Embodied Energy and Embodied Carbon of Low Income Houses in Thailand

Research Programme on Reducing Energy Consumption Cost and GHG Emission for Tropical Low-income Housing: Thailand Contribution

Submitted to

WARWICK UNIVERSITY

By

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July-September 2015

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CHAPTER 1
INTRODUCTION

This report is a part of a quarter report for a period of September 2015 of ELITH-Thailand. The past report presented alternative building models, their BOQ, embedded energy, and GHG emissions of the rest of the houses found during the surveys to illustrate the change, and the impact on energy use and GHG emissions. The representative houses of each region were selected based on designs of existing and near future house which are mostly concrete houses. This report presents embodied energy and embodied carbon of the houses found during the surveys to illustrate the change, and the impact on energy use and GHG emissions.

Chapter 1 of this report presents on introduction of this report. Background and significance of this report are described.

Chapter 2 shows embodied energy and embodied carbon of single detached houses of each region. The results are addition to the past progress report to illustrate the change, and the impact on embodied energy and embodied carbon of housing design and material use.

CHAPTER 2
EMBODIED ENERGY AND EMBODIED CARBON

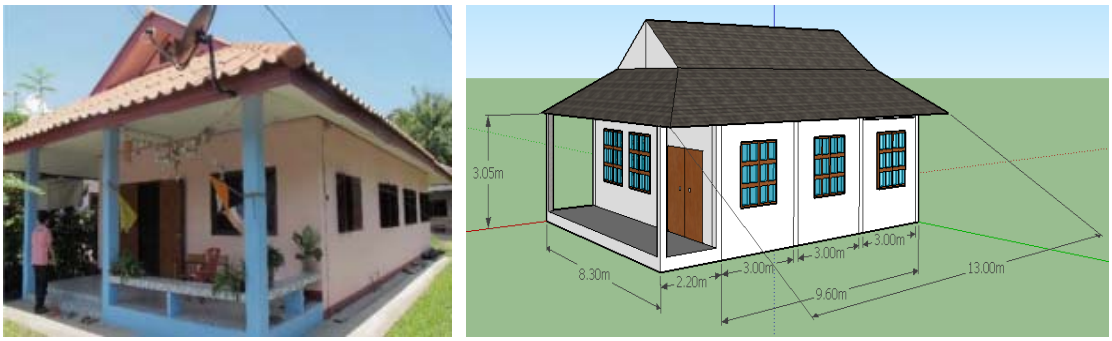
This Chapter presents Embodied energy and Embodied carbon of single detached houses of houses found during the surveys of each region. The results are addition to the past progress report to illustrate the change, and the impact on Embodied energy and Embodied carbon of housing design and material use.

2.1 Sample houses of northern region

As mentioned in the past progress report, There are 3 housing designs of Northern Thailand found in the surveys; (1) house constructed by concrete, (2) wooden house, and (3) house constructed by combination of concrete and wood. In the past progress report, only GHG emission data of the house. This report presents the Embodied energy and Embodied carbon of the housing design.

House constructed by concrete

The plot area of the house is 11.80 x 8.30 m. The height of the floor is 3.05 m. The ground floor comprises multi-function room, restroom and there are two or three bedrooms. Kitchen, cloth washing area and bathroom are at the backside of the house. They use common, affordable and durable materials for their houses. Roofing materials are roof tile. Ceilings are made from fiber cement panels. Walls are constructed from concrete block as shown in Figure 2.1.



a) Real house b) Building model

Figure 2.1 House constructed by concrete of Northern Thailand.

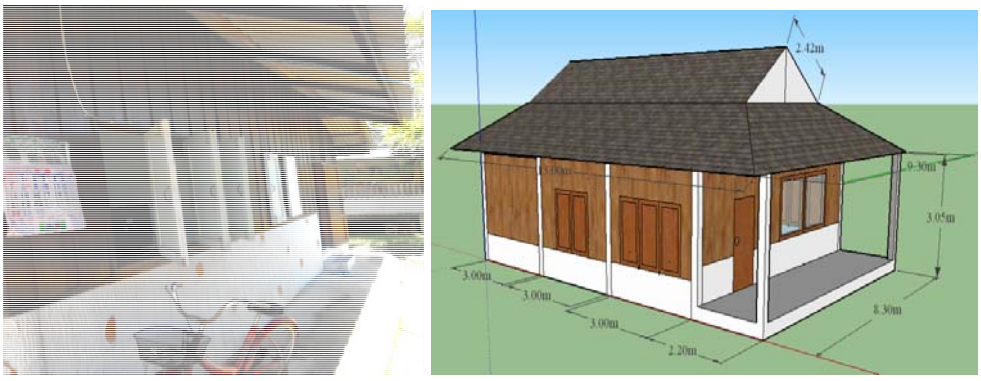
Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.1. The results show that this type of house Embodied energy of 127,172 MJ or 1,298 MJ/m^2 and Embodied carbon of 14,410 kgCO_2eq or 147 kgCO_2eq/m^2 which is higher than the wooden house, and house constructed by combination of concrete and wood.

Table 2.1 Embodied energy and Embodied carbon of materials of house constructed by concrete and wood of Northern Thailand.

Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	kgCO$_2$eq/kg	kgCO$_2$eq	kgCO$_2$eq/m^2
Foundation and structure	Sand	864	0.081	70	1	0.0051	4	0.04
	Concrete	35,314	0.75	26486	270	0.107	3779	39
	Steel	796	20.1	15996	163	1.46	1162	12
Roof	Roof Tiles	2,104	12	25247	258	0.78	1641	17
	Fiber Cement panels	32	10.4	329	3	1.09	35	0.4
Ceiling	Fiber Cement panels	736	10.4	7657	78	1.09	803	8
Wall	Cement	5,503	4.5	24764	253	0.74	4072	42
Concrete block	Cement	929	4.5	4179	43	0.74	687	7
	Concrete	11,626	0.75	8719	89	0.107	1244	13
	Sand	6,608	0.081	535	5	0.0051	34	0.3
	Lime	532	5.3	2822	29	0.78	415	4
Doors and windows	Glass	881	11.5	10135	103	0.59	520	5
	Hardwood	22 (ft^3)	10.4	233	2	0.67	15	0.2
Total				127172	1298		14410	147

House constructed by concrete and wood

This feature of house was renovated from 2-storey wooden house to comply with their current living style of people in Northern Thailand. The family size is smaller and only elderly people are left to live alone in local area. The 2-storey house is not comfortable for them to climb up therefore the house was renovated to be a single storey. This housing feature is found around 20% of the samples and all of them are over 20 years old. Combination of the use of concrete wall and wooden wall are applied for this type of house as shown in Figure 2.2. Wall section below windows is constructed by concrete and upper part is constructed by wood (from the original house).



a) Real house b) Building model

Figure 2.2 House constructed by concrete and wood of Northern Thailand.

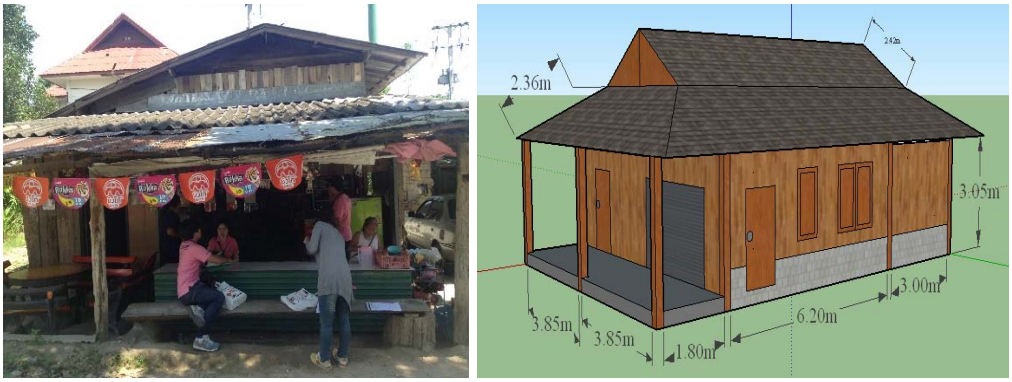
Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.2. The results show that this type of house Embodied energy of 101,921 MJ or 1,092 MJ/m^2 and Embodied carbon of 9,924 kgCO$_2$eq or 106 kgCO$_2$eq/m^2 which is lower than the concrete house because more than 50% of this house is constructed by wood.

Table 2.2 Embodied energy and Embodied carbon of materials of house constructed by concrete and wood of Northern Thailand.

Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	kgCO$_2$eq/kg	kgCO$_2$eq	kgCO$_2$eq/m^2
Foundation and structure	Sand	864	0.081	70	1	0.0051	4	0.05
	Concrete	40,411	0.75	30308	325	0.107	4,324	46
	Steel	852	20.1	17129	184	1.46	1,244	13
Roof	Roof Tiles	2,104	12	25247	271	0.78	1,641	18
	Fiber Cement panels	32	10.4	329	4	1.09	35	0.4
Ceiling	Fiber Cement panels	736	10.4	7657	82	1.09	803	9
Wall	Cement	986	4.5	4435	48	0.74	729	8
Concrete block	Cement	166	4.5	748	8	0.74	123	1
	Concrete	2,082	0.75	1562	17	0.107	223	2
	Sand	1,184	0.081	96	1	0.0051	6	0.1
	Lime	95	5.3	505	5	0.78	74	1
	Hardwood	30(ft^3)	10.4	308	3	0.67	20	0.2
Doors and windows	Glass	1,149	11.5	13216	142	0.59	678	7
	Hardwood	30(ft^3)	10.4	310	3	0.67	20	0.2
Total				101921	1092		9924	106

Wooden house

The last housing feature in Northern Thailand is wooden houses as shown in Figure 2.3. The house was also renovated from 2-storey wooden house to comply with their current living style. The house constructed by using wood from the original house. . This housing feature is found around 20% of the samples and all of them are over 20 years old.



a) Real house b) Building model

Figure 2.3 Wooden house of Northern Thailand.

Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.3. Embodied energy of 69,815 MJ or 713 MJ/m^2 and Embodied carbon of 6,583 kgCO$_2$ eq or 67 kgCO$_2$ eq/m^2 which is lower than the concrete house and the house constructed by concrete and wood.

Table 2.3 Embodied energy and Embodied carbon of materials of wooden house of Northern Thailand.

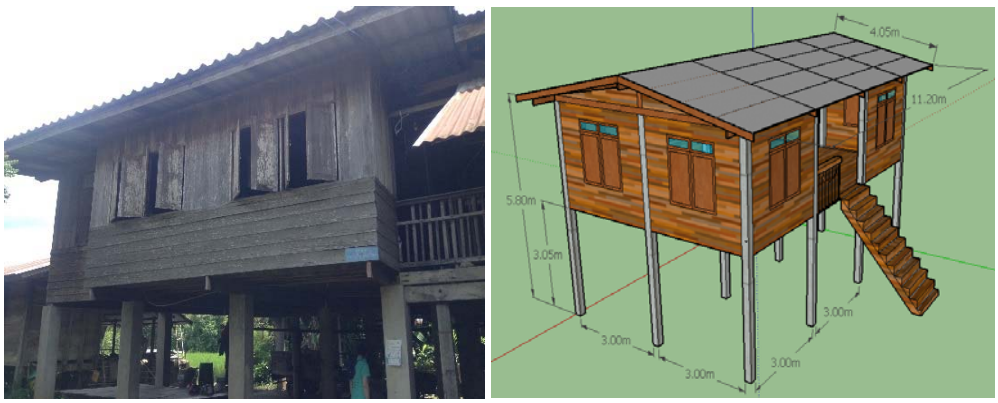
Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	kgCO$_2$eq/kg	kgCO$_2$eq	kgCO$_2$eq/m^2
Foundation and structure	Sand	864	0.081	70	1	0.0051	4	0.04
	Concrete	29,509	0.75	22132	226	0.107	3157	32
	Steel	852	20.1	17129	175	1.46	1244	13
	Hardwood	162(ft^3)	10.4	1682	17	0.67	108	1
Roof	Roof Tiles	2,182	12	26183	267	0.78	1702	17
Concrete block	Cement	138	4.5	619	6	0.74	102	1
	Concrete	1,722	0.75	1292	13	0.107	184	2
	Sand	976	0.081	79	1	0.0051	5	0.1
	Lime	79	5.3	418	4	0.78	62	1
	Hardwood	4(ft^3)	10.4	37	0	0.67	2	0.02
Doors and windows	Hardwood	17(ft^3)	10.4	175	2	0.67	11	0.1
Total				69815	713		6583	67

2.2 Sample houses of northeastern region

As mentioned in the past progress report, There are 2 housing designs of Northeastern Thailand found in the surveys; (1) wooden house, and (2) house constructed by combination of concrete and wood. In the past progress report, only GHG emission data of the house constructed by combination of concrete and wood which was selected to be representative house was presented. This report presents the Embodied energy and Embodied carbon of the rest housing design.

Wooden house

Figure 2.4 shows housing feature of wooden house of Northeastern Thailand. This feature of house is original style of house constructed by combination of concrete and wood before adding concrete walls on the first floor. The reason of adding concrete walls is to be living room and bedroom for the elderly people who have difficulty on climbing up (living style of people is quite similar to Northern region). This housing feature is still found around 10% of the samples and all of them are over 40 years old.



a) Real house b) Building model

Figure 2.4 Wooden house of Northeastern Thailand.

Bill of Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.4. Embodied energy of 52,961 MJ or 447 MJ/m^2 and Embodied carbon of 4,220 $kgCO_2eq$ or 36 $kgCO_2eq/m^2$ which is lower than the house constructed by combination of concrete and wood.

Table 2.4 Embodied energy and Embodied carbon of materials of wooden house of Northeastern Thailand.

Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	$kgCO_2eq/kg$	$kgCO_2eq$	$kgCO_2eq/m^2$
Foundation and structure	Sand	864	0.081	70	1	0.0051	4	0.04
	Concrete	6,992	0.75	5,244	44	0.107	748	6
	Steel	143	20.1	2,874	24	1.46	209	2
	Hardwood	154(ft^3)	10.4	1,597	13	0.67	103	1
Roof	Galvanized iron	1,104	22.6	24,950	211	1.54	1,700	14
Floor	Hardwood	79(ft^3)	10.4	821	7	0.67	53	0.4
Ceiling	Cement	986	4.5	4,435	37	0.74	729	6
Wall	Hardwood	30(ft^3)	10.4	311	3	0.67	20	0.2
Doors and windows	Glass	1,072	11.5	12,331	104	0.59	633	5
	Hardwood	31(ft^3)	10.4	327	3	0.67	21	0.2
Total				52,961	447		4,220	36

House constructed by concrete and wood

All houses of the samples are over 20 years old and most of them are Inheritances from their ancestor, this is why main wall materials are still wood although currently it is very expensive but after changing of living styles such as migrations of people to municipal areas cause smaller family sizes and leaving the elderly alone with children, the housing features were renovated by adding concrete walls of the downstairs as in Figure 3.6 to be easier for the elderly who is difficult to climb up and down the houses. For new houses, a single storey houses with concrete walls as increased as same as in the northern region due to cheaper and faster constructions.

a) Real house b) Building model

Figure 2.5 House constructed by concrete and wood of Northern Thailand.

Bill of Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.5. Embodied energy of 89,135 MJ or 595 MJ/m^2 and Embodied carbon of 9,338 $kgCO_2eq$ or 62 $kgCO_2eq/m^2$ which is higher than the wooden house.

Table 2.5 Embodied energy and Embodied carbon of materials of House constructed by concrete and wood of Northeastern Thailand.

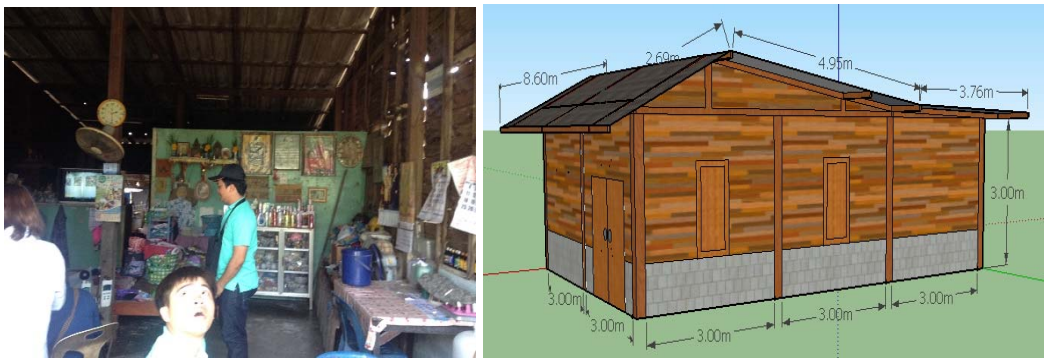
Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	kgCO$_2$eq/kg	kgCO$_2$eq	kgCO$_2$eq/m^2
Foundation and structure	Sand	864	0.081	70	0.5	0.0051	4	0.03
	Concrete	27,117	0.75	20,338	136	0.107	2,902	19
	Steel	273	20.1	5,478	37	1.46	398	3
Roof	Galvanized steel sheet	1,104	22.6	24,950	167	1.54	1,700	11
Ceiling	Cement	2,946	4.5	13,255	88	0.74	2,180	15
Concrete block	Cement	497	4.5	2,237	15	0.74	368	2
	Concrete	6,223	0.75	4,667	31	0.107	666	4
	Sand	3,536	0.081	286	2	0.0051	18	0.1
	Lime	285	5.3	1,510	10	0.78	222	1
	Hardwood	309(ft^3)	10.4	3,209	21	0.67	207	1
Doors and windows	Glass	1,142	11.5	13,134	88	0.59	674	4
Total				89,135	595		9,338	62

2.3 Sample houses of southern region

As mentioned in the past progress report, There are 3 housing designs of Southern Thailand found in the surveys; (1) 1-storey wooden house, (2) 1-storey concrete house, and (3) 2-storey concrete house. In the past progress report, only GHG emission data of the 1-storey concrete house which was selected to be representative house was presented. This report presents the Embodied energy and Embodied carbon of the rest housing design.

1-storey wooden house

The last housing feature in Southern Thailand is 1-storey wooden houses as shown in Figure 2.6. This feature of house is original style of 1-storey concrete house before changing wall materials to be concrete walls. This housing feature is still found around 10% of the samples and all of them are over 20 years old.



a) Real house b) Building model

Figure 2.6 1-storey wooden house of Southern Thailand.

Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.6. The results show that this type of house Embodied energy of 37,069 MJ or 573

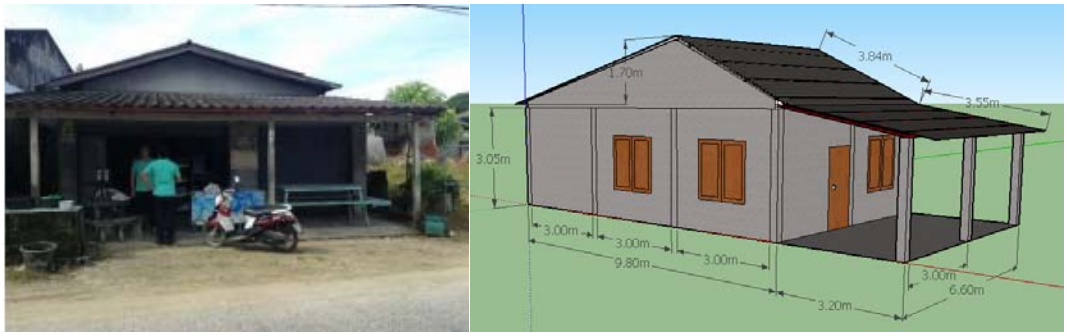
MJ/m^2 and Embodied carbon of 4,519 $kgCO_2eq$ or 70 $kgCO_2eq/m^2$ which is lower than the 1-storey concrete house and 2-storey concrete house.

Table 2.6 Embodied energy and Embodied carbon of materials of 1-storey wooden house of Southern Thailand.

Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	$kgCO_2eq/kg$	$kgCO_2eq$	$kgCO_2eq/m^2$
Foundation and structure	Sand	864	0.081	70	1	0.0051	4	0.1
	Concrete	20,939	0.75	15704	243	0.107	2,240	35
	Steel	238	20.1	4793	74	1.46	348	5
	Hardwood	139(ft^3)	10.4	1448	22	0.67	93	1
Roof	Fiber Cement panels	623	10.4	6482	100	1.09	679	11
Ceiling	Cement	896	4.5	4032	62	0.74	663	10
Concrete block	Cement	151	4.5	680	11	0.74	112	2
	Concrete	1,893	0.75	1420	22	0.107	203	3
	Sand	1,072	0.081	87	1	0.0051	5	0.1
	Lime	87	5.3	459	7	0.78	68	1
	Hardwood	35(ft^3)	10.4	361	6	0.67	23	0.4
Doors and windows	Galvanized iron	126	11.5	1451	22	0.59	74	1
	Hardwood	8(ft^3)	10.4	82	1	0.67	5	0.1
Total				37,069	573		4,519	70

1-storey concrete house

The survey results found that 1-storey house is the most popular house style in the region. The house structure needs to be strong and withstand the weather. Most houses are built from concrete block, cement and steel. Windows and doors are made from hardwood. The low slope roofing with steel structure, generally made from roof tiles, is designed to reduce the storm impacts. Due to hot and humid weather, the house has no ceiling because the people needs more space for good ventilation. The partitions are used to separate a bed room out from multipurpose area. During day time, the terrace is also utilized as a living space because the outside temperature is much lower than the temperature inside the house.



a) Real house b) Building model

Figure 2.7 1-storey concrete house of Southern Thailand.

Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.7. The results show that this type of house Embodied energy of 84,911 MJ or 909

MJ/m^2 and Embodied carbon of 10,197 $kgCO_2eq$ or 119 $kgCO_2eq/m^2$ which is lower than the 2-storey concrete house.

Table 2.7 Embodied energy and Embodied carbon of materials of 1-storey concrete house of Southern Thailand.

Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	$kgCO_2eq/kg$	$kgCO_2eq$	$kgCO_2eq/m^2$
Foundation and structure	Sand	800	0.081	65	1	0.0051	4	0.05
	Concrete	23874	0.75	17906	209	0.107	2,555	30
	Steel	761	20.1	15297	178	1.46	1,111	13
Roof	Roof Tiles	1414	12	16972	198	0.78	1,103	13
Ceiling	Cement	4609	4.5	20740	242	0.74	3,411	40
Concrete block	Cement	778	4.5	3500	41	0.74	576	7
	Concrete	9736	0.75	7302	85	0.107	1,042	12
	Sand	5536	0.081	448	5	0.0051	28	0.3
	Lime	446	5.3	2363	28	0.78	348	4
Doors and windows	Hardwood	31(ft^3)	10.4	318	4	0.67	20	0.2
Total				84911	990		10197	119

2-storey concrete house

Figure 2.8 shows housing feature of 2-storey concrete house of Southern Thailand. This feature of house is mostly built for higher income earners of Southern Thailand. This housing feature is found around 20% of the samples and all of them are between 5-10 years old.

a) Real house b) Building model

Figure 2.8 2-storey concrete house of Southern Thailand.

Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.8. The results show that this type of house Embodied energy of 88,553 MJ or 628 MJ/m^2 and Embodied carbon of 11,448 $kgCO_2eq$ or 81 $kgCO_2eq/m^2$ which is higher than the 1-storey concrete house

Table 2.8 Embodied energy and Embodied carbon of materials of 2-storey concrete house of Southern Thailand.

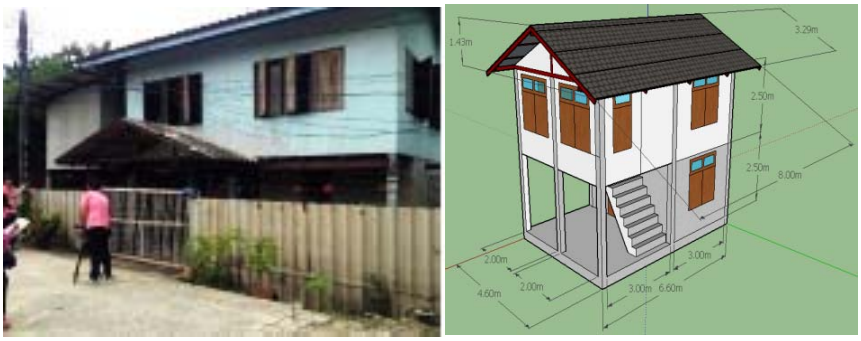
Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	kgCO$_2$eq/kg	kgCO$_2$eq	kgCO$_2$eq/m^2
Foundation and structure	Sand	864	0.081	70	0	0.0051	4	0.03
	Concrete	13064	0.75	9798	69	0.107	1398	10
	Steel	888	20.1	17840	126	1.46	1296	9
Roof	Fiber Cement panels	497	10.4	5171	37	1.09	542	4
Ceiling	Cement	6721	4.5	30244	214	0.74	4973	35
Concrete block	Cement	1134	4.5	5104	36	0.74	839	6
	Concrete	14198	0.75	10648	75	0.107	1519	11
	Sand	8064	0.081	653	5	0.0051	41	0.3
	Lime	650	5.3	3446	24	0.78	507	4
Doors and windows	Glass	280	11.5	3222	23	0.59	165	1
	Galvanized iron	80	22.6	1808	13	1.54	123	1
	Steel	26	20.1	523	4	1.46	38	0.3
	Hardwood	3(ft^3)	10.4	27	0	0.67	2	0.01
Total				88553	628		11448	81

2.4 Sample houses of central region

As mentioned in the past progress report, There are 3 housing designs of Central Thailand found in the surveys; (1) 1-storey concrete house, (2) 1-storey house constructed by zinc sheet, and (3) 2-storey house constructed with concrete and wood. In the past progress report, only GHG emission data of the 1-storey concrete house which was selected to be representative house was presented. This report presents the Embodied energy and Embodied carbon of the rest housing design.

1-storey concrete house

Central region in Thailand is located in a river basin area. In the past, most people lived nearby riversides. Agriculture was major economic sector in this region. Nowadays the population density in central area has been increasing due to the urbanization. The inland communities have been populated and industry has become more important economic sector than agriculture. This life style has an effect on their house designs. Most low-income houses along the riverside are two-storey detached houses, which the design is adapted to the intertidal environment and flooding. While the inland houses are one-storey detached houses. The details of each house are explained as follows.



a) Real house b) Building model

Figure 2.10 1-storey concrete house of Central Thailand

Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.9. The results show that this type of house Embodied energy of 46,507 MJ or 766 MJ/m^2 and Embodied carbon of 4,614 kgCO_2eq or 76 kgCO_2eq /m^2 which is lower than the 1-storey house constructed by zinc sheet and 2-storey house constructed by concrete and wood.

Table 2.9 Embodied energy and Embodied carbon of materials of 1-storey concrete house of Central Thailand.

Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	kgCO_2eq/kg	kgCO_2eq	kgCO_2eq/m^2
Foundation and structure	Sand	800	0.081	65	1	0.0051	4	0.1
	Concrete	11132	0.75	8349	138	0.107	1191	20
	Steel	761	20.1	15297	252	1.46	1111	18
Roof	Roof Tiles	772	12	9259	152	0.78	602	10
Ceiling	Cement	1089	4.5	4901	81	0.74	806	13
Concrete block	Cement	184	4.5	827	14	0.74	136	2
	Concrete	2301	0.75	1726	28	0.107	246	4
	Sand	1312	0.081	106	2	0.0051	7	0.1
	Lime	105	5.3	559	9	0.78	82	1
	Fiber Cement panels	251	10.4	2609	43	1.09	273	5
Doors and windows	Glass	171	11.5	1971	32	0.59	101	2
	Hardwood	81(ft^3)	10.4	837	14	0.67	54	1
Total				46507	766		4614	76

One-storey house constructed by zinc sheet

Figure 2.9 shows 1-storey house constructed by zinc sheet of Central Thailand. This feature of house is mostly built for very low income earners of Central Thailand. This housing feature is found around 25% of the samples and all of them are between 5-15 years old.

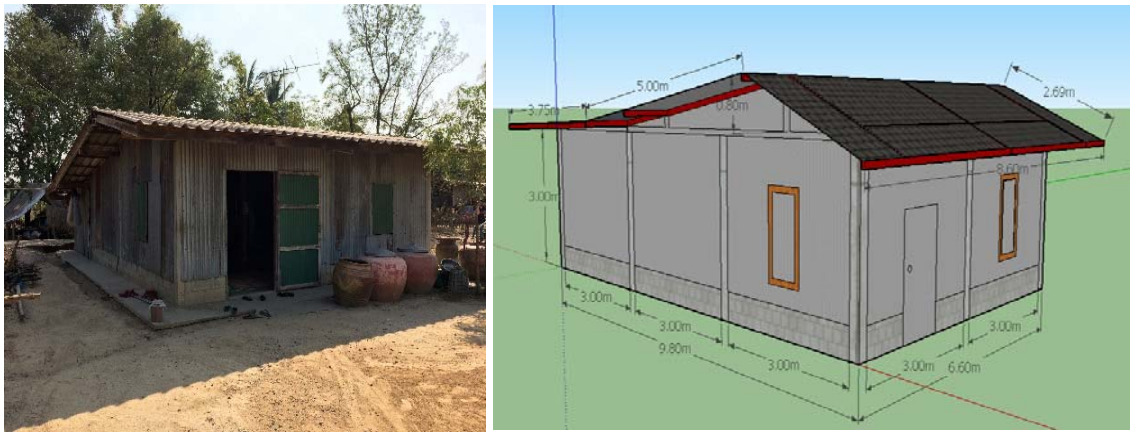


Figure 2.10 1-storey house constructed by zinc sheet of Central Thailand.

Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.10. The results show that this type of house Embodied energy of 46,912 MJ or 722 MJ/m^2 and Embodied carbon of 5,020 kgCO_2eq or 77 kgCO_2eq/m^2 which is higher than the 1-storey concrete house.

Table 2.10 Embodied energy and Embodied carbon of materials of 1-storey house constructed by zinc sheet of Central Thailand.

Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	kgCO$_2$eq/kg	kgCO$_2$eq	kgCO$_2$eq/m^2
Foundation and structure	Sand	864	0.081	70	1	0.0051	4	0.1
	Concrete	23,975	0.75	17981	277	0.107	2565	39
	Steel	238	20.1	4793	74	1.46	348	5
	Hardwood	21	10.4	215	3	0.67	14	0.2
Roof	Fiber Cement panels	623	10.4	6482	100	1.09	679	10
Concrete block	Cement	98	4.5	440	7	0.74	72	1
	Concrete	1,225	0.75	919	14	0.107	131	2
	Sand	704	0.081	57	1	0.0051	4	0.1
	Lime	56	5.3	297	5	0.78	44	1
	Galvanized iron	602	22.6	13598	209	1.54	927	14
Doors and windows	Galvanized iron	91	22.6	2054	32	2.54	231	4
	Hardwood	1(ft^3)	10.4	5	0.1	0.67	0.3	0.01
Total				46912	722		5020	77

Two-storey house constructed by concrete and wood

Figure 2.11 shows 2-storey house constructed by concrete and wood of Central Thailand. This feature of house is very similar to the 2-storey house constructed by concrete and wood of Northeastern region because of similar living style and occupation. This housing feature is found around 50% of the samples and all of them are over 15 years old.

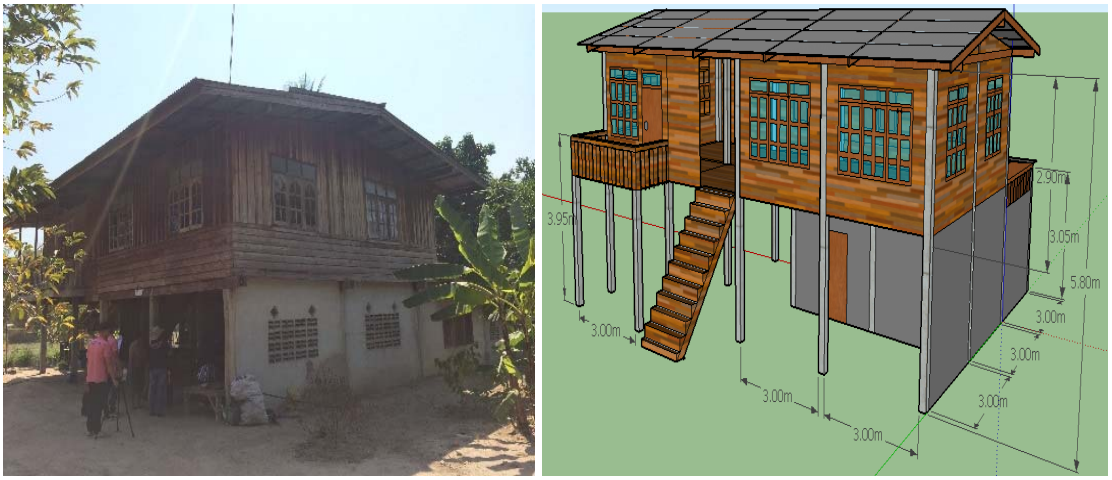


Figure 2.11 2-storey house constructed by concrete and wood of Central Thailand.

Bill of Embodied energy and Embodied carbon of the house are calculated as shown in Table 2.8. The results show that this type of house Embodied energy of 72,089 MJ or 384 MJ/m^2 and Embodied carbon of 7,839 kgCO$_2$eq or 42 kgCO$_2$eq/m^2 which is higher than the 1-storey concrete house which because of concrete columns are widely used but still lower than 1-storey house constructed by zinc sheet.

Table 2.11 Embodied energy and Embodied carbon of materials of 2-storey house constructed by concrete and wood of Central Thailand.

Part of Structure	Materials	Quantity (kg)	Embodied energy			Embodied carbon		
			MJ/kg	MJ	MJ/m^2	kgCO_2eq/kg	kgCO_2eq	kgCO_2eq/m^2
Foundation and structure	Sand	864	0.081	70	0.4	0.0051	4	0.02
	Concrete	18048	0.75	13536	72	0.107	1931	10
	Steel	213	20.1	4283	23	1.46	311	2
	Hardwood	103(ft^3)	10.4	1072	6	0.67	69	0.4
Roof	Galvanized iron	1117	22.6	25240	135	1.54	1720	9
Ceiling	Cement	2994	4.5	13475	72	0.74	2216	12
Concrete block	Cement	505	4.5	2274	12	0.74	374	2
	Concrete	6326	0.75	4744	25	0.107	677	4
	Sand	3584	0.081	290	2	0.0051	18	0.1
	Lime	290	5.3	1535	8	0.78	226	1
	Hardwood	38(ft^3)	10.4	400	2	0.67	26	0
Doors and windows	Glass	437	11.5	5020	27	0.59	258	1
	Hardwood	14(ft^3)	10.4	149	1	0.67	10	0.1
Total				72089	384		7839	42

The results of this report show that Embodied energy and Embodied carbon of materials of older houses are lower than existing or new houses because of using wood as main construction materials. The use of concrete walls increases Embodied energy and Embodied carbon highly and should be replaced by other alternative materials which will be reported in the next progress report.

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Project: Research Programmer on Reducing Energy Consumption Cost and GHG Emission for Tropical Low-income Housing:
Thailand Contribution

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