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Life cycle assessment of low costs housing in Indonesia

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Life cycle assessment of low costs housing in Indonesia

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Abstract. Housing demands in Indonesia cause an increase in the supply needs of building materials where some of these materials have a negative impact on the environment. Life Cycle Assessment (LCA) method is used to assess the potential environmental impact caused by housing demand of low-costs housing in Indonesia which its types are standardized to types of 21, 36 and 45. The data of building materials were collected from some developers that involved in development of low-costs housing. Embodied Energy (EE) and Carbon Emission (CE) were used as indicators of LCA. The result of the study showed that EE and CE value is increasing linearly by the addition of housing area. It also found out that material volume has significant value to rise EE and CE. Based on the result, with the same volume of square meters, the amount of energy used to build two types of houses 21 was higher than type of 45 houses.

1. Introduction

Indonesia as a developing country has a population growth rate of 1.4% per year. This condition leads to the fulfillment of housing demand at around 800 thousand units per year. The capacity of stakeholders to fulfill housing demand over the past five years is only 400 to 500 thousand units, while housing backlogs are currently at around 11.4 million units [1]. As regards to this situation, the Indonesian government has proclaimed a program to provide affordable housing for low-cost income [2]. The fulfillment of housing demand is then implemented in two types of housing, landed housing and vertical housing. On one hand, the program has a positive effect to fulfill affordable housing needs for society, but on the other hand, housing construction that conducts continuously and massively does require a very large amount of material supply.

The housing development constantly needs a supply of building materials in large quantities. The procurement of building materials in large quantities will lead to the exploitation of natural resources. There is a large potential environmental impact due to the procurement of building materials for the fulfillment of housing demand. The building material production process follows the building material lifecycle, from the extraction, processing, manufacturing to ready-to-use building materials [3].

Several studies that assess the environmental impact of building material and construction process used Life Cycle Assessment (LCA) as a method. LCA based on ISO 14040 is one of the environmental management techniques for risk assessment, environmental performance evaluation, environmental audits, and analysis of environmental impacts [4]. LCA is usually not used to assess social or economic aspects, but its approach and methodology can be applied to other aspects. In

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several LCA-based studies, several indicators regarding environmental impact were measured by embodied energy and carbon emissions [5-16]. Some even measure the high environmental costs that must be incurred due to these emissions, known as eco-costs [6, 7, 17-23].

In response to the issue of housing development that occurred in Indonesia, this study analysed the potential environmental impacts of building material used for low costs housing. Embodied Energy (EE) and Carbon Emission (CE) are used as indicators of impact assessment in this study. The focus of the research will be to assess the life cycle of the planning process, which is in the stage of selecting building materials to be used. The objective is to find out earlier potential environmental impacts that will be caused by design decisions and the selection of building materials. This decision can be used as a step to disaster mitigation. Meanwhile, the types of housing that measured in this study are type 21, type 36 and type 45 based on previous research that had been conducted [12][13] in measuring the EE of the three types of housing that used Building Material Analysis (WUPA).

2. Literature review

2.1. Low Costs Housing Concept in Indonesia

Low costs housing is referred to as the calculation of minimum space standard per person (m2) that has been determined to be occupied by around 3 to 4 persons. There are several provision about low costs housing such as is showed on the table 1.

Table 1. Minimum size requirement for Low-Cost Housing [24]

Standard per-person (m^2)	Areas (m^2) for 3 persons	Areas (m^2) for 4persons
Minimum Threshold 7,2	21,6	28,8
IndonesiaStandard 9,0	27,0	36,0
InternationalStandard 12,0	36,0	48,8

The observation of the building typology of low costs housing units that built by the developer, starting from the Aceh region to Papua, shows a typology that is not much different in terms of floor area, appearance and selection of building materials used that generally refer to type of floor area; 21, 36 and 45 [12][13]. The design of the building looks simple units generally called minimalist modern. The technical specifications of the building materials used by simple housing units in all regions turned out to be almost the same.

The same procedure is used to collect the use of building materials used by simple housing units. The data is compiled based on information from each developer, both through the study of information presented in housing brochures, as well as direct interviews with developers that showed on the table [12][13].

Table 2. Building components that used for low costs housing in Indonesia

Building Components	Developer 1	Developer 2	Developer n
Foundation	Stone	Stone	Stone
Floor	Concrete	Concrete	Concrete
Column	Ceramic	Ceramic	Ceramic
Wall	Brick	Brick	Brick
Window	Wood	Aluminium	Wood
Door	Wood Panel	Wood Panel	Wood Panel

Table 2. Building components that used for low costs housing in Indonesia (cont.)

Building Components	Developer 1	Developer 2	Developer n
Roof	Wood frame	Steel frame	Wood frame
Roof Cover	Aluminium	Clay Tile	Clay Tile

2.2. Embodied energy and carbon emission of building material

EE building materials in the building material lifecycle are aimed at the total energy needed to produce building materials including the procurement of raw materials, fuel for the procurement of raw materials, the process of producing building materials and the types of transportation to move raw materials to be ready on site. This is referred to as from cradle to the grave [25]. Whereas EE which is calculated from the initial process to the outgoing manufacturing products, transportation to the location, installation or construction, maintenance, and destruction or recycling is referred to as from cradle to the grave [3].

The calculation of the EE and CE value of building materials will indicate the amount of energy that needed and the magnitude of the environmental impact that might occur depending on the selected material. Designers or architects will get the prediction impact of the building materials that will help to decide suitable material for the design. It based on review and reconsideration of the EE and CE amount that embedded in building materials. Improvement decisions may involve building materials, building methods, access to material resources, and efficient use of transportation in the delivery of materials to the location. The definite goal is to make efficient use of energy based on the choice of building materials in the design.

Several studies on the value of EE that have been carried out were discussed about:

- Calculation of the amount of EE and CE value to calculate the energy-saving potential that can be done on various building objects [26-28]
- Development of methods and calculation models for EE values that will be used, to obtain methods and models that are seen to be closest to research needs that are mostly done in research is the development of EE measurement methods. The measurement of EE value is part of the Lifecycle Assumption (LCA) assessment on the building cycle (lifecycle building). However, until now there are no specific calculation standards for EE so that special studies are needed to produce specific EE calculation standards that can be referred to globally [29]

2.3. Work Unit Prices Analysis (WUPA) and Material Unit Analysis (MUA)

Analysis of Work Unit Prices (WUPA) is a method of calculating job descriptions both for the needs of the Bill of Quantity (BQ) and the total calculation of work in terms of volume and price of work [12,13]. WUPA is provided by Indonesia Standardization Board. In each component of the work consists of numbers of coefficients, units, description of employment, the volume of work and price of work. each part of the component selected only calculates that it relates to building materials so that the price of work is not counted in this study. Resources in the management of construction projects calculated in the WUPA consist of building material components, supporting equipment, and labor.

This research specifically only discusses building materials as a fixed component that provides an overview of the greatest needs of a project including the needs of the types of simple houses that are mass-built by continuous development. The results of the selection of components in the WUPA consist of the number of coefficients, units, job descriptions and volume of building materials needed and becomes a new term called Material Unit Analysis (MUA) [12,13].

3. Methodology

Key steps on doing this research:

- Determine the object of research: low costs housing of type 21, type 36 and type 45 as the models set out in this study.
- Formulation of the Material Unit Analysis (MUA) method that developed from the Analysis of Work Unit Prices (WUPA) that has been commonly used by development stakeholders in Indonesia for building/project planning
- Through the MUA process on the object of research, the inventory data of building materials are referred to as Carbon and Energy (ICE) Inventory, Bath, United Kingdom.
- The calculation of the total EE and CE value of the building to map the use of building materials and types of materials that produce the highest environmental impact value.
- Conducting a comparative analysis of environmental impact results of each low costs housing types and significant aspects that lead to high environmental impact values on the research object
- Developing environmental impact mitigation strategies through consideration of environmental impact values of building materials.

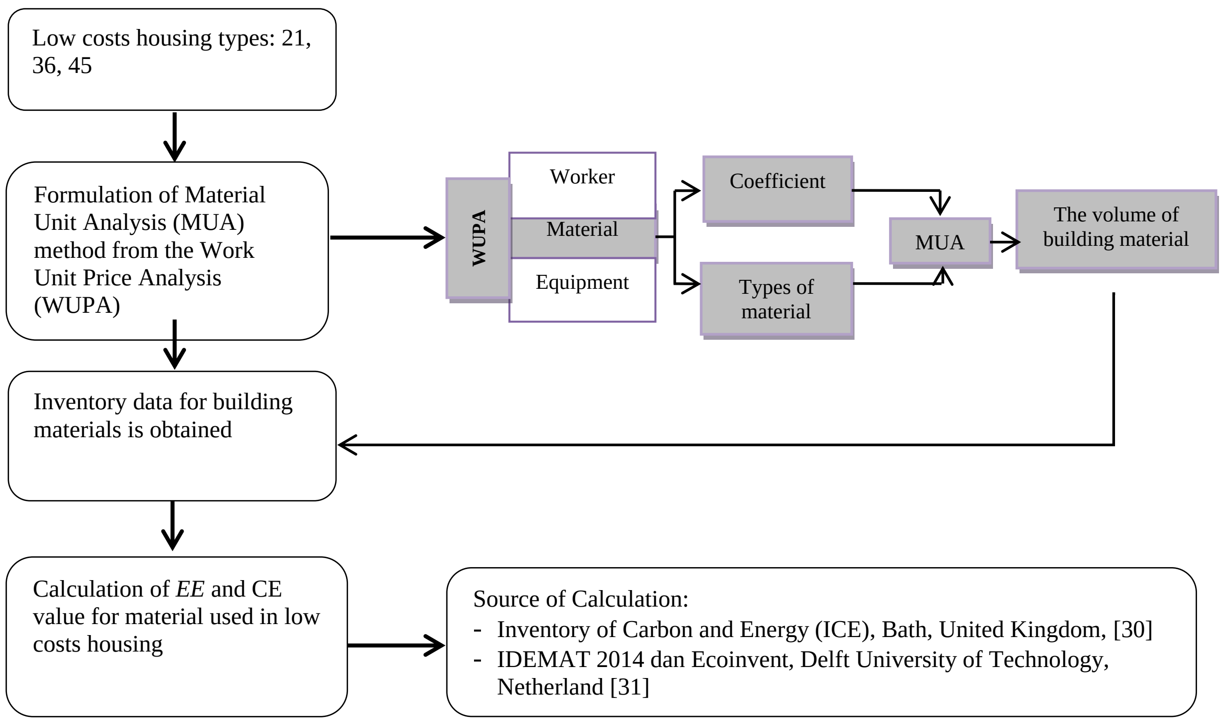

Figure 1. Steps of research methodology

3.1. Development of Material Unit Analysis (MUA) from Work Unit Prices (WUPA)

The table shows the initial format of WUPA based on SNI 6897 2008 for wall construction per 1 m2.

Table 3. Sample for work unit prices for 1 m^2 wall construction

Code	Coef	Unit	Work Detail	Vol.
1	*2*	*3*	*4*	*5*
D	WALL CONSTRUCTION			74,41
D.1	1M² Construction of bricks: Thick 1/2 brick, 1 Pc: 2 Ps			
	70	Pc	Bricks 5 x 11 x 22	5.208

Table 3. Sample for work unit prices for 1 m^2 wall construction (cont.)

Code	Coef	Unit	Work Detail	Vol.
1	*2*	*3*	*4*	*5*
	18,95	Kg	Portland Cement (Pc)	1.410
	0,0380	m^3	Sand River (Ps)	2
	0,3000	OH	Worker	22
	0,1000	OH	Stonemason	7
	0,0100	OH	Foreman	0,7
	0,0150	OH	Overseer	1,1162

Then the selection process is carried out where labor requirements are removed from the table and only show the need for building materials consisting of specifications of building materials in the form of red bricks, sand, and cement.

Table 4. Elimination process sample to get Material Unit Analysis (MUA) from Work UnitPrices Analysis (WUPA) for 1 m^2 wall construction

Code	Coef	Unit	Work Detail	Vol.
1	*2*	*3*	*4*	*5*
D	WALL CONSTRUCTION			74,41
D.1	1M^{2}Construction of bricks: Thick 1/2 brick, 1 Pc: 2 Ps			
	70	Pc	Bricks 5 x 11 x 22	5.208
	18,95	Kg	Portland Cement (Pc)	1.410
	0,0380	m^3	Sand River (Ps)	2
	~~0,3000~~	~~OH~~	~~Worker~~	~~22~~
	~~0,1000~~	~~OH~~	~~Stonemason~~	~~7~~
	~~0,0100~~	~~OH~~	~~Foreman~~	~~0,7~~
	~~0,0150~~	~~OH~~	~~Overseer~~	~~1,1162~~

The results of the selection process are shown in the table. The same process is done for other types of work.

Table 5. Material Unit Analysis (MUA) for 1 m^2 wall construction

Code	Coef	Unit	Work Detail	Vol.
1	*2*	*3*	*4*	*5*
D	WALL CONSTRUCTION			74,41
D.1	1 M^{2}Construction of bricks: Thick 1/2 brick, 1 Pc: 2 Ps			
	70	Pc	Bricks 5 x 11 x 22	5.208
	18,95	Kg	Portland Cement (Pc)	1.410
	0,0380	m^3	Sand River (Ps)	2

3.2. Conversion of building material unit

One thing that stands out from the results of the MUA calculation is that there are variations in operational units that are not following the inventory data from ICE Bath and Eco-Invent TU Delft. For example iron in kilograms (kg), concrete sand in cubic (m3) while for energy conversion kg units is needed. This variation of material units requires the next step to facilitate calculations of energy [12-15].

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Table 6. Conversion process of Building Material Unit

Code	Coef	Unit	Coef. Conversion	Unit Conversion	Work detail
1	*2*	*3*	*4*	*5*	*6*
K	70	Pc	70 x 3 kg = 210	Kg	Bricks 5 x 11 x 22
	18,95	Kg	18,95	Kg	Portland Cement (Pc)
	0,0380	m^3	p = m/V, so, m = p x V	Kg	Sand River (Ps)

4. Results and Discussions

4.1. Embodied Energy (EE) and Carbon Emission (CE) value-based on the use of building material of low costs housing

The data had been collected in previous studies showed that 9 types of material have a large percentage in each unit [12-15].

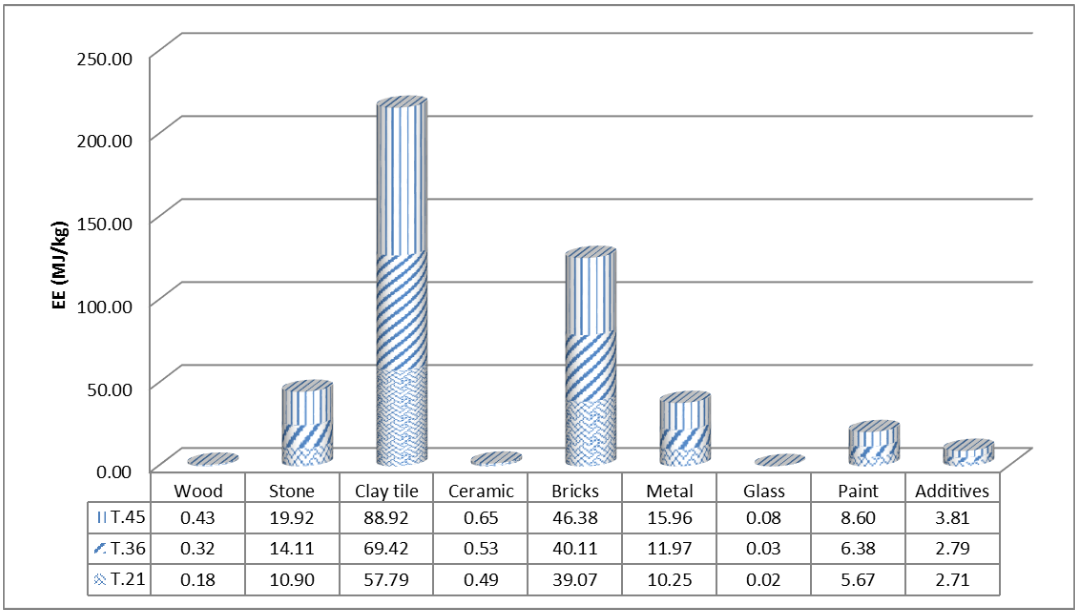
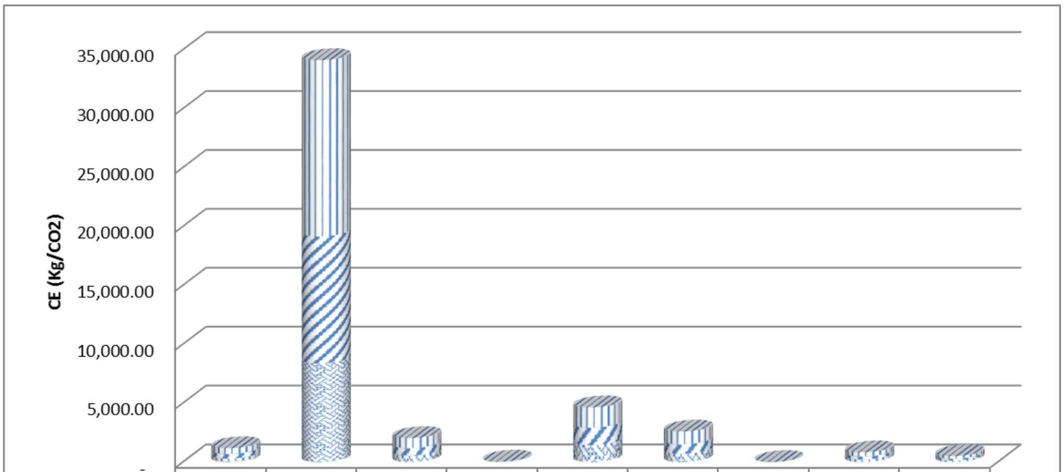


Figure 2. Building material Embodied Energy (EE) value of low costs housing

Figure 2. shows that the high EE value of building material is not determined by the EE unit value, but due to the use of material volume. For example, EE value for brick is 2.5 MJ / Kg, while for glass is 15 MJ / Kg. However, the calculation shows that EE value for brick higher than glass due to the use of brick volume is larger than glass. The picture also shows data from 9 types of building materials identified as having the highest EE value of building materials among 46 other types of building materials that had been collected by [12,13], only one type of material which includes material that is renewable resources. Whereas 8 other types of building materials are included in the category of non-renewable material resources.

Figure 3. Above also shows the value of potential environmental impacts both physically and in the form of Carbon Emission (CE) that is contributed by building materials used. Non-renewable natural resources are not following the principles required by the commitment of sustainable development. This fact should be a concern by all parties in how to suppress the use of large volumes of building materials derived from non-renewable natural resources.



	Wood	Stone	Clay tile	Ceramic	Bricks	Metal	Glass	Paint	Additives
T.45	480.25	14,963.2	835.90	15.48	1,716.82	1,079.89	5.27	344.51	210.04
T.36	400.32	10,780.6	652.62	11.79	1,484.60	809.87	2.40	255.34	151.49
T.21	298.17	8,373.89	543.31	10.64	1,445.94	703.11	1.72	227.63	140.55

Figure 3. Building material Carbon Emission (CE) value of low costs housing

4.2. Embodied Energy (EE) and Carbon Emission (CE) value-based on the types low costs housing

All low costs housing units of type 21, type 36 and type 45 are compared to the results of their calculations to find out the comparison of the total EE and CE value of building materials as shown below. The studies of EE value had been carried out [12-15].

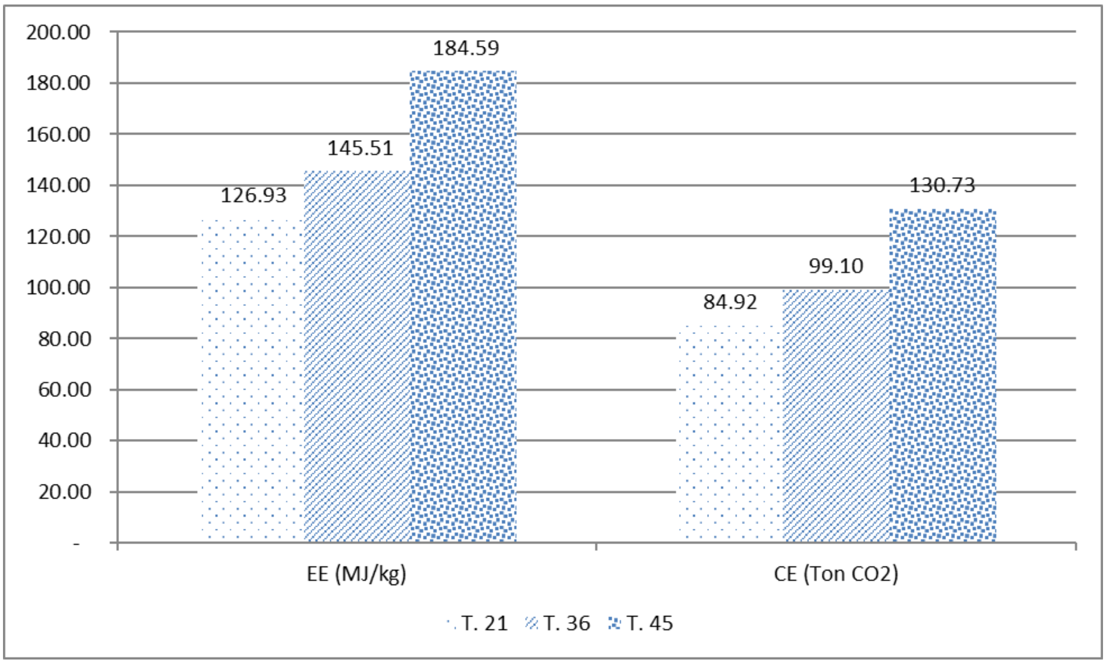


Figure 4. Embodied Energy (EE) and Carbon Emission (CE) value of low costs housing

The figure above shows the comparison of the total EE and EC value of building material between types of low costs housing unit types 21, 36 and 45 has a linear increase. This is due to the addition of space functions that have an impact on increasing the need for the volume of building materials. Thus, significant factors remain in the volume of material used in each type of housing unit.

Table 7. The Comparison of Increasing Value of EE, CE, and Area for Low Costs Housing

	T.21	T.36	T.45
T.21		EE= 1,15times CE =1,16 times	EE = 1,45times CE = 1,54 times
T.36	Area = 1,71 times		EE = 1,27times CE = 1,32 times
T.45	Area = 2,14 times	Area= 1,25 times	

It found out the increasing of total EE and CE value of building materials for type 21, type 36 and type 45. The data shows that to build 2 units of type 21 with an area of only 42 m^2, the EE is still below the area of type 45 while it contained a total EE value of 1,45 and CE value of 1,54 times more than EE and CE material contained in 1 unit type 45. This means that there is a waste in the use of EE and CE material if type 21 is built more. The reason is the high volume of material used by type 21 as the smallest unit, which has an impact on the increase of EE and CE material.

5. Conclusion

The EE and CE value of the processed unit material will be higher than the EE and CE value of the non-processed unit material. This is because the processing to produce building materials will require energy and it included in calculation EE and CE value of the material. All processed materials also have material EE and CE values that are different, so the significant factor of the EE and CE value of the material is the volume of material used. A significant factor in determining the high value of the EE and CE of a low costs housing type depends on its volume. If the volume of a material used is higher than others, then the type of material will contribute to the high EE and CE value. Otherwise, if certain types of material even have large EE and CE material values but the volume of material used is low, the EE and CE value is decreasing. In conclusion, with the same volume of square meters, the amount of energy used to build two types of houses 21 was higher than type of 45 houses.

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