Analysis on energy use in reuse cement silo for campus building

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Abstract. Semen Gresik, the first cement factory in Indonesia owned by the government was operated since 1957 and stopped the operation around 1997. The owner, PT. Semen Indonesia (Persero) intended to reuse cement factory for the campus building, Universitas Internasional Semen Indonesia (UISI). This research proposed to analyze the future Energy Use Intensity (EUI) and recommendation energy efficiency in renovating silo through simulation. The result of future EUI in existing building was 234 kWh/m².year. The scenarios created to reduce energy use in six sectors: window shades, window material, infiltration, daylighting, plug load, air-conditioning and operation schedule. The lowest EUI estimated at 98.27 by use 2/3 window shades, triple low emission window glass, lighting efficiency at 3.23 W/m², maximize daylighting and occupancy control, minimize infiltration to 0.17 ACH, and 12/5 for operation schedule.

Keywords : energy used, EUI, silo, campus building, reuse cement factory, simulation.

1. Introduction
Gresik is well known as the industrial city in Jawa Timur, Indonesia. There are several state enterprises including PT.Semen Indonesia (Persero) which produced cement from 1957 to 1997. Nowadays, ex-factory abandoned since the demolish fund could be bigger than construct the new factory [1]. PT.Semen Indonesia (Persero) Tbk plan to reuse ex-cement factory for campus building for Universitas Internasional Semen Indonesia (UISI).

On the other hand, building sector contributes 26% of the world GHG. The amount of carbon dioxide emissions increased at an annual rate of 2% during 1974 to 2004 [1]. Furthermore, the largest share of CO² emission for the building is coming from developing countries in Asia, including Indonesia. Nelson researched in the green real estate business market in some countries including Indonesia. Indonesia has significant GDP growth of 6%, but insignificant green score [2]. Indonesia has huge potential for the green building sector. It was estimated that energy efficiency in building can technically save 25% of baseline GHG or 13.5 million tCO².

Green building could measure by Energy Use Intensity (EUI), including utilization of fuel and electricity. In the case of Gresik-Indonesia, the highest energy consumption in the building is for cooling purpose, followed by lighting and equipment. Almost all buildings in the tropical area require artificial cooling system because it is in the tropical areas where humidity reaches maximum number of nearly
Energy for cooling relates to cooling load which affected by building envelope, equipment, light, people, and infiltration.  

Early design silo as campus building have to consider not only by perspective of architecture and civil, but also from energy. Early stages in design decisions have a main impact on final building performance and costs. Especially, the silo for building has unique characteristics due to its envelope. Energy use in existing design estimated through simulation and recommendation to reduce EUI could be give before construction.

Furthermore, implementing energy efficient campus buildings has to be considered because this can partly contribute to addressing global warming. Moreover, universities are the places where young people come every year to study. They can learn about sustainable low carbon activities and designs, and also apply their knowledge after graduation. 

The main objective of this research is to give recommendation design with lower EUI. The existing building design will be simulated to find future EUI and some improvement suggested for optimum EUI. Silo as UISI building is used as model in this research. Furthermore, Revit Autodesk 2017 is used for simulation because this software offers complete analysis in energy.

2. Literature Review

2.1 Energy Use Intensity (EUI)

EUI measured by kWh/m².year and used to compare the energy consumption for different space and type of buildings. ANSI/ASHRAE/IES given the standard for EUI is 176 kWh/m².year for campus building. This value is lower than Indonesia’s standard, 235kWh/m².year [4].

2.2 Attempt to Build Green Building

Major possibilities to improve energy efficiency by cooling reduction in existing building are add fabric insulation (wall, roof, partition), window retrofits (double glazing, low E coating, and shading system), cool roof, cool coating, and air tightness [4]. Graha Wonokoyo building is an example of green design and architecture energy efficient in office building in Surabaya, Indonesia. Total site area is 1870 m² with 10 floors. Energy Efficiency Index (EEI) of this building is 88.97 kWh/m².year based on 2000 operational hours. This EEI value is lower than standard office building value which is 246 kWh/m²/year in ASEAN and 189 kWh/m²/year in USA [5].

The energy efficient design concept used in Graha Wonokoyo regarded from building layout, facade design, material, lighting system, and heating, ventilating, and air conditioning (HVAC) system. In the layout arrangement, orientation and usage part in the building are important to get natural lighting and reduce cooling load. In the west part is a buffer zone, use for warehouse, file storage, and meeting room. North part, used for air conditioner ventilated outdoor space; data room, emergency exit, and pantry serve in each floor. West part used for office workshop and has maximized natural lighting. Office workspace locates in the southern part of building. In the building envelope, the facade design was followed Indonesia standard of 03-6389-2000, with cooling load ≤ 45W/m². Glass and wall material were chosen and combined with considering low Overall Thermal Transfer Value (OTTV) of 23.09 W/m². In lighting sector, lamp was controlled by using dimmer and occupancy sensor in meeting room.

The most consume energy comes from HVAC, Variable Refrigerant Volume (VRV) used as the cooling and heating, and allows one outdoor condensing unit to be connected to multiple indoor fan-coil units (FCUs), each individually controllable by its user, while modulating the amount of refrigerant being sent to each evaporator. By operating at varying speeds, VRV units work only at the needed rate allowing for substantial energy savings at part-load conditions. For air-conditioning building, space load (heating/cooling load) calculation is a very important to estimate the capacity of air-conditioning plant. In the tropical zone, only cooling load calculation that is needed. Cooling load calculation depends on: opaque surfaces (wall, roof, and door), transparent surfaces (window), partition, ventilation, occupants, and appliances [6].
The other study was conducted in typical school home with 185 m$^2$ in Florida US. The main contribution in cooling load is building envelope (windows, walls, and roof) at 56%, followed by appliances, duct leaks and gain for the air conditioner, and infiltration respectively [6].

2.3 Silo Envelope
Silo is a building used to store raw materials or materials that require special storage, storage of raw materials such as cement. Silo designed using certain materials by the type of objects that will be store in it. One of them as applied to the PT. Semen Gresik, the material used in the construction of silos with a height of ± 20 meters as the storage of raw materials, such as limestone and limestone, using concrete materials.

On the walls of the silo structures made of ordinary concrete can be modified by using prestressed concrete and the thickness around 40cm. This type of concrete gives the potential for reducing the tensile stresses due to the workload. Based on the results of the research quality of the concrete used for the silo are as follows: quality of concrete: 35 Mpa, diameter strand: 12.7 mm, modulus of elasticity: 197 000 MPa, size strand: 98.71 mm$^2$ / strand, breaking load: 187.33 kN, ultimate stress: 1897.78 Mpa and jacking Style: 60% [7].

2.4 Validation of Revit Software
Several type of research have been conducted to validate the simulation model in Revit with other software or real measurement. Bakar and Abdullah (2012) from Universiti Tun Hussein Onn Malaysia (UTHM) simulated the thermal performance using Ecotect, a previous version of Revit. The research conducted in office building of UTHM that has two floors. The thermal comfort station was measured and recorded: air temperature, globe temperature, mean radiant temperature, air velocity, relative humidity and the effect of indoor thermal environment on human comfort. The simulated results were validated with field measurement data. The thermal analysis in Revit simulation indicated a good agreement with difference value less than 10% [8].

Similar research conducted in building at Universiti Teknologi Malaysia. The thermal comfort study in this research involved the use of field measurement and computer simulation using Revit software. Validation of Revit was done by comparing the computer simulation result by the field measurement. The average difference between the measurement and simulation for ambient temperature was 5%; the maximum difference was 9% for the cavity 07:00h of indoor temperature.

3. Methodology
Weather data and building information were collected and simulated in 3D model including the specification of material to find the future EUI. This value compared by the ASHRAE standard and scenario were created.

![Flowchart of research](image)

**Figure 1.** Flowchart of research.

3.1 Collected Data
Building information data collected from section of infrastructure facilities shows in Table 1.
Table 1. Detailed data of building

| Properties of building | Detail          |
|------------------------|-----------------|
| Total floor area       | 5686 m²         |
| Exterior wall area     | 5774 m²         |
| Exterior window ratio  | 0.05            |
| Occupancy              | 1232 people     |
| Type of HVAC           | Central HVAC    |
| Average lighting power | 10.66 Watt/m²   |
| Type of floor          | Concrete floor  |
| U-value of floor       | 2.9 W/m²·K      |
| Type of window         | Single glass aluminum frame |
| U-value of window      | 6 W/m²·K        |
| Type of wall           | Concrete        |
| U-value of wall        | 9 W/m²·K        |
| Type of roof           | Suspended concrete |
| U-value of roof        | 3.1 W/m²·K      |
| Type of ceiling        | Suspended concrete ceiling |
| U-value of ceiling     | 2.56 W/m²·K     |
| Infiltration air       | 0.5 air change/hr |

Weather data were taken from Metrological Station in Gresik. The weather data contain: dry bulb temperature (°C), wet bulb temperature (°C), cloudiness (%), Relative Humidity (m/s), direct solar radiation (W/m²), and diffuse solar radiation (W/m²). All of the data were sampling hourly in 2015. Diurnal weather average, including temperature dry bulb, wet bulb, direct and diffuse solar radiation show in Figure 2.

![Figure 2](image)

Figure 2. Trend of diurnal weather average.

3.2 Simulation

SrEVIT is energy analysis software based on 3D CAD. The building model duplicates in Revit software. Input and output that considered in this study is EUI. The input of this software is: building orientation, dimension, specification of material, appliances, lamp, occupancy, and schedule. The model from Revit runs online in other energy simulation: Green Building Studio and BIM.
3.3 Improvement

Three improvements in energy use which estimated in this study shown in Table 2. The improvements consist: window’s shades, window’s material, reduce infiltration, lighting efficiency, daylighting and occupancy control, efficiency of plug load, HVAC, operating schedule, and Photovoltaic (PV) potential.

Table 2. Detail improvements.

| Number | Detailed Scenario             |
|--------|-------------------------------|
| I      | Window’s shades               |
| II     | Window’s material             |
| III    | Reduce infiltration           |
| IV     | Lighting efficiency           |
| V      | Daylighting and occupancy control |
| VI     | Plug load efficiency          |
| VII    | HVAC                          |
| VIII   | Operating schedule           |

4. Result and Discussion

4.1 Existing Design

The existing design of campus building from blueprint simulated in Revit found that future EUI estimated at 234 kWh/m².year, this value higher than standard from ASHRAE, 176 kWh/m².year. Monthly electricity use is shown in Figure 4. The average electricity usage is 62.333 kWh, the lowest is in July because of holiday in university calendar. The highest electricity use is in March because of activity in university expected to be busiest month. The contributions for energy use come from HVAC, lighting, and equipment, by 57%, 20%, and 23%.
The highest value comes from HVAC which depend on cooling load which shown in figure 5. Monthly cooling load shows in Figure 7, 350TJ to 540T. The lowest cooling load in July because of operates condition in holiday and the highest is in November because of the high temperature. The main contribution for cooling load comes from the wall. It quite different with other campus building, usually the main contribution comes from window solar. This case because of silo envelope, the wall thickness upper the ordinary building. Moreover, Window to Wall Ratio is very low 0.05 due to keeping the shape of the silo and minimizes the window and door.

Based on the simulation, it’s clear that the next improvement in energy use should be considered. The future EUI expected to be higher than standard. Some measure in early stages will be useful for cost and environment.

4.2 Improvement

Nine improvements estimated in the simulation. Even though the wall is the main problem, but the improvements can’t work on this factor. The silo wall is given and can’t change the material. The improvements will focus on the window, building operation, lighting, plug load and PV potential. The existing model or BIM (Building Information Model) show in improvement graph, it compared with other scenarios.

The first improvement is installing window shades. Figure 6(a) shows effects of installing window shades in EUI. There are four graphs which indicate directions: east, west, south, and north. Window shades will give the different effect on EUI depend on direction. The significant EUI is installing shades in north direction because the building located in south latitude and the sun mostly comes from the north. Besides, installing shades on west direction also give significant effect due to the sun set on the west.
Unlike sunrise, the heat from sun in the afternoon is unwanted. The best recommendation is installing shades 2/3 from window height to reach largest energy saving. The next improvement is changing the window material. Figure 6(b) shows effect changing glass material to low emission glass. The significant EUI comes from triple glass low emission which has lower U value at 2.4 W/m².K than BIM at 6 W/m².K.

![Figure 6](image1)

**Figure 6.** Scenario on the window a.window’s shades b.window’s material.

The third improvement is reducing the infiltration air show in Figure 7. The lowest infiltration air is 0.17 air change rate per hour (ACH) gives significant EUI, this condition reached by installing automatic door and put rubber in the window to minimize air leakage.

![Figure 7](image2)

**Figure 7.** Reducing infiltration air.

The next improvement is in lighting, including efficient lighting, maximize daylighting, and installing occupancy sensor (Figure 8). Using efficient lighting to 3.23 W/m² will reduce EUI to 25 kWh/m².year. This condition reached by using LED lamp. Furthermore, maximize daylighting and occupancy control also reduces EUI to 7 kWh/m².year.
Figure 8. EUI compared to lighting scenario.

The sixth improvement is plug load efficiency. Based on electricity usage, equipment contributes 23% of total electricity. Using efficient equipment to 6.46 W/m² could reduce the EUI to 25 W/m²/year (Figure 9). This improvement will work by choosing the energy saving equipments.

Figure 9 EUI compared to plug load efficiency.

The seventh improvement is using high efficient HVAC. Nine type of HVAC were compared, the most significant EUI is using high efficient Variable Air Volume (VAV) as shown in Figure 10. The EUI could reduce to 40 kWh/m²/year

Figure 10 EUI compared to various HVAC
The last improvement is arranging the operating schedule. It measured by operating hour in a week. In the Figure 11 shows that the lowest is 12/5, the building operates 12 hours in 5 day per week. This is the ideal operating hour for university building.

![Figure 11. EUI compares to operating schedule](image)

5. Conclusion

In summary, existing design silo for campus building simulated and the expected EUI is 234 kWh/m².year. The EUI depend on cooling, equipment, and lighting by 7%, 23%, and 20, respectively. Electricity for air conditioning relates to cooling load which mainly depend on building envelope. More specific, wall from the silo is the highest contributes for cooling load. Eight improvements combined to find minimum EUI: 2/3 length of shades, triple glass low emission, 0.17 ACH infiltration air, efficient lighting 3.23 W/m², maximize daylighting, installing occupancy control, using high efficient VAV, and 12/5 operating schedule. Combined improvements could reduce EUI to 98.27 kWh/m².year.

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