Study of Energy Saving Performance Contracts Application for Electrical Energy Efficiency in Industrial and Commercial Sectors

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Abstract. Industrial and Commercial sectors are the largest energy consumption. Building sector is one of the biggest energy consumptions, especially in Industrial and commercial devices, like air conditioning systems, lighting systems, and building transportation systems. Energy Saving Performance Contract (ESPC) could be an alternative to support implementation of energy efficiency in building sector up to 10-30%. This study investigates about application of ESPC for air conditioning system retrofit in Industrial and Commercial building, namely Chiller. Chiller retrofit could produce energy efficiency 210 MWh/year or reduce up to 30% of energy consumption with a 5-year payback period investment. This study can be broadened to develop application of ESPC in Indonesia.

1. Introduction

Energy is the main human need that needs to be managed so that its use can be carried out efficiently and rationally. Considering fossil energy resources, namely oil and coal, which have a limited amount of reserves and are non-renewable, other energy sources are needed as well as measures to improve the performance of energy so that the increasing energy needs can be met on an ongoing basis. The building sector is one of the largest users of in Indonesia, in addition to the household, transportation and industrial sectors. The use of electrical energy in the building sector to operate building utilities such as Air Conditioning, lights, lighting, elevators, pumps, and other electrical equipment. The classification of energy use in buildings is shown in Figure 1.

![Figure 1. The use of electrical energy in buildings](Image)
Figure 1 shows that the use of significant energy is the air conditioning system (AC) and lighting systems (lights). Both systems are targeted priority areas in building energy management.

Energy management carried out in the building sector, namely energy saving, can be one of the efforts to maintain the reserves of energy resources nationally. In general, the principle of saving energy in buildings is carried out through several stages, namely planning (design), operation, maintenance, and monitoring. In the planning stage (preconstruction) consider and determine design criteria such as the design of the building envelope and utility building. Whereas in the operation stage, the energy saving of buildings is related to the design of building utilities such as air conditioning, pumps, lights, and so on. In addition, in carrying out the energy management process energy management is needed which aims to make energy conservation in the building possible by reducing the amount of the building's energy operational costs.

Based on the experience of several companies, the potential for energy savings of 10-20% in building buildings is not difficult to realize by making changes and improving operational and maintenance procedures that are best practice. Greater energy savings of up to 30% can be obtained by modifying and optimizing energy equipment, but the implementation requires investment with a payback period of 3-5 years.

The application of the Energy Saving Performance Contract (ESPC) business model can be an alternative in supporting the implementation of energy efficiency in the building sector by 10-30% [1]. ESPC is a performance contract in carrying out energy efficiency efforts that can guarantee savings in energy costs. ESPC is carried out by the Energy Saving Company (ESCO), which functions to compensate all costs by reducing energy costs, ensuring the achievement of energy saving targets with performance contracts, providing comprehensive services such as energy audits and recommendations on the results of audit, planning and construction of energy-saving equipment and operations and maintenance of equipment after construction. Figure 2 shows the financing system for compensation for ESCO.

ESCO model consists 2 (two) types, namely guaranteed saving and shared saving models. In guaranteed saving ESCO provides guaranteed savings and those who make investments are the clients, while in shared saving ESCO makes investments with a greater percentage than its clients, for example a comparison of 70% investment by ESCO and the remaining 30% by companies.

The development of the ESPC business in supporting the implementation of energy efficiency in Indonesia is still very slow compared to several other countries in Asia, such as Thailand, China, Singapore, Malaysia, and India. This happens because the ESPC business modelling in Indonesia is still very little or not known by the industry, buildings and banks or financial institutions as potential clients. The low level of trust of the client as a user of ESCO services due to low information about the competence of ESCO. So it is necessary to increase the number of institutions and supporting experts in the ESCO and procure demonstration projects for the implementation of energy efficiency investments.
by ESCO that can be used as a medium of socialization to the industry and buildings to see the benefits of ESPC in energy efficiency investments.

In this study, the author investigates the application of ESPC modelling in office buildings in Jakarta that plans to retrofit air conditioning system devices in implementing efficient use of electrical energy. Modelling the calculation of energy consumption and modelling the compensation of investment costs with the ESPC, without explaining the procedures for investment funding from financial institutions or banks.

2. Research Methodology

In areas of Jakarta, there are many types of buildings, namely office buildings, commercial buildings, government buildings and so on which contribute greatly to national energy consumption and have the potential to take energy efficiency measures. The building used in this study is located in Central Jakarta, Menara Multimedia. Menara Multimedia (MM) is a building owned by PT. Graha Sarana Duta (Telkom Property) which functions as an office building. Menara Multimedia has been operating since 1985 with a land area of +3000 m² and consists of 22 floors and 1 basement.

The air conditioning system that supports Menara Multimedia performance is a chiller device. Considering the operational time period of the building and Mechanical Electrical (ME) equipment which has been operating for a long time since 1985, in recent years the performance of building ME equipment began to decline, especially for chiller devices. This is caused by the age of use of the device and also spare parts (device material) that are no longer available on the Indonesian market (discontinuous). The declining performance of the Chiller device functions affects the comfort level of the building occupants and especially on the very large consumption of building electrical energy consumption.

The existing Chiller System in the Menara Multimedia consists of 3 units of Hermetic Centrifugal Water Chiller type devices, namely 2 Chairs of 330 TR capacity and 1 Chiller of 95 TR capacity. TR or Ton Refrigeration is a unit of power used in describing the heat extraction capacity of a Chiller device. 1 TR is equal to 12,000 BTU/hour or 3.5 kW [5]. Chiller device specifications can be seen in Table 1.

### Table 1. Specifications Chiller of Menara Multimedia

| Device                  | Specification                                      |
|-------------------------|---------------------------------------------------|
| Chiller                 | 2 x 330 TR; 1 x 100 RT                            |
| Chilled Water Pump      | 22 kW/30 HP, 1450 RPM, capacity 3x80m³/h           |
|                         | 5.5 kW/7.5 HP, 1450 RPM, capacity 2x50m³/h         |
| Air Handling Unit       | Double skin, Centrifugal fan with forward curved   |
| Cooling Tower           | capacity 2 x 420 TR                               |

The three Chiller equipment units were manufactured in 1983. 1 unit of 330 TR Chiller operates normally, the other 330 TR Chiller operates in a stand-by mode, and the 95 TR Chiller operates at a certain time (overtime of building occupants). The Menara Multimedia Chiller Device operates normally for 10 hours a day in a week with 5 active working days. In Figure 3 shows the existing air system of the Menara Multimedia consists of 3 units of Chiller devices.
2.1. Electric Energy Consumption from Building Air System Devices

The electrical energy consumption of the Chiller device can be determined by the TR Chiller load spec value at the maximum working conditions within a certain time period. The condition of full load performance is the condition of a predetermined design. The value of electrical energy consumption under full load Chiller working conditions can be calculated using equation (1).

\[ W = P \times \Delta t \]  

By converting units of Electric Power, i.e. kilo Watts into TR (Ton of Refrigeration) then equation (1) can be expressed as equation (2)

\[ W_{\text{chilled water load}} = TR_{\text{cooling}} \times \Delta t \]

Where \( W_{\text{chilled water load}} \) is the energy needed for the Chiller when the condition is full workload (TRh), \( TR_{\text{cooling}} \) is the maximum load capacity of the chiller (TR), and \( \Delta t \) is the operating hours of the Chiller working (hour / hour).

Chiller efficiency ratings with full load performance conditions are expressed in the form of kW/TR or also called COP (Coefficient of Performance) or EER (Energy Efficiency Ratio). COP is the performance coefficient of the steam compression refrigeration system expressed by the ratio of the power of the refrigerator engine to the compressor motor input power.

COP or EER values can be calculated using equation (3)

\[ COP = \frac{P_{\text{refrigeration}} (kW_{\text{cooling}})}{P_{\text{motor}} (kW_{\text{input}})} \text{ atau } EER = \frac{Btu_{\text{cooling}}}{kW_{\text{input}}} \]  

For the percentage value of the Chiller efficiency expressed by the ratio between the input power on the compressor motor to the capacity of the Chiller under conditions of full load performance. Chiller efficiency values can be calculated using equation (4)

\[ \text{Efisiensi Chiller} = \frac{P_{\text{motor}} (kW_{\text{input}})}{TR_{\text{cooling}}} \]  

Chiller system energy consumption can be calculated by multiplying the value of energy consumption by the efficiency of the Chiller system under conditions of full load performance, expressed by equation (5).

\[ W_{\text{chiller system}} = W_{\text{chilled water load}} \times \text{Chiller Efficiency} \]

2.2. Modeling the ESPC Retrofit Chiller Device

In this study, 2 (two) types of ESPC modelling were used to retrofit Chiller devices in the MM Building. The two models will be compared based on the level of electrical energy efficiency and the investment cost of each model’s payback period.
For the first retrofit modelling, that is for 1 unit of existing 330 RT Centrifugal Chiller capacity replaced with a higher efficiency Centrifugal Chiller device, which is 350 RT capacity. Figure 4 shows a diagram for modelling the first retrofit.

![Figure 4. Modelling Centrifugal Chiller Retrofit with a Capacity of 350 RT](image)

For the second retrofit modelling, namely for all existing Centrifugal Chiller units (2 x 330 RT capacity and 95 RT capacity) to become a new Centrifugal Chiller installation with smaller capacity, namely 2 x 200 RT capacity. Figure 5 shows a diagram for modelling the second retrofit.

![Figure 5. Modelling Centrifugal Chiller Retrofit with a Capacity of 2 x 200 TR](image)

Prerequisites for the calculations used in this study include the cost used is the PLN Base Data, the initial cost value, the value of construction costs, and the value of maintenance is determined, and the interest rate is determined. The ESPC period is 5 years. In terms of operational, Chiller's operating hours are 10 hours in a day, which is 08.00 to 18.00.

### 2.3. Economic Calculations

Economic calculations on the modelling of ESPC Retrofit Chiller devices include the following:

- a. The initial costs for the Chiller retrofit action, namely the capital cost (initial cost) of the new chiller device.
- b. Energy consumption costs in the existing system, based on an assessment of the actual operational conditions.
- c. Operating and maintenance costs (Operating & Maintenance costs or O&M costs) for existing systems and new systems.
- d. Estimated annual energy consumption costs for new systems.
- e. Estimated annual energy efficiency costs and differences in O&M costs for existing and new systems.

An important thing that needs to be taken into account in modelling retrofit with ESPC is the payback period. Payback period is a parameter that calculates how fast the time needed to return an investment. Payback Period can be calculated by dividing the value of investment (cost of investment) by the annual net cash flow (annual net cash flow). Payback Period value can be calculated using equation (6)

\[
\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Annual Net Cash Inflows}} \quad (6)
\]
3. Results and Discussions

Calculation of the efficiency resulting from modelling Chiller retrofit in the Menara Multimedia is shown in Table 2.

**Table 2. Efficiency and Electric Energy Consumption in Menara Multimedia Retrofit Modelling**

| Parameter               | Existing System | Retrofit Model 1 | Retrofit Model 2 |
|-------------------------|-----------------|------------------|------------------|
| Chiller Capacity        | 330TR; 330TR;   | 350TR; 330TR;    | 2x200 TR         |
|                         | 95TR            | 95TR             |                  |
| System Efficiency (kW/TR) | 0,897          | 0,628            | 0,703            |
| Energy Consumption (kWh/year) | 710.424       | 497.376          | 556.776          |
| Energy Saving (kWh/year)     | 213.048        | 153.648          |                  |

By determining the ESPC contract period of 5 years and the estimated age of the device 20 years of work. Assumptions about investment costs and O&M costs are based on prices from Indonesian suppliers, contractors and best practices.

The cost components in economic calculations for model 1 retrofitting are shown in Table 3.

**Table 3. Estimated Costs For Retrofitting With ESCO Model 1**

| Cost Component                          | Rupiah Value |
|-----------------------------------------|--------------|
| Capital Cost                            |              |
| 1 unit of Chiller 350 TR                | 18.829.800   |
| O&M costs (ESPC period of 5 years)      | 493.165.716  |
| Energy Savings per Year                 | 220.670.857  |

Figure 6 shows the comparison of costs for retrofit modelling with all costs borne by the Menara Multimedia owner and retrofit 1 modelling with ESPC.

**Figure 6. Comparison of Retrofit Cost Components for Non ESCO and ESCO models 1**

Figure 7 shows a comparison of the value of costs incurred by the Building owner in retrofit modelling with all costs borne by the Menara Multimedia owner and retrofit 1 modelling with ESPC for a period of 10 years. Whereby using retrofit modelling with ESCO, the costs incurred can be divided
equally over the contract period with the calculation of the payback period for 5 years, in addition the owner gets the benefit of the value of energy savings obtained by retrofitting the Chiller device.

![Figure 7](image1.png)

**Figure 7.** Comparison of the Total Cost of Non ESCO Retrofit Modelling and ESCO Model 1 for 10 years

For the cost component in economic calculations for model 2 retrofitting, it is shown in Table 4.

| Cost Component                      | Rupee Value  |
|--------------------------------------|--------------|
| Capital Cost                         | 26,429,670   |
| 2 units of Chiller 200 TR            |              |
| O&M costs (ESPC 5-year period)       | 641,115,430  |
| Energy Savings per Year              | 318,291,050  |

**Table 4.** Estimated Cost Of Retrofitting With ESCO Model 2

![Figure 8](image2.png)

**Figure 8** shows the comparison of costs for modelling retrofit with all costs borne by the owner of MM Building and modelling retrofit 2 with ESPC.

![Figure 9](image3.png)

**Figure 9** shows a comparison of the value of costs incurred by the Building owner in retrofit modelling with all costs borne by the MM Building owner and retrofit 2 modelling with ESPC for a period of 10 years.
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Figure 9. Comparison of the Total Cost of Non ESCO Retrofit Modelling and ESCO Model 1 for 10 years

Based on the two Chiller retrofit modelling with ESCO that can be obtained savings in consumption in MM buildings reaching an average of 210 MWh / year. And by using ESPC modelling in retrofitting chillers in buildings, buildings can make it easier in terms of investment costs by setting a predetermined payback period. This can be one of the steps in efforts to improve electrical energy efficiency in Indonesia, especially for users of loads for business and industrial groups.

4. Conclusions

In this study, the technical and economic aspects of the application of ESPC in retrofitting Chiller devices have been investigated. Chiller device retrofitting can reduce energy consumption in buildings. The average efficiency of the electric energy produced is 210 MWh / year, based on the replacement of TR capacity and system efficiency in the Chiller. Retrofitting Chiller in buildings can reduce electrical energy consumption by up to 30%. By using ESPC modelling, equipment retrofit financing in buildings can be planned with a predetermined payback period system. Electrical energy efficiency obtained during the ESPC period is a benefit to ease the burden on the investment costs of building owners. This study can be expanded again to develop the application of ESPC in Indonesia, especially to further investigate the government-supported financing system.

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References

[1] Modul Manajemen Energi di Industri dan Gedung Kementerian ESDM
[2] Manajemen & Konservasi Energi PT. Krakatau Steel, 2017
[3] Hasan, Shalahudin, “Pelaksanaan Efisiensi Energi di Bangunan Gedung”, 2014
[4] Wiranto Arismunandar, Heizo Saito, “Penyegaran Udara”, Jakarta, 1980
[5] Modul Basic Chiller System, Daikin, 2017
[6] I.B.K Sugirianta, I.A.D. Giriantari, I.N. Satya Kumara, “Analisa Keekonomian Tarif Listrik Pembangkit Listrik Tenaga Surya 1 MWP Bângli Dengan Metode Life Cycle Cost”, 2016