Greenhouse gas emissions from low income house construction: case study in Baan Eua-Arthorn project in Thailand

Hathairat Loyprakhon[1], Siriluk Chiarakorn[1,*], Pattana Rakkwamsuk[2]

[1]*Division of Environmental Technology, School of Energy, Environment and Materials, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*
[2]*Division of Materials Technology, School of Energy, Environment and Materials, King Mongkut's University of Technology Thonburi, Bangkok, Thailand*

Abstract:
This study aims to evaluate greenhouse gas (GHG) emission in the unit of $kgCO_2e/m^2$ from construction materials of low income houses under the Baan Eua-Arthorn Project. The activity data of constructing materials were extracted from house plans and Bill of Quantities (BOQ) of 4 low income houses such as detached house (61.97 m^2), twin house (109.67 m^2), townhouse (552.20 m^2), and condominium (2,121.15 m^2). The greenhouse gas emissions in the unit of $kgCO_2 e/m^2$ were calculated in the scope of cradle to gate following the Thai national guideline for carbon footprint of product and Thai national life cycle inventory database (TGO, 2011). Results show that the highest greenhouse gas emission from constructing materials belongs to condominium (179.06 $kgCO_2 e/m^2$), followed by townhouse (118.73 $kgCO_2e/m^2$), twin house (107.53 $kgCO_2e/m^2$), and detached house (93.21 $kgCO_2e/m^2$), respectively. The largest greenhouse gas emission was emitted from condominium due to more concrete and cement used than other houses. Concrete, cement and steel were found to be significant emission hot spot which is consistent with the study of Aneksaen (2011). Thus, in order to reduce the greenhouse gas emission from construction materials, the conventional building envelops should be replaced by low carbon embedded materials, like lightweight concrete. It is found that the greenhouse gas emissions ($kgCO_2 e/m^2$) decrease to 28% for condominium, followed by 10.4% for townhouse, 6.4% for twin house, and 4.2% for detached house. The results of this study can be used as a guideline to reduce carbon footprint of residential buildings in the government housing project in the future.

Keywords: *Greenhouse gas emission; Low income houses; Construction process; Baan Eua-Arthorn*

**Corresponding author. Tel.: +6624708654, Fax: +662470-8660*
E-mail address: siriluk.chi@kmutt.ac.th

1. Introduction

Carbon embedded in construction materials is one of significant sources related to carbon footprint of residential houses. Many studies have focused on the estimation of greenhouse gas (GHG) emission from conventional houses and modern houses with different construction materials such as precast concrete, light-weight concrete and brick. This study reported that 98% of GHG emissions were from construction materials. Cement and steel were major sources of GHG emission (Aneksaen, 2011). However, GHG emissions from low income houses have not been investigated. In Thailand, Baan Eua-Arthorn Project is the government housing project for low income people. The project was established in 2003 by National Housing Authority (NHA) with the total units of 281,550 (Monitoring and Evaluation Division, Policy and Planning Department, 2013). This study aims to evaluate GHG emission from construction materials of low income houses under the Baan Eua-Arthorn Project and to offer alternative materials that can reduce GHG emissions. The activity data of constructing materials were extracted from house plans and Bill of Quantities (BOQ) of 4 low income houses such as detached house (61.97 m^2), twin house (109.67 m^2), townhouse (552.20 m^2), and condominium (2,121.15 m^2) as shown in Fig. 1. The GHG emissions in the unit of $kgCO_2 e/m^2$ were calculated in the scope of cradle to gate following the Thai national guideline for carbon footprint of product (TGO, 2011).

2. Methodology

The activity data of constructing materials were extracted from house plans and Bill of Quantities (BOQ) of 4 low income houses which are detached house (61.97 m^2), twin house (109.67 m^2), townhouse (552.20 m^2), and condominium (2,121.15 m^2) as shown in Fig. 1. The GHG emission was calculated in the unit of $kgCO_2e/m^2$ by the following equation.

$$GHG\ emission\ (kgCO_2e/m^2) = \sum [Activity\ data\ (unit) \times Emission\ factor\ (kgCO_2e/unit)]\ /area \qquad (1)$$

Table 1 Emission factors used in this study

Items	Unit	Emission factor ($kgCO_2e$/unit)	References
Brick	kg	0.218	TGO (2011)
Cement	kg	0.490	TGO (2011)
Concrete	kg	0.130	University of Bath (2008)
Glass	kg	1.130	SimaPro 7.1
Gypsum Ceiling	kg	0.346	SimaPro 7.1
Hardwood	Ft^3	-33.00	SimaPro 7.1
Lightweight Concrete	kg	0.220	SimaPro 7.1
Lime	kg	0.740	University of Bath (2008)
Roof Tiles	kg	0.353	SimaPro 7.1
Sand	kg	0.0037	TGO (2011)
Steel	kg	1.25	SimaPro 7.1

Emission factors used in this study came from national database (TGO, 2011), Simapro and the study from University of Bath as presented in Table 1. The GHG emissions from different building styles were then compared and the emission hotspots were pointed out. After that, alternative constructing materials were introduced in this study.

Fig. 1 Types of residential buildings under the Baan Eua-Arthorn Project (Housing Finance Association, 2005).

3. Results and discussion

Results in Fig. 2 showed comparison of GHG emissions per square meter of 4 building types. Condominium contributed the highest GHG emissions (179.06 $kgCO_2$ e/m^2), followed by townhouse (118.73 $kgCO_2e/m^2$), twin house (107.53 $kgCO_2e/m^2$), and detached house (93.21 $kgCO_2e/m^2$), respectively. Major GHG emission hotspots came from concrete, cement and steel, respectively. This is because the productions of these materials are complicated and require large energy (fossil based) consumption, resulting in their high carbon footprints. The finding is consistent with the study of Aneksaen (2011). She concluded that precast house emitted the highest GHG emissions (237.51 $kgCO_2e/m^2$), by the brick house (215.61 $kgCO_2e/m^2$), lightweight concrete house (194.65 $kgCO_2e/m^2$) and half wood-half concrete house (4.41 $kgCO_2e/m^2$), respectively. Among all buildings, construction of condominium used more cement and concrete per area than others. As a result, the GHG emission of condominium was the highest. Thus, in order to reduce the greenhouse gas emission from construction materials, the conventional building envelops should be replaced by low carbon embedded materials, like lightweight concrete. After replacing concrete block and brick with lightweight concrete, it was found that the GHG emissions decreased 28% for condominium, followed by 10.4% for townhouse, 6.4% for twin house, and 4.2% for detached house as shown in Fig. 3. Even though the emission factor of lightweight concrete is higher than concrete and brick, use of lightweight concrete can reduce amount of cement binder which has very high carbon footprint. In addition, the advantages of lightweight concrete are lighter weight, shorter construction period and lower thermal conductivity than concrete block and brick. Thus, lightweight concrete is a recommended construction material for low-income house construction in Thailand.

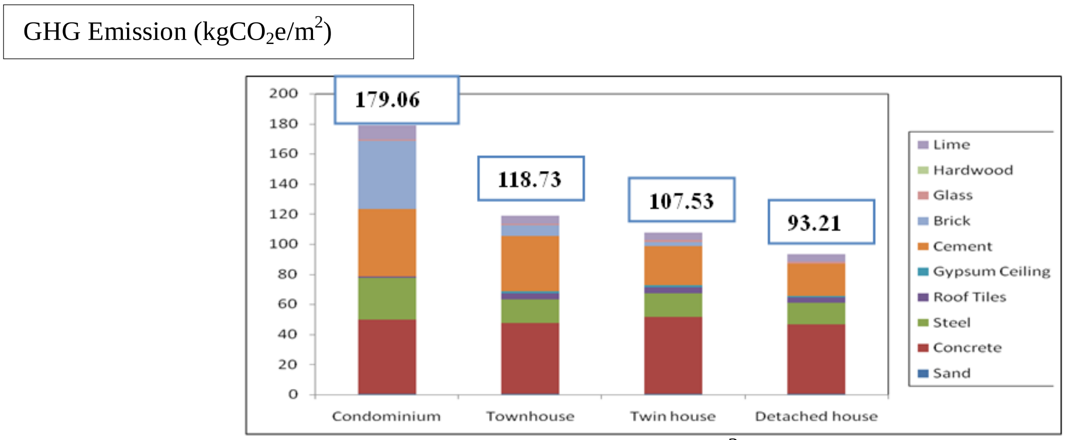

Fig. 2 GHG emissions ($kgCO_2e/m^2$) of 4 building styles.

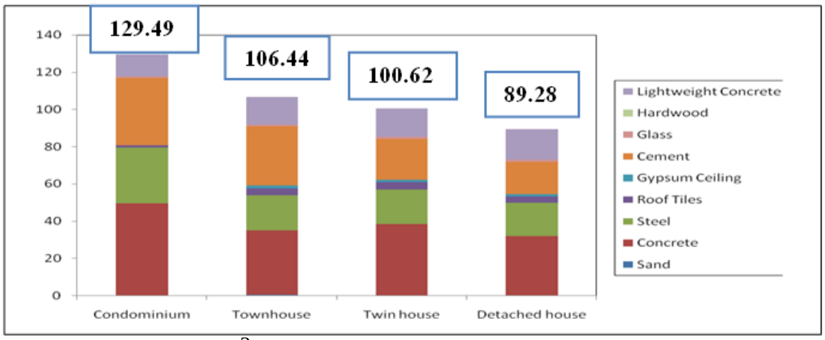

Fig. 3 GHG emissions ($kgCO_2e/m^2$) of 4 building styles after replacing brick and concrete with lightweight concrete.

4. Conclusion

The highest GHG emission from construction materials of low-income houses in Baan Eua-Arthorn Project belongs to condominium (179.06 $kgCO_2$ e/m^2), followed by townhouse (118.73 $kgCO_2e/m^2$), twin house (107.53 $kgCO_2e/m^2$), and detached house (93.21 $kgCO_2e/m^2$), respectively. Concrete, cement and steel are the hotspots of GHG emissions. Replacement of concrete block and brick with light weight concrete can reduce 4-28% of GHG emissions. The results of this study can be used as a guideline to reduce carbon footprint of residential buildings in other government housing projects in the future.

5. Acknowledgement

This work has partially been supported by ELITH project (Energy and Low-Income Tropical Housing) in Thailand, The Joint Graduate School of Energy and Environment (JGSEE) and School of Energy Environment and Materials (SEEM) King Mongkut's University of Technology Thonburi. The authors would like to express their gratitude to the National Housing Authority (NHA) for the Baan Eua-Arthorn Project information support.

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