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Study on Cost of Procuring Chilled Water from District Cooling System (DCS) Against Constructing an In-Building Chiller Plant for an Office Tower

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Abstract

A feasibility study on the cost of procuring Chilled Water from a District Cooling System (DCS) Plant versus the cost for Constructing, Owning, Maintaining and Operating a Conventional In-Building Electric Water-Cooled Chilled Water Plant was carried out. The Building is a 35 storey office building located in Kuala Lumpur. The Chilled Water Supply from the DCS Plant is envisaged for 24 hours daily for a period of 25 years. The Supply Temperature shall be 6.5 ± 0.5 ºC and the Differential Temperature ΔT shall be 7 ºC. Using A simple payback period calculation, it was found that the provision of a In-Building Chilled Water System is more economically favorable than procuring Chilled Water from a DCS Plant.

Keywords: District Cooling System; Water Cooled Chillers; Supply Temperature; Return Temperature; Differential Temperature; Cooling Load; Load Profile.

1. Introduction

A financial feasibility study on the cost of procuring Chilled Water from a District Cooling System (DCS) Plant owned by an Independent Operator versus the cost for Constructing, Owning, Maintaining and Operating a Conventional In-Building Electric Water Cooled Chilled Water Plant is presented.

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The Building is a 35 storey office building, located in Kuala Lumpur Central Business District (CBD). The Chilled Water Supply from the DCS Plant is envisaged for 24 hours daily for a period of 25 years. The Supply Temperature shall be 6.5 ± 0.5 ℃ and the Differential Temperature ΔT shall be 7 ℃ [1]. Differential Temperature being the difference in temperature between the Supply Chilled Water Temperature and the Return Chilled Water Temperature from the Building. A simple Pay Back Period calculation was carried out to determine the feasibility. It was concluded that the proposal to construct a In-House Chiller System is economically more favourable compared to procuring Chilled Water from the DCS Plant at the prevalent rates. The cost is given in Ringgit Malaysia (RM).

2. District Cooling System (DCS) Plant

In a District Cooling System, a centralised Plant generates Chilled Water via Electric Centrifugal Chillers or Absorption Chillers. The latter can be either Steam Absorption Chillers or Direct Fired Absorption Chillers. Chilled water is then delivered through underground insulated pipeline to office, industrial and residential buildings to cool the indoor air of the buildings within a district. In the respective buildings, Heat Exchangers are used to transfer the heat energy from the building to the DCS Chilled Water systems via Plate Heat Exchangers. The output of one cooling plant is enough to meet the cooling-energy demand of dozens of buildings. Some of the DCS Plants include Thermal Energy Storage (TES) systems which comprise either Ice Thermal Storage or Chilled Water Storage. With the inclusion of TES systems, low night time electric tariff can be taken advantage of. During the night, either Ice or Chilled Water is generated and stored. During the day, when electric tariff rates are higher, the Chiller operation is either stopped or reduced and the stored Ice is melted to generate Chilled Water.

3. In-building chiller plant

In contrast to a DCS plant, In-Building Chiller Plant is generally located and operated by individual building owners. Each building has a Chilled Water generating plant comprising individual Water Cooled or Air Cooled Chillers, Pumps and distribution piping. The Chiller capacities are much smaller and Electrical Centrifugal or Screw Compressor Chillers are used. The chilled water generated is not shared with other buildings in the vicinity.

4. Methodology

4.1 Cooling Load Calculation

Initially, detailed cooling load calculation to be carried out for the Building. The Cooling Load Design Calculation [2] has been carried out using the HAP (Hourly Analysis Program) version 4.50 software. This HAP v4.50 software is an approved LEED (Leadership in Energy and Environmental Design) Software [3]. This software utilises the parameters of ASHRAE Standard 90.1 – Energy Standard for Buildings Except Low Rise Residential Buildings. The Ventilation Standard, ASHRAE Standard 62.1 is also used to determine the ventilation requirements to be used in this software. This complies to the requirement of LEED (Leadership in Energy and Environmental Design).

4.2 Design Parameters

The Design Parameters used in this software complies to the requirements of LEED and Malaysian Standard MS 1525, (Energy efficiency and use of renewable energy for non -residential buildings - Code of Practice), [4].

The Ventilation (Outdoor Air) requirement used is as follows:

Table 1: Outdoor air requirement according to ASHRAE 62.1

Description	**Required by ASHRAE 62.1**
Outdoor Air Requirement 1 (People Outdoor Air Requirement)	5.0 cfm/person
Outdoor Air Requirement 2 (Area outdoor Air Rate)	0.06 cfm/ft2

The Population Occupancy Density [5] used in design as compared to the Code Requirement is as follows:

Table 2: Population occupancy density

Description	**Required by ASHRAE 62.1**
Occupancy (Office Space)	200 ft2/person

Table 3: Overhead lighting

Description	**Required by Table 11 of MS 1525**
Overhead Lighting including Ballast Multiplier	1.3 W/ft2

Table 4: Heat Gain from People

Description	**Required by Table 48 of Carrier Hand Book**
Sensible and Latent Load (Office Worker)	Sensible: 245 Btu/Hr/Pax Latent: 205 Btu/Hr/Pax

The Window Thermal Transmittance, U Values [5] used are in accordance to Double Glazing Low E Glass.

5. Cooling Load Profile

The summarised cooling load results are as follows:

Table 5: Summarised cooling load results

Description	Results
Maximum Plant Load	1,545 RT
Peak Load occurs on	June 1600 (4 pm)
ft2/RT	235 ft2/RT
Floor served by Plant	372,373 ft2
Btu/hr/ft2	49.8

The Cooling Load Profile plotted on a graph for Month of June is as shown below in Figure 1.

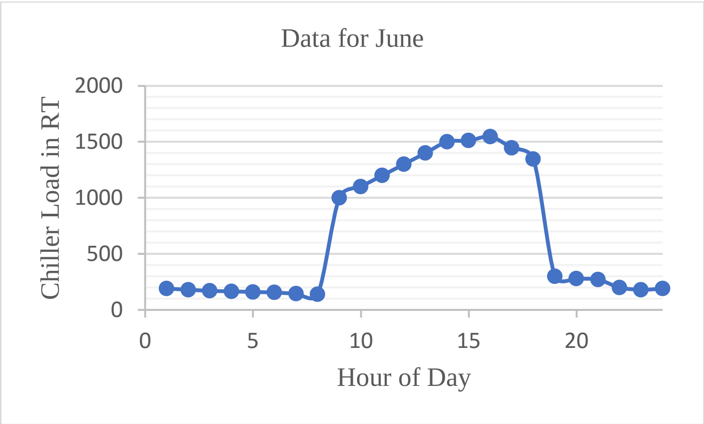

Figure 1: Chiller Load in RT vs Hour of the Day

From the cooling load profile, it is seen that the peak cooling load is 1,545 RT with a daily total cooling energy of 16,070 RTh.

6. Proposed chilled water equipment capacities

From the daily load profile, it is seen that the peak cooling load [6] is 1,545 RT with a daily total cooling energy of 16,070 RTh. The cooling load per sq ft is 49.8 Btu/Hr/ft2. To cool this load, a total of 3 x 400 RT and 3 x 200 RT electric water-cooled chillers is selected to form a total of six (6) Chiller sets, each of which comprises 1 set of Chiller, 1 set of Condenser water pump set, 1 set of Primary Chilled water pump set and 1 set of Cooling towers. The 1 x 200 RT Chiller sets is also intended for night load, for which a 140 kW standby generator set complete with Automatic Mains Failure (AMF) Board is allowed to generate essential power in case of any incoming power outage.

7. Related charges when procuring chilled water from DCS plant

The current proposed charges intended to be levied by DCS Plant Operator consists of the following elements:

- A one time connection charge [7].
- Fixed monthly demand charge of Contracted Capacity per month based on 1,545 RT.
- A variable energy charge of the actual total amount of the Chilled Water Supplied per month.
- Applicable revision to Demand and Energy Charges

8. Cost comparison DCS plant VS In-Building chiller using Simple Payback Method

The simple payback period [8] refers to the amount of time it takes to recover the cost of an investment. Simply put, the payback period is the length of time an investment reaches a break-even point.

- Option 1: Generating Chilled Water from an In-House Building
- Option 2: Procuring Chilled Water from a DCS Plant

Table 6: Simple payback period

Item	**Description**	**Option 1 (RM)**	**Option 2 (RM)**
1	**CAPITAL COST**		
1.1	Initial capital cost related to construction of a In Building Chiller System		
	i) Chillers, Cooling Towers, Condenser Water Pumps, Chilled Water Pumps, Piping		
	: RM 4,500 /RT = 4,500 x 1,800 RT = RM8,100,000	8,100,000.00	Not Applicable
	ii) 1 x 140kW standby generator set and AMF Board	100,000.00	Not Applicable
1.2	Initial Cost related to Procurement of Chilled Water from DCS Plant		
	i) One time connection charge	Not Applicable	1,950,000.00
	ii) Heat Exchanger	Not Applicable	300,000.00
	TOTAL CAPITAL COST	**8,200,000.00**	**2,250,000.00**
Item	**Description**	**Option 1 (RM)**	**Option 2 (RM)**
2	**USAGE CHARGES**		
2.1	Usage Charges related to operating an In Building Chiller System		
	i) Comprehensive maintenance and repairs to In-Building Chiller Plant per annum	275,000.00	Not Applicable
	ii) Annual manpower cost in the daily operations of In-Building Chiller Plant @ RM 6,000 per month	72,000.00	Not Applicable

	iii) Electricity Charges Consumed in In-Building Chiller Plant - Annual production cost of chilled water based on daily load profile and a maximum demand of 1,545 RT is computed as follows:		
	On Peak Energy Charge for 13,345 RTh x 30days x 12 months x 1.1 kW/RT x RM0.365/kWh	1,928,886.30	Not Applicable
	Off Peak Energy Charge for 2,725RTh x 30days x 12 months x 1.1 kW/RT x RM0.224/kWh	241,718.40	Not Applicable
	Maximum Demand Charge 1,800 RT x 1.1 kW/RT x RM 45.10/kW x 12 months	1,071,576.00	Not Applicable
	iv) Make-up water for Cooling Tower	100,000.00	Not Applicable
2.2	Usage Charges related to purchasing of Chilled Water from DCS Plant		
	i) Annual Cost of Monthly Fixed Charge for a Contract Capacity of 1,545 RT (1,545 RT x RM 80.00 X 12 Months) ii) Annual Cost of Energy Charge for 16,070 RTh per calendar year (16,070 x 30 days x 12 months x RM 0.60/RTh)	Not Applicable	1,483,200.00 3,471,120.00
	TOTAL USAGE CHARGES	**3,689,180.70**	**4,954,320.00**
3	**Simple payback period for Providing In-Building Chiller Plant with an installed capacity of 1,800 RT** (Difference in Capital Cost)/(Difference in Usage Cost) RM 5,950,000.00/ RM 1,265,139.30	**4.7 years payback period**	

9. Conclusion

From the above, it is clear that the payback period is 4.7 years. This is considered a fair period as compared to concession period of 25 years. It is then concluded that the provision of In House Chilled Water Generating System is more economically viable compared to procuring Chilled Water from a DCS Plant. This is from a stand point from an individual building owner. However, as a Nation or Global Community, a single DCS Plant provide a smaller carbon footprint and better energy efficiency as compared to the cumulative numerous In-

House Building Chiller Plants. Co-Generation Plants can also improve the energy efficiency by re-using the heat generated from the Boilers to run Gas Turbine Generators. The Boilers are used to generate Steam for the Steam Absorption Chillers in a DCS Plant. The method used is the simple payback period method. This method does not consider the time value of money and is considered a limitation of this study. For further research, it is recommended that Net Present Value is used in conjunction with payback period to improve the results.

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