ASHRAE Illinois Chapter

2012 TECHNOLOGY AWARDS

DIGITAL REALTY

Data Center Solutions

Digital Realty – Data Center Solutions

Digital Chicago Datacampus

Franklin Park, Illinois

Owner: Digital Realty Trust

Engineer of Record: ESD

Architect of Record: SPARCH

CHAPTER/REGIONAL TECHNOLOGY AWARD - SHORT FORM

1. Category (Check one and indicate New or Existing, if applicable)

- ◯ Commercial Buildings — ◯ New or ◯ Existing
- Institutional Buildings:
  - ◯ Educational Facilities — ◯ New or ◯ Existing
  - ◯ Other Institutional — ◯ New or ◯ Existing
- ◯ Health Care Facilities — ◯ New or ◯ Existing
- ◉ Industrial Facilities or Processes — ◉ New or ◯ Existing
- ◯ Public Assembly — ◯ New or ◯ Existing
- ◯ Residential (Single and Multi-Family)

2. Name of building or project: Digital Chicago Datacampus

City/State: Franklin Park, Illinois

3. Project Description: New Co-Location Data Center

Project Study/Design Period: 01/2012 (Begin date (mm/yyyy)) to 09/2012 (End date (mm/yyyy))

Percent Occupancy at time of submission: 100%

4. Entrant (ASHRAE member with significant role in project):

a. Name: Griffin (Last) Brett (First) Mason (Middle)

Membership Number: 8085146

Chapter: Illinois

Region: VI

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Chicago (City) IL (State) 60604 (Zip) USA (Country)

c. Telephone: (O) 312-762-1562 d. Email: bgriffin@esdglobal.com

e. Member's Role in Project: Mechanical Design Engineer

f. Member's Signature: Brett Griffin, PE LEED AP

5. Engineer of Record: Environmental Systems Design, Inc. (ESD)

By affixing my signature above, I certify that the information contained in this application is accurate to the best of my knowledge. In addition, I certify that I have discussed this entry with the owner and have received permission from the owner to submit this project to the ASHRAE Technology Awards Competition.

Project Overview

The project is located in Franklin Park, Illinois and is designed for multi-tenant data center usage. It is owned and operated by Digital Realty Trust (DLR). The Engineer of Record is Environmental Systems Design, Inc. (ESD) and the Architect of Record is Sheehan Partners LTD (SPARCH).

The project is a conversion of an existing single-story warehouse/light industrial facility to a high end 24x7 mission critical data center. It is a total of 120,000 usable ft^2 with an additional 5,000 ft^2 pre-assembled chiller building. The facility is designed to support four (4) 15,000 ft^2 data center suites at 1,675 kW UPS output each, and approximately 15,000 to 20,000 ft^2 of rentable office area. Each data center suite will be occupied separately and have dedicated electrical infrastructure to support it. All data center suites use a shared mechanical system via a central water-cooled chilled water plant.

The overall redundancy requirements are: (2N) electrical and water utility, (N+1) standby generators for all critical loads, (N+1) UPS system with (2N) distribution, (N+2) mechanical CRAH units serving each data center suite, (2N) mechanical CRAH units serving each UPS room and the primary point of presence (PPOP), and (N) mechanical equipment serving all of the non-critical office spaces. The chilled water plant has concurrently maintainable components at (N+1) each and the chilled water distribution system is a concurrently maintainable bi-directional flow, looped piping system. An (N) series waterside economizer, (N) condenser water storage and (N) chilled water thermal storage tanks were included in the design as well.

The Owner's Project Requirements for the mechanical systems are to achieve a robust concurrently maintainable design, while achieving local market leading PUE (Power Usage Effectiveness) values. The target annual PUE for this facility is 1.30 with a primary focus from the Owner and design team to optimize the efficiency of the mechanical system. The facility has been operational for almost a full year and has remained in full or partial economizer for a majority of the time, exceeding project expectations of annualized PUE.

Due to the success of this project, the Owner has started construction on an adjacent building of twice the size with the exact same design.

Mechanical Design Overview

The heart of the mechanical system is the chiller plant. Due to aggressive speed to market requirements, the chiller plant was designed to be pre-assembled in a modular configuration for offsite construction. The design is also modularized to defer capital cost of equipment and further improve speed to market. Two chillers, pumps, and cooling towers were installed day 1, and the remaining equipment, including the thermal storage tanks were installed at a later date when new leases were signed. The project was initially commissioned with part load and was later commissioned to full load with live data center loads.

The total capacity of the system is 2,400 tons at (N+1) and is dedicated to only the critical cooling loads (data center and UPS rooms). The system heat rejection is accomplished through cross-flow open cell cooling towers and the centrifugal chillers are arranged in a series waterside economizer configuration with plate and frame heat exchangers.

The condenser water pumping system is a constant flow system with pumps in a manifold arrangement where any pump, chiller, cooling tower, and heat exchanger can operate together for optimum reliability and uptime. However, the pumps are equipped with variable speed drives for energy efficiency and ease of operation. The VFD's allow the pumps to change speed based on the current mode of cooling without the use of balancing or control valves resulting in additional pressure drop. For example, the pumps must speed up to produce constant flow when in series economizer mode due to the added pressure drop of the heat exchangers.

The chilled water pumping system is a constant-primary, variable-secondary system. Like the condenser water pumps, the chilled water pumps are also arranged in manifolds. The primary loop only consists of the chillers, thermal storage tanks, and primary-secondary bridge. The heat exchangers and critical cooling loads are located on the secondary side of the system.

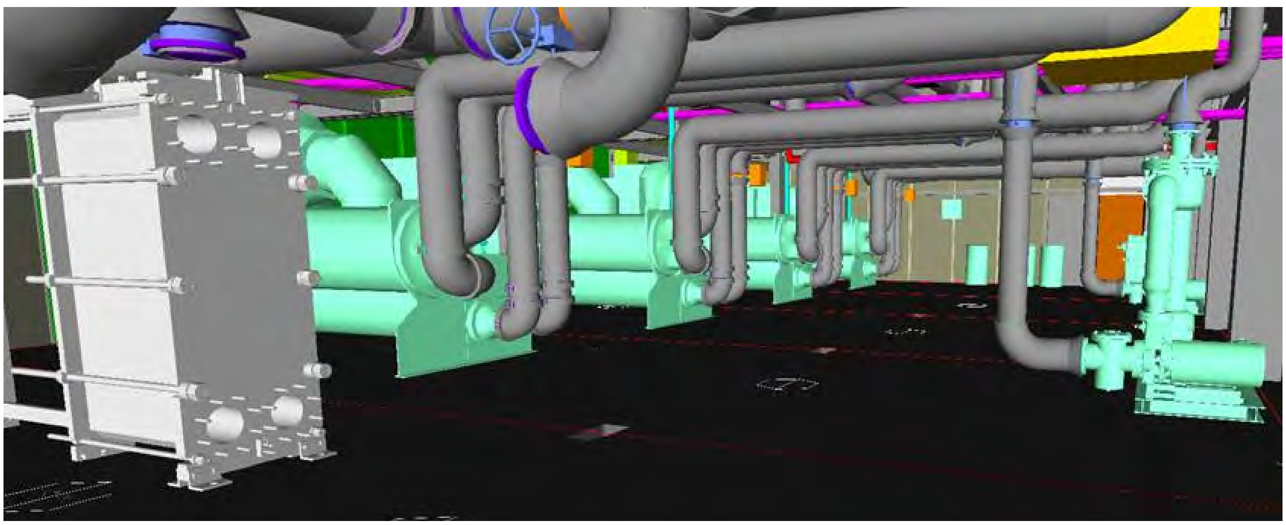


Figure 1: BIM image of the central chilled water plant.

The critical loads are all cooled with downflow chilled water computer room air handling (CRAH) units. Each CRAH unit has direct drive ECM fans, a pressure independent control valve, and is monitored through the BAS.

The ventilation system providing code minimum ventilation air, pressurization, and make-up air for the battery exhaust is handled through small (N) dedicated outdoor air systems (DOAS). These units are DX-cooled for dehumidification purposes. The small humidification requirements are handled by (N) stand-alone steam injection units.

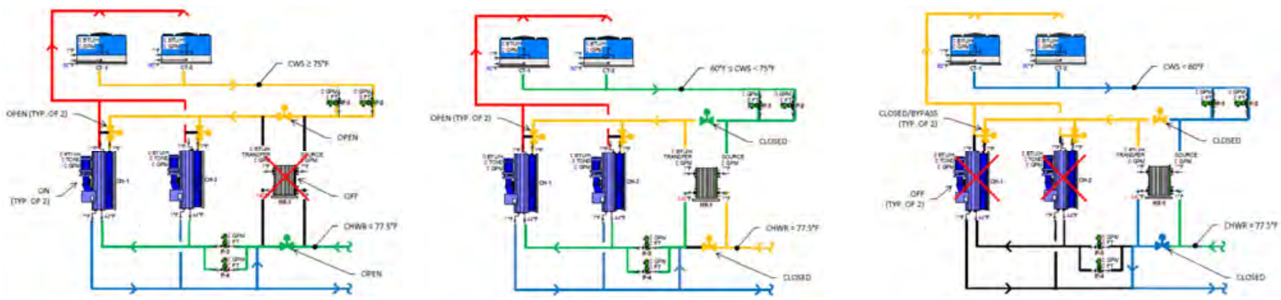
The office environments are all cooled and heated with DX-cooled VAV rooftop units with electric heat.

<u>Innovation in Design</u>

What makes this mechanical design unique is the way in which conventional components and conventional systems are used to meet the following two objectives while using very simple, intuitive controls strategies:

- Maintain optimum reliability throughout all failure scenarios and the full swing of extreme ambient conditions experienced in the Greater Chicago Area
- Obtain unconventionally low calculated PUE values

The use of series waterside economizer, and its configuration, is critical to the design in achieving these goals. With this in mind, the system was broken down into three modes of cooling: 100% mechanical cooling, partial economizer, and 100% economizer.



100% Mechanical Cooling **Partial Economizer** **100% Economizer**

Figure 2: General conceptual flow diagrams of chiller plant in all three modes of cooling (all flow diagrams in this report are color-coded based on water temperatures and are shown as single piping path for simplicity purposes)

In order to take full advantage of the ambient temperature profile of the site environment and the series waterside economizer concept, it is crucial to maximize the annual hours of economization. Two design concepts were used in order to achieve this goal: 1. Elevate the chilled water supply temperature, 2. Maximize the chilled water system delta T in order to elevate the chilled water return temperature.

The configuration of the series waterside economizer is one of the main innovative features of the system. Typically, the chillers and heat exchangers are located on the primary chilled water loop. In this system, the heat exchangers are located on the secondary side of the system to avoid using a blended return water temperature of primary and secondary return water. This allows the system to optimize the hours of partial economizer from minimum load all the way to design load by taking advantage of the warmest water in the system. At partial loads, the primary loop becomes heavily blended with cold supply water and partial economizer hours minimally available. In addition, the primary pumps are allowed to turn off in 100% economizer mode.

The chilled water supply temperature was elevated by separating the thermal comfort and ventilation cooling loads from the chilled water system and putting them on their own DX-cooling systems. Even though the water-cooled concept is more energy efficient, the thermal comfort and ventilation cooling loads are less than 2% of the total cooling loads of the facility, thus treated separately. By using the chilled water system purely for the critical cooling loads, the chilled water supply temperature set-point is driven by the critical cooling loads. ASHRAE TC9.9 recommends continuous supply air temperatures to the IT equipment between 64.4°F and 80.6°F. From this criteria, the chilled water supply temperature was elevated from a conventional 42°F or 44°F for thermal comfort cooling and/or dehumidification control to 60°F, resulting in a supply air temperature within this range. The system also has the flexibility to increase the set-point even further to 65°F pending lease agreements.

Because series waterside economizer is based on chilled water return temperature as well as supply temperature unlike its counterpart, parallel waterside economizer which only relies on supply temperature, increasing the system delta T also helps optimize the hours of free cooling. The chilled water system delta T is 17.5°F, roughly 5.5°F to 7.5°F higher than conventional systems. Care was taken in the selection of the CRAH units to optimize the performance of the chilled water coils at these conditions. Furthermore, achieving this chilled water return temperature at part-load is equally, if not more, important than just achieving this at design load as the data center will operate at part-load for most of the time. Bin data shows that this system will only operate in 100% mechanical cooling for only 409 hours per year, regardless of load. Most data centers never achieve full design load conditions and thereby never fully experience peak design load efficiencies. This system will operate at full design delta T throughout the entire operating range from minimum load to design load by virtue of locating the heat exchangers on the secondary loop in lieu of the primary loop like conventional systems and by the use of pressure independent control valves. These valves are fully modulating and dynamically balancing, thus effectively matching the required flow rate to the cooling demand, independent of load or system pressure. These also play a vital role in the scalability requirement of the design, allowing the system to add load without totally rebalancing it. This results in a variable flow, constant return water temperature scenario. This means that the economizer cycle is purely based on secondary return temperature, and is independent of load or flow rates. The system return water temperature is 77.5°F.

Two other design features that marginally improve the hours of economizer even further are the selection of the cooling towers and heat exchangers. The cooling towers were optimized for a 5°F approach in lieu of the typical 7°F and the heat exchangers were optimized for a 2.5°F approach in lieu of the typical 4°F, picking up another 3°F of bin hours.

The control of the central chilled water plant is achieved through just a three simple steps (keep in mind the only variable affecting operational modes is system water temperature):

1. The plant operates in 100% mechanical cooling when the condenser water supply temperature is greater than 2.5°F below the chilled water return temperature.

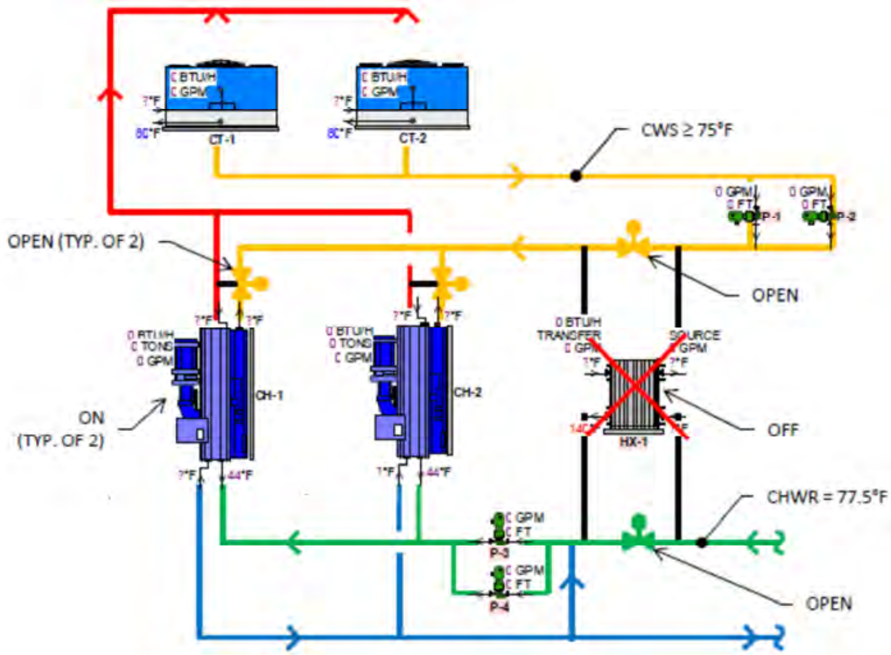


Figure 3: 100% mechanical cooling flow diagram.

2. The plant operates in partial economizer when the condenser water supply temperature is between the chilled water supply set-point and 3°F below the chilled water return temperature (only two valves change position based on two temperature measurements).

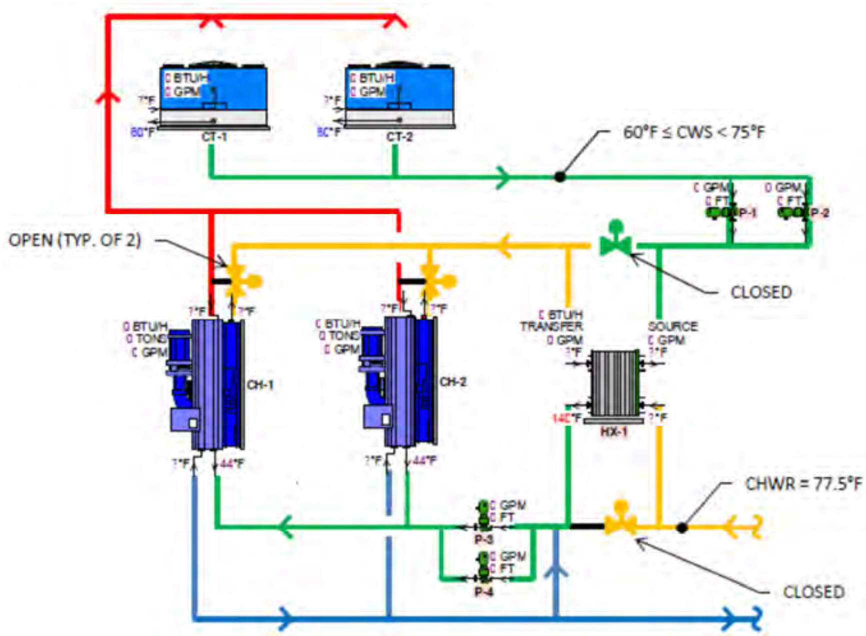


Figure 4: Partial economizer flow diagram.

3. The plant operates in 100% economizer when the condenser water supply temperature is at or below chilled water supply temperature set-point (only two valves change position

based on one temperature measurement and one set-point). This allows the chillers to turn off at 62.5°F in lieu of 60°F supply water to pick up a few extra hours of economizer and avoid the chillers from running with less that 10% load on them.

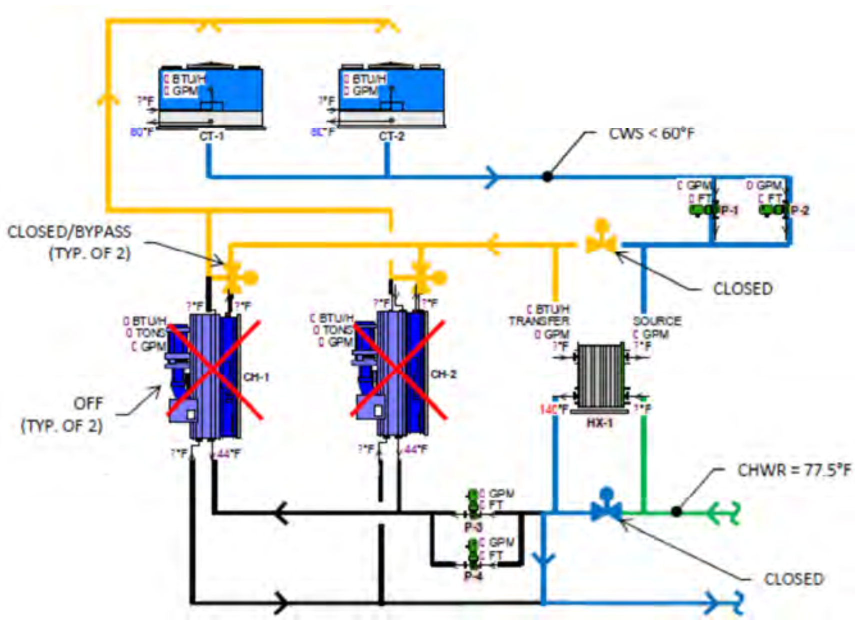


Figure 5: 100% economizer flow diagram.

Energy Performance

The design features mentioned in this report result in a chilled water system that operates in 100% mechanical cooling at ambient wet-bulb temperatures above 70°F (409 hours - 5% of annual bin hours), partial economizer at ambient wet-bulb temperatures between 52°F and 70°F (3,032 hours - 35% of annual bin hours), and 100% economizer at ambient wet-bulb temperatures below 52°F (5,319 hours - 60% of annual bin hours).

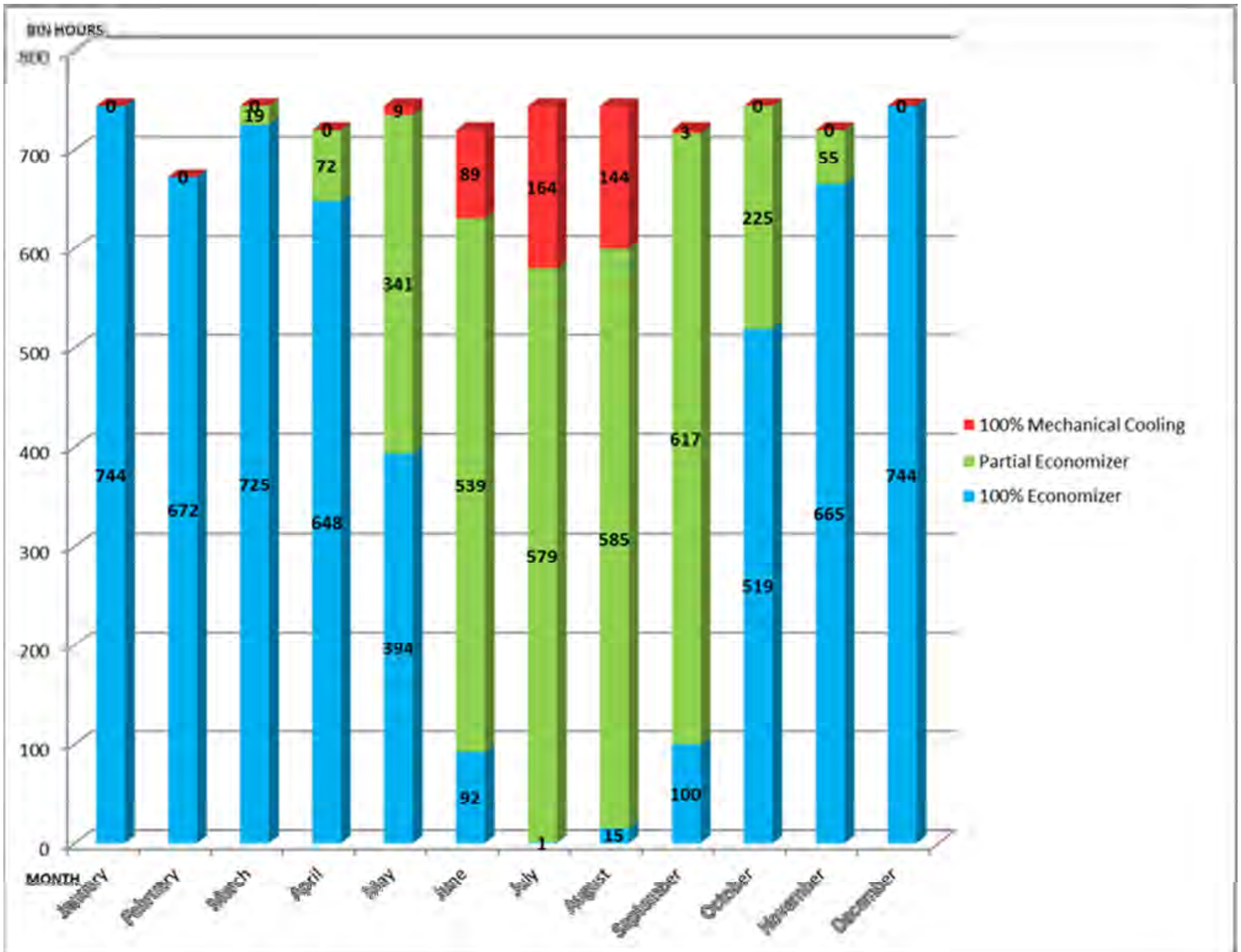


Figure 6: Chicago O'Hare bin hours and free cooling switch-over temperatures.

A detailed energy study was performed on the entire mechanical system and each of the mechanical energy consumers are represented in the following table that was used for the annual PUE determination.

Table 1: Mechanical system energy usage in each mode of operation. All values are normalized to kW/ton of the total combined cooling loads, not just the kW/ton of the equipment (the MAU represents a very low percentage of total cooling load, thus very low kW/ton). The total plant kW/ton based on hours of operation is less than the ASHRAE 90.1 IPLV kW/ton for a constant speed centrifugal chiller only.

	kW/ton		
	Full Mech Cooling	**Partial Economizer**	**Full Economizer**
Cooling Tower	0.037	0.037	0.028
Condenser Pump	0.061	0.070	0.061
Chiller (constant speed)	0.438	0.243	0.000
Primary Chilled Water Pump	0.020	0.020	0.000
Secondary Chilled Water Pump	0.039	0.051	0.051
CRAH Units	0.220	0.220	0.220
Make-Up Air Units	0.073	0.001	0.068
Total Cooling Plant	0.887	0.642	0.428
% Hours Annually	5%	35%	60%
Annualized kW/ton	0.04	0.22	0.25

Total Plant Energy Usage Annualized	**0.510**	**kW/ton**
Compared to ASHRAE 90.1 IPLV (chiller only!)	**0.539**	**kW/ton**

Table 2: Annual PUE based on information populated from Table 1. Without any mechanical loads, the ideal PUE for this system would be 1.10. For every 1.0 kW of critical load, the electrical load required by the mechanical system is only 0.19 kW.

Energy Usage	**Annual Value**
IT Load (kWh)	58692000
Mech. Loads (kWh)	
Equip. Load	6125699
Elec. Load Losses (kWh)	
MV Switchgear Losses (0.25%)	146730
MV-LV Xfrmr/Swgr Losses (1.5%)	880380
UPS Losses (8%)	4695360
Distribution Losses (0.25%)	146730
Total kWh (Mech. + Elec. Loads)	75653901
PUE	1.29