Life Cycle Cost Analysis of Air Conditioning System for Residential Sector in Thailand

Wirat Sriamonkul, Rittirong Intarajinda, Nipon Tongsuk, Suttichat Saengsuwan, Pornrapeepat Bhasaputra and Woraratana Pattaraprakorn

Abstract— *The propose of this paper to used Life Cycle Cost (LCC) Analysis Technique to optimal type of air conditioning system for residential sector in Thailand. This study is focused on three standard cooling system technologies of residential air conditioning system in Thailand. Most common standard cooling systems at capacity of 18,000 B.T.U. in local market are including of standard split type system, inverter system and evaporative condensing system. The results of market survey for those three standard air conditioning systems with current local market pricing, energy efficiency performance and consumers buying decision criteria are reported in this article. In addition, the LCC of those residential air conditioning systems with 18,000 B.T.U. are evaluated base on 7 years life time of the compressor unit to find out the optimal type of air conditioning system with minimizing LCC. According to the rapid growth rate of air conditioning market in Thailand, the trend of energy consumption in residential sector is also increased and the awareness of energy conservation are promoted by the government agents. The consumers in Thailand are encourage to review energy efficiency performance via energy labeling number 5 be a factor to decision in purchasing of the new air condition system for the family. Finally, the analytical results of LCC for residential air conditioning system can conclude that the LCC technique is an effective financial analysis to select the optimal type of household electric appliances which significantly affects to sustainable energy efficiency in Thailand.*

Keywords— **Life Cycle Cost (LCC), Inverter System, Evaporative Condensing System.**

1. INTRODUCTION

Temperature rising is one of the environmental impact from climate change especially in Thailand, which located close to the equator. The effect of adapted the urban living style in short term period, the air conditioning systems are introduced in numerous customers especially commercial and residential sectors to fulfill the acceptable indoor air quality within a desired environmental conditionings for the people, products or equipment. By this reason, the air condition market growth trend is continuous increasing and the key successive factors drive manufacturers to global leading in consumer market are cost against efficiency. This aim was emphasis manufacturer to produced products with high productivities and cost effective but improve efficiency performance. In addition, the innovations of new technologies to response of global market demand to improve product quality, performance, green product and energy conservation for new air condition system market is emphasis the development of new products to compliant with those aspects for manufacturer in the competitive market.

The electricity consumption in Figure 1 is illustrate the industrial sector has a highest consumption with the 44.70% share while the commercial and residential sectors are consumed 24.60% and 21.40% of total electricity consumption, respectively [1]. To focusing on the energy distribution in the residential sector, the main equipment which consumed the large amount of energy is evaluated the portion of energy consumption. It is clearly that air conditioning system is taken account to 41.40% while the lighting and refrigeration systems are also the large electricity consumed with 28.41% and 28.18% of total electricity consumption in the residential sector, respectively. Therefore, these appliances have a large potential to implement the energy conservation program which is one of the sustainable energy policy in Thailand.

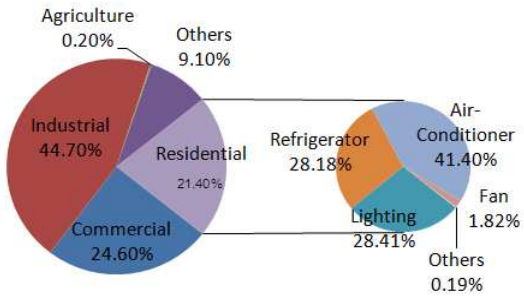

Fig. 1. Thailand household electricity consumption.

The result of the survey from the Department of Alternative Energy Development and Efficiency (DEDE) is reported that a significant electrical energy consumption in most of the designated buildings were consumed by air conditioning system with a ratio greater than 50% of the overall consumption [2].

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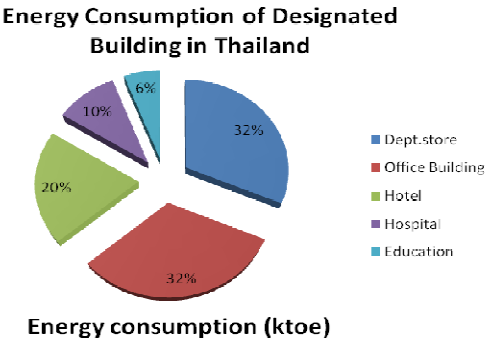

Fig. 2. Energy Consumption of Designated Building in Thailand.

From the energy consumption in Figure 2, the results of survey had identify the department store and office building are the greater user of energy consumption (ktoe) in Thailand at 32% and 32% of over energy consumption follow by hotel, hospital and education building respectively. The Figure 3 is indicate the air conditioning system in hospital sector has the highest consumption greater than 50% of electrical energy consumption, followed the office building and department store sector. The reason of highest electricity consumption at office building and department store are designed to service their customers with a comfortable condition. The air condition system was design to fulfill the indoor air quality within the humanity comfortable environmental.

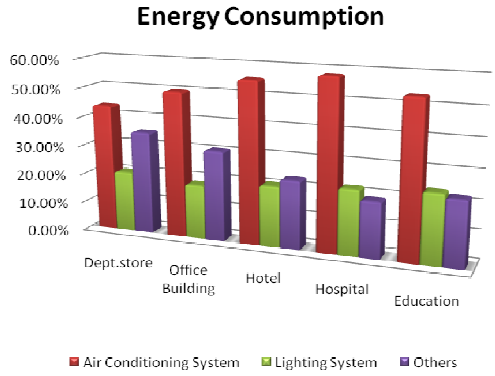

Fig. 3. Electrical energy consumption classification by type of consumption for each designated building in Thailand.

In addition, the Energy Policy and Planning Office (EPPO), Ministry of Energy, Royal Thai Government had reported the requirement of air conditioning system in residential sector continuously increased for a few years [3]. That mean the electrical energy consumption of residential sector is also arising.

The relative number of air conditioning system per family vs. the monthly electric power consumption is display in Figure 4. The air conditioning system in the residential sector and the electric power consumption were relative increasing in the same direction. The large housing which high electric energy consumption is always had multiple air conditioning systems in the family. In the other hand, the families who not used air conditioning system could be spending the electric energy less than 150 units per month.

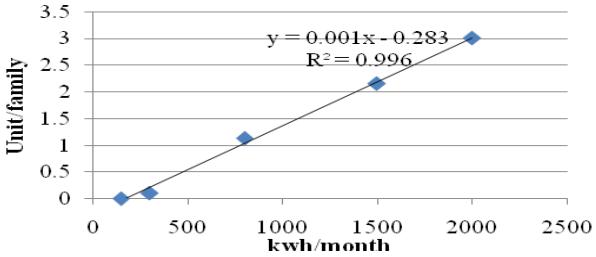

Fig. 4. The relative of air conditioning quantities per family vs. electric power consumption.

By natural of consumer to decision and select the new air conditioning system in Thailand from local market survey report had presented that 58% of consumer in local market given the decision to select the new air conditioning system with the saving energy label as a first priority of choice followed the pricing factor with 25% of consumer. The factor of brand name is contribution about 14% of consumer to select the new air conditioning system and the remaining would prefer in air conditioning style.

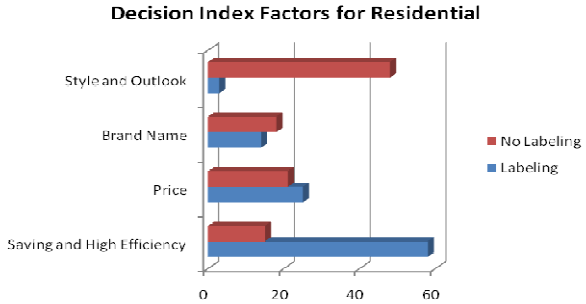

Fig. 5. The decision index factors for residential sector to purchase air conditioning system.

The result of survey in Figure 5 is explain the question about how does user make a decision to select new air conditioning system for residential sector in Thailand. For these reasons, The Electricity Generating Authority of Thailand (EGAT) had launched the Demand Side Management (DSM) program to encourage the people to use the electricity with efficiency and saving since the 3rd December 1991. Under the DSM program, EGAT launched the compaigns “Together Conservation” and “Saving Electric Energy by Labeling number 5” during the 20th September 1993. This campaign had indentified a lable number 5 on the electrical appliances for residential sector from year 1993 to 2004 as presented in Figure 6. In addition, the campaign of electronic ballast and thin fluorescent T5 are lunched in year 2007 and 2009, respectively. The time line of energy conservation for residential sector is present in the following:

1993: Together conservation by thin lamp

1994: Energy conservation with refrigerator number 5

1995: Energy conservation with air conditioning number 5

1996: Energy conservation with fluorescent number 5

1998: Energy conservation with safety ballast number 5

1999: Energy conservation with jasmine rice number 5

2001: Energy conservation with electrical fan number 5

2004: Energy conservation with electrical cooking rice number 5 and high efficiency electrical lamp number 5

2007: Energy conservation with electronic ballast

2009: Energy conservation with thin fluorescent T5

Fig. 6. A cycle of promotion label number 5 to electrical appliances.

Furthermore, the Thai Industrial Standards Institute (TISI) had determined the Minimum Energy Performance Standard (MEPS) of a new air conditioning which the capacity is less than 8,000 watt and 12,000 Watt. The two types of air conditioning system should be met the energy efficiency ratio (EER) greater than 2.82 and 2.53 (9.6 BTU/hr/W and 8.6 BTU/hr/W), respectively. Moreover, the High Energy Performance Standard (HEPS) for air conditioning system should be met the energy efficiency ratio (EER) greater than 10.6 BTU/hr/W. Therefore, the consequence of improvement energy efficiency for air conditioning system lead the EGAT to optimize EER of label number 5 for a new air conditioning system from 10.6 to 11.0 in year 2006. At the present, the EER of air conditioning system with label number 3 to 5 is categorized as shown in Table 1. By this change is able to reduce electricity consumption about 5%.

Table 1. The Energy Efficiency Ratio (EER) of a new air conditioning system label number 5

Efficiency Level	Energy Efficiency Ratio (EER)
Label No.5	Greater or equivalent to 11.0
Label No.4	Greater or equivalent to 10.6 but less than 11.0
Label No.3	Greater or equivalent to 9.6 but less than 10.6

In the recently, new technologies to produce a new air conditioning system had improved EER to met EGAT efficiency level label number 5. The other alternative lower efficiency could not compliance to level label number 5 still available in lower level market of Thailand. According to all above reason, this paper is intended to study and analyze the optimal selection criteria of air conditioning system for residential sector in Thailand by using the Life Cycle Cost (LCC) analysis technique.

2. METHODOLOGY

To evaluate the potential of energy saving in this paper, an energy management opportunity has been identified as a first choice to make the final decisions and to justify any capital expenditure for the project. Then this paper applies the technique of LCC analysis to determine the cost-effectiveness of the energy management opportunity for residential air conditioning systems which including:

- Standard label number 5,
- Standard label number 5 with inverter system,
- Standard label number 5 with evaporative condensing.

The analysis was computed with air conditioning system based on the capacity of 18,000 B.T.U. per unit, 7 years lifetime and the average operating time of 8 hours per day. The total LCC covers initial cost, operating cost, maintenance cost and water supply cost for evaporative condensing system only. The financial index in term of Net Present Value (NPV) is used as the key indicator to implement the energy conservation programs. In addition, the factors that effect to the decision making, the purchasing criteria of air conditioning system for residential sector including energy saving, pricing, brand, and style are assigned as the survey factors which devided into two cases between with energy label number 5 and without energy label.

Standard energy label number 5 or air conditioning split type system is a regular air conditioning system by separate condensing unit out of evaporation unit. The condensing unit consists of compressor unit, condenser and fan coil unit [4]. This condensing unit always install at outdoor while the evaporation unit is placed indoor. The evaporation unit and fan sometime called as fan coil unit or indoor unit. The diagram of regular air conditioning system is shown in Figure 7. The pattern of compressor power for on-off operation with constant speed is illustrated in Figure 8 [5].

The regular air conditioning split type is the most popular and common use in most of the building include residential sector. Because of the condensing unit which is the noisy part was installed at outdoor. The operating of the noisy condensing unit is less effect to the user. This is the advantage of this split type system. But the disadvantage of this split type system is difficult to relocate. The relocation of air condition system requires professional personal to install refrigerant pipe and drain pipe. In addition, the installation is necessary to drill the wall for connecting the refrigerant pipe from outdoor unit to indoor unit. Moreover, the split type requires a space for ventilating the hot air from condensing unit.

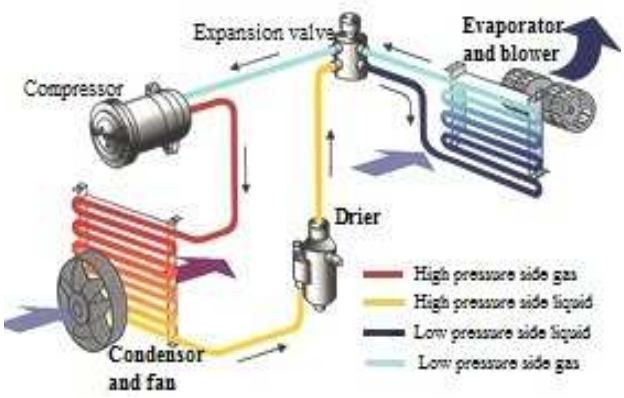

Fig. 7. Operating principle of regular air conditioning split type system.

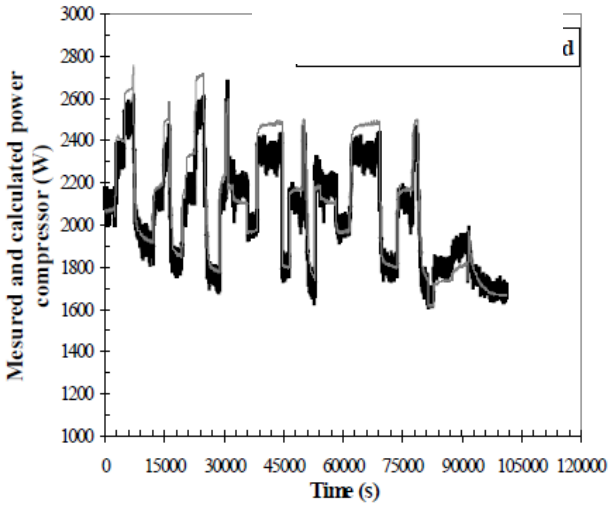

Fig. 8. Characteristics of fix speed compressor power during on-off operation.

Standard label number 5 with inverter system or the inverter technology is a technology of controlling motor speed at the compressor to optimize operation frequency [6]. The input variable of inverter system is the actual temperature of environment during the control period. The system control calculates the optimal frequency set point and generates an appropriate motor speed. As a result, an optimal power is applied in all cooling ranges and maximum comfort is achieved. By this technology of speed controlling system, the electrical consumption during condensing unit operation on-off is minimum effect to this inverter system. This technology will be an advantage if user using at high heat load condition. Because of the optimum motor on-off is direct reduce electrical current and power consumption at start up motor. The fundamental of inverter technology is display as block diagram in Figure 9.

The fundamental of inverter system is different to the common type of compressors. The common type of compressors will operate with fixed speed compressor that run at 100% of its capacity and will stop and start automatically to maintain the designed temperature, but the inverter operate by variable speed compressor that will variable its speed in order to maintain a consistent temperature. Then, EER of air conditioning type with inverter will be inversed to cooling load. When the speed of compressor is reduced, the flow rate of refrigerant is also decreased. In this case, the EER at this operating point will be improved while the common type of compressors is not able to improve the EER because the refrigerant is still maintaining the same flow rate. The study of Benamer A. and Clodic D. show the cooling load from 10%-100% to investigate the pattern of compressor power as shown in Figure 10. The optimal desired speed for compressor at actual heat load indicated that the air conditioning with inverter system provides a large potential of energy saving when compared to the regular or fixed speed in air conditioning system.

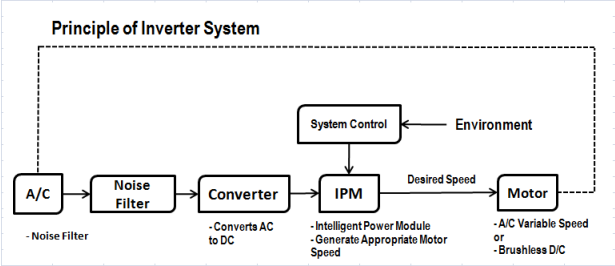

Fig. 9. The control principle of air conditioning with inverter system.

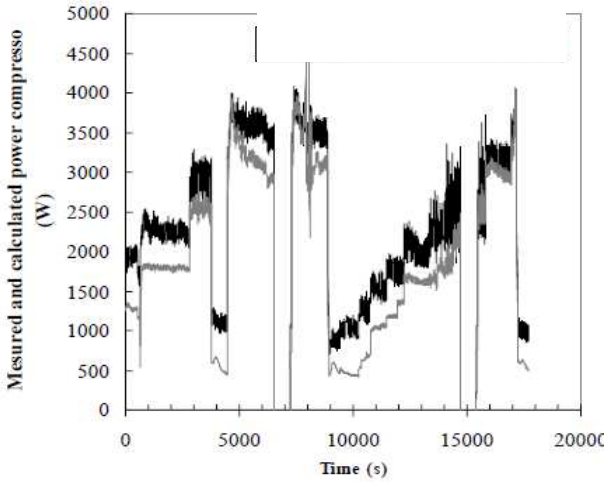

Fig. 10. Characteristics of variable speed compressor power during on-off operation.

Standard energy label number 5 with evaporative condensing or air conditioning hybrid system is combine condensing unit with the water cooling and blower at condenser unit [7]. The diagram of air conditioning with water evaporative system is display in Figure 11. This machine is using energy conservation and heat transfer technique to reduce electrical energy. The ambient temperature is reducing with cooling water which passed through cooling pad media before entering the condensing fan. Then, compressor unit will not run in full load and made the overall power consumption of the system is reduction.

The concern feedback comments from the questionnaire of air conditioning system with water

evaporative condensing system are provided in below paragraph. The summarized of concerns can be concluded as following:

- The installation of evaporative condensing system was difficult than the regular air conditional system, because hybrid system requires water piping feed into condensing unit.
- The water quality is required to be controlled.
- The material in condensing unit may get corrosion, rusty easy and short life time of those materials.

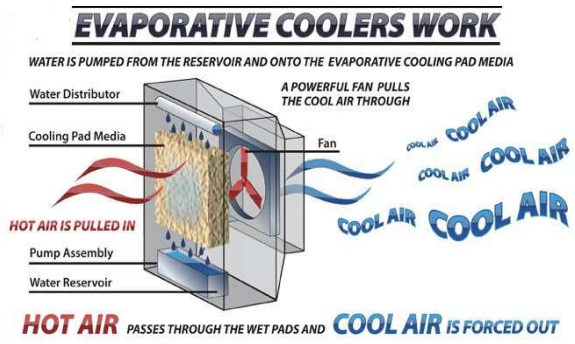

Fig. 11. Air conditioning with water evaporative system.

3. ENERGY COMSUMPTION COMPARISONS

The three types of air conditioning systems varying the heat loads are tested. The result is shown in Fig.10. In addition, the discrete load step from 20% to 100% is examined to illustrate the relative of the power consumption and heat load variation.

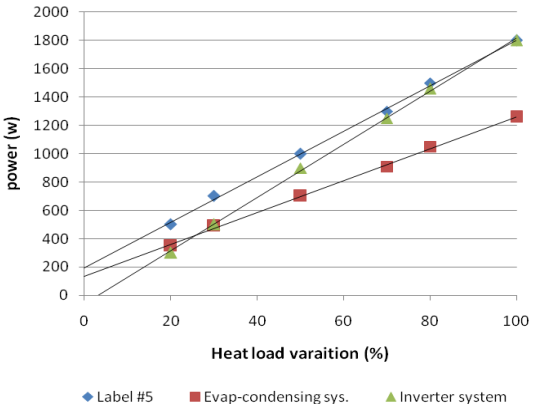

Fig. 12. Power consumption at different heat load

The standard air compressor split type and the air conditioning system using water to cooling at condenser unit is controlled by a simple repeat cycle of on/off system when the set temperature at the evaporator outlet is reached.

When the cooling capacity loads are low, the differential of power consumption between the two compressors system is higher. To correspondence of above graph in Figure 12 is concluded the lower cooling capacity yield is the larger energy savings associated with the variable speed. The scenarios of where the lower heat loads are most frequent performed and confirmed measurements taken by step of power.

4. REFERENCE DATA

To calculate the LCC analysis of residential air conditioning systems with fixed capacity of 18,000 B.T.U., the reference data in Table 2 and Table 3 are applied to the LCC evaluation. Under the same capacity, the local market prices and EER for three technology system imply that evaporative condensing system provides the best of EER while the cost of installation is also higher than common fixed speed type of compressor and inverter system.

Table 2. Market prices of air conditioning system in Thailand during May – June 2010

Type	Capacity (BTU)	Cost (Baht)	EER (BTU/hr/W)
Split type Label #5	18,000	20,000	11.20
Inverter system	18,000	25,000	12.00
Evaporative condensing system	18,000	29,000	15.51/12.73*

Remark: * = in case without water supply cooling

Table 3. Operating costs of each air conditioning system

Annual Cost (Thai Baht)	Regular Type	Inverter system	Evaporative condensing system
Electrical cost	5,142.86	4,832.21	3,713.73
Water cost	n/a	n/a	250.00
Maintenance cost	1,000.00	1,000.00	1,000.00
Installation cost	2,500.00	2,500.00	3,000.00

5. LIFE CYCLE COST ANALYSIS OF RESIDENTIAL AIR CONDITIONING SYSTEMS

The LCC of air conditioning systems is calculated based on the air compressor lifetime of 7 years with average 8 hours of operating time. The analytical results show that the life cycle cost of air conditioning controlled by evaporative condensing system is lowest investment cost with 67,113.18 Baht under the 80% duty cycle.

To investigate the effect of LCC in different duty cycle of 50%, 30% and 20% are set as the sensitivity variables, the results of sensitivity analysis show in Figure 13. The evaluation of LCC analysis from Table 4 at heat load variation 80% illustrates that the capital cost, the initial cost from Table 2 and the installation cost from Table 3, had lower cost value than operating cost (energy consumption cost plus water consumption cost and plus maintenance cost) [8]. While, the heat load variation 50% of the capital cost was equivalent to operating cost. In case of the heat load variation lower than 50%, the capital cost was higher than operating cost. The LCC

analysis results in the table 4 were plotted in Figure 15. This result illustrates the LCC analysis of air conditioning type of residential sector in Thailand. The assumption of air conditioning system are operating time of air conditioning system during period of 10:00 PM to 6:00AM with an average heat load at 60% of the full heat load at the noon time. Finally, the result of this analysis is able to conclude that the lowest LCC analysis cost of air conditioning for residential sector in Thailand is the standard split type air conditioning system with labeling number 5 [9]. The LCC analysis cost of air conditioning label number 5 is lower than other two types of the inverter system and the water evaporating system. The key parameter factor to made the LCC cost analysis of both types of air conditioning system higher than standard split type air conditioning system are initial investment cost of inverter system and evaporating system are significant higher than standard air conditioning label number 5. Otherwise, the standard split type air conditioning system consumed the electrical energy higher than other two types.

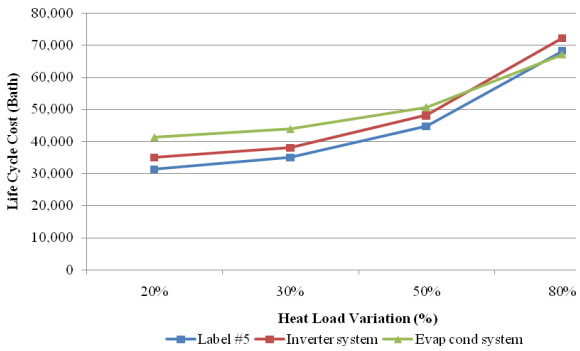

Fig. 13. Sensibility analysis of LCC with heat load variation from 20-80%.

6. DISCUSSIONS

In typical usage of regular air conditioning system in residential sector in Thailand was in the night time. The heat loads of air conditioning were below 60% of the designed performance of the air conditioning system. The life cycle cost of air conditioning system with the standard split type is lower than the other high efficiency air conditioning systems. Because of the behavior of user and the environmental during air conditioning operating made the significant impact to the result of LCC analysis of air conditioning system in Thailand. The high efficiency performance of air conditioning system had positioning product at high market segment; it made the systems were significant higher initial cost than standard split type air conditioning system. This paper focuses on the air conditioning system capacity size 18,000 B.T.U for residential sector only. The result of LCC analysis for residential sector was supported the standard split type air conditioning system label number 5 as show in Figure 14. The key significant impact factor to make LCC analysis cost is coming from the initial cost of investment new air conditional system in Thailand market. The cost saving differentiate from inverter system and evaporative condensing system are lower than the initial cost of the new air condition system.

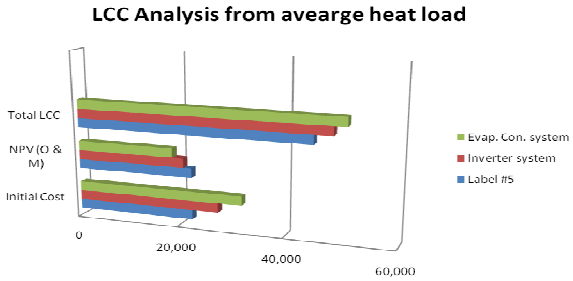

Fig. 14. LCC Analysis for air condition capacity 18,000 B.T.U. in Thailand market.

However, the high efficiency air conditioning system both inverter type and evaporative condensing type are appropriate for the commercial sector, industrial sector and service buildings. The high heat load and long operating time of these sectors can provide more attractive financial investment. Moreover, air conditioning systems with high efficiency performance can applied in the residential sector in case of the financial promotion or subsidy measures is provided by the government agents. The benefit of this promotion activities are the overall reduction of electricity energy in majority consumption with air condition system for all residential and designated building in Thailand.

7. CONCLUSIONS

The environmental and the climate change have impact to quality of life and living style of people. The economic growth of South East Asia countries in the past few decades made the new standard of living style in South East Asia countries had change requirement of all building, designed the good indoor air quality at the comfortable to the people. Although to climate in the countries near the equator are very hot and high humid weather. But most the countries in South East Asia include Thailand had install air condition systems to improve the indoor air quality in the most of the building and also residential building. As per the information in this article the most consumption of the electrical energy greater than 50% of overall consumption in every sectors of the building are spending in air condition system. The greater of electrical energy consumption portion in air condition system motivated to study this article, how to give the decision guideline to the consumer especially in residential sector in Thailand to get a good decision making to select the new air condition system for their family.

The Life Cycle Cost Analysis (LCC) is a simple and effective technique to apply and assessment the economics solution for air conditioning system. This article had selecting of three air conditioning systems from the available technology in local Thailand market to comparison by LCC technique, including standard label number 5, the inverter type and the evaporative condensing type with capacity of 18,000 B.T.U. for residential sector.

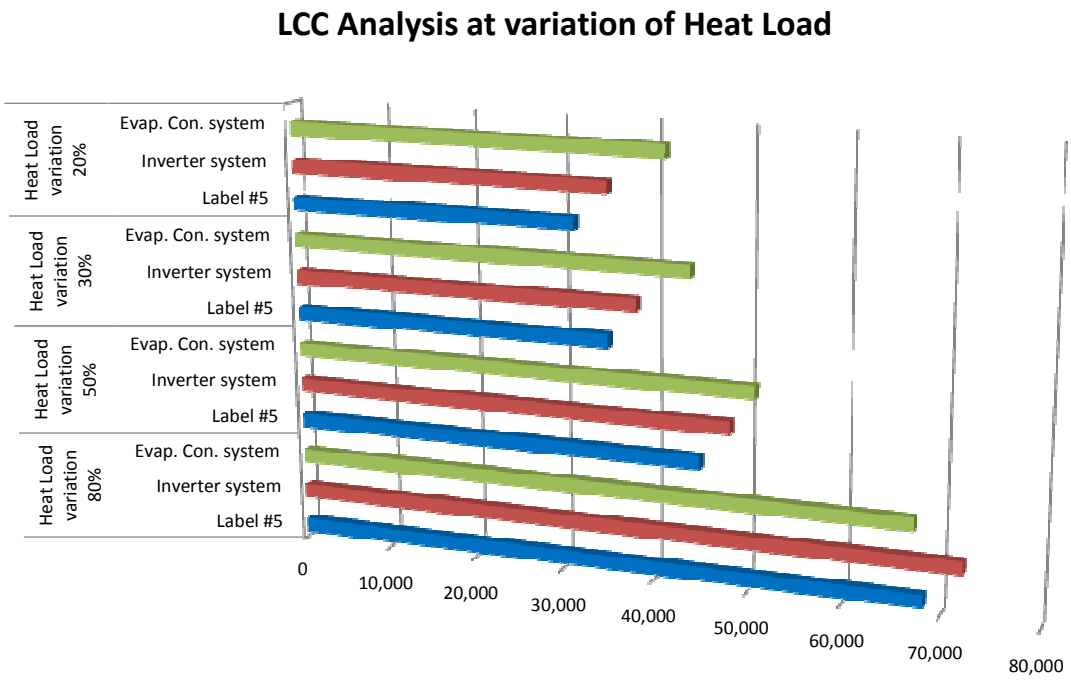

Fig. 15. The total LCC analysis at variation of Heat Load for air condition capacity 18,000 B.T.U.

Table. 4. Life cycle cost anlysis of three types system with sensibility analysis from heat load variation

	Heat Load variation 80%			Heat Load variation 50%			Heat Load variation 30%			Heat Load variation 20%		
	Label #5	Inverter system	Evap. Con. system	Label #5	Inverter system	Evap. Con. system	Label #5	Inverter system	Evap. Con. system	Label #5	Inverter system	Evap. Con. system
Capital cost	22,500	27,500	32,000	22,500	27,500	32,000	22,500	27,500	32,000	22,500	27,500	32,000
Year 1	8,200	8,008	6,290	4,000	3,700	3,350	2,260	1,900	2,132	1,600	1,360	1,670
Year 2	8,200	8,008	6,290	4,000	3,700	3,350	2,260	1,900	2,132	1,600	1,360	1,670
Year 3	8,200	8,008	6,290	4,000	3,700	3,350	2,260	1,900	2,132	1,600	1,360	1,670
Year 4	8,200	8,008	6,290	4,000	3,700	3,350	2,260	1,900	2,132	1,600	1,360	1,670
Year 5	8,200	8,008	6,290	4,000	3,700	3,350	2,260	1,900	2,132	1,600	1,360	1,670
Year 6	8,200	8,008	6,290	4,000	3,700	3,350	2,260	1,900	2,132	1,600	1,360	1,670
Year 7	8,200	8,008	6,290	4,000	3,700	3,350	2,260	1,900	2,132	1,600	1,360	1,670
NPV O&M	45,775	44,703	35,113	22,329	20,654	18,701	12,616	10,606	11,901	8,932	7,592	9,323
Total LCC (THB)	68,275	72,204	67,113	44,829	48,155	50,701	35,116	38,106	43,902	31,432	35,092	41,323

The analytical results in this study offer the lowest life cycle cost analysis to select the optimal type of air conditioning systems for residential sector. In addition, the duty cycle of compressor is varied from 20%-80% to investigate the sensitivity of financial index. For this analysis, the significant factor which impact to LCC analysis of air conditioning for residential sector is initial cost of the new air conditioning. The result of total LCC analysis cost study against the variation of heat load had a significant total cost saving if operating air conditional at 80% or greater than 80% duty cycle for air condition with evaporative condensing system. In the other hand, if operating lower than 80% duty cycle for residential air condition system the regular split type with label number 5 is better than other system as display in Figure 15. Furthermore, factors in Thailand environmental and behavior of users to utilize the air conditioning at the night time, made the variation factor of heat load lower than 65%. Finally, the lowest of LCC in this study is the split type air conditioning system with label number 5 and followed by the air compressor split type with inverter system and air conditioning system using water to cooling at condenser unit, respectively.

Moreover, one of the key factors to encourage consumer to select high efficiency air conditioning system in the residential sector is initial cost. If the local government agency able to reduce the capital cost of investment by subsidiary some cost of the high efficiency air conditioning system or given the financial support to the residential sector. The high efficiency air

conditioning system will be selected by the consumer and the result of using high efficiency equipment will reduce the electrical energy consumption in the national wide.

The result of this LCC analysis in air conditioning system for residential sector in Thailand is require further study for another sectors of designated building. The high efficiency air conditioning system, an inverter air conditioning system or evaporative condensing system may suitable for large scale building, office rental building, department store building, hospital or industrial sector with require operating air condition system in day time at high duty cycle.

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