

Evaluation of greenhouse gas emission from residential buildings in Thailand

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Abstract:

Apart from energy sector, greenhouse gas (GHG) emission from the construction industry has become more significant especially indirect GHGs from carbon embedded in construction materials. This paper presents the evaluation of GHGs from construction materials in different residential buildings such as detached houses with different styles (contemporary, modern and Thai modern houses) and low-rise and high-rise condominiums in Bangkok. The concept of carbon footprint was applied in this study to evaluate how much GHG emitted from construction process. The activity data were extracted from floor plans and Bill of Quantities (BOQ) of 42 houses and 12 condominiums. The GHG emissions in the unit of $\text{kgCO}_2\text{e/m}^2$ were calculated in the scope of cradle to gate, following Thai national guideline for carbon footprint of product and Thai national life cycle inventory database (TGO, 2011). The high-rise condominium built from precast concrete emitted the highest GHGs ($326.77 \pm 22.01 \text{ kgCO}_2\text{e/m}^2$). While the Thai-modern house built from half wood-half concrete emitted the lowest GHGs ($2.47 \pm 36.37 \text{ kgCO}_2\text{e/m}^2$) due to the large carbon offset from wooden construction materials.

Keywords: Greenhouse gas emission; Residential building; Construction process

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1. Introduction

Greenhouse gas (GHG) emission from construction process of residential building has been widely concerned due to high population growth and housing demand. It was reported that the housing market in Thailand has expanded up to 200% since the economic crisis in 1997. In 2013, the total of new residential houses in Bangkok and metropolitan area was 130,046 units. The largest share belonged to condominiums, accounted for 53%, followed by detached houses (24%), townhouses and commercial buildings (21%) and twin houses (2%) (Government Housing Bank, 2014). GHG emissions from house construction are mainly from two processes: acquisition of construction materials (cement, steel, brick, concrete etc.) and energy consumption (electricity and fuel) during construction process. The Life cycle inventory of embodied energy and carbon in construction materials in UK indicated that steel had highest embodied energy (8.8-56.7 MJ/kg) and embodied carbon (0.11-1.67 kgC/kg), followed by glass, concrete, cement and timber (Hammond, 2008). Additionally, this study estimated the embodied energy and carbons from 14 building cases such as houses, apartments and energy-efficient houses and energy-efficient apartments in UK and USA using the LCA method. The average embodied carbon of the buildings was $403 \text{ kgCO}_2\text{e/m}^2$. The largest GHG emission contributed from concrete and brick (50%). The rest were steel, clay, insulation, glass, plastic and timber. The greenhouse gas emissions from life cycle of building construction in Hong Kong indicated that materials manufacturing was the main source of GHG emission accounted for 82-87% of all emissions (Hui et al., 2009). In Japan, the embodied energy and GHGs emitted from residential construction were studied. The results showed that the energy consumption and GHG emissions from reinforced concrete structures were $8\text{-}10 \text{ GJ/m}^2$ and $850 \text{ kgCO}_2\text{e/m}^2$, respectively. While the wood structures consumed the least energy consumption (3 GJ/m^2) and emitted the least GHGs ($250 \text{ kgCO}_2\text{e/m}^2$) (Suzuki et al., 1995). Another comparative CO_2 emission study found that green architecture design and materials selection can significantly reduce environmental impacts (Gonzalez and Garcia, 2006). This study aims to calculate GHG emissions from different residential buildings such as detached houses with different styles

(contemporary, modern and Thai modern houses) and low-rise and high-rise condominiums located in Bangkok. The life cycle assessment based on cradle to gate was applied in this study. The expected results would be useful technical databases for developing low carbon emission plans in building sector.

2. Methods

In this research, the construction data was collected from 42 houses in Bangkok which had different styles (contemporary style, modern style and Thai-modern style) and had different building envelope materials (brick, lightweight, precast concrete and half wood-half concrete). The scopes of GHG emissions included embodied carbons in construction materials and energy consumption during construction. The activity data were extracted from floor plans and Bill of Quantities (BOQ). The use of fuel and electricity during construction was conducted by field survey at construction sites. GHG emission in the unit of kgCO_2/m^2 was calculated by multiplying activity data with relevant emission factors, following Thai national guideline for carbon footprint of product and Thai national life cycle inventory database (TGO, 2011) and SimaPro 7.1.

3. Results and discussion

As shown in Table 1, the high-rise condominium built from precast concrete emits the highest greenhouse gases ($326.77 \pm 22.01 \text{ kgCO}_2\text{e}/\text{m}^2$). While the Thai-modern house built from half wood-half concrete emits the lowest greenhouse gases ($2.47 \pm 36.37 \text{ kgCO}_2\text{e}/\text{m}^2$) due to the large carbon offset from wooden construction materials. The GHG emissions from consumption of electricity and diesel during construction process contribute only 5 % of total GHG emissions. Electricity was used for equipments tools such as electrical drills and insertion concrete vibrators. While diesel was used in drop hammers, electrical generators, backhoe loaders and tower cranes. Fig. 1 and 2 presents the greenhouse gas emissions broken down by types of construction materials. Among all types of materials, cement and steel are the major sources of greenhouse gas emission. This is because the production of both materials emits large amount of greenhouse gases. In other words, cement and steel are high carbon footprint construction materials. According to SimaPro 7.1 database, the emission factors (cradle to gate) of cement and steel are 0.375 and 1.25 $\text{kgCO}_2\text{e}/\text{kg}$, respectively. While the emission factor of wooden materials is $-33 \text{ kgCO}_2\text{e}/\text{ft}^3$. As a result, the half wood-half concrete house has very low greenhouse gas emission. The results from this study suggest that the high carbon footprint materials, like cement and steel should be replaced by alternative construction materials with low carbon footprint. Hard wood and recycled steel are recommended for the development of residential buildings under low-carbon building scheme in the future.

Table 1 Specific GHG emissions from residential buildings in Thailand ($\text{kgCO}_2\text{e}/\text{m}^2$)

Building styles	CO ₂ emission ($\text{kgCO}_2\text{e}/\text{m}^2$)			
	Brick	Lightweight Concrete	Precast concrete	Half wood-half concrete
Contemporary house ¹	206.08±24.17 (6 data)	195.89 ± 26.86 (18 data)	237.51 ± 40.28 (6 data)	N.A.
Modern house ¹	185.58 ± 28.66 (1 data)	211.45 ± 3.92 (3 data)	N.A.	N.A.
Thai-modern house ¹	N.A.	N.A.	N.A.	2.47 ± 36.37 (8 data)
Low-rise condominium	186.08 ± 7.60 (2 data)	276.54 ± 7.97 (2 data)	297.86 ± 16.18 (2 data)	N.A
High-rise condominium	N.A	296.97 ± 14.78 (3 data)	326.77 ± 22.01 (3 data)	N.A

Note: ¹ Rakkwamsuk *et al.*, 2012, N.A. not applicable

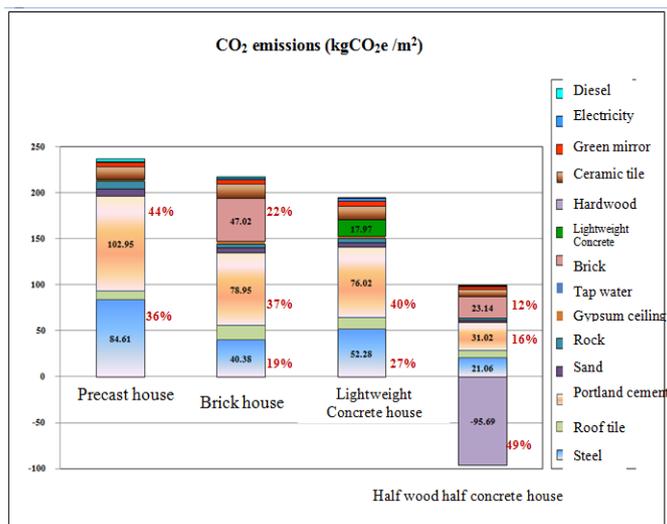


Fig. 1 GHG emissions from houses broken down by types of construction materials.

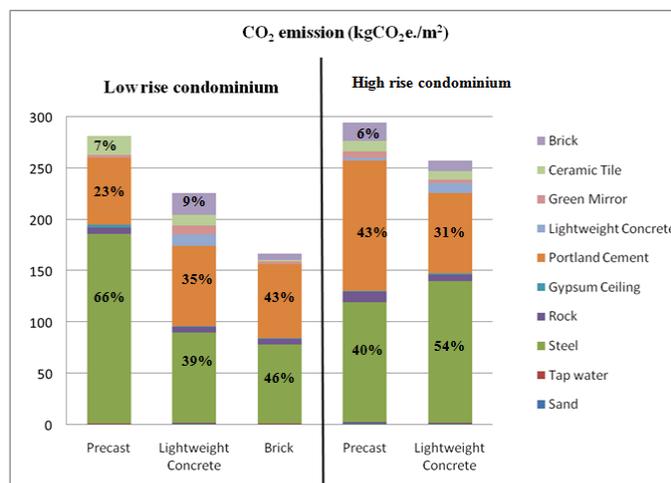


Fig. 2 GHG emissions from condominiums broken down by types of construction materials.

4. Conclusion

The GHG emissions from construction materials accounted for 95% of total GHG emissions (cradle to gate). The rests were GHG emissions from consumption of electricity and diesel during building construction. The high-rise condominium built from precast concrete emitted the highest GHGs ($326.77 \pm 22.01 \text{ kgCO}_2\text{e/m}^2$). While the Thai-modern house built from half wood-half concrete emitted the lowest GHGs ($2.47 \pm 36.37 \text{ kgCO}_2\text{e/m}^2$). Among all construction materials, cement, concrete and steel were identified as the emission hotspots. Replacement of these high carbon embedded materials with alternative low carbon embedded materials was recommended in order to reduce the impact of GHG emissions from building constructions.

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