Life cycle assessment of a residential building for environmental impact reduction in Malaysia

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Abstract

The building industry has a significant impact on the environment due to massive natural resources and energy it uses throughout its life cycle. This paper presents a typical residential building construction in Malaysia as a case study and assesses the environmental impact under cradle-to-grave which consist of pre-use, construction, use and end-of-life phase by using CML 2001. Five impact categories were evaluated namely, acidification, eutrophication, global warming potential, ozone layer depletion and human toxicity. The building operation under use phase contributed the highest global warming potential and acidification with 2.41E+03 kg CO2 eq and 1.10E+01 kg SO2 eq respectively. In pre-use phase, concrete in the substructure has the most significant impact overall especially to global warming potential with 3.40.E+02 kg CO2 eq with cement as the primary raw materials. The recycling of steel and aluminium during end-of-life shows a significant reduction by up to 78% in every environmental impact category. The results showed that the residential building in Malaysia has a higher impact in GWP and HT and lower in acidification and ODP compared to other studies. The results from this study can assist policymakers and building professional to make informed decisions in

reducing environmental impact in Malaysia other countries in the world with similar environmental condition.

1 Introduction

Building industry contributed significantly to the economy and social development, but also responsible for the massive impact on the environment because of natural resource consumption and emission released (Arena and de Rosa, 2003). Roodman et al. (1995) suggested that buildings responsible for world's fresh water withdrawals, wood harvest and material and energy flows that consist of 17%, 25% and 40% respectively. Due to the significant environmental impact to the industry, numerous studies have been conducted to reduce the energy consumption and its environmental impact (Singh et al., 2011).

Life cycle assessment (LCA) has been accepted as a tool to evaluate the environmental impact throughout product life cycle (Fava et al., 2009; Oyarzo and Peuportier, 2014). The life cycle of a product or cradle-to-grave which consist of the pre-use (extraction and acquisition of raw materials, material production and manufacturing process), use and end-of-life (EOL) was used to identify systematically and avoid the potential impact on the environment (ISO, 2006a). The introduction of LCA to building is relatively recent. The first study was conducted by Adalberth (1997) that paved the research in this area. Recent reviews suggested that LCA studies to buildings were conducted all over the world using ISO 14040 series as a basis, but the methodologies were varied (Abd Rashid and Yusoff, 2015).

In Malaysia, LCA was initially introduced to assess the sustainability of palm oil production (Ismail and Chen, 2010). Since then, it has been used in other industries such as electronics, consumer goods, potable water production, electricity generation, waste management and buildings (Bin Marsono and Balasbaneh, 2015; Fujita et al., 2008; Hassan et al., 1999; Omar et al., 2014; Shafie et al., 2012; Sharaai et al., 2009a, 2009b; SIRIM, 2011; Sumiani et al., 2009; Syafa Bakri et al., 2008; Thannimalay et al., 2013, 2012; Wen et al., 2014). Buildings studies in Malaysia mainly focused on the impact assessment of different materials. The studies also compared the benefit of integration of industrialised building system (IBS) to conventional construction system. Fujita et al. (2008) used LCA to estimate CO_2 emission for concrete and timber based house using input-output method during pre-use and operation phase. Omar et al. (2014) compared the pre-use phase of two-storey houses with a conventional concrete house and an IBS system house with precast wall panel using hybrid method for concrete and steel reinforcement. Wen et al. (2014) compared a conventional four-storey apartments Johor Bahru and a four-storey IBS apartment in Iskandar Malaysia, Johor. Bin Marsono and Balasbaneh (2015) compared seven different materials used for the wall of a single-family unit house in Johor, but only global warming potential (GWP) was measured.

All studies mentioned were conducted without considering full building life cycle or 'cradle-to-grave' which consist of pre-use, construction, use and end-of-life (EOL) phases. Moreover, full environmental impact on residential buildings in Malaysia has yet to be evaluated especially on the global warming impact. Thus, the aim of this study is to estimate the life cycle impact of a residential building in Malaysia from cradle-to-grave in five impact categories specifically on global warming potential (GWP), acidification, ozone depletion (ODP) and eutrophication and human toxicity (HT). The results of this study provide detail information which can be used to reduce the environmental impact of residential buildings in Malaysia and to other locations in the world with similar environment condition.

2 Methodology

This study follows the LCA methodology standardised by ISO 14040 series which include four stages namely goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation (ISO, 2006a, 2006b).

2.1 *Goal and scope definition*

The functional unit selected in this study was 1 m^2 of gross floor area (GFA), and the building lifespan estimated within 50 years. The building type selected was a semi-detached house within a residential development area located in the district of Seri Kembangan, Selangor about 25 km from Kuala Lumpur. The building size is 246 m^2 GFA with five bedrooms, one living room, a dining room, a dry kitchen, a wet kitchen, a family area, a study area and five bathrooms as shown in Fig. 1. The building frame structures are reinforced concrete with clay bricks as the building envelope.

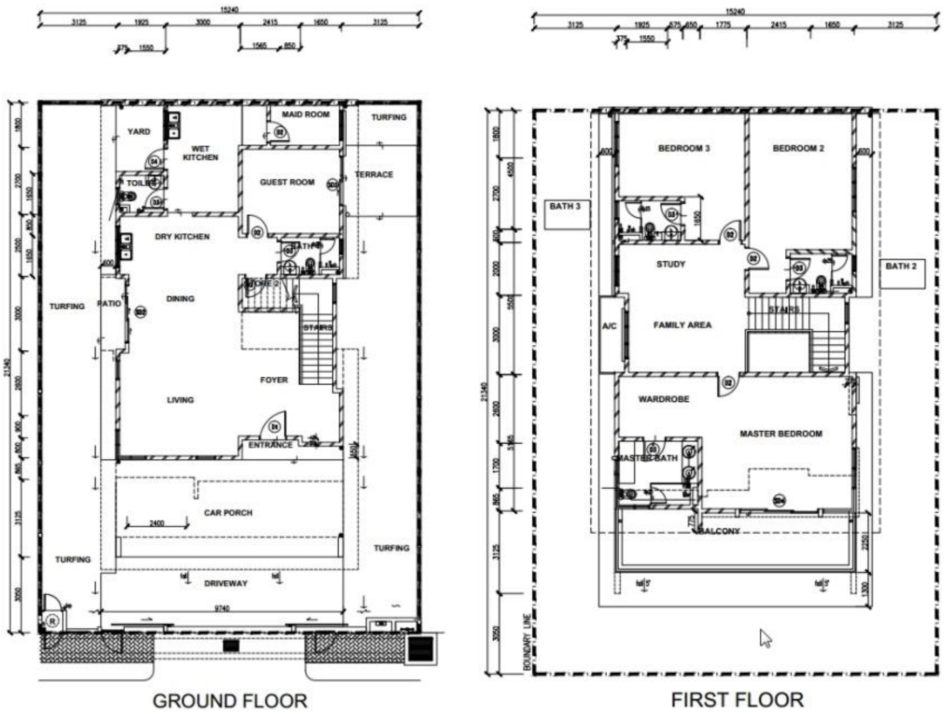

Fig. 1 Floor plans of the house

2.1.1 *System boundaries*

The whole building life cycle was evaluated from cradle-to-grave within specific system boundaries outlined in Fig. 2. The site clearance works, external works and infrastructure works that involved the overall development were excluded which did not represent the case study.

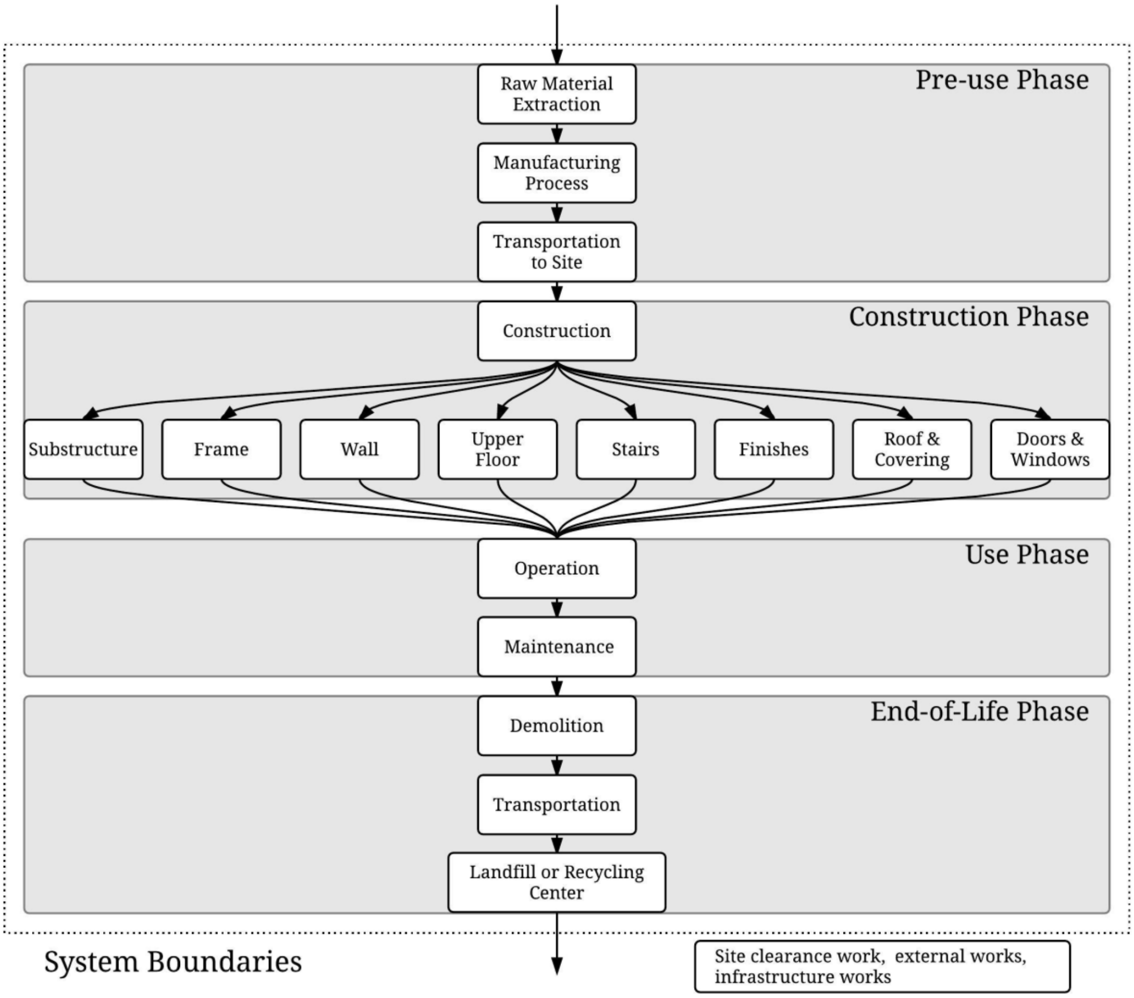

Fig. 2 System boundaries of the life cycle model

The LCA modelling has been carried out in SimaPro V7.3.3 (PRé, 2015). Malaysia Life Cycle Inventory Database (MYLCID) was used in the LCI especially on raw materials such as cement and diesel to produce significant results for Malaysian scenario (MY-LCID, 2013). Due to data limitation, Ecoinvent database was used and adapted to Malaysian conditions by replacing the local electricity mix data set as suggested by Horváth & Szalay (2012).

2.2 Life Cycle Inventory

2.2.1 Pre-use phase

The data for LCI for the pre-use phase is obtained from the bill of quantities. The quantities are then divided into GFA of the building as shown in Table 1. Few assumptions have been considered due to the limitation of the databases as follows:

- An additional of 5% of material waste during construction was added as suggested by previous studies (Buchan et al., 2003; Rossi et al., 2012).
- The types and materials are limited to process data equipped in the databases.
- Acrylic emulsion paint was substituted with alkyd paint due to the limitation in the databases.
- The transportation distances from the manufacturer to the construction site were assumed to be 300 km for all materials, meanwhile the distance is 50 km for ready-mix concrete, as suggested by Wittstock et al. (2012).
- A 16-ton lorry was used to transport materials from manufacturers to site whereas a 24-ton ready-mix lorry was used to transport concretes.

Table 1
LCI of materials in pre-use phase

Item	Materials	Quantity	Quantity/m^2 GFA	Unit
A	**Substructure**			
	Excavation	86.02	0.35	m^3
	Hardcore	15.44	0.06	m^3
	Concrete Grade 7 blinding	21.74	0.09	m^3
	Concrete Grade 25	184.03	0.75	m^3
	Steel Reinforcement	2,561.62	10.41	kg
	Timber Formwork	4.13	0.02	m^3
B	**Frame**			
	Concrete Grade 25	23.20	0.09	m^3
	Steel Reinforcement	3,883.00	15.78	kg
	Timber Formwork	7.69	0.03	m^3
C	**Upper Floor**			
	Concrete Grade 25	28.73	0.12	m^3
	Steel Reinforcement	1,709.62	6.95	kg

Item	Materials	Quantity	Quantity/m^2 GFA	Unit
	Timber Formwork	3.35	0.01	m^3
D	**Stairs**			
	Concrete Grade 25	2.78	0.01	m^3
	Steel Reinforcement	243.00	0.99	kg
	Timber Formwork	1.07	0.00	m^3
E	**Brickwall**			
	Clay brick			
	Half brick thick	381.00	1.55	m^2
	One brick thick	37.14	0.15	m^2
F	**Roof and covering**			
	Fascia board	0.31	0.00	m^3
	Painting	21.61	0.09	m^2
	Timber Roof Trusses	10.65	0.04	m^3
	Clay roof coverings	213.84	0.87	m^2
G	**Finishes**			
	Cement screed	9.47	0.04	m^3
	Ceramic tiles	357.59	1.45	m^2
	Timber strip	116.09	0.47	m^2
	Plasterwork	18.57	0.08	m^3
	Painting	1,229.50	5.00	m^2

2.2.2 Construction phase

Only three construction processes were taken into consideration namely excavation, transportation of the excavator to the construction site and temporary timber formwork. Excavator was used during excavation works meanwhile other installation works were assumed to be completed by manual labours. The transportation of the excavator was considered to be 50 km distance from the construction site using a 40-ton low-loader. The formwork was expected to be used multiple times before disposal as suggested by Abdullah (2005).

2.2.3 Use phase

2.2.3.1 Operation data

The total electricity consumption was estimated about 2,949.78 kWh per m^2 as shown in Table 2. Energy simulation software OpenStudio V1.2.0 (OpenStudio, 2014) with EnergyPlus was used to estimate the annual electricity consumption of air conditioning, illumination and electrical equipment. The Kuala Lumpur weather data for the year 2013 was used as the basis. The air-conditioning system was set at 20.8 degrees Celcius from 10.00 pm to 6.00 am every day in the master bedroom, and two other bedrooms on the first floor based on findings by Kubota et al. (2011). The electricity consumption was assumed to be constant throughout the operation of the house.

Table 2
Estimated electricity consumption during building operation for 50 years lifespan

Elements	Amount (kWh)
Air conditioning	341,236.50
Illumination	119,142.50
Electrical Equipment	265,266
Total	725,645.00
Total/GFA (kWh/m^2)	2,949.78

2.2.3.2 Maintenance data

Maintenance data was estimated based on selected elements such as painting, replacement of roof coverings and also changing of windows as suggested by other studies (Ochsendorf et al., 2011; Ortiz-Rodríguez et al., 2010). The replacement intervals are based on the report by National Association of Home Builders (NAHB) due to data limitations in Malaysia (Iyer-Raniga and Wong, 2012). The replacement interval is shown in Table 3, which includes the productions and transportation of selected building materials.

Table 3
Replacement interval of selected building elements in maintenance phase

Elements	Expected Lifespan	Number of replacement in 50 years
Painting	10 years	4 times
Roof covering	25 years	1 times
Window	30 years	1 times

2.2.4 EOL phase

EOL phase was incorporated into the LCA studies due to the ability of recycling potential of building materials, which reduced the embodied energy (Blengini and Di Carlo, 2010). In Malaysia, only steel and aluminium were recycled whereas other materials are transported to the landfill as suggested by Arham (2008). Recycled of aluminium and steel scrap were used as the raw material instead of iron and aluminium ore to reduce environmental impact as suggested by SimaPro (2015). The transportation distances from the construction site to landfill and recycling centre were assumed to be 300 km.

2.3 Life cycle impact assessment (LCIA)

Only five common impact categories were used in this study for midpoints assessment using CML 2001 namely, global warming potential (GWP), acidification, ozone depletion (ODP) and eutrophication and human toxicity (HT) impact categories as suggested by Khasreen et al. (2009).

2.4 Interpretation

LCIA will be interpreted according to the goal and scope of the study that shall include an assessment and a sensitivity check of the significant inputs, outputs (ISO, 2006b). The findings later will be validated by comparing it to other published studies (Ochsendorf et al., 2011).

3 Results and discussion

3.1 Overview of the results

Table 4 shows the result of the total LCIA. The operation phase within the building life cycle has the highest impact on GWP and acidification compared to other phases due to fossil fuel used in the electricity generation mix in Malaysia. The pre-use phase has the highest impact on ODP and HT compared to other phases mainly contributed by materials and processes in the production of wall (6.28E-06 kg CFC-11 eq) and windows (8.66E+01 kg 1,4-DB eq) respectively. The construction phase has the lowest overall environmental impact which similar to previous studies (Blengini and Di Carlo, 2010; Ochsendorf et al., 2011; Rossi et al., 2012). EOL has the highest impact in eutrophication compared with other phases with 8.93E-01 kg PO4-eq which contributed by disposal of clay bricks to landfill. The maintenance phase has a lower impact in comparison to pre-use phase due to limited quantity of materials used.

Table 4

LCIA result based on building phases

Impact category	**Unit**	**Total**	**Pre-use**	**Construction**	**Maintenance**	**Operations**	**End of Life**
Acidification	kg SO2 eq	1.51E+01	3.23E+00	1.74E-02	4.09E-01	1.10E+01	4.62E-01
Eutrophication	kg PO4 eq	3.81E+00	6.19E-01	5.04E-03	1.49E-01	1.12E+00	1.92E+00
Global warming (GWP100)	kg CO2 eq	3.72E+03	8.25E+02	3.29E+00	9.19E+01	2.41E+03	3.89E+02
Ozone layer depletion (ODP)	kg CFC-11 eq	3.77E-05	2.39E-05	2.03E-07	9.42E-06	1.31E-07	4.05E-06
Human toxicity (HT)	kg 1,4-DB eq	7.77E+02	2.94E+02	1.56E+00	1.06E+02	2.36E+02	1.39E+02

Table **5** shows the environmental impact of every element in pre-use phase. The substructure has the highest impact of acidification, eutrophication and GWP largely contributed due to the substantial quantity of cement in concrete based building elements which account for 77%, 53%, 81% respectively. The stair has the lowest overall impact due to small quantities of material use per GFA.

Table 5

LCIA in pre-use phase based on building elements.

Impact category	**Unit**	**Sub-structure**	**Frame**	**Wall**	**Upper floor**	**Stairs**	**Finishes**	**Roof & covering**	**Door**	**Window**
Acidification	kg SO2 eq	1.47E+00	2.10E-01	3.31E-01	2.12E-01	2.24E-02	4.17E-01	6.99E-02	8.44E-02	1.53E-01
Eutrophication	kg PO4-eq	2.12E-01	5.00E-02	7.39E-02	2.80E-02	4.36E-03	9.13E-02	1.70E-02	3.31E-02	6.55E-02
Global warming (GWP100)	kg CO2 eq	3.48E+02	5.14E+01	1.09E+02	5.02E+01	5.41E+00	1.16E+02	2.05E+01	2.00E+01	4.01E+01

Ozone layer depletion (ODP)	kg CFC-11 eq	3.48E-06	1.07E-06	5.98E-06	4.16E-07	8.50E-08	4.96E-06	1.21E-06	1.68E-06	3.61E-06
Human toxicity	kg 1,4-DB eq	7.39E+01	1.66E+01	1.73E+01	9.96E+00	1.47E+00	3.26E+01	4.81E+00	3.51E+01	8.25E+01

During the maintenance phase, painting and aluminium frame window have been identified as the highest environmental impact contributors. Painting has the largest impact on acidification, eutrophication and ODP meanwhile, the aluminium frame window has the highest impact on GWP and HT as shown in Table 6.

Table 6
LCIA in maintenance phase

Impact category	**Unit**	**Aluminium window**	**Clay roof tiles**	**Painting**
Acidification	kg SO2 eq	1.61E-01	3.54E-02	2.13E-01
Eutrophication	kg PO4-eq	6.88E-02	5.20E-03	7.52E-02
Global warming (GWP100)	kg CO2 eq	4.21E+01	1.46E+01	3.53E+01
Ozone layer depletion (ODP)	kg CFC-11 eq	3.79E-06	8.13E-07	4.81E-06
Human toxicity (HT)	kg 1,4-DB eq	8.66E+01	1.87E+00	1.78E+01

The environmental impact during EOL phase has the highest level of eutrophication with relatively high GWP. Table 7 shows the LCIA of transportation to the landfill and disposal of building materials. The impact of disposal of clay bricks was the highest in all impact categories followed by cement based products.

Table 7
LCIA in EOL phase based on building materials

Impact category	**Unit**	**Baseplaster**	**Cement Screed**	**Ceramic Tiles**	**Clay Roof Tiles**	**Concrete Blinding**
Acidification	kg SO2 eq	1.51.E-02	7.79.E-03	8.99.E-03	9.14.E-03	1.33.E-02
Eutrophication	kg PO4 eq	3.04.E-01	1.58.E-01	1.82.E-01	1.82.E-01	3.57.E-03
Global warming (GWP100)	kg CO2 eq	5.44.E+01	2.81.E+01	3.24.E+01	3.25.E+01	2.60.E+00
Ozone layer depletion (ODP)	kg CFC 11 eq	4.12.E-07	2.13.E-07	2.46.E-07	2.47.E-07	1.13.E-07
Human toxicity	kg 1,4 DB eq	2.16.E+01	1.12.E+01	1.29.E+01	1.29.E+01	5.37.E-01

Impact category	Unit	Concrete G25	Door Single Glaze	Aluminium Door	Timber Door	Formwork
Acidification	kg SO2 eq	1.60.E-01	4.78.E-08	4.76.E-06	1.76.E-07	3.90.E-05
Eutrophication	kg PO4 eq	4.31.E-02	1.28.E-08	1.15.E-06	4.73.E-08	1.05.E-05
Global warming (GWP100)	kg CO2 eq	3.14.E+01	9.37.E-06	8.52.E-04	3.45.E-05	7.65.E-03
Ozone layer depletion (ODP)	kg CFC 11 eq	1.36.E-06	4.06.E-13	1.31.E-10	1.49.E-12	3.31.E-10
Human toxicity	kg 1,4 DB eq	6.48.E+00	1.93.E-06	2.04.E-04	7.11.E-06	1.58.E-03

Impact category	Unit	Clay Brick	Painting	Timber Product	Timber Strip	Aluminium Window
Acidification	kg SO2 eq	2.08.E-01	1.75.E-03	1.63.E-03	2.69.E-03	2.63.E-05
Eutrophication	kg PO4 eq	8.93.E-01	6.12.E-02	4.37.E-04	6.41.E-04	6.35.E-06
Global warming (GWP100)	kg CO2 eq	1.84.E+02	1.45.E+00	3.19.E-01	5.15.E-01	4.71.E-03
Ozone layer depletion (ODP)	kg CFC 11 eq	1.21.E-06	4.73.E-08	1.38.E-08	1.13.E-09	7.24.E-10
Human toxicity	kg 1,4 DB eq	6.16.E+01	4.98.E+00	6.58.E-02	1.94.E-02	1.13.E-03

3.2 Process contribution analysis

3.2.1 Impact of materials

Contribution analysis process has been carried out to identify materials or processes that produce the highest impact on the environment. In pre-use phase, the substructure has been identified as the largest impact for acidification, eutrophication and GWP. Concrete was dominant in every impact category as shown in Table 8. In the production of concrete, cement has been identified as the highest contributor, followed by transportation of concrete to site as shown in Table 9.

Table 8
Process contribution of LCIA of substructure

Impact category	Unit	Hardcore (crushed stone)	Concrete	Steel Reinforcement
Acidification	kg SO2 eq	2.44.E-03	1.44.E+00	2.62.E-02
Eutrophication	kg PO4 eq	8.61.E-04	1.93.E-01	1.81.E-02
Global warming Potential (GWP100)	kg CO2 eq	4.32.E-01	3.40.E+02	7.28.E+00
Ozone layer depletion (ODP)	kg CFC-11 eq	4.09.E-08	2.96.E-06	4.84.E-07

Human toxicity	kg 1,4-DB eq	3.97.E-01	6.79.E+01	5.67.E+00

Table 9

Process contribution analysis of LCIA of concrete in selected impact categories

Impact category	Unit	Total	Cement		Transportation of concrete		Remaining process	
Acidification	kg SO2 eq	1.47.E+00	1.13.E+00	(77%)	1.74.E-01	(12%)	1.66.E-01	(11%)
Eutrophication	kg PO4 eq	2.12.E-01	1.11.E-01	(52%)	4.48.E-02	(21%)	5.62.E-02	(27%)
Global warming potential (GWP100)	kg CO2 eq	3.48.E+02	2.82.E+02	(81%)	3.40.E+01	(10%)	3.20.E+01	(9%)

In comparison to other building elements, wall contributed the highest ODP mainly from transportation of natural gas with 3.24E-06 kg CFC-11 eq (54%) and crude oil productions with 2.47E-06 kg CFC-11 eq (41%). Windows contributed the highest HT from chromium oxides flakes with 5.20E+01 kg 1,4-DB eq (60%) used in the production of aluminium windows.

3.2.2 Impact of recycling potential

Only steel and aluminium were considered to measure the recycling potential impact. A comparison analysis of two data processes were conducted between recycle and normal production of 1 kg of steel reinforcement and 1 m^2 of the aluminium window frame. The reduction of LCIA was very significant in both building materials as shown in Table 10, especially to acidification and GWP in steel and almost all impact categories in aluminium.

Table 10

Estimated reduction of LCIA by recycling of steel and aluminium

Impact category	Unit	Steel Reinforcement (1 kg)				Aluminium Window Frame (1 m^2)			
		Recycle	Normal	Reduction		Recycle	Normal	Reduction	
Acidification	kg SO2 eq	2.12.E-03	5.09.E-03	2.97.E-03	58%	7.63.E-01	2.09.E+00	1.32.E+00	63%
Eutrophication	kg PO4--- eq	1.64.E-03	3.18.E-03	1.54.E-03	48%	3.28.E-01	7.90.E-01	4.62.E-01	58%
Global warming (GWP100)	kg CO2 eq	6.22.E-01	1.47.E+00	8.51.E-01	58%	2.01.E+02	4.77.E+02	2.76.E+02	58%
Ozone layer depletion (ODP)	kg CFC-11 eq	4.31.E-08	5.59.E-08	1.28.E-08	23%	1.81.E-05	3.35.E-05	1.54.E-05	46%
Human toxicity	kg 1,4-DB eq	5.29.E-01	8.68.E-01	3.40.E-01	39%	4.14.E+02	1.92.E+03	1.51.E+03	78%

3.3 Sensitivity analysis

This step had been conducted to determine the influence of assumption in this study specifically on the transportation distances. The predetermined distances were 50 km for concrete and 300 km for other materials. The standard deviation of ±20% is allocated for transportation distance as suggested by Wen et al. (2014). Substructure element was used as base case scenarios as it has the largest impact. The result shows that the transportation distances were not give a significant impact overall with the maximum effect of 8.78% in ODP while other impact categories were below 6% variances as shown in Table 11.

Table 11

LCIA with ±20% standard deviation for transportation distance for substructure

Impact category	Unit	Percentage
Acidification	kg SO2 eq	3.06%
Eutrophication	kg PO4 eq	5.51%
Global warming (GWP100)	kg CO2 eq	2.54%
Ozone layer depletion (ODP)	kg CFC-11 eq	8.78%
Human toxicity	kg 1,4-DB eq	1.85%

3.4 Comparison with other studies

Since no full LCA studies for Malaysian residential building available, therefore detail comparison is not possible. The comparison of selected impact categories at different type of residential building with other studies as shown in Table 12. The GWP of this study was 8.02E+02 kg CO_2 eq while the flat was much lower at 3.44+E02 kg CO_2 eq and 2.98.E+02 kg CO_2 eq. The ratio of certain elements such as roof, wall, floor and ceiling were shared between multiple units which reduced the impact per m^2 GFA. The specification and the quantity per m^2 also contributed to the difference, for example, detail specification of the brick used in the 4-storey flat were not explicitly mentioned. In general, a low to medium cost houses uses cheaper cement-based brick which also has lower energy used in production in comparison to clay bricks which influenced the overall GWP (Utama and Gheewala, 2008).

Table 12

Comparison of selected impact categories at different type of residential building with other studies

	Impact categories					
Building	**Global warming (GWP100) Cradle-to-gate (kg CO2 eq)**	**Global warming (GWP100) Cradle-to-grave (kg CO2 eq)**	**Acidification (kg SO2 eq)**	**Ozone layer depletion (ODP) (kg CFC-11 eq)**	**Human toxicity (HT) (kg 1,4-DB eq)**	**References**
Flat (cast in situ)	3.44.E+02	-	-	-	-	Wen et al. (2014)
Flat (IBS)	2.98.E+02	-	-	-	-	Wen et al. (2014)
Semi-detached house	-	3.50.E+03	-	-	-	Cuéllar-Franca and Azapagic (2012)
Semi-detached house	-	2.43.E+03	1.85.E+01	1.17.E-04	7.18.E+02	Ortiz et al. (2009)
Semi-detached house	8.02.E+02	3.72.E+03	1.51.E+01	3.77.E-05	7.77.E+02	This study

The comparison of GWP impact category for cradle-to-grave between 2 semi-detached houses is relatively comparable. Since the larger share of GWP is from use phase, the method used in determining the energy consumptions, climates and impact from electricity generation in different countries contributed to the variation in the results. The results for acidification and HT were also primarily contributed by the use phase for both buildings. However, the ODP for this study was lower in comparison to other building and largely contributed by the pre-use phase rather than the use phase.

4 Conclusion

The operation during the use phase of the semi-detached house in Malaysia produced the highest GWP and acidification. In pre-use phase concrete in the substructure was the largest contributor to the overall impact with cement as the primary raw material. In the maintenance phase, painting has the highest impact on acidification, eutrophication and ODP, while aluminium window frame has the highest impact on GWP and HT. In EOL, material such as clay brick and concrete has been identified as the largest impact on landfill. The recycling potential of steel and aluminium shows a massive reduction in all impact categories. The results in this study showed that the residential building in Malaysia produced higher impact in GWP and HT and lower in acidification and ODP in compared to other studies. The findings from this study can help policymakers and building professionals to assess the environmental impact of building materials of complete life cycle in Malaysia or other countries in the world with similar environment condition.