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## Evaluation of Material Selection on the Initial Embodied Energy Value of Low-Middle Apartment in Indonesia

To cite this article: Yulita Hanifah *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **294** 012036

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# Evaluation of Material Selection on the Initial Embodied Energy Value of Low-Middle Apartment in Indonesia

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**Abstract.** Construction of low-middle class apartment in Indonesia's big cities is increasing steadily as the government set The One Million Houses Program to overcome the problem of housing backlog. As the construction project increasing, the use of construction materials is also raising. These phenomena raise concern on the energy consumption and carbon emission in Indonesia as buildings are the biggest materials consumers and responsible for up to 40% energy consumption and 33% carbon emission in the world. Moreover, in Indonesia, buildings consume 1/3 of national resources in their construction process. Certainly, this housing program can be considered to have a large contribution to energy consumption and carbon emissions in Indonesia. Therefore, the material selection in low-middle apartments is very important to consider as a factor that can contribute to energy consumption. In order to prevent the increase of energy consumption in the construction of low-middle apartments, prevention efforts in the initial phase of construction can be carried out such as the selection of materials that have low embodied energy. This study aims to evaluate the value of initial embodied energy based on factors in the material selection that can affect embodied energy using the AI-O and WUPA approaches, which are materials and workers. This study uses quantitative methods to obtain embodied energy values on these factors. The method used is AI-O method. There are four case studies that obtained from low-middle class apartments in one of urban cities in Indonesia, which is Bandung.

## 1. Introduction

The one million houses program was launched in mid-2015 by the government to provide adequate housing facilities to low-income families for the development of socio-economic in Indonesia. Construction of low-middle class apartment in Indonesia's big cities is increasing steadily as the government set the program since 2015 [1]. Furthermore, the development of apartments in Indonesia is expected to continue to grow as the population in Indonesia are also growing significantly. By the end of 2020, the percentage of urban residents will become 60% or 217.47 million [2]. This increased number of populations will boost the demand for housing. Looking at that projection, the government needs to boost the construction of the low-middle apartment class to fulfil the socio-economic of the society. In 2017 the government targets to build 700,000 houses for low-income families and 300,000



houses for those who enjoy a higher income. As the construction project of the low-middle class apartment increasing, the use of construction materials is also raising. Data from the Indonesian Central Bureau of Statistics show that the money spends on material construction increasing significantly since 2007 [3]. The data shows that there is an increase in material consumption in building construction. Based on this data, it can be assumed that the increase in apartment construction contributes to the increase in building materials consumption. As the construction of the low-middle apartment is essential for the growth of Indonesia development, however, the material consumption in the construction can give serious negative impacts in the environmental as buildings are the biggest materials consumers and responsible for up to 40% energy consumption and 33% carbon emission in the world [4]. Moreover, in Indonesia, buildings consume one-third of national resources in their construction process [5]. Certainly, the prevention efforts are needed to supporting the construction of apartments to improving the socio-economic quality in Indonesia without reducing environmental quality.

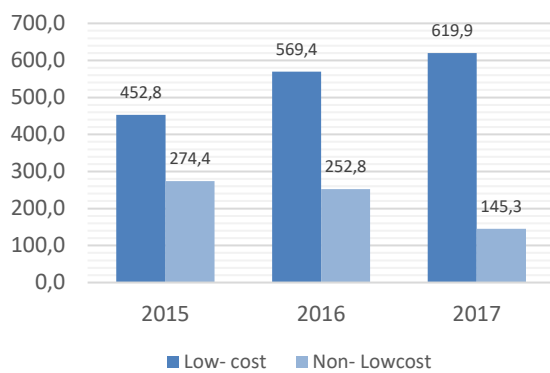


Figure 1. Achievement of One Million Houses Program, by Indonesian Government, in the period of 2015-2017 [1][2]

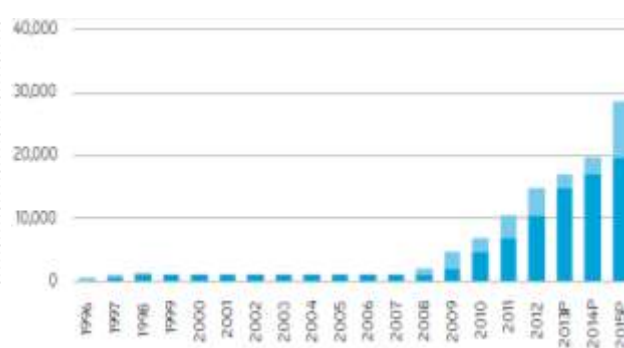


Figure 2. Amount of money spent for building materials (Trillion Rupiah) [3]

In order to prevent the increase of energy consumption in the construction of low-middle apartments, prevention efforts in the initial phase of construction can be carried out such as the selection of materials that have low embodied energy. The selection of material is very important because in the material contained the initial embodied energy which consisting embodied energy of the extraction process, manufacture, and transportation of building materials, and also the energy needed for the construction process [6]. It is known that the largest embodied energy consumption is driven by material production and its respective transportation to the site [7], so it is necessary to evaluate the initial embodied energy value.

This study aims to evaluate the material selection in the construction of low-middle class apartments in terms of the initial embodied energy value. This research is substantial for the future environment of Indonesia, as the construction of the apartment will continue to increase in line with increasing population growth. Hopefully, this research can be a reference for the Indonesia government to improve the socio-economic quality without leaving the quality of the environment through the construction of apartments that have a low embodied energy value.

### 1.1. Initial Embodied Energy

Embodied energy scope in building life cycle is already stated by many researchers. Embodied energy scope is consisting of three phases, which are initial embodied energy, energy use or operational embodied energy and end of life (EoL) embodied energy (see figure 3.) [8]. This research will focus on the initial embodied energy value which consists of embodied energy in the production phase and the construction phase. As shown in figure 3, the initial embodied energy of a building consists of the energy

embodied from raw material process to the construction process. Certainly, based on figure 3, initial embodied energy will be influenced by material selection, because the production energy, material mass, transportation distance, construction methods and context of application will be affecting the initial energy consumption of the whole building.

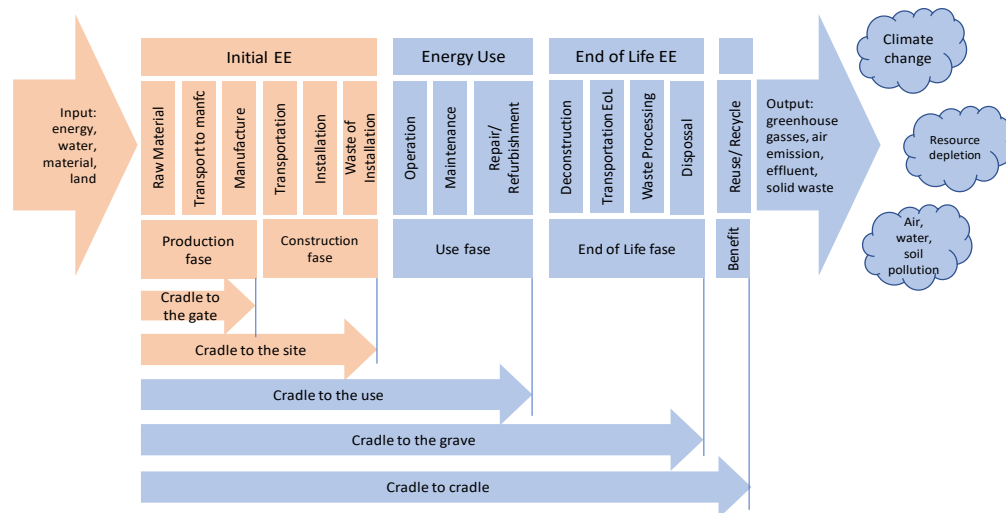


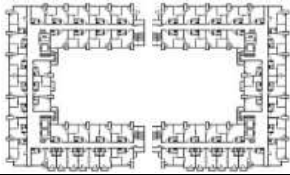
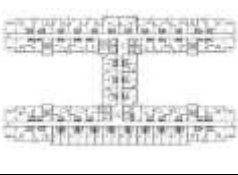
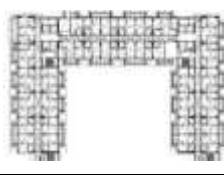
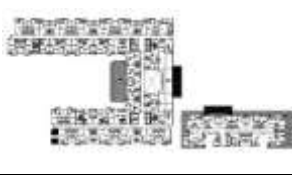
Figure 3. Scope of EE calculation for each phase in the building life cycle [8]

## 2. Method

### 2.1. Case study

There are four case studies, which are Parahyangan Residence, Landmark, Grand Asia Africa, and Jarrrdin. Those four apartments were chosen to represent the low and middle class in Bandung. The general information about the apartment is explained in table 1.

Table 1. General information of the case studies

			
<b>Case 1.</b> <b>Jarrrdin</b> <b>Bandung</b>	<b>Case 2.</b> <b>Grand Asia Africa</b> <b>Bandung</b>	<b>Case 3.</b> <b>Landmark</b> <b>Bandung</b>	<b>Case 4.</b> <b>Parahyangan Residence</b> <b>Bandung</b>
Class : Low	Class : Low	Class : Middle	Class : Middle
No.of Floor: 23 floor	No.of Floor: 26 floor	No.of Floor: 44 floor	No.of Floor: 35 floor
Unit type :	Unit type :	Unit type :	Unit type :
Studio (24 m2)	Studio (22 m2)	Studio (24 m2)	Studio (24 m2)

The case study in this research was taken from the regions that had the highest apartment growth according to the data, which is Bandung, the major city of West Java. According to data of the Indonesian Central Bureau of Statistics, the most constructed apartment in almost one decade are in the West Java with 9962 apartments (see figure 4) [9].

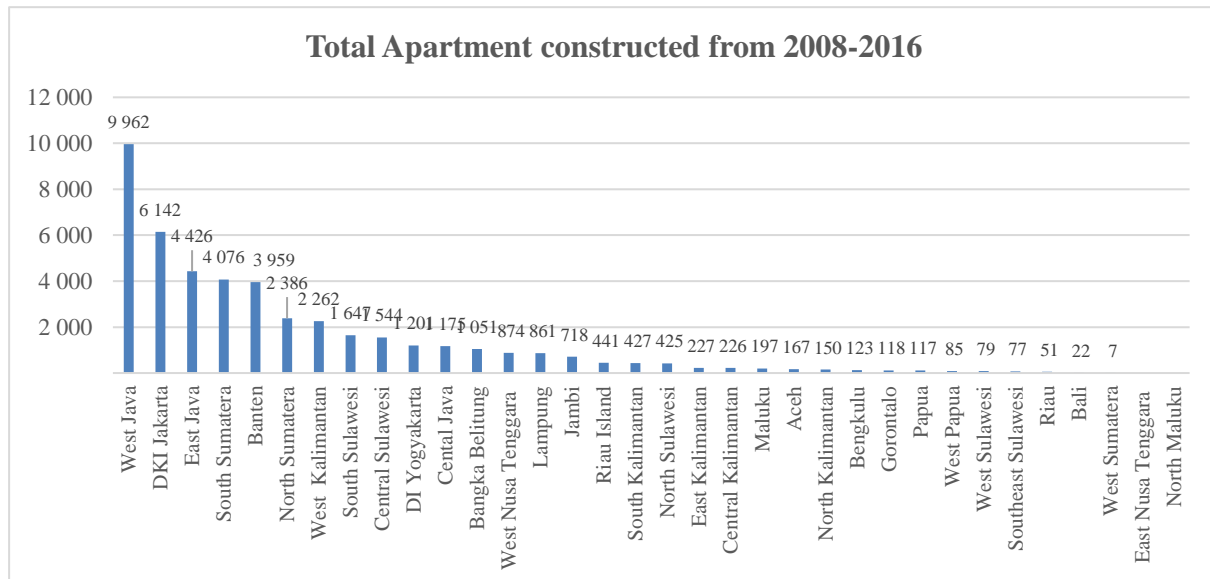


Figure 4. Total Apartment constructed from 2008-2016 [9]

Furthermore, based on the data, each apartment that was built are assumed to be more than 27 low-middle class units available from each of its apartments [9]. Therefore, it can be estimated that more than 268 thousand low-middle apartment units have been built in West Java. There are three types of unit that is developed by the government, which are studio units, 1 BR units and 2 BR units. However, from the overall types of unit, the studio (approx. 20 m<sup>2</sup>) and 2 BR (approx. 36 m<sup>2</sup>) are the most popular types of consumers as most of the buyer profiles are new families. Based on previous explanations, it is predicted that the development of unit studio will continue to increase, therefore, in this research, the evaluation of the embodied energy material value will focus on the embodied energy value of the studio unit material in each case study.

## 2.2. Input-Output Process

In order to measure the value of embodied energy and embodied carbon contained in the material, there are three analytical methods that can be used, including process analysis (AP), analysis of input-output (AI-O), and hybrid analysis (AH). The hybrid analysis is divided into the process-based hybrid analysis (AHBP) and hybrid analysis based on input-output (AHIO) [11]. The analysis of input-output (AI-O) is a method that estimates the materials, energy use and the emissions related to the economic sector. Therefore, this method is more complete in system boundaries, however, the method lacks process specificity [12]. Even though the AI-O method is lack specificity, this method is easier and more effective to use to determine the approximate embodied value of energy in the material.

Furthermore, because the data consist of the whole sector in the economy, the liability AI-O data is good enough to trace the energy consumption of the material in the initial phase. Moreover, this method is able to obtain the embodied energy value between production and transportation from cradle to the site. Based on the explanation, it highly possible to trace the value of the production and transportation embodied energy, which is the significant factor that contributes to energy consumption in the initial

phase. The process to calculate embodied energy and embodied carbon through the AI-O method are consisted of several stages, starting from the calculation of the IO matrix to the calculation of embodied energy and embodied carbon intensity value. Details of the calculation are organized into flowcharts (see figure 5) [12], as follows. Certainly, to get more valid and reliable results, all data mentioned in the flowchart comes from government data of Indonesia.

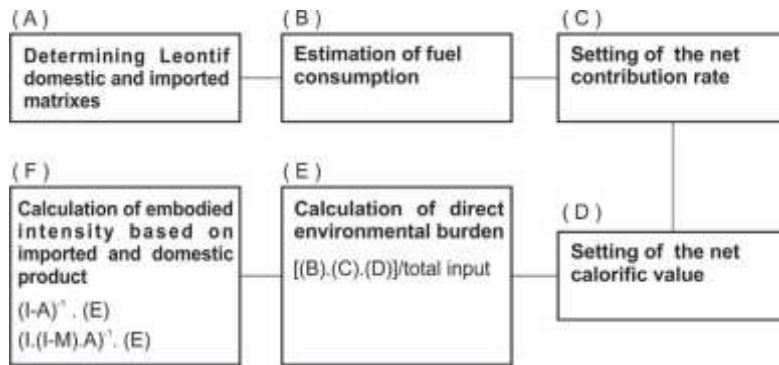


Fig. 5. The calculation of embodied energy through AI-O method flowchart [12]

### 2.3. Work Unit Price Analysis (WUPA)

In the calculation of embodied energy through AI-O, the calculation of selected material in building construction is necessary as primary data to calculate the embodied energy calculation. However, in building construction, the selected material related to worker productivity. The productivity of workers also has embodied energy which should also be taken into account. So, in this research, the calculation of the material approach based on the calculation of the Indonesian Work Unit Price Analysis (WUPA). In WUPA, the calculation of material is related to worker productivity per day which is then very possible to calculate embodied energy both from the material and the workers' side. Based on these explanations, this research will explain the results of material selection analysis of each architectural work item, both in terms of embodied energy material from the cradle to site and also material selection based on embodied energy from workers while working at the site.

The EE material calculation is obtained by multiplying the EE Intensity (EEI) material obtained from the IO table with material volume, material coefficient and material unit price per works that refers to WUPA. Likewise, the EE calculation of workers at the site is obtained by multiplying EEI construction services from IO table data with material volume, worker productivity coefficients, and worker wage unit prices which also refer to WUPA. So those calculations can be arranged into formulas, which are equation 1-3.

$$\sum_{i=1}^n EE \text{ construction works} = EE_m + EE_w \quad (1)$$

while:

$$EE_m = Qty_m \cdot \alpha_m \cdot Y_m \cdot EEI_m \quad (2)$$

$$EE_w = Qty_w \cdot \alpha_w \cdot Y_w \cdot EEI_w \quad (3)$$

EE : Embodied energy (GJ)

$EE_m$  : EE material

$EE_w$  : EE workers

EEI : Embodied Energy Intensity (GJ/Million Rupiah)

Qty : Quantity (unit: m<sup>2</sup>/m<sup>3</sup>)

$\alpha$  : Coefficient

Y : Price/Quantity (Million Rupiah/unit)

### 3. Result and Discussion

#### 3.1. Embodied energy of architectural works

##### 3.1.1. Embodied energy of wall works

There were three major groups of wall work which are wall installation work, wall layering work, and wall finishing work. Each of these jobs is then analyzed by the construction work productivity approach which includes material and worker wages. In the work of installing walls, there are three materials used in four case studies, including light weigh brick, precast, and curtain wall. As for the wall layering work, there is two types of work, which are mortar and waterproofing. Meanwhile, the finishing work consists of ceramic work and painting work.

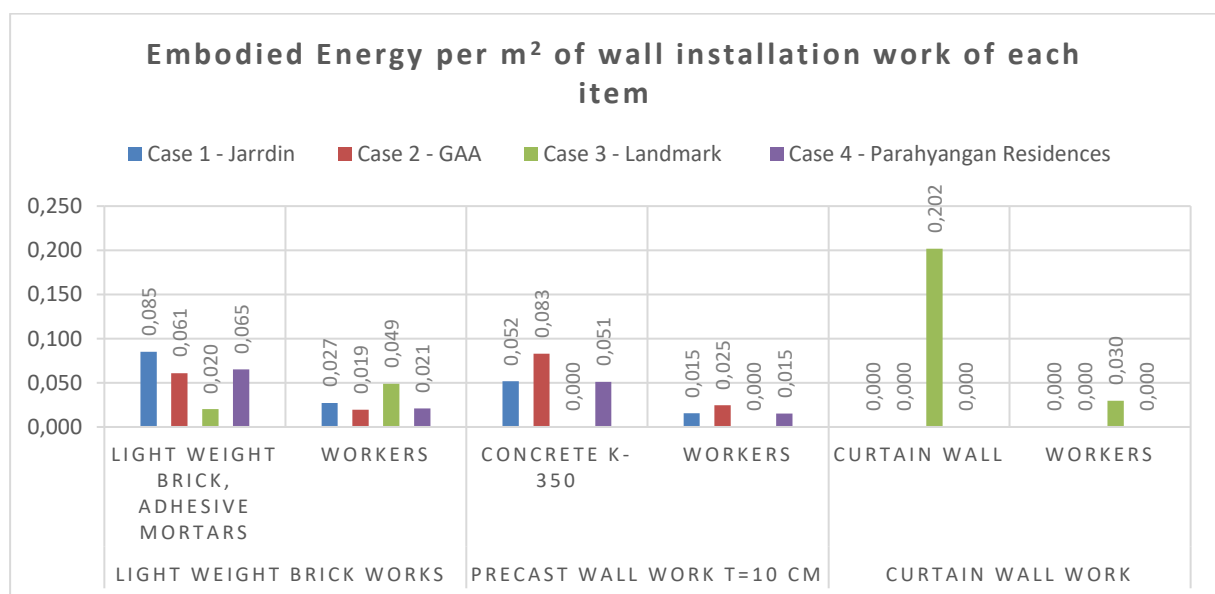
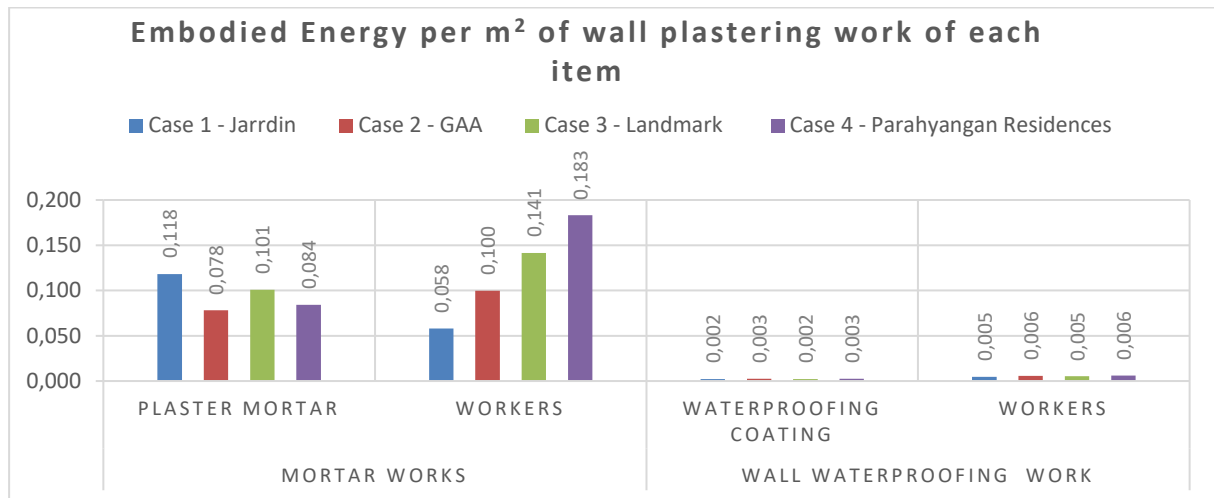
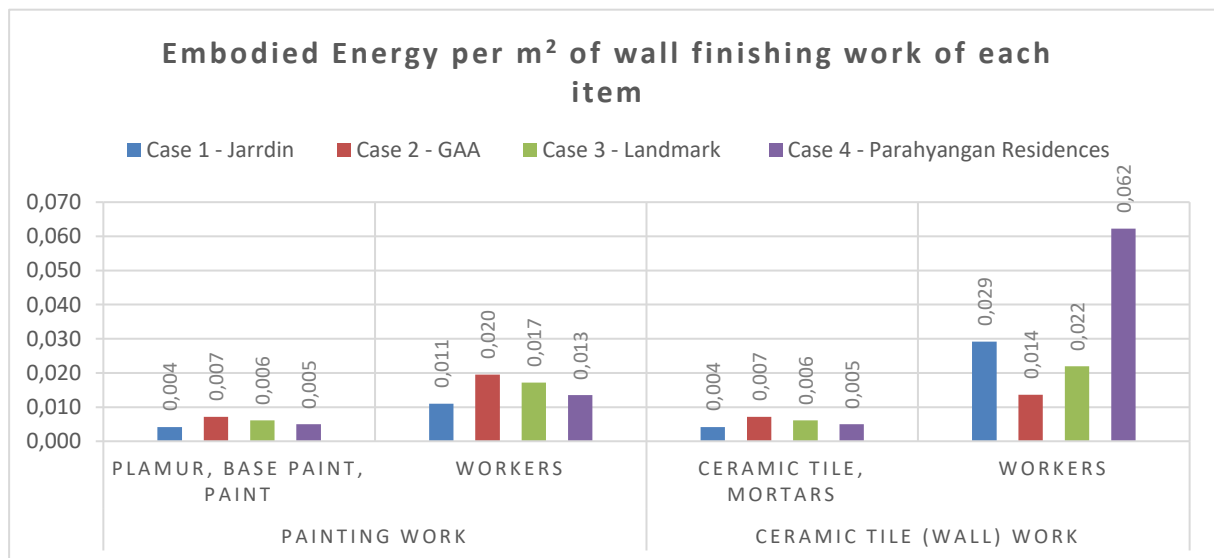


Figure 6. The embodied energy per m² of wall installation work

Based on the data in figure 6, all material identified in whole wall installation work of studio unit are curtain wall, lightweight brick, and precast. From the diagram, it appears that both in terms of material and workers, precast has the lowest EE followed by lightweight brick and curtain wall work. Based on the exposure it can be concluded that precast is a material choice which can be chosen as the lowest EE material both in terms of material and workers. However, the actual use of precast materials is only used a little, which only on the outside. In addition, there is no significant difference between the use of lightweight brick and precast. So, it can be concluded that the combination of precast and lightweight brick can be the best choice for design and construct studio unit compared to the combination of lightweight brick with curtain wall which in the diagram exceeds the total combined precast and lightweight brick.

Figure 7. The embodied energy per m<sup>2</sup> of wall plastering work

As for the data figure 7 It was identified that material used in the case study in plastering work is mortar and waterproofing. Based on the diagram, it can be seen that mortar have higher EE both in the material or in the workers. However, the plaster is used in the whole of the floor apartment while waterproofing is only used in the bathroom area which only has area 2.3-2.6 m<sup>2</sup> from the total unit area 22-24 m<sup>2</sup>. Which means mortar has a significant contribution to the value of the initial EE in apartment units. Furthermore, mortars are the highest EE compared to any material in wall works, including material in installation and finishing. Thus, the use of mortar needs to be reviewed in relation to embodied energy, because if the apartment units prefer to use lightweight brick, it will be affected to the use of mortars, as both materials are related to each other. The more use of lightweight brick, the more mortars are used and the higher value of EE apartment unit will be.

Figure 8. The embodied energy per m<sup>2</sup> of wall finishing work

Meanwhile, from the data figure 8 it was identified that material used in the case study in finishing work is paint and ceramic tile. Based on the diagram, it can be seen that paint and ceramic material have similar EE. However, in the workers, the EE value of ceramic is higher, even though the use of ceramics are only in the bathroom area. As in the diagram, it can be seen that EE workers in case 4 are significantly higher than the others, it is because the use of ceramic is applied to all areas of the wall, while in other



cases only half the walls. Thus, it can be concluded that the use of ceramics should be done sufficiently, as in cases 1-3 so that EE workers can be lower. Another possibility is to replace the use of ceramics with a waterproof paint or combine ceramics with waterproof paint.

### 3.1.2. Embodied energy of floor works

There was one major group of floor work which is the floor installation. In the installation works, there is one material used in four case studies, which is homogenous tiles. The size of the homogenous tiles is different in each case study. Meanwhile, the waterproofing work only consists of waterproofing coating works in the bathroom.

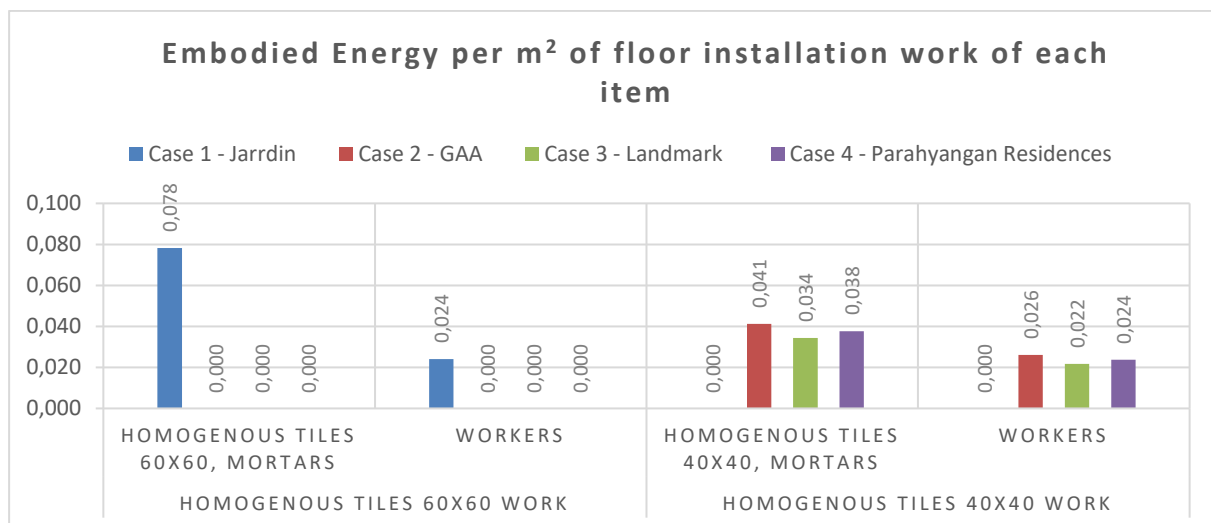


Figure 9. The embodied energy per m<sup>2</sup> of floor installation work

Based on the data in figure 9, all material identified in whole wall installation work of studio unit is homogenous tiles which have different size, 40x40 cm, and 60x60 cm. From the diagram, it can be seen that both tiles have similar EE in workers. However, in the material, the EE value of 60x60 tiles are higher. This identifies that the bigger the tiles, the bigger the EE material. This might be because the price of expensive tiles is related to the price of material production and the carrying capacity once which is less due to size. However, the margin value of EE on both tiles is not very large and its use in studio units is not too much, so the use of tiles for both sizes can still be used as material considerations to be chosen for the design of the unit.

### 3.1.3. Embodied energy of ceiling works

Similar to the flooring works, the ceiling work only consists of installation work of the ceiling. In the installation works, the material is similar in terms of raw material and size. Both of material is 2.4 x 1.2 m gypsum, however, one of the gypsums have waterproofing properties inside the material.

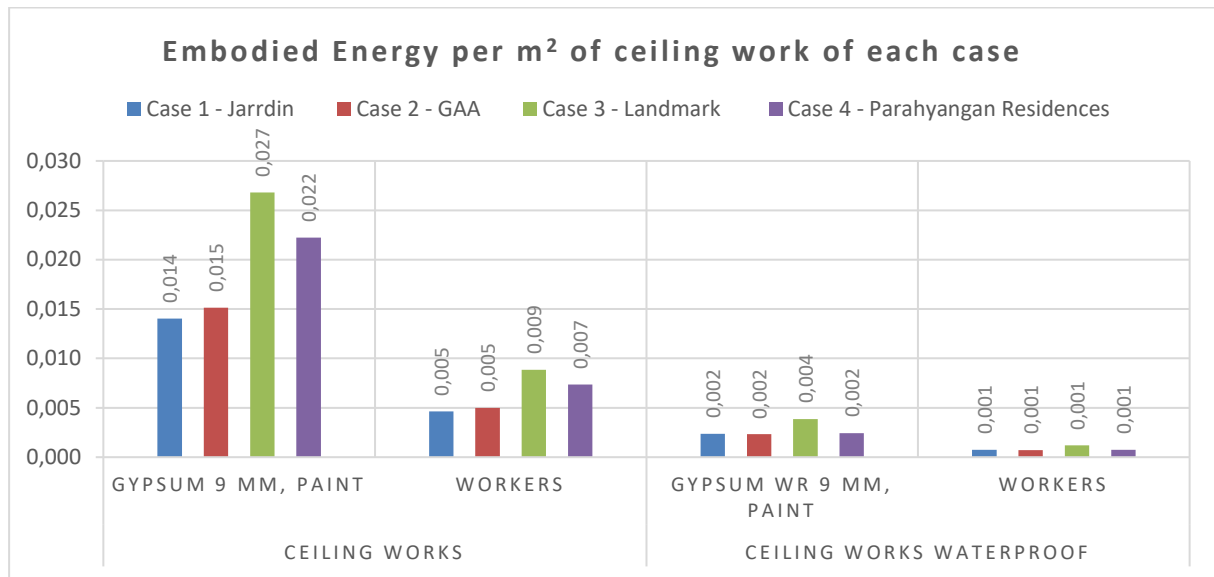


Figure 10. The embodied energy per m<sup>2</sup> of ceiling installation work

From the diagram, it can be seen that gypsum 9 mm with no waterproof has higher EE both in the material and workers. This happens because the use of waterproof gypsum is only used in the bathroom area, approximately only 2.5-3.3 m<sup>2</sup> of the total unit area which is 22-24 m<sup>2</sup>, so the differences between waterproof and non-waterproof gypsum are big. Furthermore, compared to other materials, gypsum has a fairly low EE, so the use of gypsum is quite safe and can be considered as a low EE material chosen for the ceiling. However, for more valid data it may be necessary to have further comparisons between other materials specifically for low EE material of ceilings.

#### 4. Conclusion and Recommendation

The construction work is consisting of material items and worker productivity that are interrelated in changes in EE values. Construction work, especially architectural work can be assessed from the work of material walls, floors, and ceilings. Based on data from those works, the wall works are the most significant factor that contributes to the EE value of apartment units, compared to floor and ceiling works. Stakeholder needs to reevaluate the selection of wall material in the apartment as the wall is the most significant factor in contributing to EE value. However, it also possible to lower the EE from wall works as these works have several scenarios that can be considered and also several materials that can be used.

Based on the evaluation of each work data, it was found that the lowest EE of wall works in the studio unit apartment in Bandung are paint works for finishing, followed by precast and lightweight brick for basic materials. As for the highest EE of the wall, works are mortar works in plaster. As mortar is the highest, using lightweight brick requires special design considerations because EE mortar work has the greatest value among all works in the unit studio, where mortar will almost always be used for lightweight brickwork. Government, consultants or stakeholders involved in designing may be able to try other materials that have lower EE such as gypsum as a combination of wall or wall plaster itself as an effort to reduce EE on wall work. Besides mortars, the use of ceramics in the bathroom need to be reconsidered, as the EE workers are the highest. Stakeholders involved in designing may be able to try to combine the use of ceramics and paint as a solution to reduce EE on wall finishing work.

## 5. References

- [1] Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR) 2017 *Info Publik SP.BIRKOM/XII/2017/594* Jakarta: Biro Komunikasi Publik
- [2] Bappenas BPS UNFPA 2013 *Proyeksi Penduduk Indonesia 2010 – 2035* Jakarta: BPS
- [3] BPS 2018 *Statistik Konstruksi 2017* Jakarta: BPS
- [4] Kumanayake *et al* 2018 *J. Energy & Buildings* **B** 166 250
- [5] DFID World Bank *Executive Summary: Indonesia and Climate Change* Jakarta: DFID
- [6] Monteiro A C S 2015 *Assessing Initial Embodied Energy in Building Structures using LCA Methodology (Unpublished master thesis)* Lisboa: Universidade Nova de Lisboa
- [7] Rasmussen *et al* 2018 *J. Energy and Buildings* **B** 158
- [8] BPS 2015 *Statistik Kesejahteraan Rakyat (Subdirektorat Statistik Rumah Tangga, Ed.)* Jakarta: BPS
- [9] BPS 2016 *Ringkasan Statistik Konstruksi 2010-2016* Jakarta: BPS
- [10] PUPR 2015 *Rencana Strategis Rumah Susun* Jakarta: PUPR.
- [11] Treloar G J 1998 *A Comprehensive Embodied Energy Analysis Framework (Unpublished doctoral dissertation)* Deakin: Deakin University
- [12] Surahman U 2014 *Life Cycle Assessment of Energy and CO2 Emissions for Residential Buildings in Major Cities of Indonesia (Unpublished doctoral dissertation)* Hiroshima: Hiroshima University