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Assessment of Environmental Impact of Thai Housing

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ABSTRACT

Building and construction has consumed a lot of various resources and emitted pollution. These cause environmental problems, especially global warming. The buildings and constructions in various regions and different styles will lead to different environmental problems and levels of seriousness. The objective of this research is to assess the global warming impact from the use of construction materials in residential buildings since this type of building represents about 89% of all buildings in Thailand. The principles of ISO 14040:2006 and ISO 14044:2006 were used as the research methodology. The study started with collection of data and analysis of residential buildings in Thailand to conclude which type of building would be studies. Based on the data collected, most of the residential buildings in Thailand are two-storey reinforced concrete houses with an average space of 152 m2 consisting of 3 bedrooms, 2 restrooms, 1 kitchen, 1 dining room, 1 living room, hip roof and 1 car-parking area. This information was used as the functional unit. The system boundary of this study included all life cycles of building materials i.e. raw material extraction and processing, product manufacturing, transportation, installation, operation and maintenance, and disposal (at the end of the life-span of the materials). The life-span of the building is 50 years. From the calculation, it is found that the value of global warming potential of Thai housing is 4.98E+07 gCO_2 eq. A reinforced concrete causes global warming of 4.98E+07 gCO_2 eq, and concrete is the construction material having the greatest environmental impact representing up to 2.55E+07 g CO_2 eq or 54.80%, followed by mortared brick wall of 1.35E+07 gCO_2 eq or 29.08%, and steel structures of 6.12E+06 gCO_2 eq or 13.13%. However, laminated timber and door timber both have a positive effect upon the environment.

Keywords: environmental impact; global warming; Thai housing; building materials; life-cycle assessment.

1.INTRODUCTION

Global building construction consumes more than 40% of the existing resources each year [1], and this is a significant source of environmental pollution and is the cause of such forms of pollution as acidification, poisonous smog, increasing amounts of garbage, human health problems, and particularly global warming in terms of both resources consumption and pollution release. These forms of pollution start from the design stage, and continue during the periods of construction, utilization and maintenance until the final demolition stage when the building is no longer needed [2]. Information provided by the U.S. Environmental Protection Agency: EPA [3] reveals that one-third of all existing buildings are what can be termed 'sick' buildings, due to the fact that the environmental impact caused by the design has not been taken into consideration, and neither the architects nor designers have performed as a solution center [4].

Since 2000, the Thai construction industry has been growing steadily as evidenced by the number of buildings built each year. Of these buildings, 89% are constructed for residential purposes [5]. With respect to the types of building materials utilized, the use of virgin wood has shown a decrease accounting for only 5% of the building materials used in buildings [5]. This decrease can be

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attributed to the fact that the forest area in Thailand is decreasing and wood has become more expensive. As a result of these factors, the use of alternative materials in place of wood will also help preserve the environment.

In addition, several methods have been applied in order to help reduce the environmental impact resulting from buildings such as a decrease in energy consumption, reduction of garbage, rapid construction and the selection of environmentally friendly construction materials. However, the most important consideration is that we have to know how existing buildings cause environmental impact in order to determine the most practical improvements to current construction methods so as to effectively minimize such impact.

This paper therefore analyzes the degree that a residential building in Thailand contributes to global warming by applying the Life Cycle Assessment (LCA) which is the tool widely used for environmental impact assessment of products and buildings [6].

2. GOAL AND SCOPE

The objective of this research is to assess the global warming impact from the use of construction materials in residential buildings in Thailand throughout the building life-cycle. This assessment can be said to cover the period "from the cradle to the grave", throughout the life of the materials used from the stage of raw material extraction and processing, product manufacturing, transportation, installation, operation and maintenance, and disposal (at the end of the life-span of the materials). The life-span of the building is taken to be 50 years [11] so if the life of any construction material used is less than 50 years, a material replacement will be taken into account. For example, a rubber tile with a 20-year life span in any building will be replaced at least two times.

3. METHODOLOGY

The assessment of the product life-cycle pursuant to the principles of ISO 14040:2006 and ISO 14044:2006 is divided into four steps [7, 8] i.e. determination of the goal and scope based on the demand of results and ability to find information; inventory for separating building input-output in which the input includes water, energy, utilization of land and other resources and the output affects air, soil and water of each type of material in the building; impact assessment and characterized inventory. The results will be then explained and applied as per the specified purpose. (Figure 1).

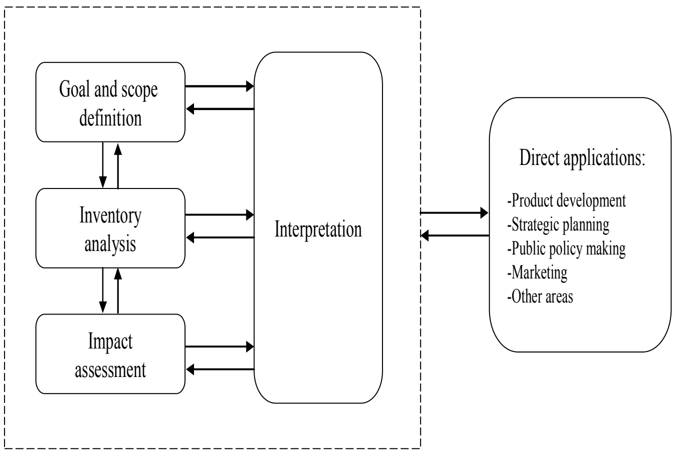

Figure 1. Stages of an LCA

4. FUNCTIONAL UNIT

According to the National Statistical Office's study of Thai residences [9], 36% of residences are single houses (Figure 2), and the Real Estate Information Center's residence price information shows that the estimated residence price can be classified as follows:

(i) less than 1 MB 21% ;

(ii) 1 MB to 2 MB 46%; and

(iii) 2 MB to 3 MB, 17%.

It was also found that 85% of house buyers wish to purchase residences in Bangkok and its surrounding provinces [10].

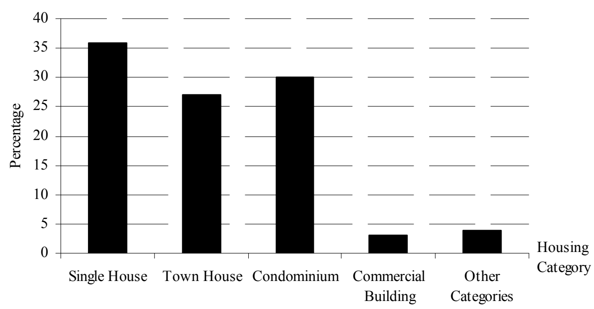

Figure 2. Overall picture of residences in Thailand

It can be concluded from the afore-mentioned data that most residences in Thailand are single houses with prices ranging from 1 MB to 2 MB (excluding payment for land plot). Accordingly, this study has collated the various designs of single houses constructed in Bangkok and its surrounding provinces in 12 housing projects with house prices ranging from 1 MB to 2 MB; one government project providing the public with free-of-charge housing plans; and nine housing plans produced and submitted by applicants to the District Offices in Bangkok and its surrounding provinces. It was found that most of them have structures and useful space as detailed below: (Figure 3 and 4)

(i) average space of 156 square meters;

(ii) reinforced concrete structure;

(iii) two-storey houses;

(iv) three bedrooms, two restrooms, one kitchen, one dining room and one living room;

(v) hip roof; and

(vi) one car-parking lot.

Figure 3. 1st and 2nd floor plan

Fig. 4: Building elevation

According to the afore-mentioned data collected, construction materials used in the construction of single houses can be grouped into five categories as follows:

(i) structural engineering work;

(ii) architecture work such as roof, ceiling, wall, floor, painting, windows and doors;

(iii) sanitary work;

(iv) electricity system work; and

(v) communication work.

In this research, interior design and sanitary work have been excluded. Additionally, no analysis of sanitary work, electricity system and communication work has been made. Therefore, the construction materials used for the building environmental impact assessment can be summarized as below (Table 1).

Table 1 Summary of materials used in construction of residences in Thailand

Materials		Quantity (Q_i)	Unit	Replacement Time(s)
Category	Type			
Structure	Reinforced concrete	96	m^3	0
Roofing	Steel structure	4500	kg	0
	Concrete tiles	5480	kg	0
Ceiling	Gypsum plaster board	4950	kg	1
	Glass fiber insulation	123	kg	2
Walls	Mortared bricks	61870	kg	0
Flooring	Ceramic tiles	1473.4	kg	0
	Laminated Timber	4.4	m^3	0
Painting	Emulsion paint	102.9	kg	4
Windows	Aluminum	502.2	kg	0
	Glass	780	kg	0
Doors	Timber	1.8	m^3	0

5.1 Structure

With respect to materials for structural work i.e. foundation, pillars and beams, after examining 22 sample plans, it was found that all of these plans feature reinforced concrete structures so the material used in the construction work is reinforced concrete.

5.2. Materials for roofing

5.2.1. Roof structure and roofing materials:

It was found that there are two types of roof structures – steel structure (95.5%) and wood structure (4.5%). In this research, only steel roof structures have been studied.

5.2.2.Roofing materials:

The study shows that roofing materials for all single houses are either concrete or cement tiles.

5.3 Ceiling materials

5.3.1 Ceiling

All ceilings are constructed from gypsum boards (100%).

5.3.2 Insulation for residences

There are two types of insulation, namely, Polyurethane, PU – Foam (18.1%) and Glass Fiber (81.8%). In regard to the assessment of building environmental impact, only glass fiber has been studied for the purpose of this research.

5.4 Walls - internal and external

5.4.1 Internal walls

Three types of materials are used – mortared bricks, gypsum board with galvanized steel ceiling frame (9%) and mortared lightweight concrete blocks (50%). Since there is no study on the environmental impact of lightweight cement brick, mortared brick walls are studied in this research.

5.4.2.External wall

Two types of materials are used equally – mortared bricks and lightweight cement bricks. Since there is no information on the environmental impact of mortared bricks available, mortared bricks are studied in this research.

5.5. Flooring

More than one type of material is used in flooring. It was found that the most commonly used flooring materials are ceramic tiles in wet areas such as living rooms and rest rooms, with wooded materials used in personal areas such as bedrooms.

5.6. Painting

Painting is required in both internal and external areas.

5.7. Windows

A total of 36.4% of windows are made from wood and glass, and 63.6% of windows are made from aluminum and glass. In this paper, aluminum window frames and glass window panels are studied.

5.8. Doors

Some doors are made from aluminum and glass, but most of them (86.4%) are made from wood. In this paper, therefore, wood doors are studied.

6. ENVIRONMENTAL IMPACT ASSESSMENT

Information on global warming caused by materials has not been developed in Thailand so, in this paper, the database from ecoinvent v.2 from 2000 to 2008 has been used, and the information closest to the situation in Thailand has been selected as per the details in Table 2.

Table 2. Quantity of impact from one residential building

Building Materials (i)	GWP of Building Material I (GWP_i)	Environmental Impact of Building Material ($g\ CO_2$-eq)
Concrete	2.66E+05 gCO_2/m^3	2.55E+07
Steel	1.36E3 gCO_2/kg	6.12E+06
Concrete tiles	3.55 gCO_2/kg	1.95E+04
Gypsum plaster board	362 gCO_2/kg	3.58E+06
Glass fiber insulation	1.49E+03 gCO_2/kg	5.50E+05
Mortared bricks	219 gCO_2/kg	1.35E+07
Ceramic tiles	211 gCO_2/kg	3.11E+05
Laminated Timber	-6.11E+05 gCO_2/m^3	-2.69E+06
Emulsion paint	2.58E+03 gCO_2/kg	1.33E+06
Aluminium	6.05E+03 gCO_2/kg	3.04E+06
Glass	541 gCO_2/kg	4.22E+05
Timber	-1.08E+06 gCO_2/m^3	-1.94E+06
Total		4.98E+07

According to the data processed and based on secondary data, residential buildings of the type of single house in Thailand cause global warming of 4.98E+07 gCO_2 eq as per the following sequence:

(i) concrete of 2.55E+07 g CO_2 eq;

(ii) mortared brick wall of 1.35E+07 gCO_2 eq;

(iii) steel of 6.12E+06 gCO_2 eq; and

(iv) aluminum of 3.04E+06 gCO_2 eq.

The environmental impact from laminated timber and door timber are -2.69E+06 and -1.94E+06 respectively. Fig. 1 shows that concrete (54.80%) has the greatest environmental impact, followed by mortared brick walls (29.08%), steel structure (13.13%) and aluminum (6.52%) (Figure 5).

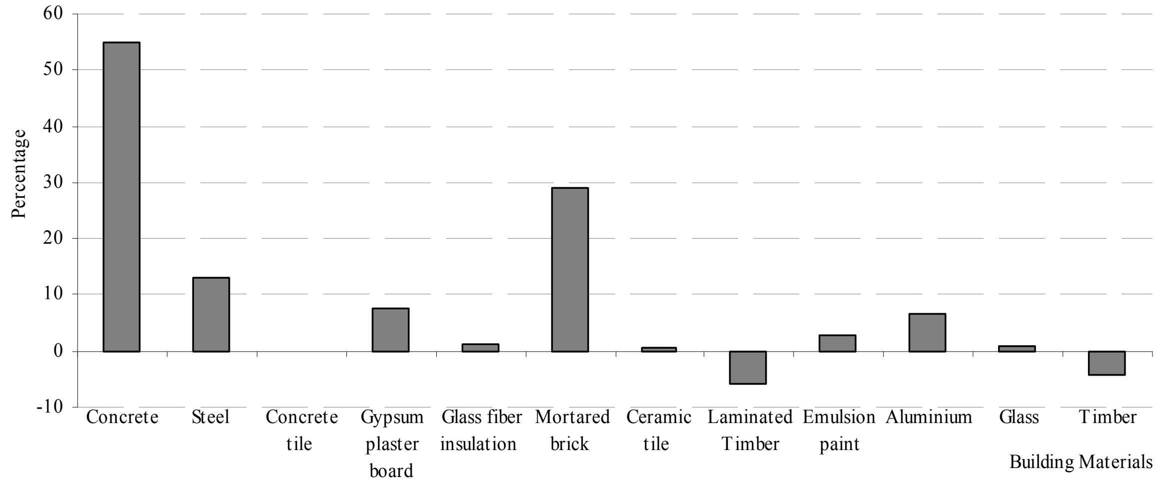

Figure 5. Percentage of environmental impact from each type of material.

Calculation formula:

$$BEI_{GW} = \sum[GWP_i \times Q_i \times (T_i + 1)]$$

BEI_{GW} refers to global warming from a building.

GWP_i refers to global warming from a material i (gCO_2 eq).

Q_i refers to the quantity of such type of material (i).

T_i refers to the number of replacements of a material (i) during the building life of 50 years.

7. DISCUSSION

From the calculation, it can be seen that concrete has the greatest environmental impact in respect of the construction of residential buildings in Thailand. This is in line with M. Asif [6] who studied the environmental impact of residential buildings in Scotland and deduced that 1m3 concrete brings global warming up to 2.66E+05 gCO2. In addition, a much greater amount of concrete is used for the construction of residential buildings in Thailand when compared to other types of materials and concrete cannot be re-used.

Laminated timber and door-timber are shown to have a negative environmental impact, which means that the use of these materials has a positive effect upon the environment. Since wooden materials such as wooden doors are construction materials which are prepared and manufactured in an un-complicated process, and wood can decompose naturally and also be replanted. In addition, after use the energy is also recovered, calculating from heat energy from firewood incineration and the cinder thereof also decompose naturally.

Any reduction in the use of wood for the construction of residential buildings in Thailand does not actually help minimize environmental impact or global warming, but a practical method of reducing environmental impact from residential buildings in Thailand would be to decrease the quantity of concrete used and focus on sources of alternative construction materials, together with the life-cycle, the re-use of materials, and methods of destruction after expiration of the life-cycle.

However, this research has a limitation in respect of global warming information (GWP) used for calculation. The database from abroad may lead to a deviation in calculation since the database from LCA in each country or source is different [12, 13, 14]. Each country, especially developing countries, should therefore expedite the development of their databases since this crucial information is required for the design and improvement of products to further minimize the environmental impact.

The global warming impact in this research derives from the analysis of the construction material throughout the building life cycle, excluding the environmental impact from consumption of energy and water within the building. In the future, if a complete analysis of environmental impact from a building is made, consideration on the consumption of energy and water, release of waste during the use of building as well as other environmental problems such as acidification, indoor air quality and habitat alteration is to be made.

8. CONCLUSION

A 156-square meter reinforced concrete residential building in Thailand causes global warming of 4.98E+07 gCO2 eq, and concrete is the construction material having the greatest environmental impact representing up to 2.55E+07 g CO2 eq or 54.80%, followed by mortared brick wall of 1.35E+07 gCO2 eq or 29.08%, and steel structures of 6.12E+06 gCO2 eq or 13.13%. However, laminated timber and door timber both have a positive effect upon the environment.

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APPENDIX

MB : Million Baht

ISO : International Organization for Standardization

GWP : Global Warming Potential

CO_2-eq : Carbon dioxide equivalent

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