The Importance of Building Criteria on Cooling Energy Demand of a Low Cost Residential House: Thailand Case Study

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Abstract: - This paper presents a research finding on the cooling energy demand of a low cost residential house in Thailand. A detached house originally is no mechanical cooling systems as a favour of cost saving. Recently, a number of existing two-storey houses installed an air conditioning unit gradually increase. The effect of current situation on building energy demand is investigated using the energy simulation. The study parameters include one air conditioned bedroom, two types of wall materials, house orientation and one row houses arrangement. Two study scenarios referred as a period of air conditioning unit work with 12 months and 8.5 months, except mild weather months, are computed, analysed and presented. The results point out that the energy demand in the scenario two is 30.8% or 52.6 kWh/ m^2.year lower than the scenario one. The cooling energy demand could be reduced up to 28.4 % or 50.1 kWh/m^2.year for only changing wall material from concrete block hollow to aerated concrete. The east facing house consumes less energy followed by north, west and south due to the transparent and opaque area of east orientation that influenced by the solar gain is smaller. However, it should be noted that the different between the east and south orientation is as little as 6 % or 12 kWh/m^2.year. Similarly, the simulation result on a row of ten houses shows that the first and the last house in the row consume more energy than the less only 3%. Thus, the influential parameter on the cooling energy demand of this low cost residential house is period of air conditioning unit operation, wall material, direction of house facing and, almost no effect, the house arrangement in a row.

Key-Words: - residential house, energy simulation, cooling, energy demand, Thailand

1 Introduction

The energy consumption gradually increases in all categories among them a building sector shares significantly large percentage. A comfortable interior is required by the modern living for both residential and office buildings. In Thailand, the electricity consumption of residential buildings accounts for 21.3 % in 2008 which increases by 4.5% from a previous year [1]. Space cooling, electrical appliances and lighting are the main end use. The Energy Conservation Promotion Act (ECP Act) was legislated by the Thai government in 1992 [2]. The energy conservation for designed buildings and the mandatory requirement were acted out in 1995. An up to date version of the building code was released in 2009. To estimate the annual energy consumption of the building, the formula of the overall thermal transfer value, regarding to building envelopes, and the performance index of lighting and air conditioning were used. A life cycle energy analysis method was used to analyse embodied and operating energy of a typical office in Thailand [3]. Results showed the concentration of the life cycle energy on the operating phase; however, the embodied energy of the building cannot be neglected. The electricity energy consumed by the lighting and HVAC, the heating ventilating and air conditioning, system in the operating phase and the manufacturer of concrete and steel are significant factors in the life cycle energy. The life cycle energy analysis, LCEA, was suggested to be included in an existing Thai building code. A number of studies showed that the demand of air conditioning has increased in the building sector which expands from commercial buildings to residential buildings. Currently, the number of houses started installing air conditioning systems has increased rapidly. This new living style would definitely affect the building energy demand thus the present building criteria are considered important.

The project of low price houses was launched by the national housing authority (NHA), Thailand, since 2003. This aims to encourage people to own a house with an attractive low-cost. A two-storey detached house is one of the models that receive a good response. Nowadays, there are more than 200,000 houses being occupied. This house project could be extended regarding high demand. Prior researches on the thermal comfort of this conventional house model with no air conditioner and the architecture opinions for the NHA project were studied [4-5]. The internal air temperature and the energy demand of the building were computed using the DOE.2.1 software [4]. The thermal comfort day was presented. Several suggestions were given which included the modification of wall by adding air gap and employing different wall material for the two floors, an installation of awning to the window frame and the utilisation of night ventilation. A survey on architecture design and economic point of view was studied [5]. The statistical results showed the medium satisfaction for the building design, materials selection, usefulness, beauty and environmental impact but with high satisfaction on the economic for the house investment and selling price. Another study on this house model was presented and the energy demand of the house with one air conditioner was calculated by the DOE.2.1 program [6]. The house baseline is the north facing house. The new design for a low energy consumption house was introduced. The new design house has larger total utilization area than the conventional one for comfortable living. On the other hand, the prior has about 3 per cent lower air conditioned area than the latter with the purpose of lowering space cooling load. The building material was carefully chosen for low overall heat transfer coefficient. In cooperate with a low energy lighting system, the simulation result show this new design house could achieve 25% energy saving. However, the high investment cost requires further study on the economics and people acceptation.

Increasing thermal mass is beneficial to the building energy efficiency; particularly, the reduction of heating and cooling operation was found [7]. The occupants shall consider this before adding an air conditioner into the house. The selection of building materials for residential Indonesian house is an influential factor on the energy demand [8]. The utilization of local materials in the building structure was found promising. A research carried out in Romania has concluded that the building construction is significant to the reduction of energy consumption [9]. Materials, technologies and idea of low energy requirement of the buildings are equally important to the use of equipment with high performance. An additional insulation of the building envelop was required. The control of heating system to satisfy occupants comfortable was crucial in order to achieve the reduction of energy consumption.

A thermal insulation of building should be adequate in order to benefit environmentally and financially [10]. The EnergyPlus program was used to evaluate the energy performance of Greek buildings. The simulation results reveal the insulation on the roof and the floor of existing house was a big advantage for the current situation where many houses started installing air conditioning units.

The installation of air conditioning system into the existing house obviously affects its energy demand. The current study pays mainly attention on the influential building criteria to cooling energy demand of the low price house, NHA Thailand, with one air conditioner in the bedroom. In this paper, the building energy demand is calculated by the EnergyPlus software and Bangkok weather data is referred [11]. The studied parameters are an air conditioned bedroom, two types of wall materials, house orientation and one row houses arrangement. Two scenarios are period of air conditioning unit operation as 12 months and 8.5 months. The result of this study can be guided for achieving energy efficient building in the future.

2. Methodology

A two storey detached house, NHA Thailand, is selected as the case study. The building is compact and classify as lightweight. The building geometry is created using Google SketchUp and OpenStudio Plugin as shown in Fig.1 and Fig.2. There are three rooms which include a combination of living and dining room in the ground floor, a multi-function room and bedroom in the first floor. The thermal zones set based on the room utilisation as the three rooms, one bathroom, one staircase and one attic.

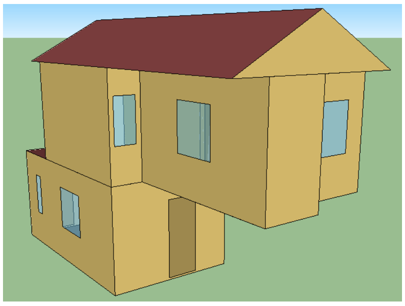

Fig.1. The front of the house

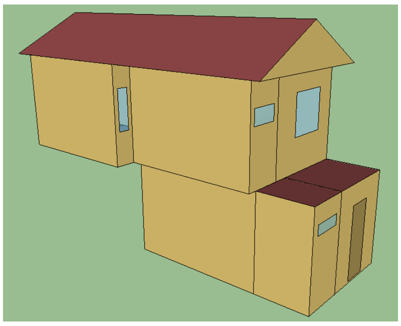

Fig.2. The back of the house

The construction materials, properties and utilization behavior were the input data of the EnergyPlus software. The installed capacity of electrical appliances, lighting load and the information of an average use per day on the weekdays and weekends from Yooprateth [6] were used as input in EnergyPlus. The location and weather data refers to Bangkok, Thailand. The energy demand is computed by utilizing the EnergyPlus software version 7 [10]. The current study parameters are two different wall materials, house orientation and a row of ten houses with three meter in between them. The real building plan is employed for the current geometry with the useful floor area of around 42 m^2. That excludes the open area at the front of the house in the ground floor, which is below the bedroom, and the roof. The information for the five active thermal zones is shown in Table1. The number of people in the house is assumed 4 as a small family with parents and two children. It should be mentioned here that the study houses are typical for a low income family. The house is occupied mostly during the night on the weekdays and whole day on the weekend.

Table 1. Thermal zones and area

Zone	Function	Area (m^2)
1	Living and dining room (G floor)	15.26
2	Bath room (G floor)	1.8
3	Multi-function room (1st floor)	9.19
4	Stair case	3.94
5	Bedroom (1st floor)	12.18

Basic electrical appliances e.g. the colour television, refrigerator, kettle and etc. are included. Electrical appliances and lighting loads are weighted for each thermal zone based on the actual utilization [6]. This sets constant for all simulations as a control parameter. Materials used in the baseline building structure are listed in Table 2. A single glaze window is commonly used and assumed here. The 6 mm clear float glass with the total U-value of 5.8 W/m^2.K, solar energy transmittance of 80% and shading coefficient of 0.96 is referred. Furthermore, the operating schedule for an air conditioner in the bedroom is weekday from 20.00 to 06.00 and the weekend from 19.00 to 08.00.

Table 2. Lists of materials in building structure arranged from outside to inside [6]

Structure	Materials
Wall	Cement plaster 10 mm, Concrete block hollow 75 mm, Cement plaster 10 mm
Floor	150 mm concrete
Door	Wood 30 mm
Roof	Cement tile 6 mm, Aluminium foil 2 mm
Ceiling	Glass fibre 102 mm, Gypsum board 9 mm

2.1 Study scenarios

Two scenarios are a house with one air-conditioned bedroom with 12 months and 8.5 months operation period, from mid of February to October but not operates during mild weather in other months, operation. The schedule of running air conditioner remains the same. The orientation studied when the front building faces north, south, east and west. The impact of an arrangement of the ten houses in a row as shown in Fig.4 is investigated. The distance between each house is three meter as referred in the original planning [4]. Furthermore, the original wall material, a concrete block hollow, is replaced by aerated concrete which is suggested by the current study in order to reduce the heat transmission through wall. The price of second wall material is currently more affordable. The aerated concrete offers lower thermal conductivity twice as much compared to the concrete block.

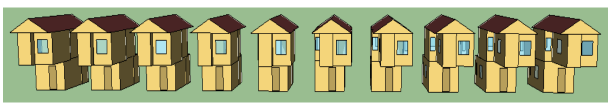

Fig.3. The ten houses arrange in one row with three meter distance in between

ISBN: 978-1-61804-110-4

3. Results and discussion

The pre-test of simulation model on the same house orientation with no air conditioning unit was compared with the measured data available in the literature [4]. The similar trend of the room temperature was well met. Due to the different year of weather data, the validation cannot be made. However, the same trend of temperature variation during the day provided that the current model is accurate and reasonable.

The results from energy simulation on the house with air conditioned bedroom and load schedule show that the building electric energy demand is 95.15 kWh/m^{2}year as shown in Fig.4. The dining/living room consumes higher electric energy than others due to the number of electrical appliances in this room and also the most utilization area. The electricity consumption for the lighting system shares only about 8% for especially the dining/living room. The second most consuming electric energy as expected is the bedroom with 92.81 kWh/m^2.year.

Occupants could experience uncomfortable temperature several months throughout a year. This has caused in running the air conditioning unit throughout the year and most likely is in Bangkok. However, the case of not turning air conditioning system in winter is also considered. Cooling energy consumption of the north facing house with 12 months of air conditioning is 194.6 kWh/m^2.year this result provided by EnergyPlus is slightly lower than the DOE.2.1 [6] as of 3.4 kWh/m^2.year or 1.7%.

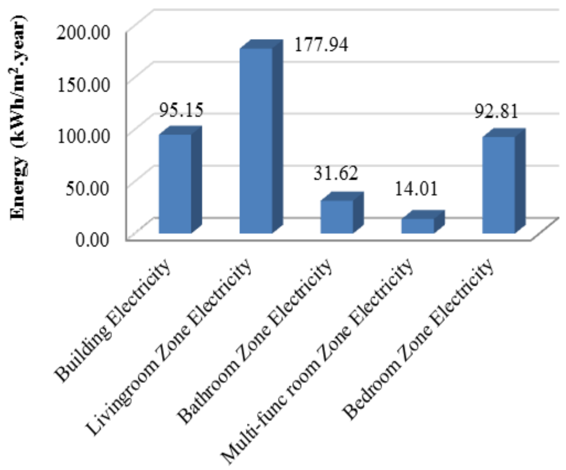

Fig.4. Electric energy consumption of the building and each zone

The model is further utilised to simulate for other house orientation and period of air conditioning system operation. The energy demand reduced greatly as one can predict for 8.5 months operating air conditioner as seen in Fig.5. The reduction of cooling energy demand of 30.8% or 52.6 kWh/m^2.year is met by the south facing house. To make this possible, the night ventilation can be considered in the combination of low energy consumption of such an active cooling by a fan. This shall be further study on the possibility of reaching the thermal comfort.

Next, the wall parameter is simulated. The results show that the change of wall material from concrete block, wall 1, to aerated concrete, wall 2, can reduce the cooling energy consumption up to 28.4 % or 50.1 kWh/m^2.year in south facing as shown in Fig.5. Regarding the orientation, the east facing house offer lower cooling energy consumption compared to others. It is followed by the west, the north and the south facing houses. The front building faces east offers 6 % or 12 kWh/m^2.year lower cooling energy than the one that faces south.

In the current model, the air conditioned bedroom is located in the front; thus, it receives the direct solar radiation only in the morning for the east facing house. The north facing house comes the second. Then the west facing house receives the solar radiation through window half of the day in the afternoon with high thermal transmission. Finally, the high energy demand house is that the house faces south. This can be considered by the high area of both glazed and opaque surface on east and west side; thus, this highly contributes to the solar gain or cooling load. The surface area of each house orientation is shown in Table 3. Thus, the orientation of such a south facing house, with air conditioned room in the front, should be avoided as much as possible.

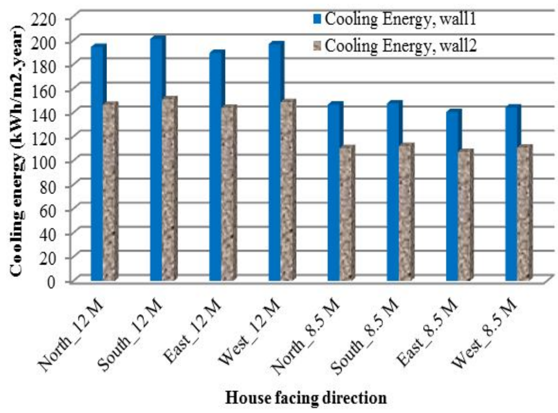

Fig. 5. Cooling energy of each house oriented with two wall materials; wall1: concrete block hollow, wall2: aerate concrete, and two operating modes of air conditioning unit

The impact of houses arrangement in the row with 3 meters distance between the houses is simulated. The simulation result shows that it has little effect on the cooling energy demand. The first and the last house in the row consumed only 1-3 % more than the others.

Table 3. Area of opaque and glazed surface for each house orientation

Components \ Orientation	Surface area (m^2) S	W	N	E
Opaque surface N	0.77	8.24	6.03	10.66
Opaque surface S	6.03	10.66	0.77	8.24
Opaque surface E	10.66	0.77	8.24	6.03
Opaque surface W	8.24	6.03	10.66	0.77
Glazed surface N	0.33	1.21	1.21	0
Glazed surface S	1.21	0	0.33	1.21
Glazed surface E	0	0.33	1.21	1.21
Glazed surface W	1.21	1.21	0	0.33

4 Conclusion

The low cost residential house, the National housing authority project, Thailand, was selected for studying the impact of building criteria on the cooling energy consumption. The energy simulation utilise the EnergyPlus program. The simulation results show that the influential parameter on the cooling energy demand of this house is the operating period of an air conditioner, wall material, house orientation and the house arrangement in a row.

Acknowledgments:
The first author (Waraporn Rattanongphisat) undertook this work with the support of the ICTP Programme for Training and Research in Italian Laboratories, Trieste, Italy. Further thanks to Dr.Wathanyoo Rordprapat for his helpful information.

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