# Chiller TCO

There are many factors to consider when deciding between air or water cooled chillers, which can impact TCO and swing the decision.

To understand the sensitivity of different parameters — such as capital cost, power cost, water cost, and weather — consider the model of a typical 1,200-ton plant for a data center application operating 24/7 in four cities, representing different weather profiles:

- Beijing (mixed and dry, ASHRAE Climate Zone 4)
- Singapore (hot and humid, ASHRAE Climate Zone 1)
- Dubai (hot and humid, ASHRAE Climate Zone 1)
- San Francisco (warm and dry, ASHRAE Climate Zone 3)

For each plant location, we compared high-efficiency, air cooled screw and water cooled centrifugal chillers, both with variable-speed drives. Additionally, two load profiles are considered in the comparison:

1. Heavy load profile: Load variation between 100% to 80%, assuming a consistent high internal load application.
2. Medium load profile: Load variation between 100% to 50%.

## DECIDING FACTORS

With that model in mind, we posited initial capital costs, annual operating costs, and a combination of both, along with the total cost of ownership (TCO), all of which are typical deciding factors in equipment selection. Sensitivity to these factors influences different decisions based on capital or financing available to the data center owner. Of course, many technical, commercial, compliance, and site-specific factors can also influence the choice by eliminating either option as a non-starter.

| Ambient | | Dubai | Singapore | Beijing | San Fran. |
|---|---|---|---|---|---|
| *Design DBT* | *deg F* | 115 | 95 | 105 | 95 |
| *Design WBT* | deg F | 86 | 83 | 78 | 68 |

**FIGURE 1.** Design ambient conditions.

| Utility | | Dubai | Singapore | Beijing | San Fran. |
|---|---|---|---|---|---|
| *Electricity Rate* | *US $/KW* | 0.06 | 0.16 | 0.13 | 0.10 |
| *Water Rate* | *US $/Gal* | 0.01 | 0.006 | 0.002 | 0.01 |

**FIGURE 2.** Utility rate for power and potable water.

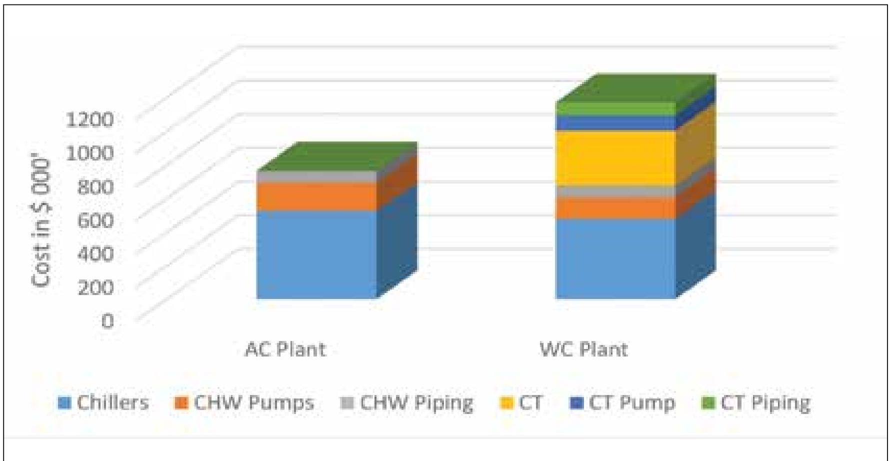


**FIGURE 3.** Equipment cost 4x400 air cooled screw chiller vs. water cooled centrifugal chiller.

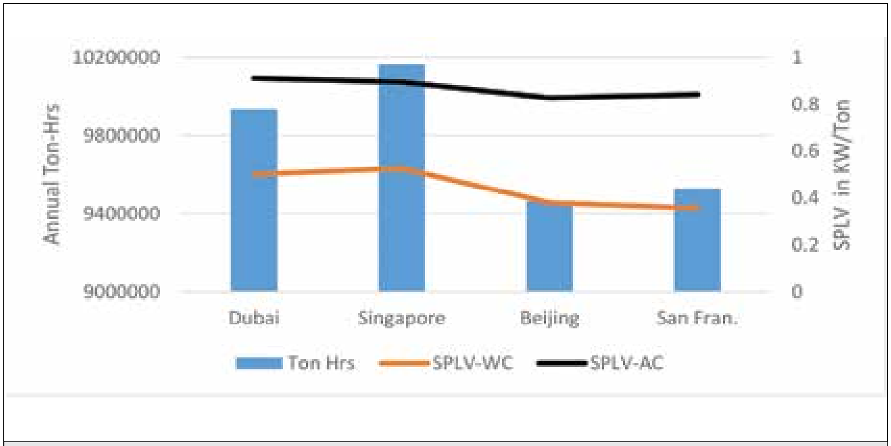


**FIGURE 4.** Ton/hours and plant system part load variable (SPLV) with heavy load profile.

## FIRST COST (CAPITAL COST)

For a critical data center application with a 1,200-ton plant and N+1 configuration of chillers and pumps, the cost of water cooled chillers is modeled as 10% lower than with air cooled chillers. However, when including the ancillary labor associated with a water cooled chiller plant (condenser water pumps, piping, valves, and cooling tower), the air cooled chiller plant cost is 35% lower for that plant design (Figure 1). In our comparison, capital and labor costs use values for San Francisco. The absolute value may vary for other cities, but the costs are relative. This difference may vary based on size, design, location, material, and labor cost.

However, for a 1,200-ton plant, an air cooled chiller application will have a lower first cost than a water cooled application, although electrical system costs may have an impact.

## LOAD AND ENERGY CONSUMPTION

Building annual load (ton hours) is calculated based on the ASHRAE Modified Bin Method using weather data for each selected city. System part load value (SPLV) is calculated for two load profiles. For simplicity, the relationship between ambient and load is considered linear. The calculated annual ton-hours and SPLV (kW/ton, including chillers, primary pump, condenser water pump, and cooling tower) are represented in Figures 2 and 3. This calculation accounts for the cooling design power, pump peak power, and heat rejection peak fan power, which include the design mechanical load component used in the proposed revision to ASHRAE Standard 90.4. Air-handler unit fan design power is a constant in all configurations.

## OPERATING COSTS (ENERGY AND WATER)

This comparison accounts for operating power and water consumption. By including the water utility cost, we arrive at the total operating cost.

The difference between air cooled and water cooled is about 10% to 15% for cities like Beijing, Singapore, and San Francisco. For Dubai, which has a very low cost of power and high cost of water, the air cooled chiller operating cost is marginally higher than the operating cost of water cooled chillers (Figure 4).

For the heavy load profile in Dubai, the trend is very similar. The dollar amount is based on the current cost of electricity and water (Figure 5). However, if resource costs go up due to an increase in utility rates, the comparison will change accordingly.

## TOTAL COST OF OWNERSHIP (TCO)

When deciding between equipment types, it is valuable to compare the TCO for a plant using a detailed analysis based on operating cost, which includes both energy and water costs for the facility.

For all cities except Dubai, the operating cost savings produced a payback in one year for Singapore, 1.3 years for Beijing, and 2.8 years for San Francisco, regardless of the higher capital cost of water cooled chillers used in those locations. This payback was reduced by half for a heavy load profile due to more ton hours than with the SPLV for a medium load profile. A comparison of capital costs and multi-year operational costs are included in Figure 6. This figure is based on a medium load profile, but the metrics for a heavy load profile are similar.

For Dubai (ASHRAE Climate Zone 1), the operating cost savings for a water cooled chiller plant are marginal, so the payback period is 17 years. This case is unique, because, compared to all other cities, the cost of electricity is lower and the cost of water is high (Figure 7). Consequently, when the high capital cost of a water cooled chiller plant is factored in, the operational savings are insufficient to shorten the payback period.

Additional savings potential can be achieved with a free cooling chiller, which is not considered for this comparison.

## FACTORS OUTSIDE THE CHILLER ITSELF

Water source: Although centrifugal chillers may have lower operating costs, potable water for cooling towers may be scarce. In such cases, other sources like sea, lake, river, or pond water, or even treated sewage effluent, may be used. However, these sources may require more expensive construction materials, corrosion protection, etc.

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Sewage water cost: Many of the city municipalities charge for sewage disposal, which may need to be accounted for, and in some areas, cost more than the water. The bleed-off from the cooling tower, plus the additional water usage for the cycle of concentration, will impact the payback period for water cooled chillers.

Site limitation: Due to depleting water resources in many parts of the world, water availability may be a challenge in the near future or be uncertain over the long term. Stakeholders that face this issue may consider a hybrid system. The hybrid approach can mitigate future risks and optimize present resources.

## REPAIR AND MAINTENANCE COSTS

Repair and maintenance factors are difficult to assess. These costs depend on a complex subset of variables, including the quality of air and water, size and complexity of plant design, quality and make of equipment, location and distance from the nearest service center, and labor cost per hour for skilled resources in a particular city.

## SPACE AND BUILDING CONSTRUCTION

Space availability and cost are a major concern for data centers in large cities, where real estate costs can be as high as $4,000 per square foot ($43,000 per square meter). Water cooled chillers are normally housed in an enclosed space within the data center. This lost space is an opportunity for the owner who could otherwise sell or rent out the floor area. In contrast, air cooled chillers are normally kept on the roof of the data center, not occupying cost.

Where space cost is not at a premium, it's not a factor. Building construction cost may be relatively small, or go substantially higher, if local codes require extra load-bearing capacity for an air cooled chiller or a seismic design requirement of the site. In this regard, an air cooled chiller has an advantage because it can be kept on the roof without any change in roof construction cost. However, if a water cooled chiller must be kept on the roof for floor space, not only the load-bearing capacity of the roof should be increased due to the concentrated load, but the equipment must also be modified to withstand ambient conditions outdoors.

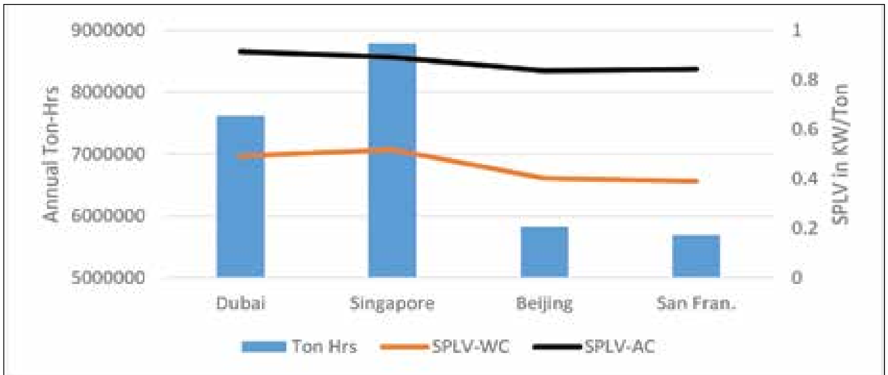



**FIGURE 5.** Ton/hours and plant system part load variable (SPLV) with medium load profile.

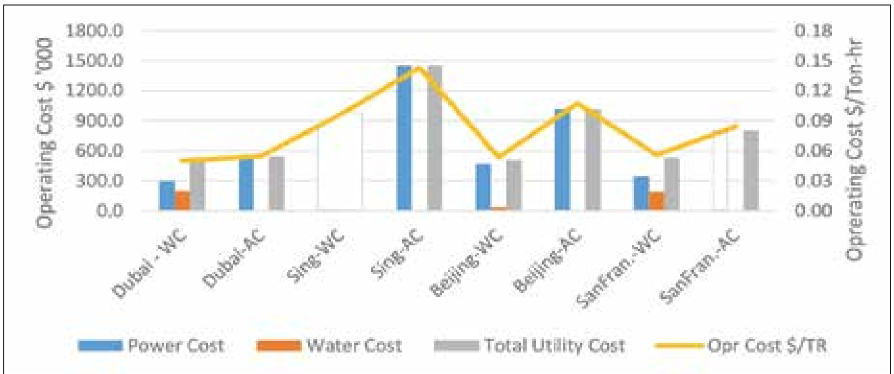



**FIGURE 6.** Operating cost, power, and water-heavy load profile.

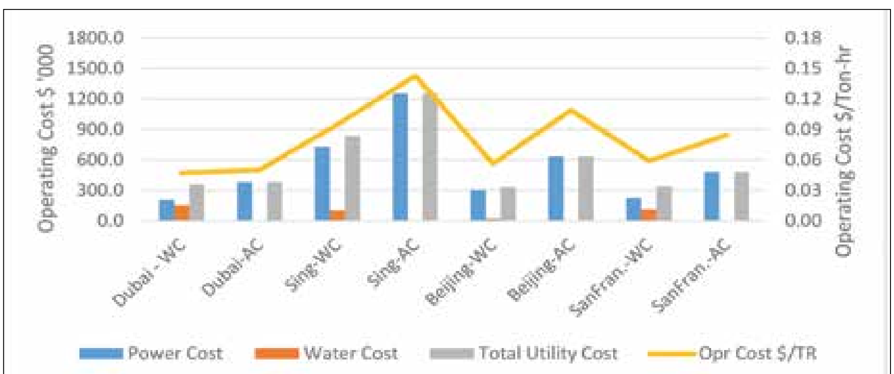


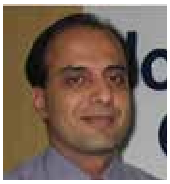

**FIGURE 7.** Operating cost, power, and water-medium load profile.

## FACTORS THAT RESULT IN A SIMPLE GO/NO-GO DECISION

Other factors can result in a simple go/no-go decision. These factors include, but are not limited to, local guidelines and legislation, scarcity of water, cooling tower restrictions, and sound emissions.

## CONCLUSION

Each data center site and application is unique and warrants a detailed analysis of factors to make the best chiller selection. But the variables influencing mid-capacity data center applications can be modeled to simplify air cooled screw or water cooled centrifugal variable-speed chiller selections. After determining the capital expenditure and annual energy and water costs for a particular center, TCO can be evaluated based on the particular financial model being used by the owner. Whether using a non-performing asset (NPA), simple payback, internal rate of return (IRR), opportunity cost of capital, or some other budgeting method, the total cost of ownership can be used to reach a sound decision about selecting air cooled or water cooled chillers for the application. ■



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