Annex

Case Study: Potential Energy Savings of a Hotel's Chilled-water Air-conditioning System

Leong Siew Meng and Lee Yuen How

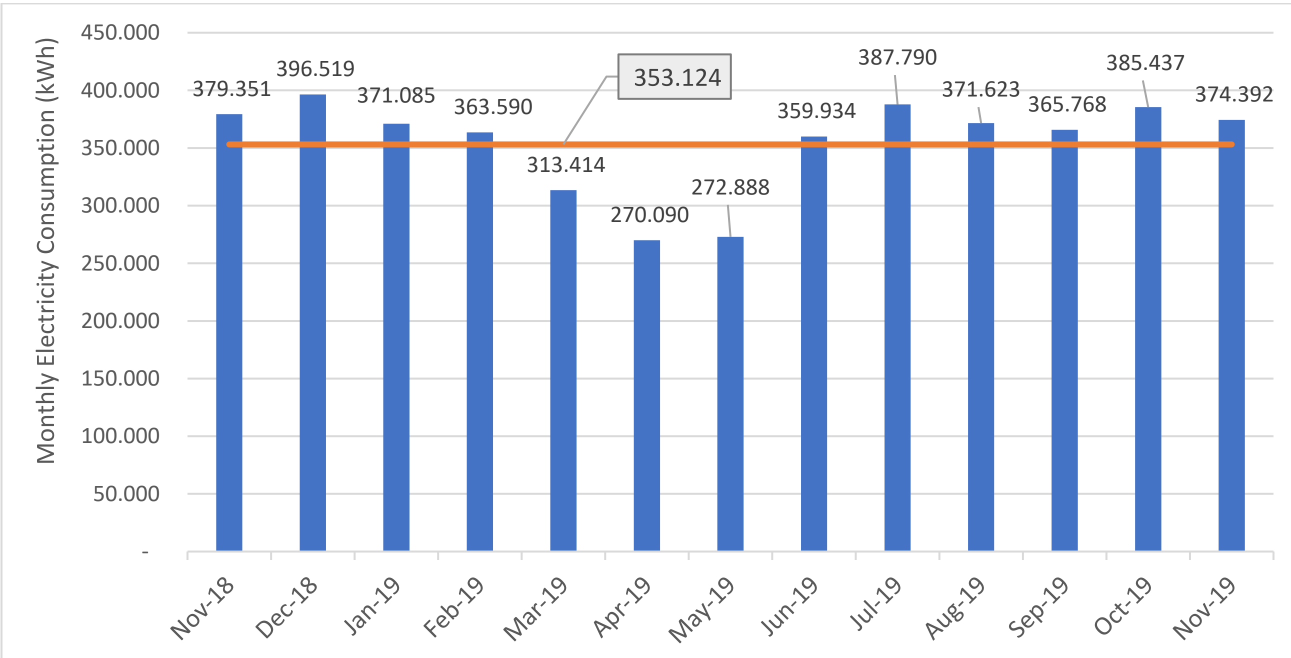
A case study was carried out at a hotel in Phnom Penh to review and investigate whether its chilled-water air-conditioning system has energy saving potential. In view of the non-disclosure agreement with the hotel, this report on the findings will not reveal the name of the hotel, which had contributed useful information for this study. Nevertheless, we acknowledge with appreciation the hotel management's cooperation in granting permission to visit the air-conditioning facilities and in making energy consumption records available.

This case study aims to explore any energy saving potential in an existing chilled-water system that has operated for more than 20 years. In view of improved and energy-efficient chillers available in the market, the case study would focus on making a preliminary assessment of the chiller operation. Hotels, operating for 24 hours, would likely have energy saving potential. How this case study was conducted is equivalent to a walk-through audit without any measurement taken; only basic information was obtained. The hotel has 250 rooms, and the technical information obtained is summarised as follows:

- Chillers installed:
  - 2 units of 1,000 refrigerator tons (RT) centrifugal chillers
  - 1 unit of 400 RT screw compressor chiller
- Monthly electricity consumption data is presented in Figure A1.
- Electricity tariff is US$0.16/kWh

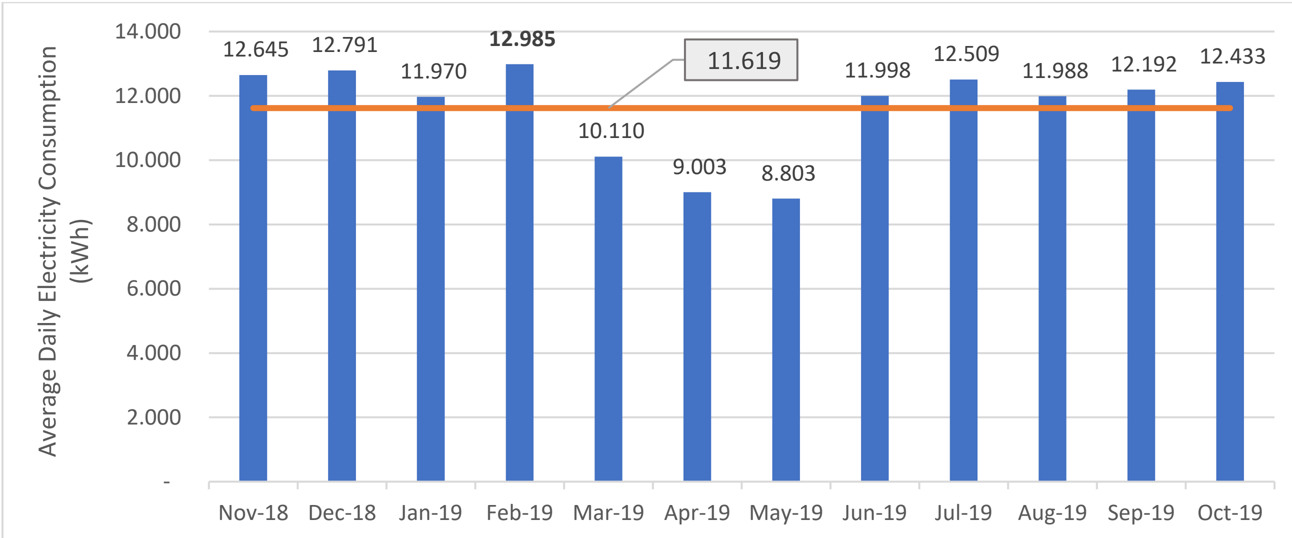
The monthly electricity consumption of the hotel's air-conditioning system from November 2018 to October 2019 was consistent, except for March to May in 2019 (Figure A1). April and May 2019 recorded a dip in electricity consumption. This was because of electricity rationing during these 2 months, which was due to the extremely dry weather that time. Supply of electricity was restricted during this period. The hotel had to generate its own electricity using diesel generator sets during the power outage. The monthly electricity consumption shown in Figure A1 did not include the self-generated electricity because the power generated was to cater mainly to lighting and essential services. The air-conditioning service had to be shut down for a brief period in 2019 during the staggered power rationing arrangement per day. The air-conditioning service was turned on again after the electricity supply was restored during the day. Although the highest consumption per month was recorded in December 2018 (Figure A1), the highest average daily consumption occurred in February 2019 (Figure A2). This was due to the shorter month of February, hence, the highest average daily consumption of 12,985 kW/day. This highest average daily consumption was used to estimate the average daily chilled-water generation load in terms of refrigeration ton and the daily chiller load profile on a worst-case basis.

Figure A1: Monthly Electricity Consumption (2018–2019)



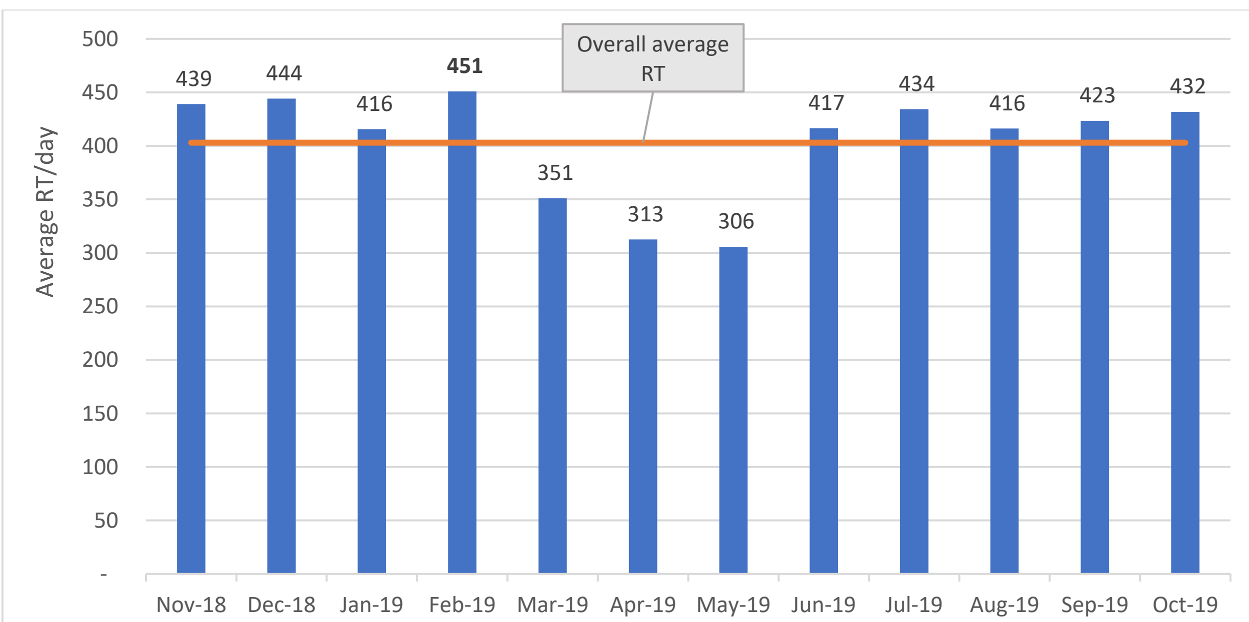
Source: Author, based on the monthly electricity bills provided by the hotel.

Figure A2: Average Daily Electricity Consumption (2018–2019)



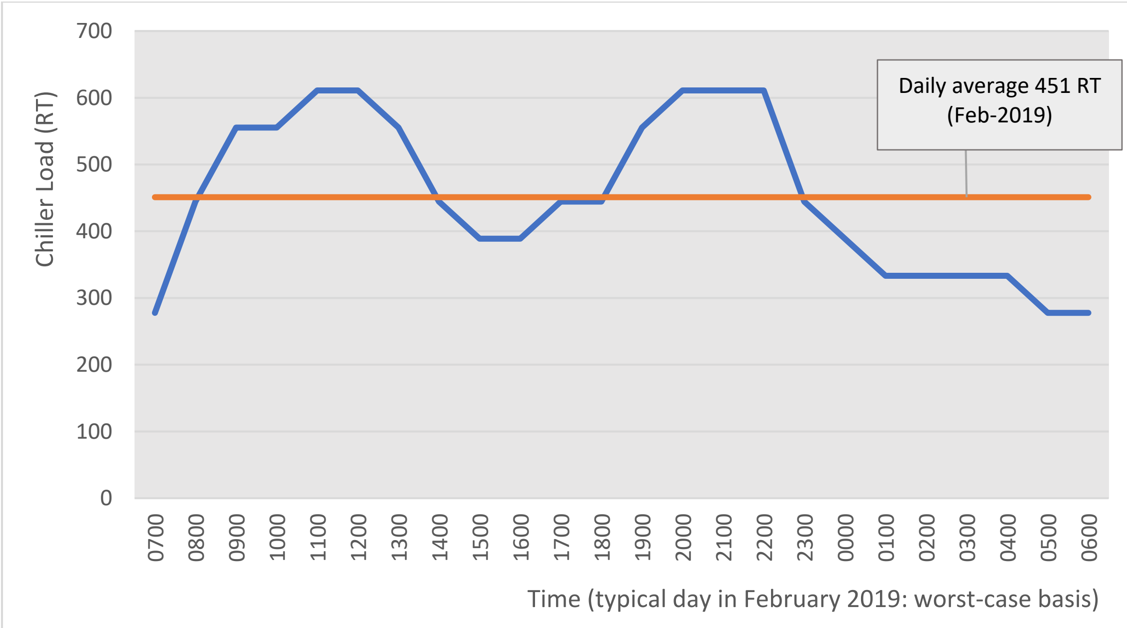
Source: Author, computed from the monthly electricity consumption provided by the hotel.

Figure A3: Average Daily Chilled-water Generation in RT (2018–2019)



RT = refrigerator ton.
Source: Author, estimated from the highest daily electricity consumption of 12,985 kWh that occurred in February 2019, as shown in Figure A2.

Figure A4: Estimated Daily Chiller Load Profile Derived from Chilled-water Generation (in RT)[1]



RT = refrigerator ton.
Source: Author, based on the highest daily electricity consumption in Figure A3 on worst-case basis.

Average daily electricity consumption for each month was computed and is shown in Figure A2. Based on the daily electricity consumption, it is possible to estimate the daily chilled-water generation requirement in terms of refrigerant tons (Figure A3). For estimation purposes, the average system efficiency was assumed to be 1.2 kW/RT (based on industry experience for old water-cooled system and discussion with hotel staff). The average daily chilled-water generation capacities in terms of refrigeration tons were estimated (based on system efficiency of 1.2 kW/RT) (Figure A3). The highest daily average chiller load was 451 RT, which occurred in February 2019 (Figure A3).

Based on the worst-case scenario of 451 RT that occurred in February 2019 (for highest cooling load demand situation), an estimated daily load profile was computed as illustrated in Figure A4. For a detailed study, the proper method is to conduct an energy audit, which would include data logging of a full-day operation of the chiller/s. The purpose of a load profile is to assess the daily cooling load requirements and determine the peak load demand for more accurate chiller selection. Figure A4 shows that the cooling load fluctuates during the daily operation of chillers. The peak load is expected to reach about 610 RT, which usually occurs in mornings and evenings, as described by the hotel operations staff. During the morning and evening operation, it would be necessary to operate the 1,000 RT chiller.

Based on the estimated peak load, a new chiller is selected to compare and evaluate a chiller replacement, in order to examine whether there is any potential to save energy. With this in mind, the following new

[1] Figure A4 is not based on measured hourly loads but an estimated load profile, which was based on the highest estimated daily average chiller load of 451 RT that occurred in February 2019 as shown in Figure A3.

chiller configuration is identified and is used as a basis for comparing with the performance of the existing system:

Proposed new chiller system configuration:

a) New chiller: Daikin magnetic 550 RT chiller

Chiller efficiency: 0.575 kW/RT, power input of 316 kW, rated at chilled water 54/44^{0}F, condenser water 87/97^{0}F

b) Existing chiller: 1 x 400 RT screw compressor chiller

1 x 1,000 RT centrifugal chiller (optional to retain one unit of existing 1,000 RT chiller, which would become redundant, but hotel operation expressed preference to retain one unit for operation on rotation basis.

c) Retrofitting of new cooling towers, piping, AHUs and FCUs to be installed.

d) Estimated cost of chiller: US$380,000

e) Estimated retrofitting work: US$700,000

f) Estimated design and supervision fee: US$170,000

This new chiller configuration is expected to efficiently generate chilled water for the hotel's air-conditioning requirements. For estimation and comparison purposes, the hotel's air-conditioning requirements are estimated using industrial practice (rule-of-thumb method) of 2.0 RT maximum cooling load per hotel room, which is estimated slightly on the high side for a 4-star hotel. For proper assessment, the engineering designer's method of evaluating the hotel cooling load requirements – based on the physical dimensions, building orientation, hotel rooms configuration and construction, facilities and amenities – would need to be carried out to compute for more accurate total cooling load requirements. However, for the purpose of this case study, the following are estimated:

1) Estimated daily maximum cooling load: $250\ x\ 2 = 500\ \mathrm{RT}$

2) Estimated average daily cooling load requirement: $500\ x\,\frac{451}{610} = 370\ RT\ *$

   Note: * The ratio of 440:600 was taken from Figure A4 to compute the average daily cooling load, based on the estimated peak load of 500 RT

3) Assuming a system efficiency at 0.75 kW/RT, the estimated daily chiller plant electricity consumption: 370 RT x 0.75 kW/RT x 24 = 6,660 kWh

4) Assuming hotel occupancy rate of 85% (for conservative estimates), estimated new yearly electricity consumption: 6,660 x 365 x 0.85 = 2,066,265 kWh

5) Estimated cost of new electricity cost: 2,066,265 x US$0.16 = US$330,602/y

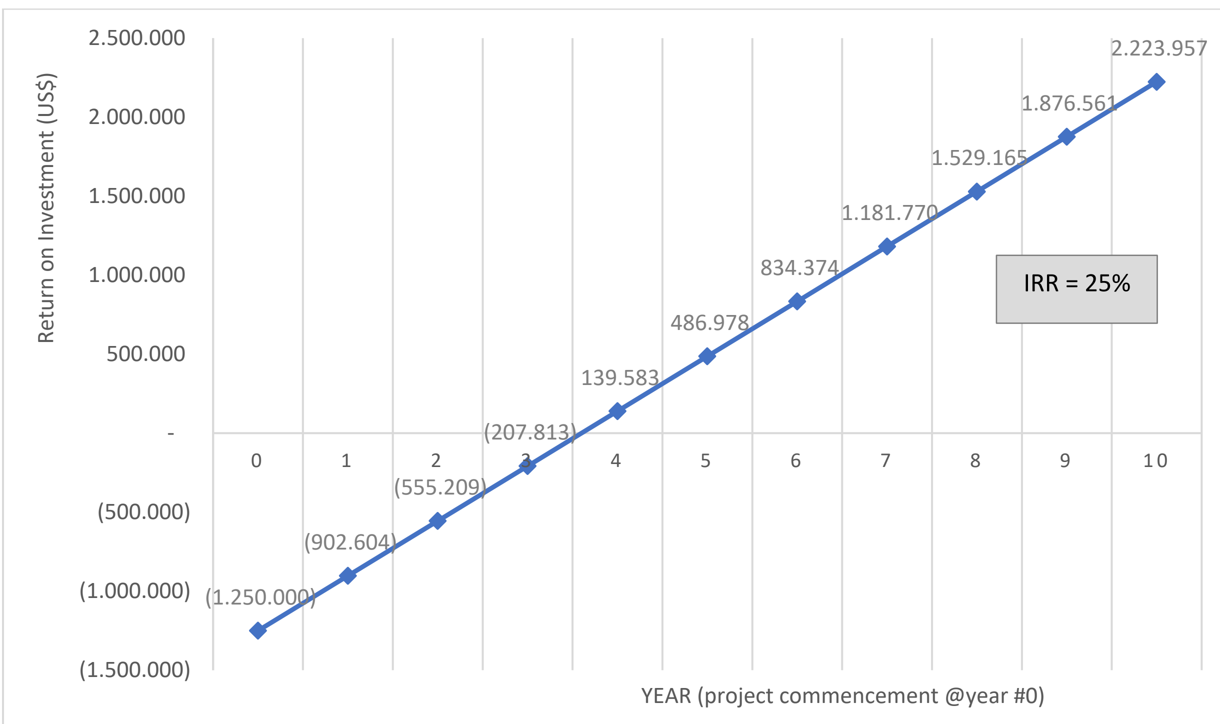
The above estimated electricity consumption of the proposed system is compared with the existing records of electricity consumption as follows:

1) Based on the records of total electricity consumption from November 2018 to October 2019: 4,237,489 kWh/y
2) Estimated electricity cost of existing operation: 4,237,489 x US$0.16 = US$677,998/y
3) Estimated electricity saving: $4{,}237{,}489 - 2{,}066{,}265 = 2{,}171{,}224\ \mathrm{kWh/y}$
4) Estimated electricity cost savings: US$677,998 – US$330,602 = US$347,396
5) Estimated cost of new chiller, retrofitting and design/supervision work:

$$380{,}000 + 700{,}000 + 170{,}000 = \mathrm{US\$}1{,}250{,}000$$

6) Estimated simple payback period: $\frac{1{,}250{,}000}{347{,}396} = 3.6$ years

Figure A5: Cash Flow for Case Study



IRR = internal rate of return.

Source: Shigeru Kimura and Leong Siew-Meng.

Based on the estimated yearly electricity savings and estimated investment costs, the cash flow and internal rate of return (IRR) were computed (Figure A5). The IRR is estimated to be 25% and the breakeven would occur in the fourth year after project commencement. The cumulative savings in the tenth year of operation is expected to be about US$2.224 million. Based on the above, the case study shows that the proposed replacement of old chillers and auxiliary equipment appears to be a viable project. The above assessment was based on the following assumptions:

a) Hotel occupancy rates remain the same every year throughout the period of IRR analysis as that of the study period (i.e. November 2018 to October 2019).

b) The estimation of the new electricity consumption was based on 85% hotel occupancy rate.

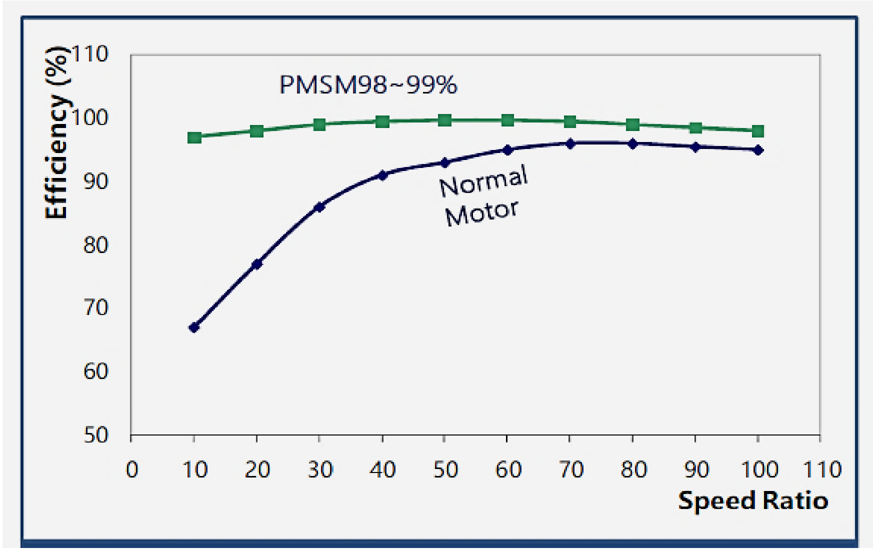
c) The electricity tariff remains constant at US$0.16 throughout the period of IRR analysis.

However, the above computation did not consider the following (in addition to previously mentioned exclusions):

1) Operations and maintenance costs

- Such costs are assumed to be about the same between the old and new systems, although the manufacturer claims that the maintenance cost of magnetic chillers is lesser due to its state-of-the-art magnetic bearing with oil-free technology and, hence, no requirement for oil change, associated shutdown, and savings incurred on oil accessories compared with conventional chillers.
- The magnetic chiller is expected to provide higher operational savings as it can retain high energy efficiency on part-load operation, compared with lower energy performance at part-load operation for old and conventional chillers (as illustrated in Figure A6). Higher chiller efficiency would yield greater energy savings. Chillers that are highly energy efficient at part-load would suit hotel operations in view of the cooling load fluctuations due to seasonal demands and the fluctuating daily cooling loads. Therefore, the chillers are expected to operate on part-load conditions.

Figure A6: Comparison of Energy Performance of Chillers at Part-load and Full-load Operations between Magnetic Chillers and Conventional Chillers



Source: Daikin Applied (Malaysia) Sdn Bhd.

- Consequential operational loss was not considered in the above cash flow and IRR analysis.

2) Costs of demolition work due to unforeseen site conditions

- The cost of retrofitting work was only an estimation but the extent of demolition work requirements and constraints at the existing site would require thorough investigations and site survey. The estimated cost of retrofitting work does not include interior design work.
- However, some of the costs may be defrayed by possible resale value of the existing chiller/s subject to the hotel's decision whether to retain any existing chiller.

Summary of Case Study

Despite some limitations of this case study, there are some interesting findings summarised as follows:

1) Through a walk-through audit and available energy consumption and other basic data, energy saving potential can be identified and quantified.
2) This case study demonstrates a method to make a preliminary analysis of energy savings and indicative project viability.
3) Chiller replacement of old units can offer potential energy savings and reasonable return on investment.

4) Walk-through audit can generate useful information and directions for more detailed studies. Energy audit is necessary to determine a project's viability for investment decisions.

5) This case study shows that EEC case studies or demonstration projects can showcase the benefits of EEC measures.

Acknowledgements

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