventory Data, they can input it to the application. The application administrator will periodically check the new data, in order to validate the data by looking in other references or by doing self-calculation.



Figure 8 Input New Material for Inventori EE Material Data

The third option offers the ways in unit conversion to the reference unit, kg (kilogram). This function informs how to convert units which not in mass unit to be converted to the mass unit of kg. The information is then used by the users to do a self-conversion, aided by the calculator provided in this page.



Figure 9 Unit Conversion Display

4. Simulation page

This page is named as EE Calculator. The function is to process the calculation of the total EE value a low-cost house. Firstly, the users need to input the list of materials of the building that they are going to measure. The input function is in the top left of the display as shown by Figure 11. The users also need to fill in their identity at this first step, as shown by Figure 12.



Figure 10 Simulation Section

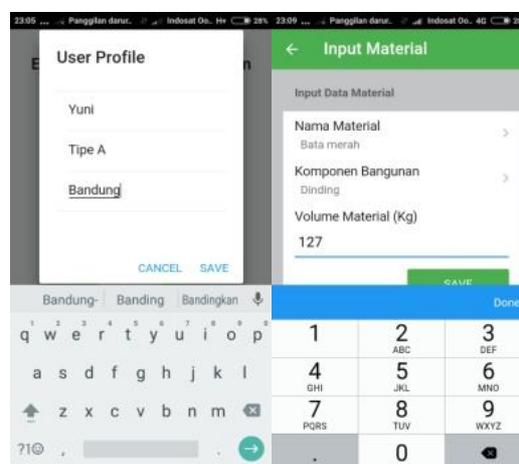


Figure 11 User Profile and Input Material Data

Secondly, after the data complete, the calculation can be conducted. It is important to be noted that data entry should be done thoroughly. Finally, after the calculation is finished, the users can see the results in three displays as mentioned in the previous part. First display (Figure 13) is EE value of each material as well as its specifications and volume. The second display (Figure 14) explains the EE value of every building's component such as foundation, wall, roof, and its detailed list of materials and volume. The third display is the whole EE value of the building, as shown by Figure 15.



Figure 12 EE Calculation Result of Material Specification



Figure 13 EE Calculation Result of Building Component



Figure 14 Total EE Calculation Result of Building Unit

5. Contact page

This page includes information of communication media between the users and the application administrator. The information consists of the website, the corresponding email, also the frequently asked question.

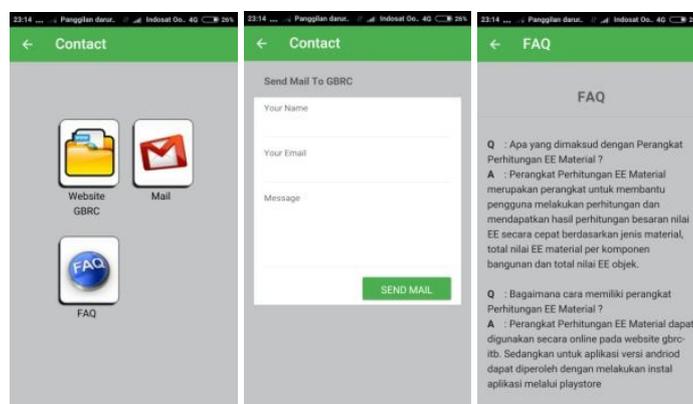


Figure 15 Contact Section

4.3 Evaluation of the Application Trials

The application has passed some trial processes. The trials are done in order to get reviews from the users before it is officially launched. The result is summarized as follows:

1. 95% of the users say that the application's display is interesting;
2. 80% of the users say that the application is easy to use;
3. 85% of the users say that the application is quite delicate for the internal storage their smartphones.

Some users also mention that calculation done by the application is valuable in knowing the total EE value of their building, and thus the brief information of its carbon emission level. Some of the users are also have a proper awareness to the environment, so the software is really useful for them in planning the mitigation of their building's environmental impact.

Nonetheless, there are also some obstacles in the development of the application. The obstacles are especially in the preparation stage. The obstacles are:

1. adjustment of material names and types from the ICE inventory to the Indonesia's standard;
2. unit conversion of the materials takes quite a long time and effort, especially in collecting data about the density of the materials;
3. the application requires network stability in a good internet network along with a supporting device.

5. CONCLUSION

Development of android-based EE calculation software is done after the computer-based program and the website work properly. This application offers simplicity in EE calculation of a building. The users can use it anywhere and anytime by using their smartphone. To summarize this research, some conclusions can be derived.

1. The application is acceptable to the users, and they can use it properly.
2. The trial reveals that 80% of the users feel satisfied to the application.

The disadvantage of the application that is felt by the users are instability of the internet and the unsuitable smartphone, also the user's familiarization to the application

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