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# ECONOMICS ANALYSIS OF AN INVERTER AND NON-INVERTER TYPE SPLIT UNIT AIR-CONDITIONERS FOR HOUSEHOLD APPLICATION

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## ABSTRACT

The best selection of residential air conditioner require consumers to justify the advantages of any potential model over other potential models. The payback period (PP) analysis between possible potential models can be used as a indicator for consumers to justify which type and model they should choose. This report presents an analysis to investigate the PP between inverter and non-inverter split type air-conditioners for household application. The selected air conditioners used in this study are from 1.5 horse power inverter and non-inverter types spilt unit, residential air conditioner. The mathematical model of economic analysis is developed based on proposed model developed by previous researches. The operating cost for each air conditioner are determined from the data provided by the manufacturer. In this analysis, the increment of percentage on energy saving, hours of daily operation and decrement of interest rate reduce the PP of inverter type split unit air conditioner compared to non-inverter type. It is found that an inverter type air conditioner with highest energy saving of 65% has shortest PP of only 3.42 years, followed by an inverter air-conditioner with highest operating time of 12 hours per day (3.75 years), and an inverter air-conditioner with lowest interest rate of 1% (4.33 years). Meanwhile, the service work at the middle of unit's life time (month 90) has no effect on its PP. In short, the percentage of energy saving has dominant effect on PP followed by the effect of operating hours per day and rate of interest.

**Keywords:** economic analysis, payback period, inverter type, split unit, residential air-conditioning system.

## INTRODUCTION

Human thermal comfort in buildings is one of the major issues. In commercial buildings, it can affect the efficiency and productivity of workers. Meanwhile, thermal comfort in residential buildings can improve the quality of daily life, which also affect the efficiency and productivity of occupants while they are at work. Due to this reason, air conditioners are now becoming a standard accessory for household application. Sukri *et al.* (2012) highlighted that air-conditioning contributes highest energy demand for typical commercial buildings about 50-60%. The same situation also occurs in transportation sector where the air-conditioning system consumes the largest of energy among accessories equipped in typical land vehicles (Sukri *et al.* 2016). In residential buildings, as shown in Table-1, percentage of energy used for space conditioning is also significant, of up to 70% from total building energy consumption, especially for extreme hot and cold countries.

**Table-1.** The residential energy consumption and percentage of energy used for space conditioning in few countries (Pérez-Lombard *et al.* 2008).

| Countries | Residential energy consumption (%) | Space conditioning share (%) |
|---|---|---|
| Saudi Arabia | 50 | 70 |
| USA | 22 | 52 |
| UK | 28 | 62 |
| Spain | 15 | 42 |
| European Union | 26 | 68 |

Many models of air conditioners are available in the market for customer to choose. For split type air conditioner, there are models known as inverter and non-inverter types. The inverter model is more complex in its system leading to more energy-efficient but at a higher initial cost compared to standard non-inverter type. However, manufacturers claim that the higher initial cost of this energy-efficient model will be repaid to the consumers several times during its life time through saving in its energy cost.

The inverter air conditioner is more energy-efficient because it comes with an advance direct current (DC) inverter technology to drive highly efficient DC motor in the compressor and enable a wider output power range for more energy saving and higher power (Panasonic 2014a). This type of DC inverter technology has dramatically reduced power consumption of up to

50%, compared with conventional alternating current motor driven compressor (Panasonic 2014a). With addition of other latest advanced technologies such as dual human activity sensor, sunlight sensor and temperature wave, the energy saving can be increased of up to 65% compared to the same capacity of standard non-inverter type (Panasonic 2017).

Since air conditioner is one of the most expensive accessories for residential buildings due to its high initial and energy costs, consumers must properly determine the suitable model and type that economically suits with their application. An economic analysis can be conducted to predict the payback period (PP) of potential model over other potential model. From this PP, consumers can justify which one of the models is the best for their daily usage.

In the past few years, few economic analysis related to air conditioning system had been carried out (Aktacir *et al.* 2006; Li *et al*. 2010; Sanaye *et al*. 2010; Subiantoro and Kim 2013; Allouhi *et al.* 2015; Almutairi *et al.* 2015; Chaiyat 2015; Al-Ugla *et al.* 2016; Cai *et al*. 2016; Kharseh and Al-Khawaja 2016; Oropeza-Perez 2016; Yue *et al.* 2016; Yu *et al.* 2017). Table-2 summarized researches related to economic analysis of air-conditioning system by previous researchers.

**Table-2.** Summaries of previous economics analysis researches related to building air-conditioning system.

| Authors | Objectives | Summary of findings |
|---|---|---|
| Aktacir *et al*. 2006 | To evaluate the economic feasibilities of constant-air-volume (CAV) and variable-air-volume (VAV) air-conditioning systems. | It was found that for all considered cases, although initial cost of the VAV system was higher than that of the CAV system, the present-worth cost of the VAV system was lower than that of the CAV system at the end of the lifetime due to lower fan-operating costs. |
| Li *et al*. 2010 | To study the economic feasibility for integrating a solar liquid desiccant dehumidification system with a conventional vapour compression air-conditioning system for the weather condition of Hong Kong. | The annual operation energy savings for the hybrid system was 6760 kWh and the payback period was around 7 years. The study showed that the solar assisted air-conditioning system is a viable technology for utilizations in subtropical areas. |
| Sanaye *et al*. 2010 | To conduct an economic analysis of using gas engine heat pumps (in comparison with the electrical heat pumps) at various climate regions of Iran, for both residential and commercial buildings, and for both cooling and heating modes. | The annual operating cost for electrical heat pumps was higher than that for the gas engine heat pumps in both residential and commercial sections and all studied climate regions. Gas engine heat pump was more economical than the electrical heat pump in residential section and various climate regions. In commercial section and all four climate regions, the electrical heat pumps in all capacities were more economical than gas engine heat pumps. The selection of gas engine heat pump instead of an electrical heat pump showed that the payback period decreases with increment of system capacity. |
| Subiantoro and Kim 2013 | To perform an economic analysis of the installation of expanders on to existing vapour compression cooling systems, particularly medium scale air conditioners with various refrigerants. | With a 50% of expander efficiency, the payback periods of most conventional systems were below 3 years in high temperature countries with high electricity tariffs, and were above 5 years in other countries. Expanders were attractive for the transcritical $CO_2$ and the R404A systems. The payback periods were shorter for systems with highly efficient expanders, high cooling loads, high ambient temperatures and for low refrigerating temperature applications. |
| Allouhi *et al*. 2015 | To investigate the potential of solar closed cycle over conventional cycle air-conditioning systems in Morocco based on economic indicator. | The solar air-conditioning systems in hot climates must be an attractive alternative to mitigate $CO_2$ emissions and increase energy savings. The high installation cost was a main obstacle facing their implementation. |
| Almutairi *et al.* 2015 | To evaluate the relationship of economics to environmental effects, life cycle cost and payback period. | In the economic point of view, an energy efficient air conditioner was not attractive in the locations where the cooling energy consumption was the lowest. It is marginally attractive for buildings in regions requiring the greatest consumption of cooling power. From the government's perspective, the use of more efficient air conditioners was always beneficial from an economic perspective, as well as improving environmental quality. Emerging non-fossil sources of electricity may have the greatest positive impacts on the environment and require some policy decisions. |
| Chaiyat 2015 | To perform an economic analysis of air conditioner using phase change | The electrical consumption of the air-conditioner with PCM could be decreased around 3.09 kWh per day. The saving cost from the PCM |

| | | |
|---|---|---|
| | material (PCM) under Thailand climate. | bed could be 9.10% with payback period of around 4.15 years. |
| Al-Ugla *et al.* 2016 | To develop viable recommendations in mitigating the electrical peak power demand in Saudi Arabia by utilizing solar cooling technology in commercial buildings as well as to establish the tangible economic benefits from applying such technology. | The results showed that a solar absorption system was more economically feasible than a solar PV-vapor-compression system. Moreover, the feasibility of both solar-powered systems improved as the size of the commercial building and the electricity rate increased. |
| Cai *et al.* 2016 | To conduct green retrofit survey and analysis for HVAC system in public institutions in Shenyang, China. | The energy saving effects were obvious, especially coal saving effect. The coal saving rate was as high as 64.1%, and electricity saving rate was between 21.1 to 29.2%. |
| Kharseh and Al-Khawaja 2016 | To study the effect of different retrofitting measures for reducing cooling load of buildings in hot climate. | Replacing single glazed window with double glazed reduced the cooling load by 4.5%. Adding 2 cm of polyurethane to the external walls reduced the cooling load by 28%. 53% reduction in the cooling load can be obtained by implementing all measures. The payback period of considered retrofitting measures varies between 0.5 and 4 years. |
| Oropeza-Perez 2016 | To analyse the economic impact of different energy performances of air conditioning within the Mexican housing sector | An annual saving of up to USD 770 within a single air-conditioned dwelling was achieved. A payback period of 3 years for using a combination of passive cooling techniques and increasing the comfort temperature set-point, or a 2 years payback period if the air-conditioning was changed by high-efficient equipment. |
| Yue *et al.* 2016 | To investigate the payback periods of an energy system of an organic Rankine cycle (ORC) coupled with vehicle air conditioning for different type of refrigerants. | The payback period decreased with decrement of condensation temperature and increasing of evaporation temperature of ORC. At lower condensation temperature, the lowest payback period was found in the case of R134a, followed by pentene, R245fa and cyclopentane. The system using R134a and cyclopentane produce economic performance advantage for evaporation temperature of ORC below 370 K and in the range of 370-420 K respectively. |
| Yu *et al.* 2017 | To analyse the economic benefits of an air-cooled chiller retrofitted with advanced heat rejection features. | For a chiller system serving an office building, the mode of variable speed control for condenser fans with an adjustable condensing temperature gave the highest economic benefit with a simple payback of 10.83 years and an internal rate of return of 4.38% over a 15 years lifetime. |

So far, however, research of economics analysis to investigate the effect of energy saving, daily operation hour, rate of interest and service cost on the PP of an inverter type, compared to non-inverter type split unit air-conditioner for household application is yet to be investigated, at least to the authors' knowledge. From this PP, consumers can justify which one of the models is the best for their daily usage. Therefore, it is the intent of this paper to justify the effect of energy saving, daily operation hour, rate of interest and service cost on the PP of an inverter type, compared to non-inverter type split unit air-conditioner for household application.

## METHODOLOGY

Figure-1 shows research methodology flow chart in a diagrammatic form.

### Cost Mathematical Models

In an operation of electrical and mechanical appliances, over their life time, the cost involved or total costs (TC) are initial or unit cost (IC), installation cost

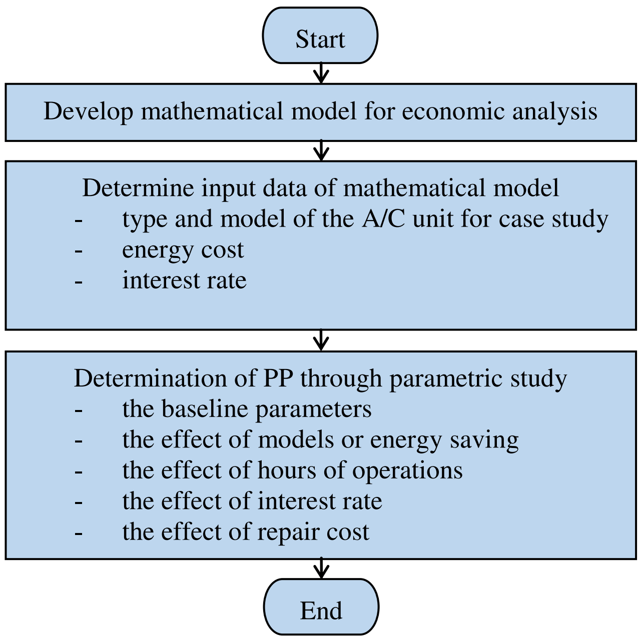


**Figure-1.** Methodology flow chart.

(INC), energy cost (EC), repair cost (RC) and maintenance/service cost (MC), where

$$TC = IC + INC + EC + RC + MC \quad (1)$$

**Initial and installation costs**

The *IC* depends on type and model of the unit as specified by the manufacturer. Common real practices in Malaysia show that retail sales price covers both, *IC* and *INC* for the case of back-to-back installation of indoor and outdoor units. Figure-2 shows back-to-back installation of indoor and outdoor units.

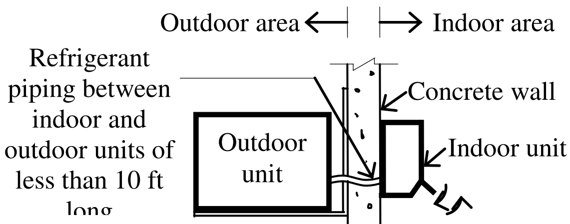


**Figure-2.** Back-to-back installation of indoor and outdoor units of spit type air conditioner.

**Energy cost**

The energy usage (*EU*) depends on three factor; unit capacity, energy efficiency ratio (*EER*) and operating time (Almutairi *et al,* 2015) where

$$EU = \frac{Unit\ capacity}{EER} \times operating\ time \quad (2)$$

Then, the energy cost can be determined if the cost per unit energy (*CUE*) is known where

$$EC = EU \times CUE \quad (3)$$

According to Tenaga Nasional Berhad (main power producer and seller in Malaysia), residential buildings are categories under "Domestic Consumer", means a consumer occupying a private dwelling, which is not used as a hotel, boarding house or used for the purpose of carrying out any form of business, trade, professional activities or services (Tenaga Nasional Berhad, 2017). Effective on January 1st, 2014, tariff rates are as in Table-3.

**Table-3.** Energy cost for residential buildings in Malaysia since January, 1st 2014 (Tenaga Nasional Berhad, 2017).

| Tariff category | CUE (RM/kWh) |
|---|---|
| For the first 200 kWh (1 - 200 kWh) per month | 0.218 |
| For the next 100 kWh (201 - 300 kWh) per month | 0.334 |
| For the next 300 kWh (301 - 600 kWh) per month | 0.516 |
| For the next 300 kWh (601 - 900 kWh) per month | 0.546 |
| For the next kWh (901 kWh onwards) per month | 0.571 |
| The minimum monthly charge is RM3.00 | |

**Repair cost**

Normally, the time and cost required for repair work of any type of breakdown and etc. is unpredictable. However, Almutairi *et al.* (2015) proposed simple correlation between repair cost *(RC), IC* and unit's life time, where

$$RC = \frac{0.5 \times IC}{Unit's\ Life\ time} \quad (4)$$

It is expected that the average lifetime of each unit of air conditioner is 15 years (assumption due to compressor warranty by the manufacturer).

**Maintenance cost**

To ensure an optimal performance of the air conditioners, manufacturers recommended to perform scheduled maintenances of filter cleaning for every 2 weeks, and chemical *cleaning* for every 12 to 18 months (Panasonic, 2014b). Almutairi *et al.* (2015) highlighted that the MC of the air-conditioner is 2.5% of the unit price where

$$MC = 0.025IC \quad (5)$$

**Type and model of the air-conditioners**

Table-4 summarized two selected models for household application available in the open literature that being used in this study, ranging from premium inverter to standard non-inverter type. These air-conditioners are manufactured by Panasonic (M) Sdn. Bhd.

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**Table-4.** Summaries of single unit split type residential air-conditioners selected for the case study.

| Specifications | 1.5HP Standard Non-Inverter Air Conditioner CS-PV12SKH (CU-PV12SKH) (Panasonic 2014c) | 1.5HP Premium Single Split Inverter Air Conditioner CS-S13SKH (CU-S13SKH) (Panasonic 2014d) |
|---|---|---|
| Horse power (HP) | 1.5 | 1.5 |
| Cooling capacity (min-max) kW | 3.51 | 3.66 (0.92-4.20) |
| Power Input (W) | 1,160 | 1,040 (260-1,200) |
| Refrigerant Type | R410A | R410A |
| EER (Btu/Hw)@(W/W) | 10.3@3.0 | 12.0@3.5 |
| Energy Saving (%) | - | up to 65* |
| Energy Star | 3 | 5 |
| Retail Sales Price** (RM) | 1,488.00 | 2,068.00 |

*Comparison of 1.5HP Inverter model with ECONAVI (with Dual Human Activity Sensor, Sunlight Sensor, and Temperature Wave) ON and 1.5HP standard non-Inverter (Cooling).
**Assumed inclusive installation cost for back-to-back location of indoor and outdoor units.

**The baseline parameters**

The baseline parameters for the base case simulation are shown in Figure-3. A 1.5 HP of air-conditioner is equivalent to 1119 W. It is assumed that each unit operates 10 hours per day, 30 days per month. With energy cost of RM 0.218/kWh (Table-3) and EER of 3.0 (Table-4), EC per month of standard non-inverter type can be determined using equations (2) and (3), where it costs consumer of around RM 24.39 (Figure-3a). By using a premium inverter-type with 50% of energy saving, the EC reduced to RM 12.26 (Figure-3b). The RC is calculated using equation (4) and it cost RM 49.33 per year or RM 740 for its entire lifetime of the standard non-inverter type. Meanwhile, premium inverter type costs RM 68.93 per year or RM 1034 for its entire lifetime. It is almost impossible that each unit has problem that needs repair each year, therefore, repair work is expected once of its entire life span at month 90 (middle of the unit life span). The MC is predicted through equation (5) where it costs consumer of around RM 37.00 per service for non-inverter model (Figure-3a) and RM 51.70 for inverter model (Figure-3b). As recommended by the manufacturer maintenance activities are expected each 18 months. The interest rate is expected at 3% per year.

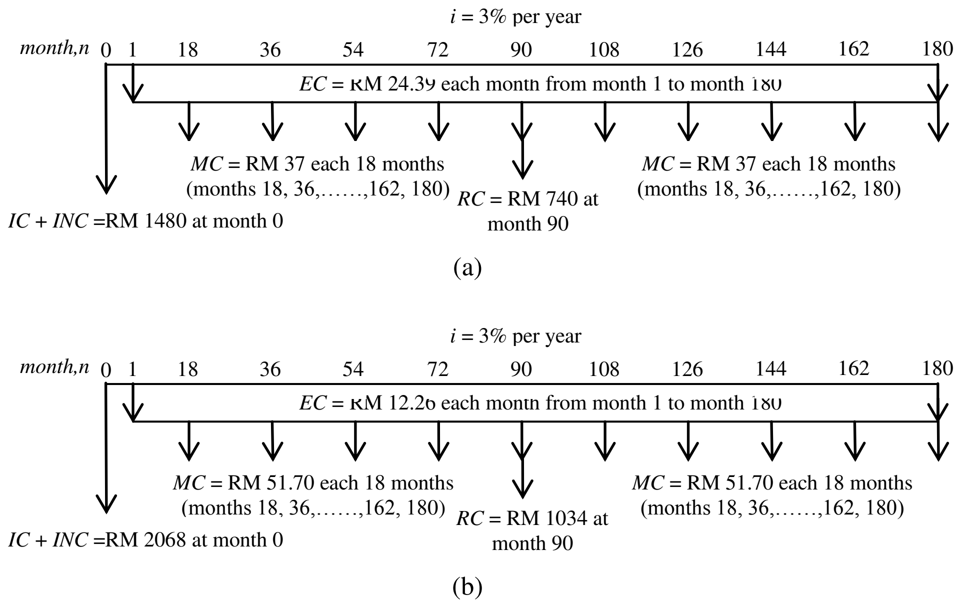


**Figure-3.** Cash flow (a) standard non-inverter type, (b) premium inverter type with 50% energy saving.

**Time value of money**

Time value of money represents the effect of time to the value of money. It is the idea that money available at the present time is worth more than the same amount in the future due to its potential earning capacity. Thus, the value of RM 1 today (present time) is not the same as RM 1 on one year ahead (future time). The relation between future value (*FV*) at time *n* with present value (*PV*) at time 0 is calculated where

$$FV = PV \cdot (1+i)^n \tag{6}$$

with *n* is the number of periods and *i* is the interest rate at which the amount compounds at each period.

**DISCUSSIONS**

In the parametric study, percentage of energy saving and daily hour of operations are selected because these two parameters have significant impact and closely related to consumer daily life. Interest rate and cost of repair are unpredictable parameters. Therefore, it is also meaningful to investigate how these parameters influence customers on decision making of what kind of air conditioner they should chose. In this investigation, these four parameters are changed one at a time in the runs, while the other parameters are held constant at the base values.

**The effect of model or energy saving**

Manufacturer claims that with the technology of inverter, the inverter type air conditioner can produced 50% of energy saving compared to non-inverter type, and up to 65% saving with additional features of dual human activity sensor, sunlight sensor, and temperature wave. As shown in Figure-4, compared to non-inverter type, an inverter type with highest energy saving of 65% has lowest PP of 3.42 years, followed by an inverter models with 50 and 35% of energy savings (4.67 years and 10.25 years respectively). Therefore, the percentage of energy saving has significant and good impact to PP. In the case of 65% energy saving, after 3.42 years and onwards, the consumer gain significant cost saving if they are using this inverter type (with 65% energy saving) compared to standard non-inverter type.

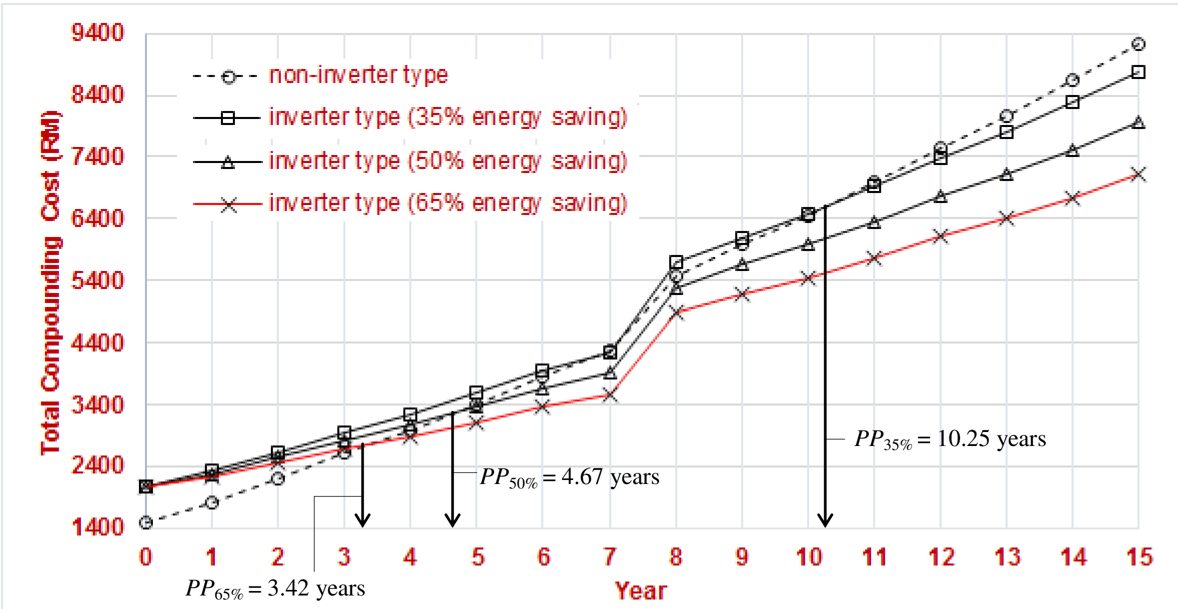


**Figure-4.** Payback periods of an-inverter type air-conditioner at different percentage of energy saving compared to non-inverter type.

**The effect of daily hours of operations**

Daily operating hour is directly proportional to EC. The longer the operating hour, the higher the EC. Therefore, higher operating hour has a big advantage for energy-efficient, inverter type air conditioners due to increase EC saving compared to non-inverter type. As a result, as shown in Figure-5, an inverter type air conditioners with highest operating time of 12 hours has shortest PP of only 3.75 years, followed by inverter type air conditioners with 10 hours (4.67 years) and 8 hours of daily operation (5.92 years).

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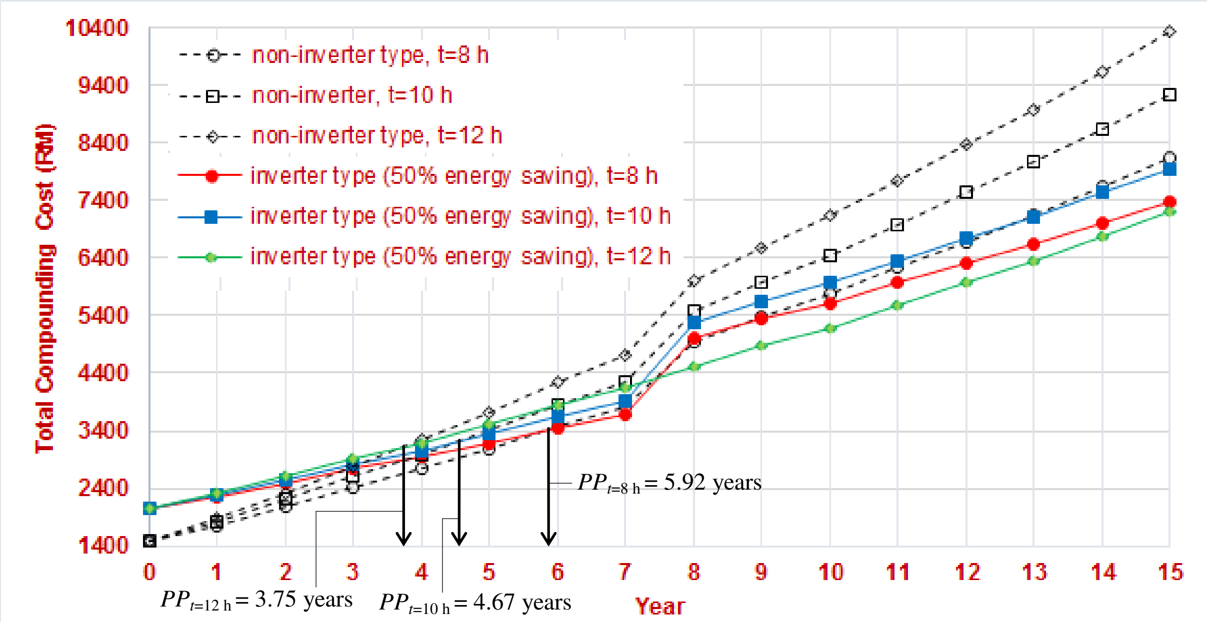


**Figure-5.** Payback periods of an-inverter type air-conditioner at different daily operating hours compared to non-inverter type.

**The effect of interest rate**

The effect of time value of money over the years on PP of inverter type air conditioners compared to non-inverter type is shown in Figure-6. It can be seen that the effect of interest rate due to time value of money has a negative impact to the PP of the inverter type air conditioner. An increment in interest rate from 1 to 3% increase the PP from 4.33 years to 4.67 years (7.9% increase), and the PP increases from 4.67 years to 4.92 years (5.4%) if the interest rate increase from 3 to 5%.

The negative impact is due to two reasons. The first reason is the different in IC between non-inverter and inverter types is relatively high compared to monthly different in EC. The second reason is the IC was spent in month 0, therefore the higher IC of inverter-type with the effect of time value of money with compounding effect increase the PP at the increment of interest rate.

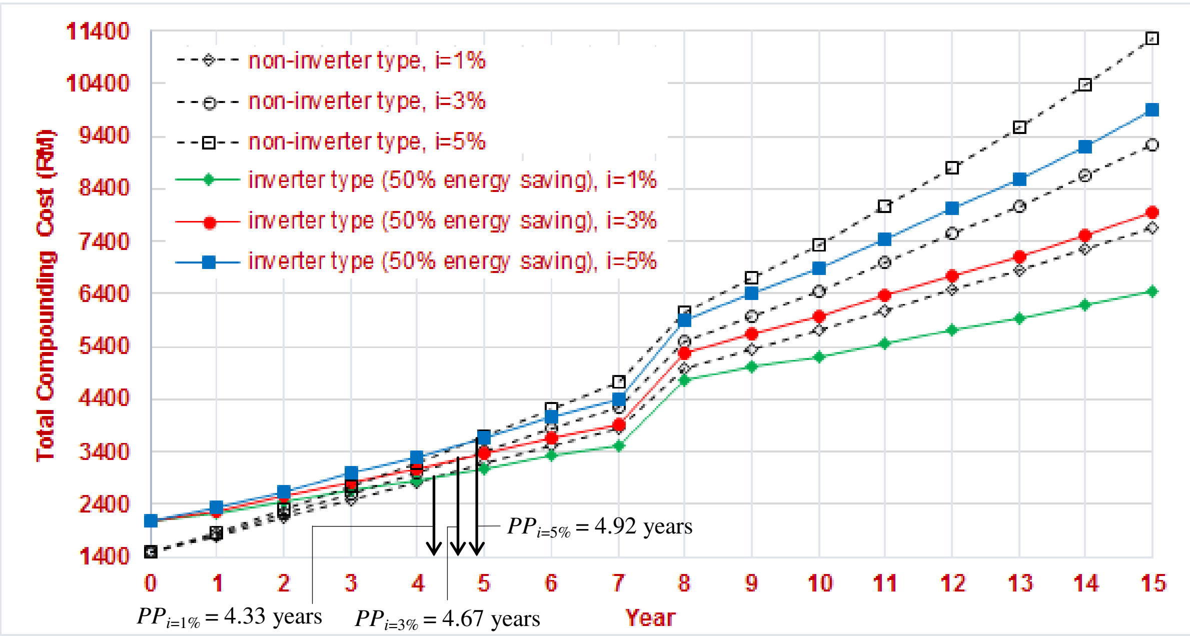


**Figure-6.** Payback periods of an-inverter type air-conditioner at different interest rate compared to non-inverter type.

**The effect of cost of repair**

According to equation (4), the estimated yearly RC is RM 49.33 and RM 68.93 for non-inverter and inverter types respectively. Therefore, in 15 years life time of each unit, the estimated total RC for non-inverter and inverter types are respectively at RM 740.00 and RM 1034.00.

In this analysis, besides line condition, two additional cases are considered. The first is ideal case where there is no need for repair for the entire life time of the air conditioner (RC = 0). Meanwhile, the second case expecting a repair work in the middle of unit's life time (month 90) with the RC equal to half of total RC of the entire life time.

Figure-7 shows there is no effect of RC to the PP of an inverter type air conditioner compared to non-inverter type. It is because the PP of each case (4.67 years) is lower than the year (7.5 years) where all air conditioners require service work. Therefore, the effect of RC is only significant after the year of service work which is at the year 7.5 years and onwards.

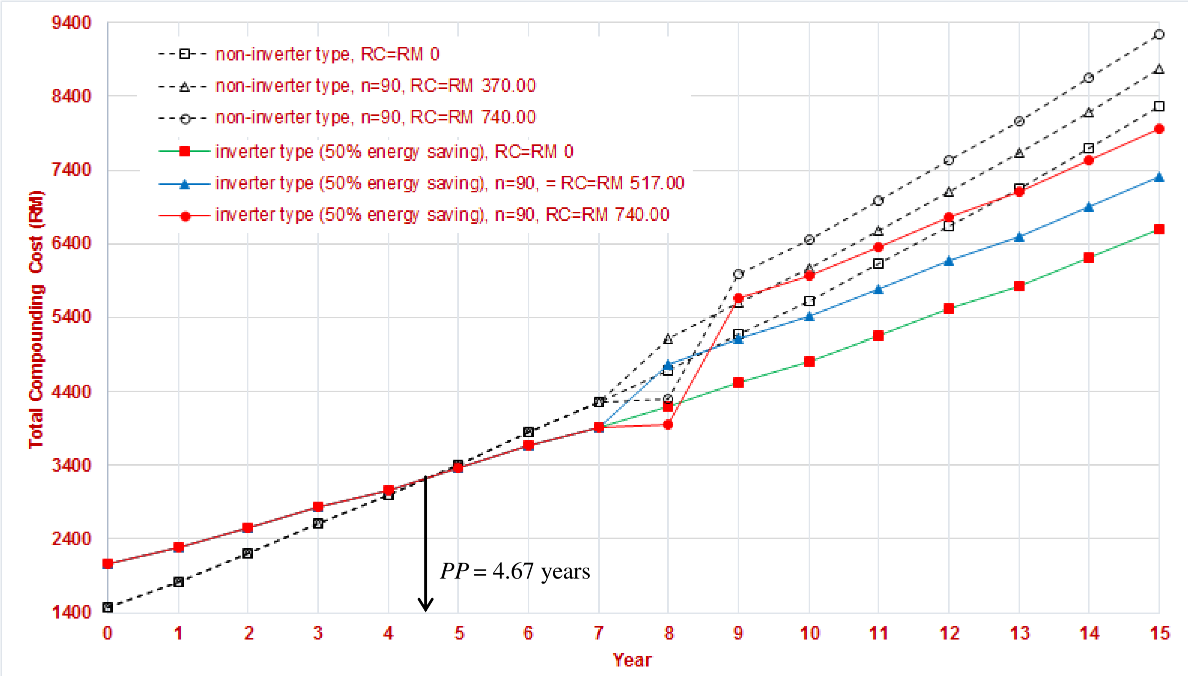


**Figure-7.** Payback periods of an-inverter type air-conditioner at different cost of repair compared to non-inverter type.

## CONCLUSIONS

In this analysis, the increment of percentage on energy saving, hours of daily operation and decrement of interest rate reduce the PP of inverter split type air conditioner compared to non-inverter type. An inverter type air conditioner with highest energy saving of 65% has shortest PP of only 3.42 years, followed by an inverter air-conditioner with highest operating time of 12 hours per day (3.75 years), and an inverter air-conditioner with lowest interest rate of 1% (4.33 years). Meanwhile, since the PP is actually lower than the year where the service work is required, the service work at the middle of unit's life time (month 90) has no effect on its PP. In short, the percentage of energy saving has dominant effect on PP followed by the effect of operating hours per day and rate of interest. In the authors' point of view, an air conditioner with PP of less than 50% of the unit's life time compared to other options of air conditioner is wroth to choose. It is due to potential cost saving of another half time of the unit's life time.

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## REFERENCES

Aktacir M.A., Bu¨yu¨kalaca O. and Yılmaz T. 2006. Life-cycle cost analysis for constant-air-volume and variable-air-volume air-conditioning systems. Applied Energy. 83: 606-627.

Al-Ugla A.A., El-Shaarawi M.A.I., Said S.A.M. and Al-Qutub A.M. 2016. Techno-economic analysis of solar-assisted air-conditioning systems for commercial buildings in Saudi Arabia. Renewable and Sustainable Energy Reviews. 54: 1301-1310.

Allouhi A., Kousksou T., Jamil A., Rhafiki T.E., Mourad Y. and Zeraouli Y. 2015. Economic and environmental assessment of solar air-conditioning systems in Morocco. Renewable and Sustainable Energy Reviews. 50: 770-781.

Almutairi K., Thoma G., Burek J. Salem Algarni S. and Nutter D. 2015. Life cycle assessment and economic analysis of residential air conditioning in Saudi Arabia. Energy and Buildings. 102: 370-379.

Cai X., Li H., Feng G., Yu S. and Zhao Y. 2016. HVAC system green retrofit survey and analysis of public institutions building in cold region. Procedia Engineering. 146: 218-223.

Chaiyat N. 2015. Energy and economic analysis of a building air-conditioner with a phase change material (PCM). Energy Conversion and Management. 94: 150-158.

Li Y., Lu L. and Yang H. 2010. Energy and economic performance analysis of an open cycle solar desiccant dehumidification air-conditioning system for application in Hong Kong. Solar Energy. 84: 2085-2095.

Kharseh M. and Al-Khawaja M. 2016. Retrofitting measures for reducing buildings cooling requirements in cooling-dominated environment: Residential house. Applied Thermal Engineering. 98: 352-356.

Oropeza-Perez I. 2016. Comparative economic assessment of the energy performance of air-conditioning within the Mexican residential sector. Energy Reports. 2: 147-154.

Panasonic 2014a. How is the Energy Saving of Inverter Model. http://eng-au.faq.panasonic.com/app/answers/detail/a_id/29372/~/how-is-the-energy-saving-of-inverter-model.

Panasonic. 2014b. What is the recommended time for remedial maintenance/servicing for air con. http://eng-au.faq.panasonic.com/app/answers/detail/a_id/31172/~/what-is-the-recommended-time-for-remedial-maintenance%2Fservicing-for-air-con.

Panasonic. 2014c. 1.5HP Standard Non-Inverter Air Conditioner CS-PV12SKH (CU-PV12SKH). http://www.panasonic.com/my/consumer/home-appliances/air-conditioner/single-split-air-conditioner/cs-pv12skh-1_5hp.html.

Panasonic. 2014d. 1.5HP Premium Single Split Inverter Air Conditioner CS-S13SKH (CU-S13SKH). http://www.panasonic.com/my/consumer/home-appliances/air-conditioner/single-split-air-conditioner/cs-s13skh-1_5hp.html.

Panasonic. 2017. Cool.Eco.Together - The Perfacct Energy Saving Match. http://www.panasonic.com/my/consumer/ home-appliances/air-conditioner/single-split-air-conditio-ner/cs-s13skh-1_5hp.html.

Pérez-Lombard L., Ortiz L. and Pout C. 2008. A review on buildings energy consumption information. Energy and Buildings. 40(3): 394-398.

Sanaye S., Meybodi M.A. and Chahartaghi M. 2010. Modeling and economic analysis of gas engine heat pumps for residential and commercial buildings in various climate regions of Iran. Energy and Buildings. 42: 1129-1138.

Subiantoro A. and Ooi K.T. 2013. Economic analysis of the application of expanders in medium scale air-conditioners with conventional refrigerants, R1234yf and $CO_2$. International Journal of Refrigeration. 36: 1472-1482.

Sukri M.F., Salim M.A., Mohd Rosli M.A., Azraai S.B. and Mat Dan, R. 2012. Analytical Investigation of Overall Thermal Transfer Value on Commercial Building in Malaysia. International Review of Mechanical Engineering. 6(5): 1050-1056.

Sukri M.F., Musa M.N., Senawi M.Y. and Nasution H. 2016. Experimental investigation of an automobile air-conditioning system using integrated brushless direct current motor rotary compressor. MATEC Web of Conferences 74, 00013, doi: 10.1051/matecconf/20167400013.

Tenaga Nasional Berhad. 2017. Tariff Rates. https://www.tnb.com.my/residential/pricing-tariffs/.

Yu F.W., Ho W.T., Chan K.T., Sit R.K.Y. and Yang J. 2017. Economic analysis of air-cooled chiller with advanced heat rejection. International Journal of Refrigeration. 73: 54-64.

Yue C., You F. and Huang Y. 2016. Thermal and economic analysis of an energy system of an ORC coupled with vehicle air conditioning. International Journal of Refrigeration. 64: 152-167.