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DC PRO
ENGINEERING

Current & Future Cooling and Power Trends in Data Centres

Thursday 18th April 13:30 – 14:00

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Assisted by Hessam Seifi – Design Manager

Current most Efficient Data Centres cooling Trends

Google Sample Campuses	Quarterly PUE	Trailing 12 M PUE	Design Ambient Temp. DB / WB ^{O}C
Douglas County, Georgia – USA Utilize TSE water	1.16	1.12	34.4 / 25.1
Lenoir, North Carolina - USA	1.13	1.11	33.6 / 24.6
Berkeley County, South Carolina - USA	1.15	1.12	34.6 / 27.0
Council Bluffs, IOWA - USA	1.11	1.1	3.0 / 27.4
Mayes County, Oklahoma - USA	1.13	1.11	37.5 / 26.2
The Dalles, Oregon - USA	1.13	1.13	32.9 / 20.8
Dublin, Ireland	1.11	1.11	22.1 / 18.0
St. Ghislain, Belgium Utilize industrial Canal water	1.1	1.09	29.1 / 20.8
Eemsthaven, Netherlands	1.12	1.11	28.2 / 21.0
Hamina, Finland Sea water cooled (0.3 – 22.8 ^{O}C)	1.1	1.09	26.8 / 19.2
Changua County, Taiwan	1.17	1.15	34 / 28.7
Singapore	1.18	1.18	33.2 / 27.7

Indirect Evaporative cooling using cooling tower water to circulate via 8 Rows coil via hot isle / cold isle design.

Assisted Chilled water cooling when cold isle temperature goes beyond 27^{O}C in humid regions.

Hamina Finland utilize sea water indirect cooling.

Taiwan Campus chills water at night, when temp. are cooler, storing the cooled water in large insulated tanks (**Thermal Storage**) where it retains it's temperature before being pumped throughout the facility to cool our servers during the day.

Managing air flow by blanketing unutilized racks via flat sheet metals, use plastic curtain to define hot isle and to isolate hot Power Supply Units PSU's.

Utilize most efficient transformers, Power Distribution Units PDU's and Uninterruptable power supply UPS's.

European Data Centers' sample data

Figure 9. Number of data centres per IT Rated Load (kW)

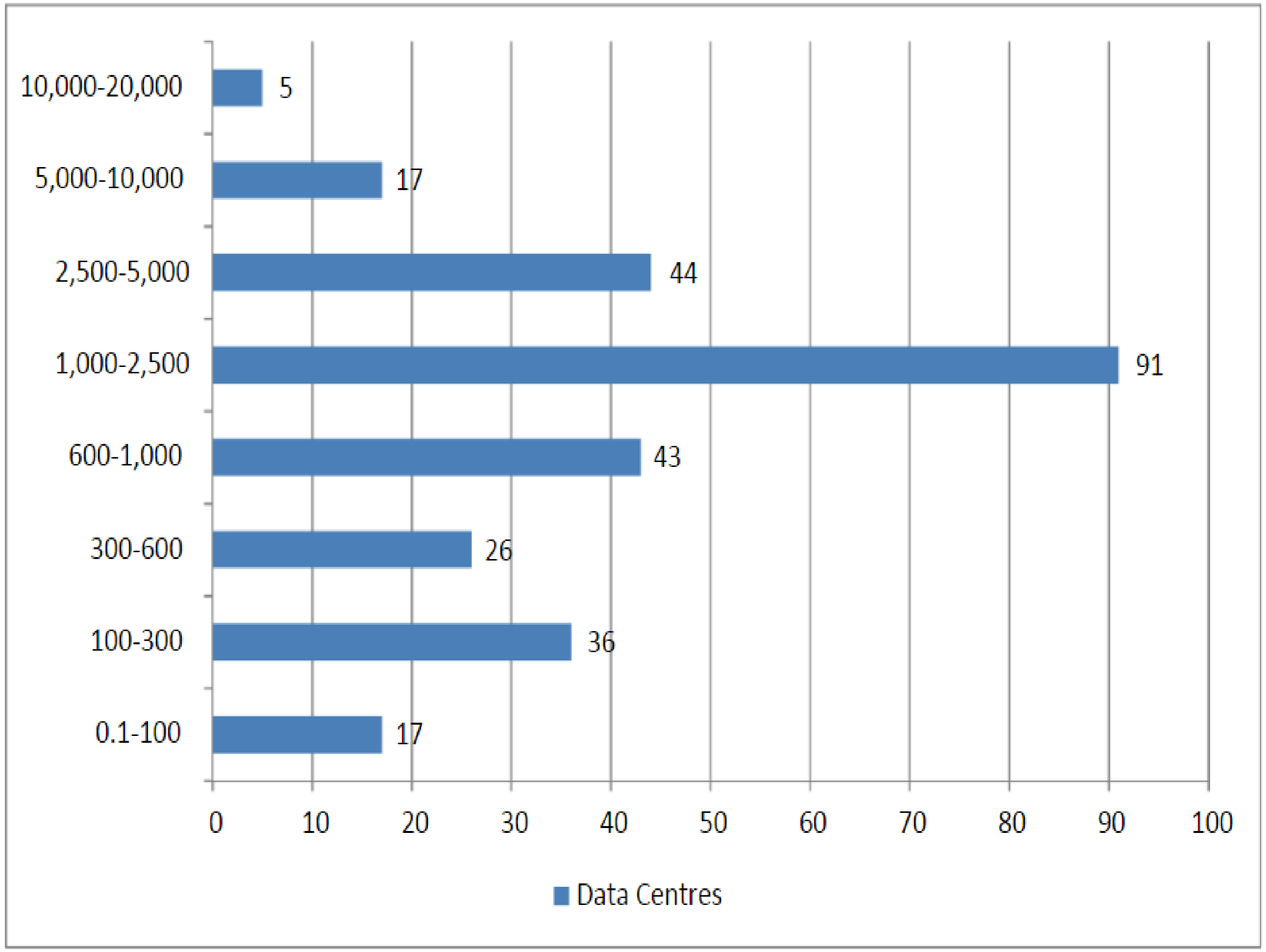


Figure 10. Average PUE values for different IT Rated Load classifications (kW)

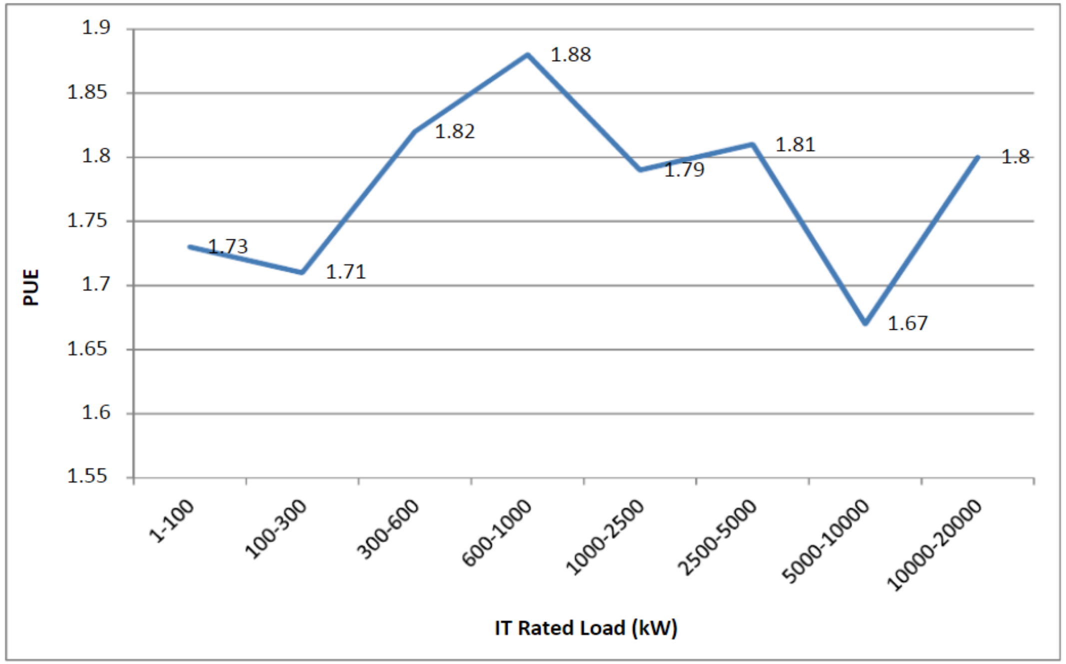
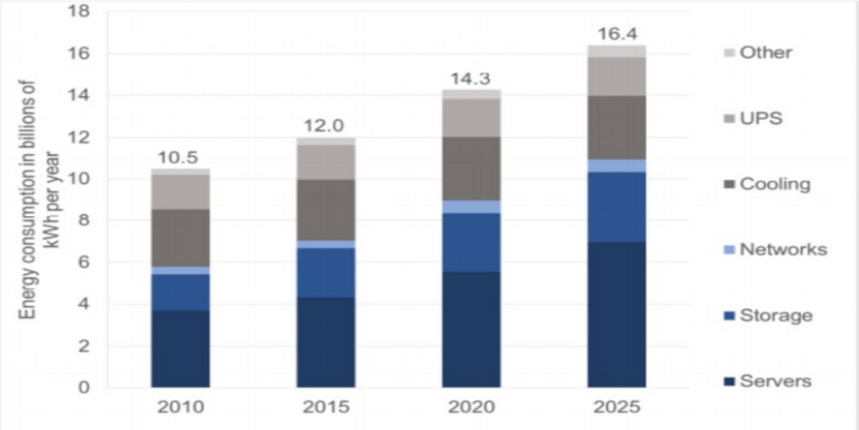


Figure 1. Energy consumption of servers and data centres in Germany from 2010 to 2015 and forecast to 2025



Source: Hintemann, 2015

PUE Definition

Power Usage Effectiveness (PUE) is an important metric in measurement of the effectiveness of a data center facility which has been introduced and standardized by The Green Grid Association.

Unlike to what the original definition calls for (Power) , the accepted usage is by measuring “Actual Energy in kWh” (instead of kW).

$$PUE = \frac{Total\ Facility\ Energy}{IT\ Equipment\ Energy}$$

Special attention shall be given when interpreting and comparing the reported PUEs between published data by different industries as there are various ways and levels of reporting **(Level of PUE L1, L2 or L3)** which shall be taken into consideration , each level measures IT Energy at different locations :

At **UPS output (L1)** , at **PDU output (L2**) or at **IT equipment input (L3)** with different measuring and reporting intervals (e.g. monthly , weekly, hourly, continuous).

Typical Data Centre Power Consumption Profile

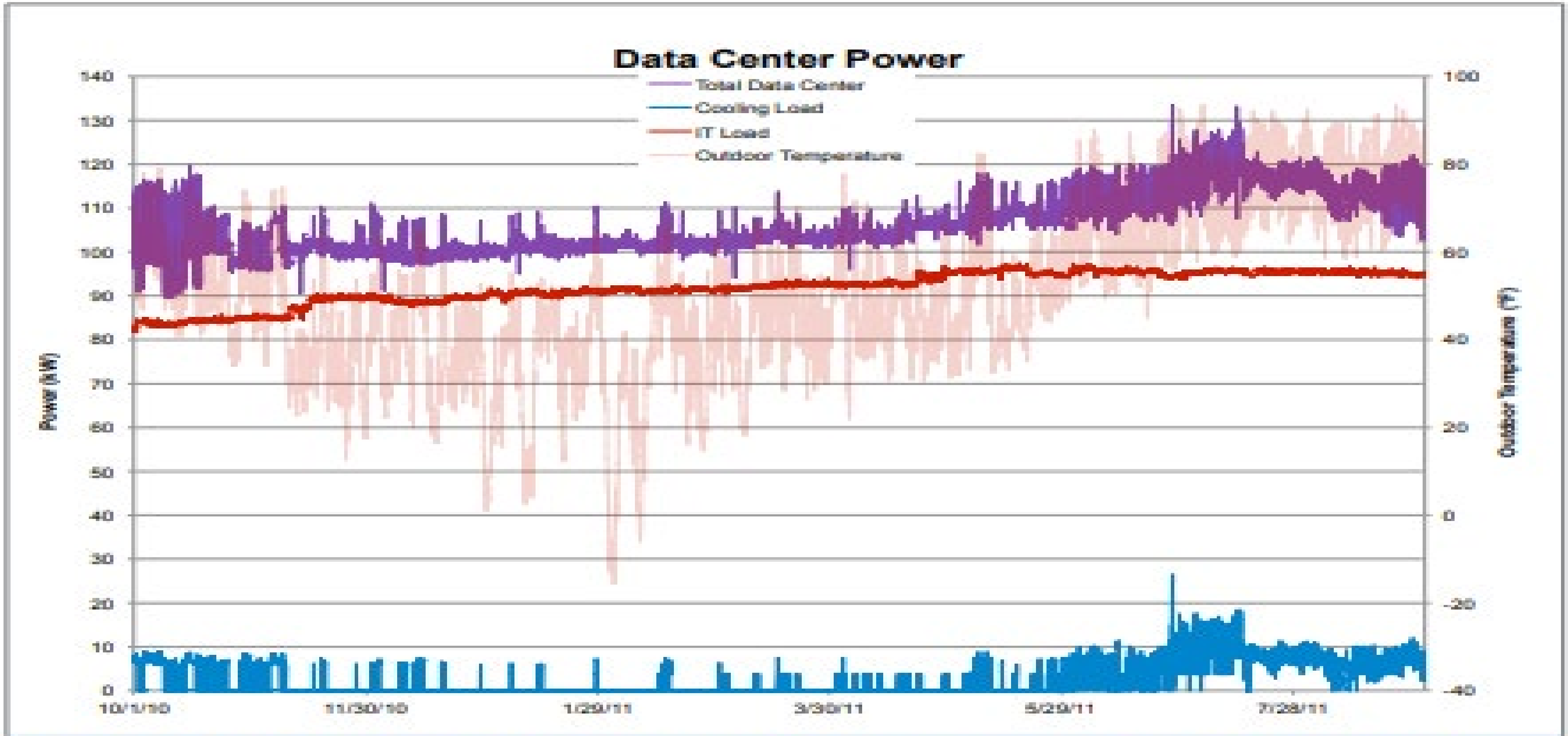
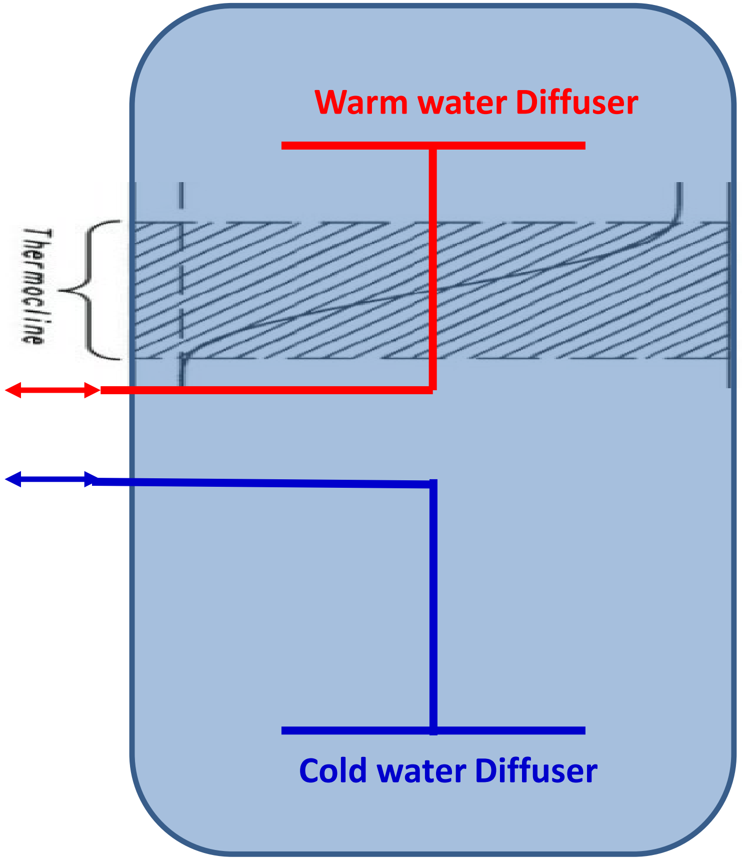


Figure 5 2. Load profile for the RSF data center over the first 11 months of operations *Illustration by Chad Lobato, NREL*

Stratified Chilled Water Thermal Storage

Thermal Storage stratified chilled water tanks benefits

- **Currently utilized to provide continuous cooling via dedicated small power chilled water pumps linked to the UPS.**
- **Compared to buffer tanks, provide more stable chilled water supply temperature for around 80% to 90% of the tank volume.**
- **Should be oversized and used in daily operation routine to produce chilled water at night and avoid part load chillers operation.**



How Thermal Storage compares to UPS batteries storage

Batteries Power Pack

Price:	US $ 250 - 300/kwh e
Expected Lifetime:	10 Years
Round Trip Efficiency:	88–89%
Footprint:	68–70 kwh/m^2

Stratified Chilled water Thermal Storage Tank

Several Suppliers:	US $ 20 - 25 / kwh thermal
Expected Lifetime:	50 Years
Round Trip Efficiency:	98 -99%
Operating Efficiency:	105 – 110%
Footprint:	200 – 220 kwh/m^2

Stratified Chilled water Thermal Storage Design Guide

- Sized for 4 hours of full cooling capacity storage as compared to 10 to 15 minutes of current common practice. i.e. if a data center with IT load of 4,000 kw would typically require 5,200 to 5,600 KW (1.3 to 1.4 x IT load) of cooling capacity and hence the thermal storage capacity should be 4 Hrs. x 5,600 kw = 22,400 kwh or 6,370 Ton-Hr.
- Maximize Chilled water ΔT to reduce chilled water TES tank volume for example ΔT = 6^{O}C would require around a chilled water storage volume of 0.6 m^3 / Ton-Hr as compared 0.4 m^3 / Ton-Hr ΔT = 9^{O}C.
- Preferably open to atmosphere and at least 2 m higher than the highest CRAH, FCU or AHU coil.
- Can be put in the basement but require complex sustaining valves' and dedicated pumps and controls arrangement.
- Can be pressurized but require thicker steel and critical diffuser design. Experience is insufficient and usage is extremely rare.
- Cold and warm diffusers requires 450 mm height each and thermocline is typically 600 mm in height and hence around 1.5 m of the height of water Colum is unutilized.
- Thermal losses are around 1% a day and requires walls, bottom and roof insulation of at least 100 mm thick.
- Metal cladding above insulation is typically uses with specialized seamed profile and some time more rough external rivets is used by less experienced installers.

Air Cooled vs Water Cooled Chillers

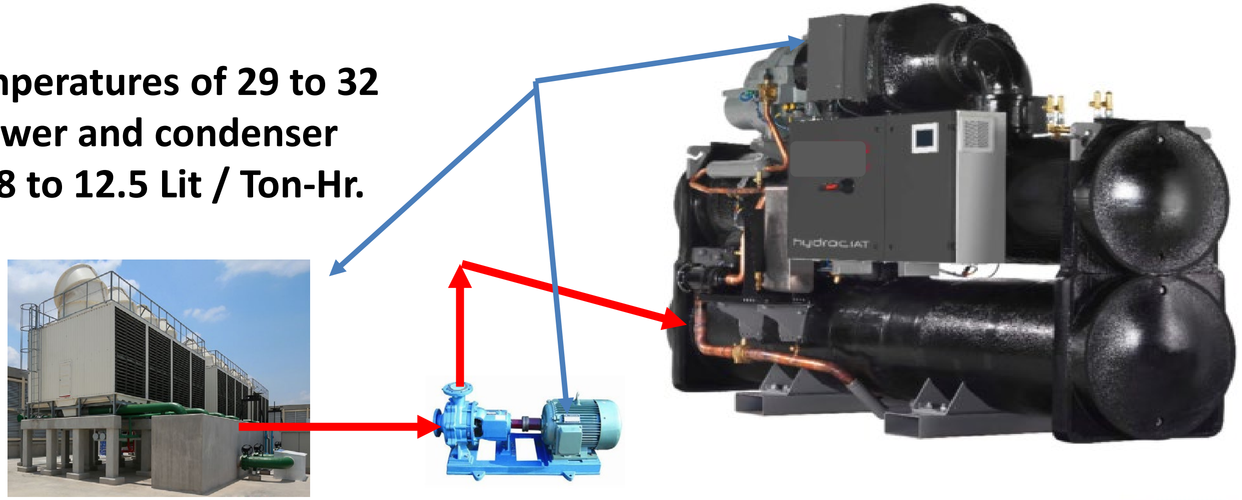
Comparison & Optimization

Air Cooled Vs water Cooled Chillers and chilled water optimization

- **Typically Chillers' compressors consume power in proportion to the pressure lift where they compress gas from the low temperature low pressure evaporator refrigerant gas to the high pressure high temperature condenser refrigerant Gas.**

- **Typically air cooled are sized for ambient temperatures of 45 to 50 Deg C and have power consumptions of chiller (compressor + Condenser fans) 1.3 to 1.6 KW / Ton.**

- **Typically water cooled are sized for ambient wet bulb temperatures of 29 to 32 Deg C and have power consumptions of chiller, cooling tower and condenser pump of 0.7 to 0.85 KW / Ton and water consumption of 8 to 12.5 Lit / Ton-Hr.**



Chilled Water Plant typical cost and power demand in Dubai

Description	Unit	Air cooled Chiller Plant	Water Cooled Chiller Plant	Remarks
CAPITAL COST ESTIMATES				
Central Plant	USD/TR	**1,292**	**1,714**	Including civil costs and one chiller standby with noise treatment and coil coating
Utility Connection Cost	USD/TR	**693**	**367**	Based on 150 USD/KW Utility Connection Fee
TOTAL CAPITAL COST	**USD/TR**	1,985	2,081	
POWER AND WATER REQUIREMENTS				
Power Consumption	KW/TR	**1.70**	**0.90**	Central Plant Equipment Only including pumping power
Peak Water Consumption **(Potable Water)**	Lit/Tonh	**0.00**	**8.50**	Based on potable water quality supplied
Peak Water Consumption **(TSE Water)**	Lit/Tonh	**0.00**	**12.50**	Based on TSE water quality supplied
Estimated Annual Power Consumption Cost	USD/Tonh	**0.2059**	**0.1090**	Based on 0.445 DH/Kwh
Estimated Annual Water Consumption Cost **(Potable Water)**	USD/Tonh		**0.0264**	Based on 11.45 DH/m3 potable water cost
Estimated Annual Water Consumption Cost **(TSE Water)**	USD/Tonh		**0.0075**	Based on 2.2 DH/m3 TSE water cost
TOTAL OPERATING COST (Potable Water Makeup)	**USD/Tonh**	**0.206**	**0.135**	
TOTAL OPERATING COST (TSE Water Makeup)	**USD/Tonh**	**0.206**	**0.116**	

5,200 Ton Cooling Plant for DATA CENTER SYSTEM CONSUMPTION COMPARISON in Dubai

Description	Unit	Air cooled Chiller Plant	Water Cooled Chiller Plant	Remarks
CAPITAL COST ESTIMATES				
TOTAL DEVELOPER CAPITAL COST	USD	10,160,888	10,651,678	With Utility Connection fee
TOTAL CONTRACTOR COST	USD	6,614,302	8,774,074	Without Connection fee
TOTAL O&M COSTS				
TOTAL UTILITIES COST (based on equivalent 5,000 full load hour operation for data center)	USD/y	5,267,926	3,465,709	Based On Potable water
	USD/y		2,980,140	Based On TSE water
O&M COST - PARTS & LABOR	USD/y	255,911	325,546	
TOTAL O&M COST	USD/y	5,523,837	3,791,255	Based On Potable water
	USD/y		3,305,686	Based On TSE water
Capital Cost Payback Period	Months	Base case	3.4	Based On Potable water
			2.7	Based On TSE water

Chilled Water Supply Temperature Optimization

		Air Cooled Chiller			Water Cooled Chiller		
		Low CHW T	Med CHW T	High CHW T	Low CHW T	Med CHW T	High CHW T
	Unit	Value	Value	Value	Value	Value	Value
		Base			Base		
Chilled water Supply Temperature	°C	9	15	20	9	15	20
Chilled water Return Temperature	°C	18	24	29	18	24	29
Suction Sat. temperature	°C	7.5	13.5	18.5	7.5	13.5	18.5
Condenser Supply Temperature	°C				35	35	35
Condenser Return Temperature	°C				40.6	40.6	40.6
Ambient Air Temp.	°C	48	48	48			
Condensing Sat. temperature	°C	63	63	63	41.8	41.8	41.8
Compressor Lift	°C	55.5	49.5	44.5	34.3	28.3	23.3
Cooling Capacity	Ton	100	100	100	100	100	100
Compressor Power Input	KW	130.0	115.9	104.2	65.0	53.6	44.2
Compressor Power Input Ratio	KW/Ton	1.300	1.159	1.042	0.650	0.536	0.442
% Power Savings		Base	10.8%	19.8%	Base	17.5%	32.1%
Calc. Compressor Power Input	KW / Ton	Base	1.159	1.042	Base	0.663	0.546

Chilled Water Supply Temperature Optimization

- Using Cold Isle (27^{O}C) / Hot isle arrangement (42^{O}C) allows increasing chilled water temperature to 20^{O}C.
- Utilizing water cooled chillers and high chilled water temperature gives more benefit in energy saving as compared to air cooled.
- Utilizing half the chillers' compressor with variable speed drives can save substantial energy particularly in water cooled centrifugal chillers with magnetic bearings.
- A separate system AC system (Chilled water 9^{O}C or lower or DX system) should be used for fresh air dehumidification and comfort cooling for offices and other occupied areas. Typically that would account from 5 to 10% of the total air conditioning load.

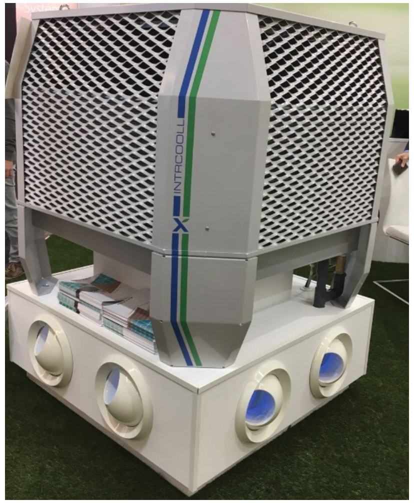
Direct Indirect Evaporative Cooling
(2 stages Evap. Cooling)

Application in hot and dry climates

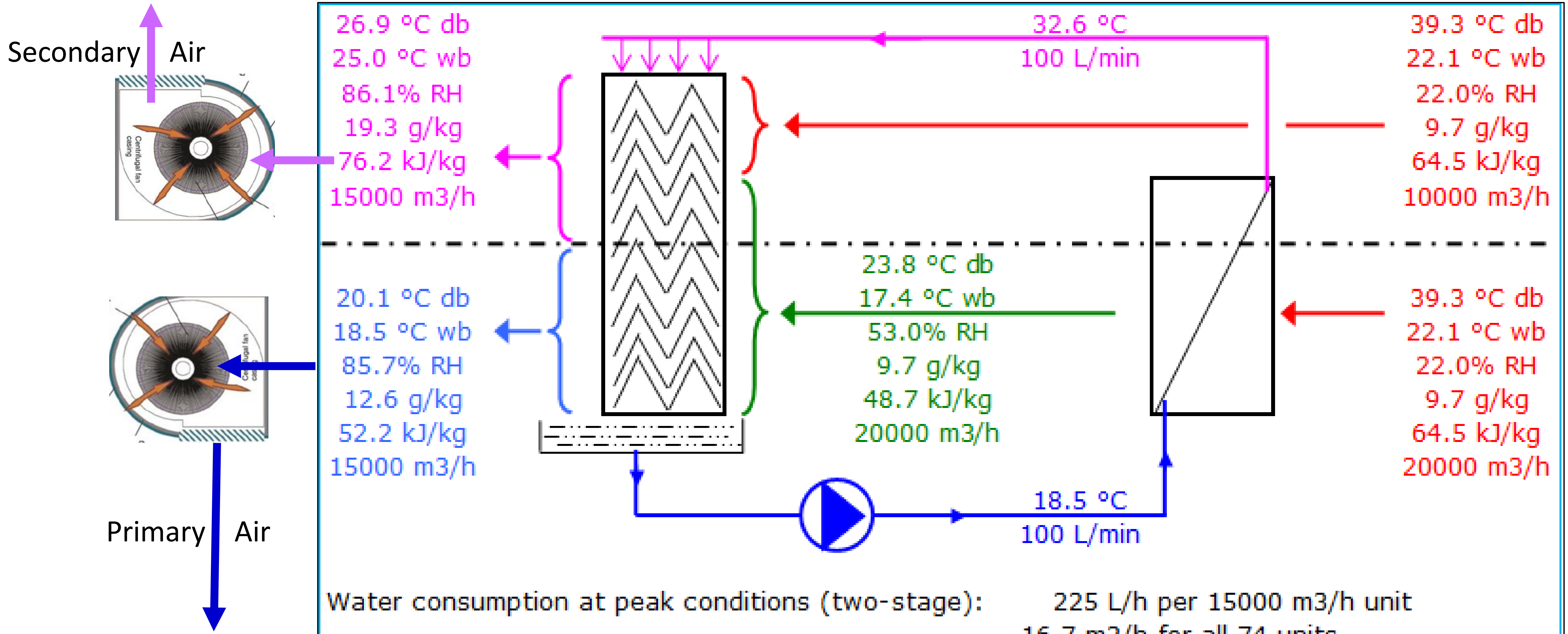
Selecting DC Locations with dry weather

City	Riyadh	Al Madinah	Abha	Tabuk	Najran
Dry Bulb ^{O}C	44.8	45	30.9	40.8	39.8
Wet Bulb ^{O}C	20.5	21.9	19.6	20.8	21.3

- KSA has several locations with hot and ultra dry weather and should be idle candidate for DC locations provided adequate communication highway is available.
- These Cities has the possibility of using direct / indirect cooling technology.



Direct / Indirect Evaporative Cooling Typical Selection

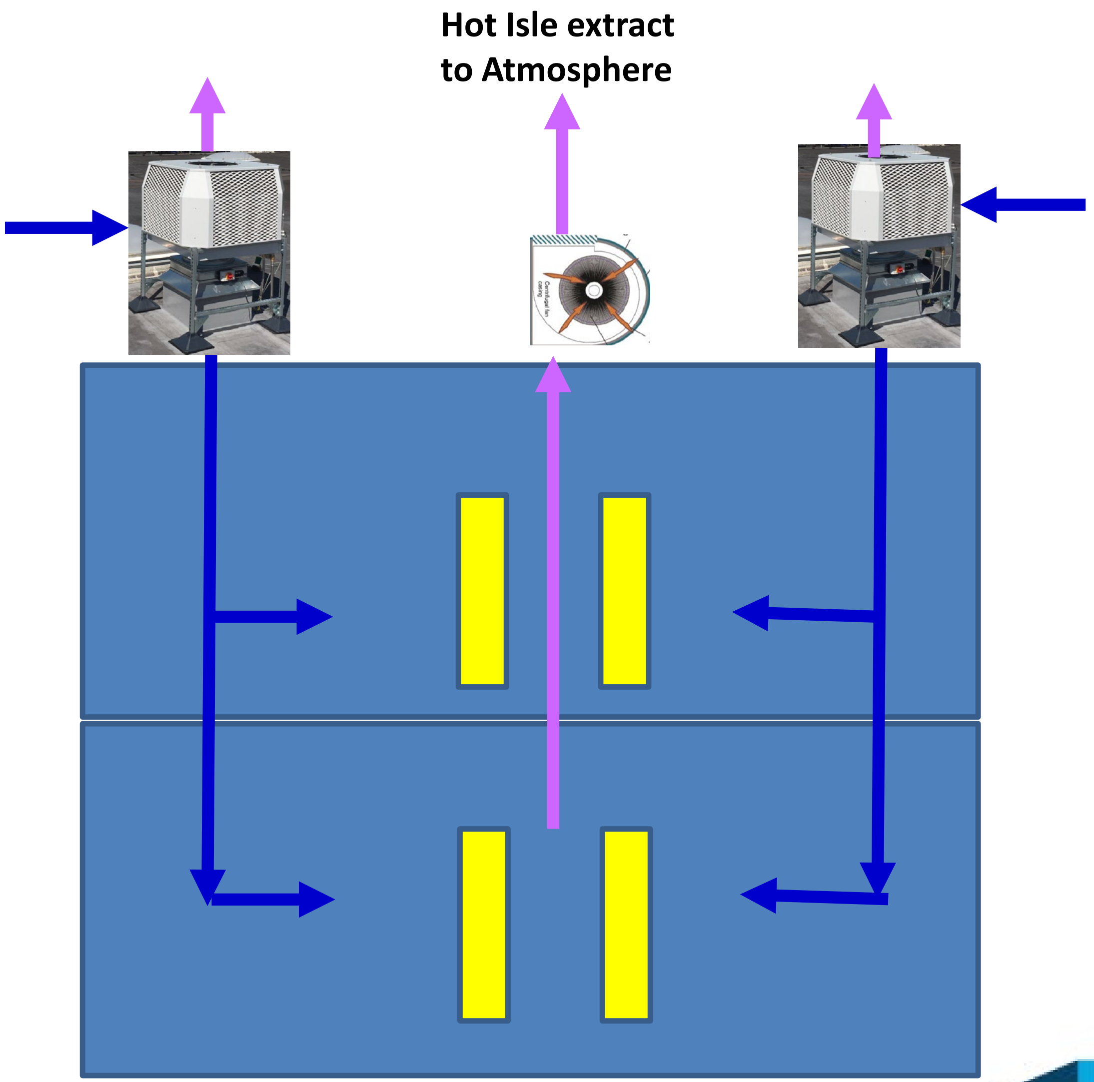


Water consumption at peak conditions (two-stage): 225 L/h per 15000 m3/h unit
16.7 m3/h for all 74 units

Water consumption at peak conditions (standalone): 18.0 m3/h for all units

Direct / Indirect Evaporative Typical Application

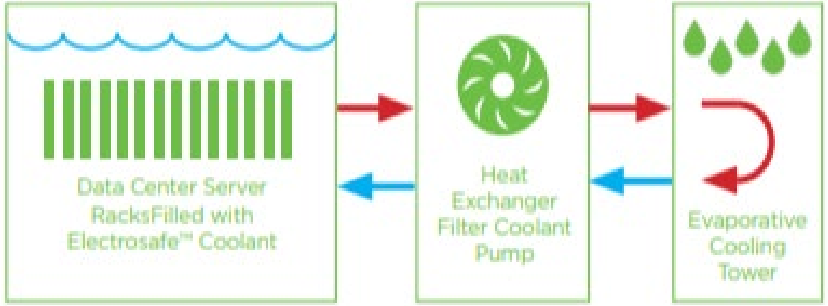
- Primary air is filtered and ducted to the white space cold isle.
- Hot Isle air extracted to atmosphere.
- Humidity is increased to acceptable comfort level as these ultra dry conditions increase static electricity.



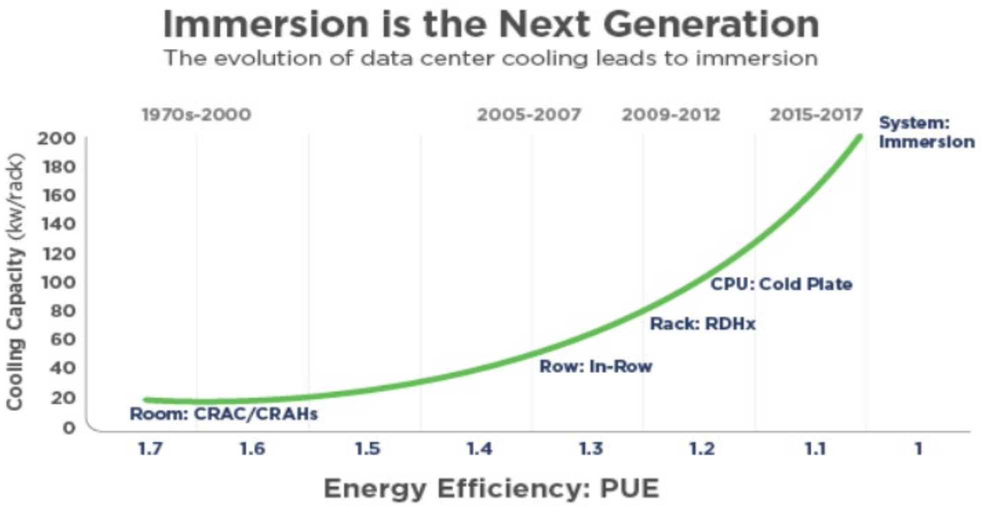
Emerging Technology

Immersion cooling

Immersion Cooling ….. Eliminate chillers



- Data center immersion cooling involves directly immersing IT hardware in a non-conductive liquid that cost around $ 80 / Lit.
- Immersion liquid typical operation temperatures is between 15 to 65^{O}C.
- Saves space by allowing high power racks (up to 100 kW) to be cooled effectively.
- Uses indirect evaporative cooling to cool the non-conductive fluid saving around 80% of the chiller plant power and saving the entire fan power.
- The main reasons for rising demand are:
  - AI & Big Data requires high density computing.
  - High frequency trading & Blockchain.
  - Reduction in power demand.



Immersion Cooling ….. Sample Projects

- Headquartered in Geneva, the CERN is one of the largest scientific research centers in the world for particle physics. It will now use Immersion cooling solution for data center cooling. It comes in a 22u and 45u configuration to dissipate 25kW to 50kW of heat extraction capacity.

HPC Gets Bigger in Texas: 40,000 Servers, Immersed in Coolant

- One of the world’s most powerful computing systems is coming to Houston, featuring over 40,000 servers immersed in liquid coolant. The massive system from DownUnder GeoSolutions (DUG) is expected to deliver 250 petaflops – more computing power than the world’s top supercomputers. Phase 1 include 15 MW of IT high performance computing.

Thank you

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