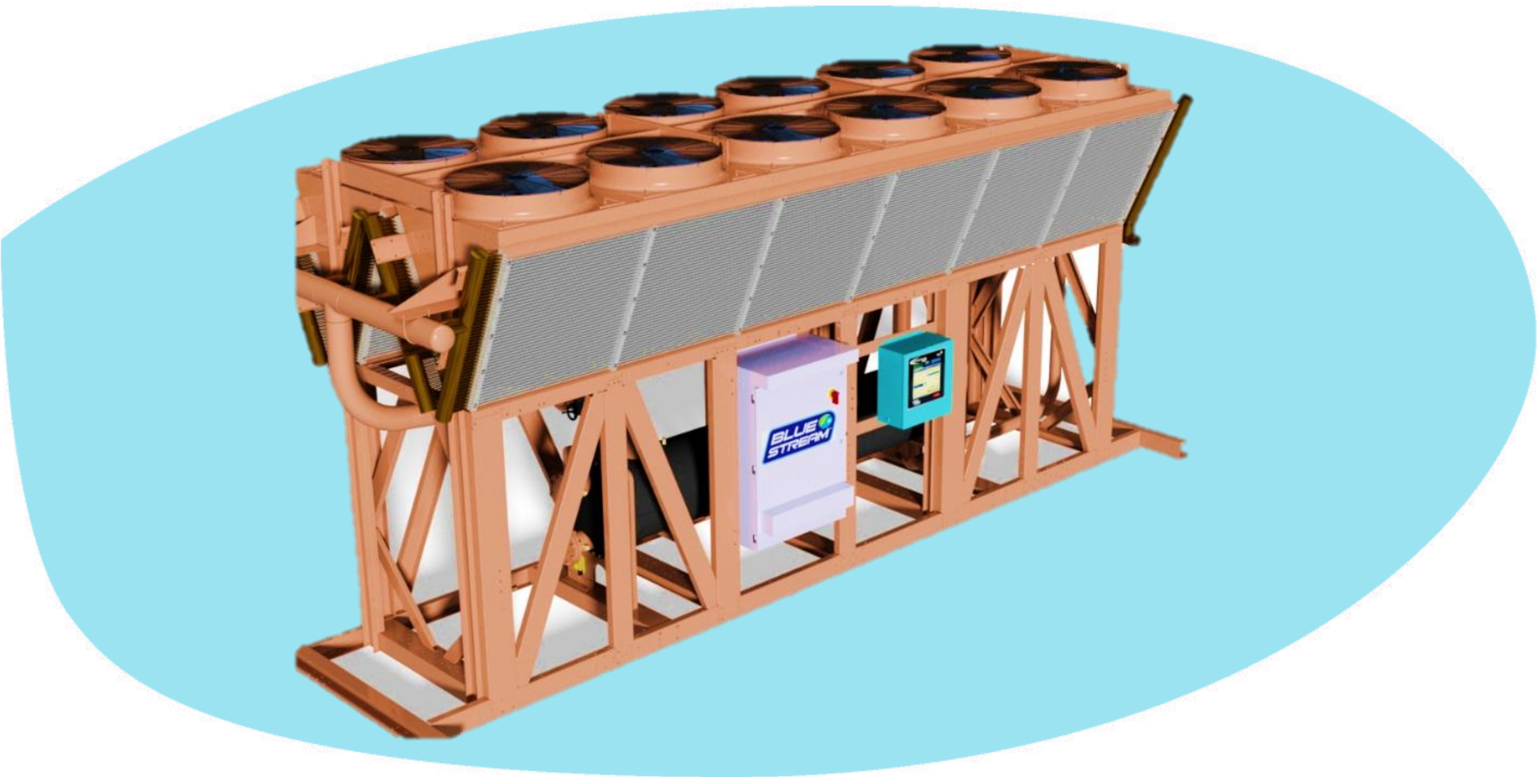
Options for Reducing Water Consumption and Improving Operational Resiliency in Central Chiller Plants

Water-Smart and Energy-Smart Heat Rejection



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February 8-12, 2016 | JW Marriott Austin Hotel | Austin, TX

Johnson Controls

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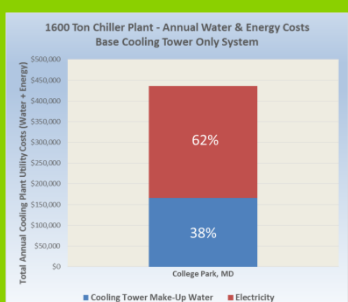
  - Stacy Nurenberg
- Johnson Controls
  - Zan Liu, Ph.D.

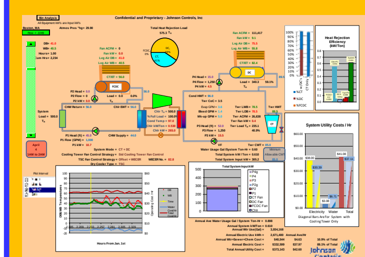
Four Key Points to Remember

Water Costs Are Becoming An Increasing Larger Component of a Chiller Plant's Total Operating Cost



Drought and Water Availability Can Pose A Risk For Chiller Plant Operations

Analysis of Alternatives Requires a Thorough Annual System Evaluation

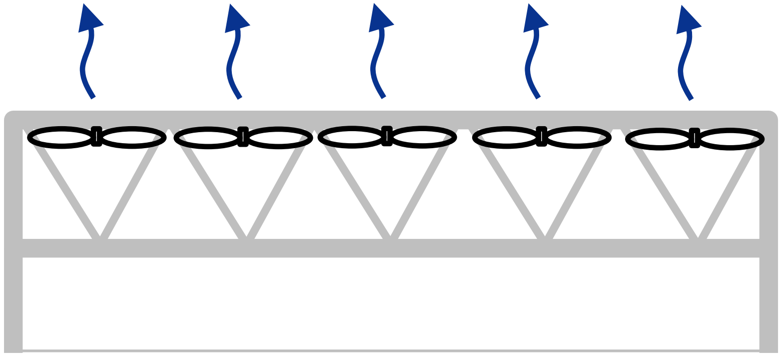


Hybrid Systems Offer a Cost Effective Way to Reduce Chiller Plant Water Use

Air and Water Cooled Heat Rejection System Options

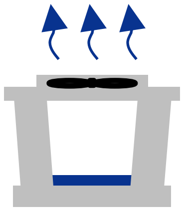
Air-Cooled System

- Design day is based on **DRY BULB** temperature
- Consumes no water (no evaporative cooling)
- Large footprint / Requires very large airflow rates



Water-Cooled System

- Design day is based on the lower **WET BULB** temperature
- Evaporative cooling process uses water to improve cooling efficiency
  - **80% LESS AIR FLOW → Lower Fan Energy**
  - Lower cost and smaller footprint
- Colder heat rejection temperatures improve system efficiency

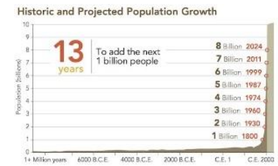


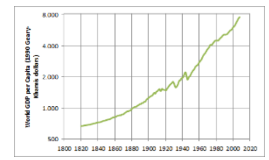
However, water cooled systems depend on a reliable, continuous source of low cost water

Freshwater Stress - The Global Perspective

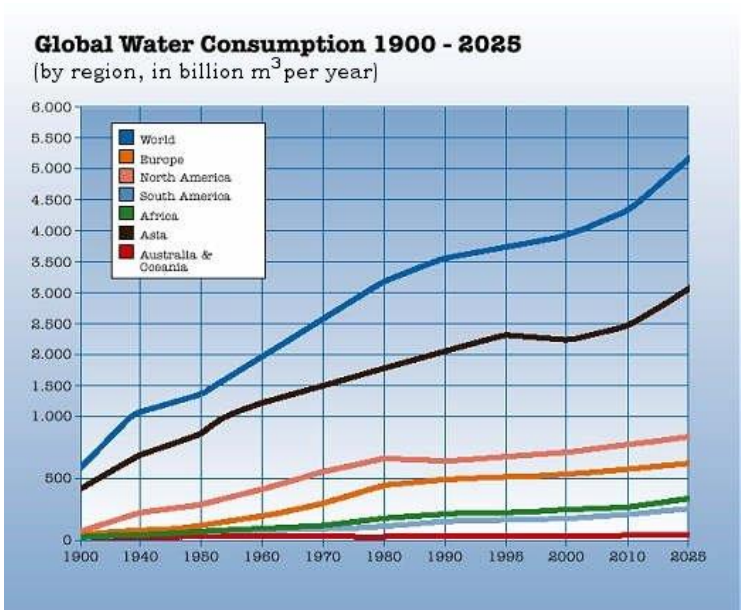
Forces Driving Fresh Water Consumption:

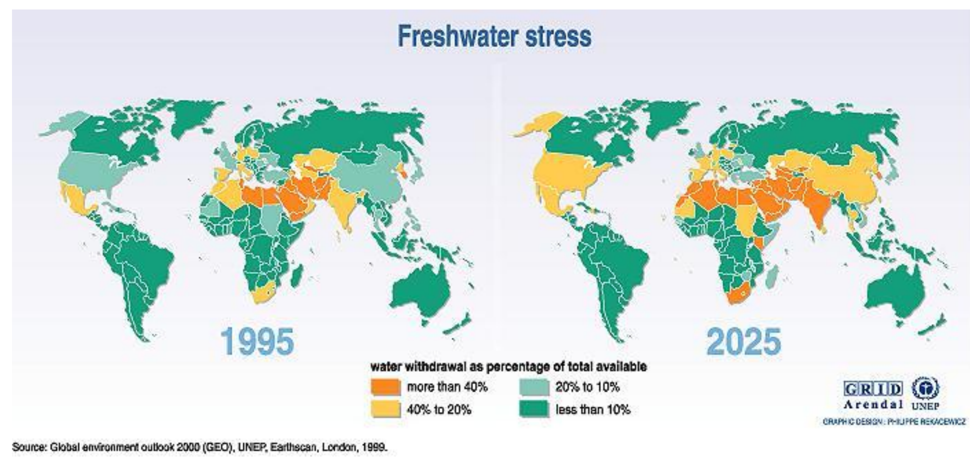
- **Population growth increases total demand**
- **Economic growth increases per capita demand**





Consumption increases … ***driving Freshwater Stress worldwide***





When the well's dry we know the worth of water.
- Benjamin Franklin, 1746

Freshwater Stress – Increasing Prices and Concerns About Continuous Availability

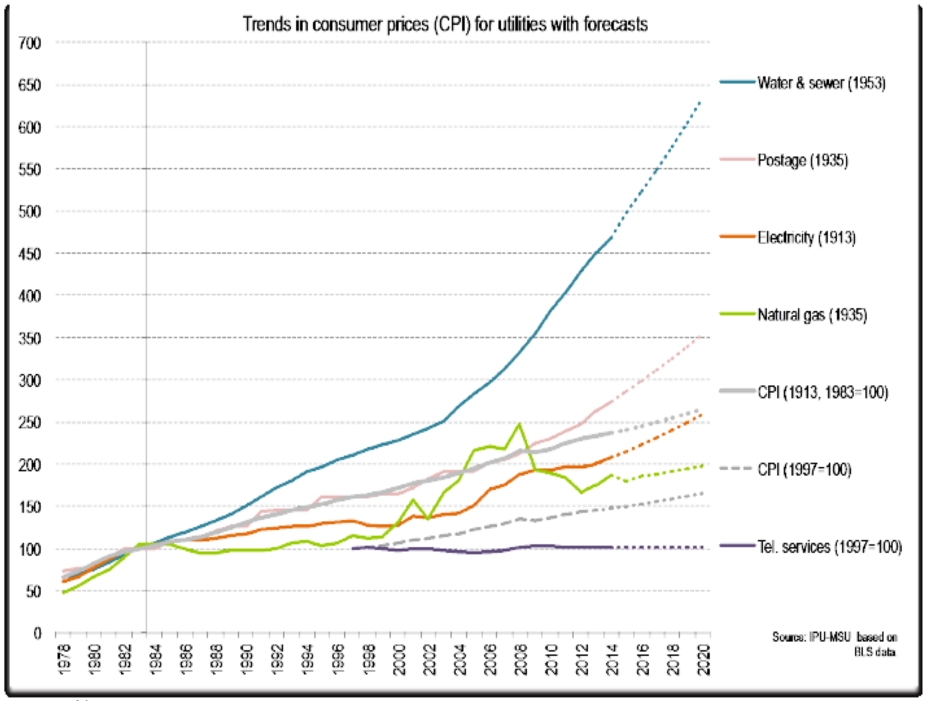
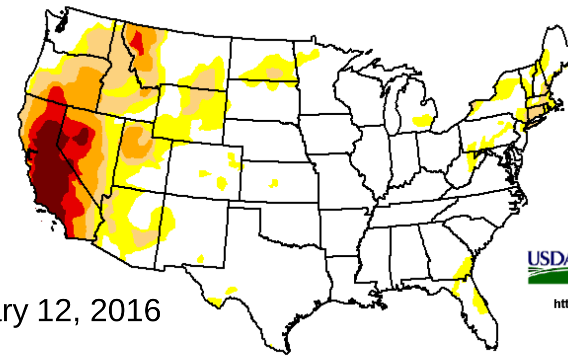


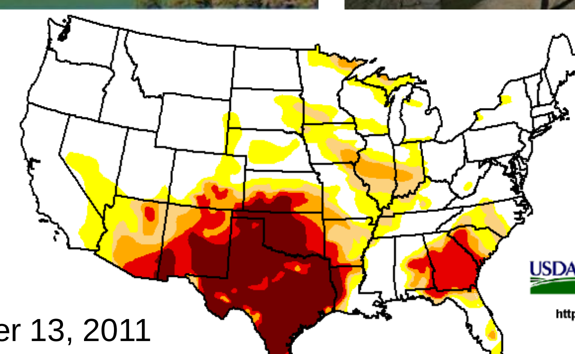
Exhibit 3. Trends in the Consumer Price Index for utilities (1978-2014, with forecasts).
The index is set to 100 for 1982-1984 except for telephone services, where the index is set to 100 for 1997. Year (*) indicates start of series.
Heuristic forecasts are based on auto-regressive, integrated, moving average (ARIMA) methodologies.

 [4]



January 12, 2016

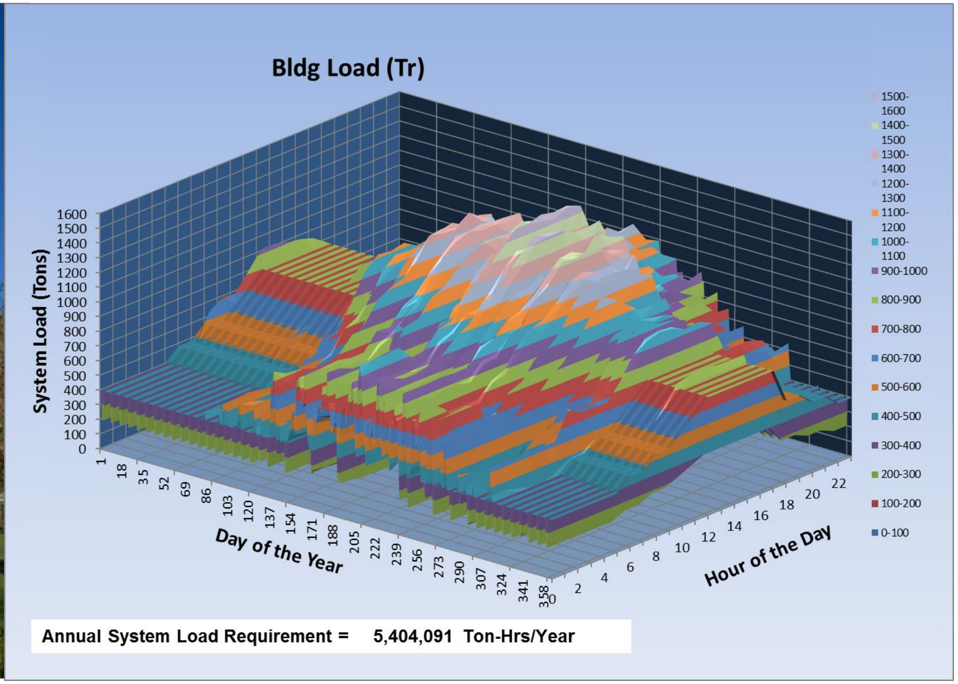
http://droughtmonitor.unl.edu/



September 13, 2011

http://droughtmonitor.unl.edu/

University of Maryland College Park – Physical Sciences Building



Model Assumptions

Energy		
Energy	$0.0809	$/kWh
Monthly Demand	$5.28	$/kW

Water Related Costs		
Make-up	$ 7.29	$/1000 gal
Sewer		
Blowdown	$10.70	$/1000 gal
Evaporation	$10.06	$/1000 gal
Chem. Treatment	$ 2.78	$/1000 gal Blowdown
CoC	4.5	
Fully Burdened	$18.11	$/1000 gal of Mk-Up

Chillers

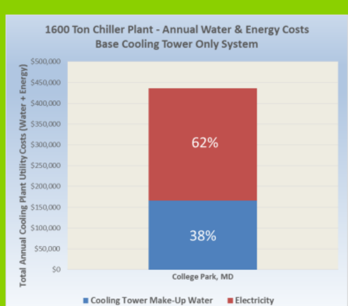
Type	Qty	kW / Ton
Water Cooled	2	0.579
Air Cooled	4	1.216

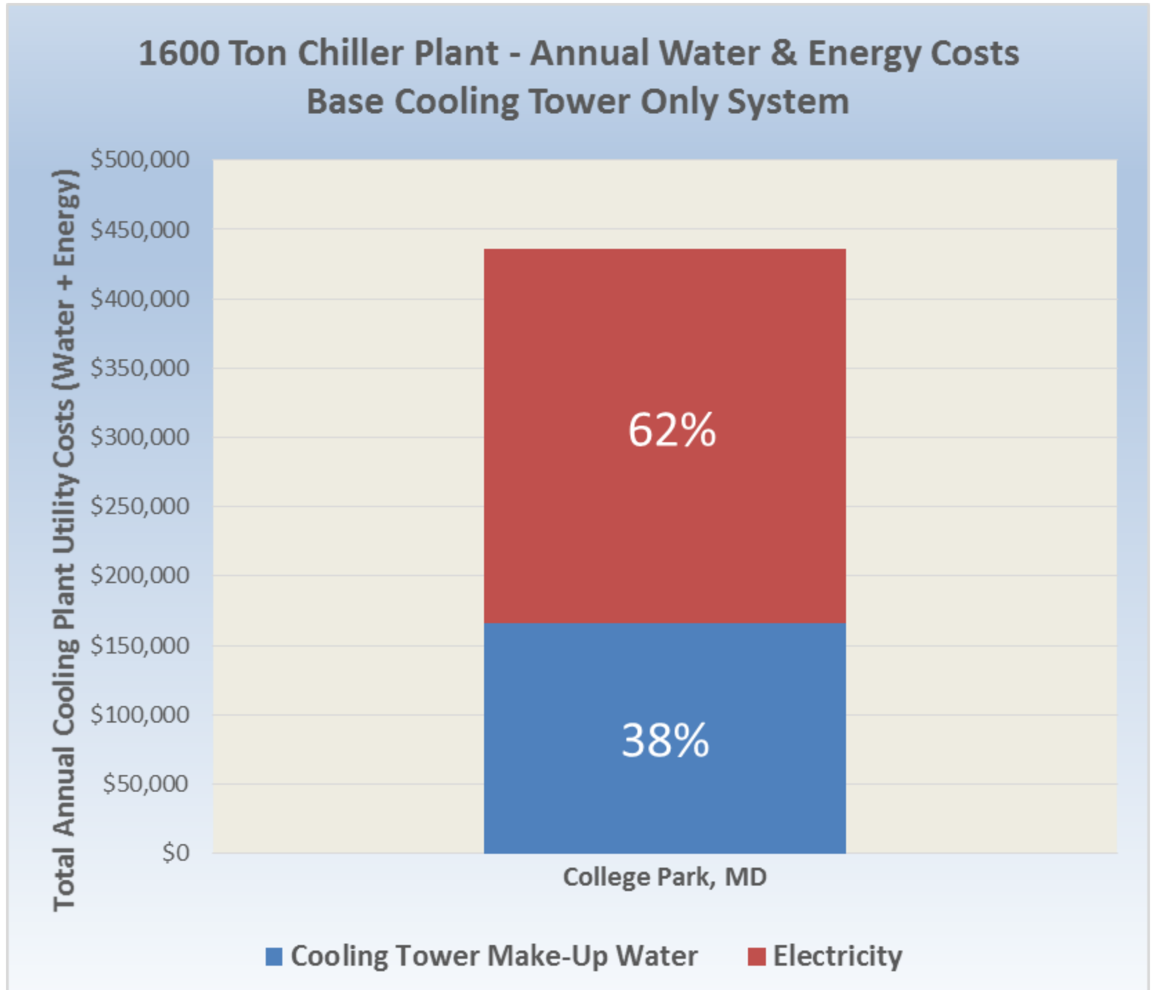
Other Assumptions:

- 42°F Chilled Water Supply
- 2.0 GPM/Ton Chilled Water Flow Rate
- 3.0 GPM/Ton Condenser Water Flow Rate
- Cooling Tower Sized to Produce 85°F Condenser Water at the Summer Design WB

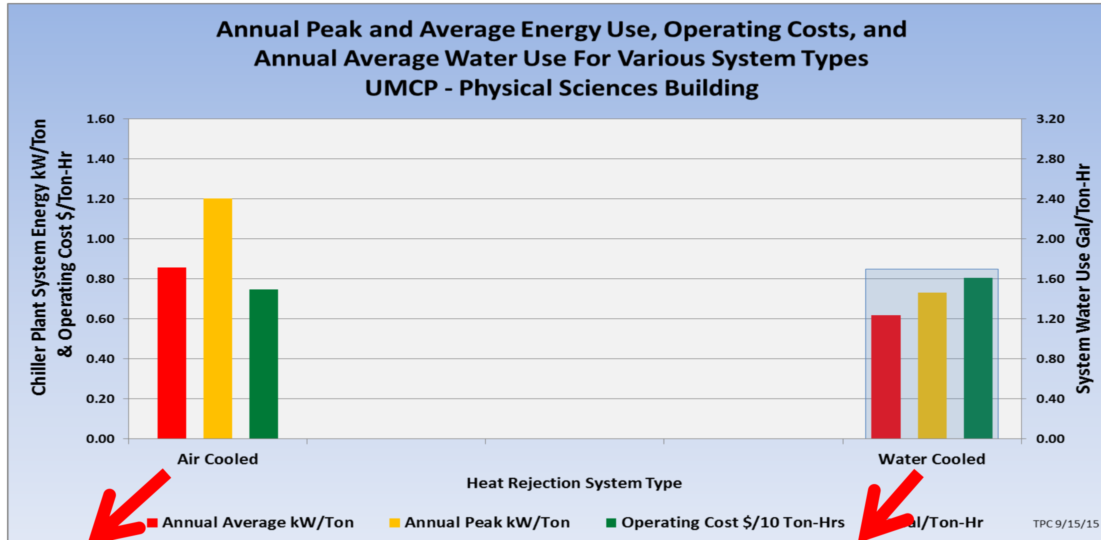
Water & Waste Water Costs Represent A Growing Portion of Total Utility Spend for Many Chiller Plants

Water Costs Are Becoming An Increasing Larger Component of a Chiller Plant's Total Operating Cost



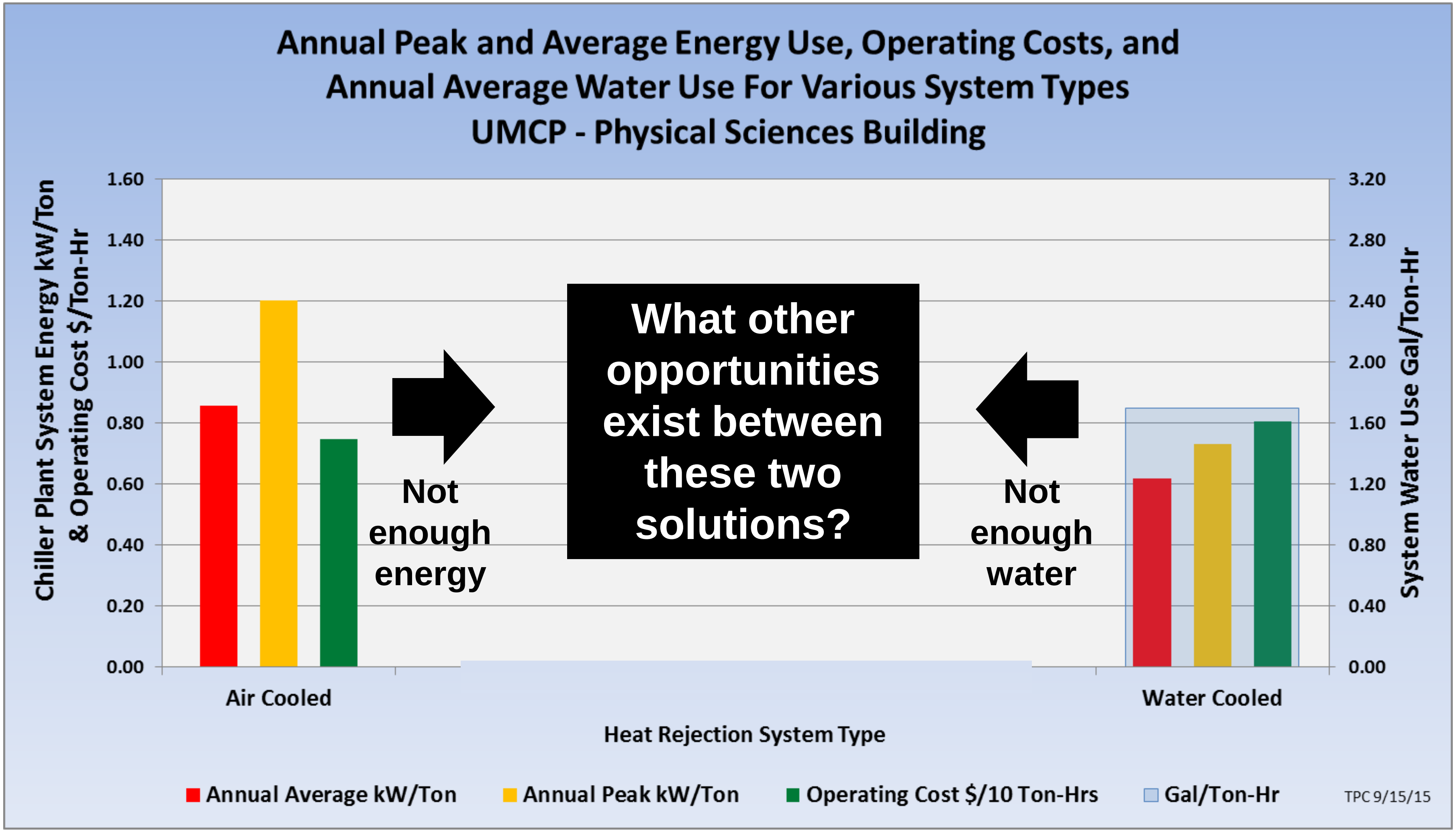


Air-Cooled System vs Water-Cooled System
UMCP Physical Sciences Building



System Metrics	Air Cooled System	Compared to Water Cooled	Water Cooled System
Average kW / Ton	.857	+38.9%	.617
Peak kW / Design Ton	1.203	+65.0%	.729
Operating Cost $ / 10 Ton-Hrs	$.747	-7.3%	$.806
Water Use Gal / Ton-Hr Gal / Year	0 0	-100% -9,171,760	1.697 **9,171,760**

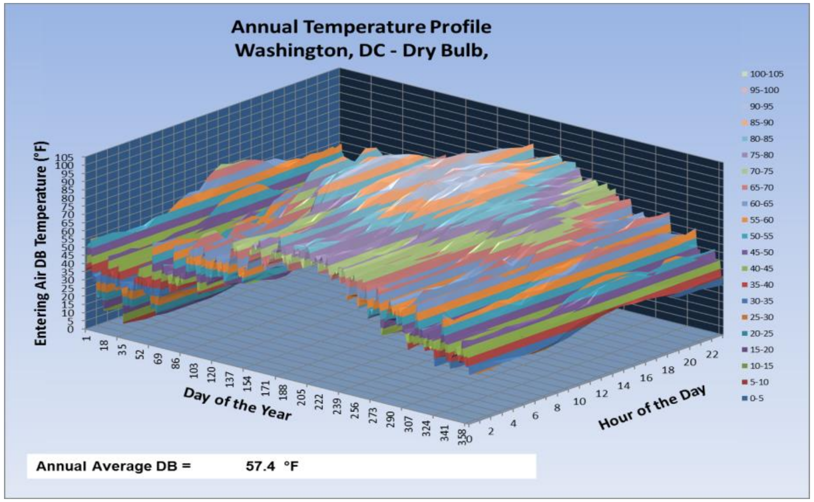
Air-Cooled System vs Water-Cooled System
UMCP Physical Sciences Building

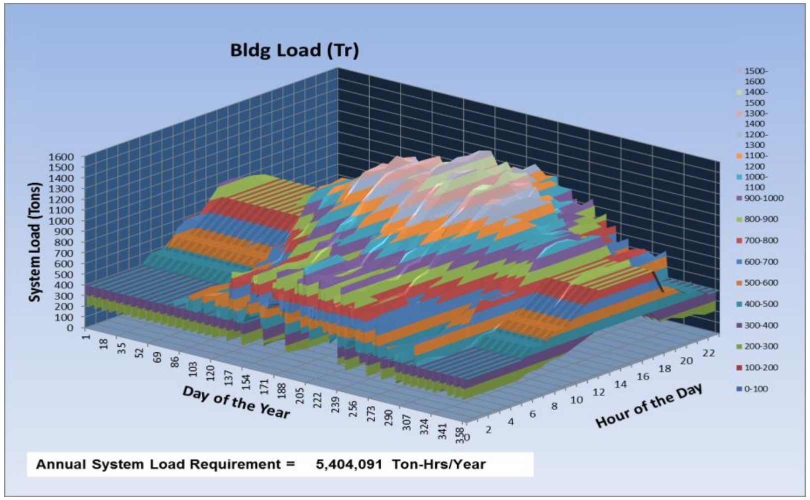


Weather and Load Variations Provide Opportunities for Hybrid Wet / Dry Solutions

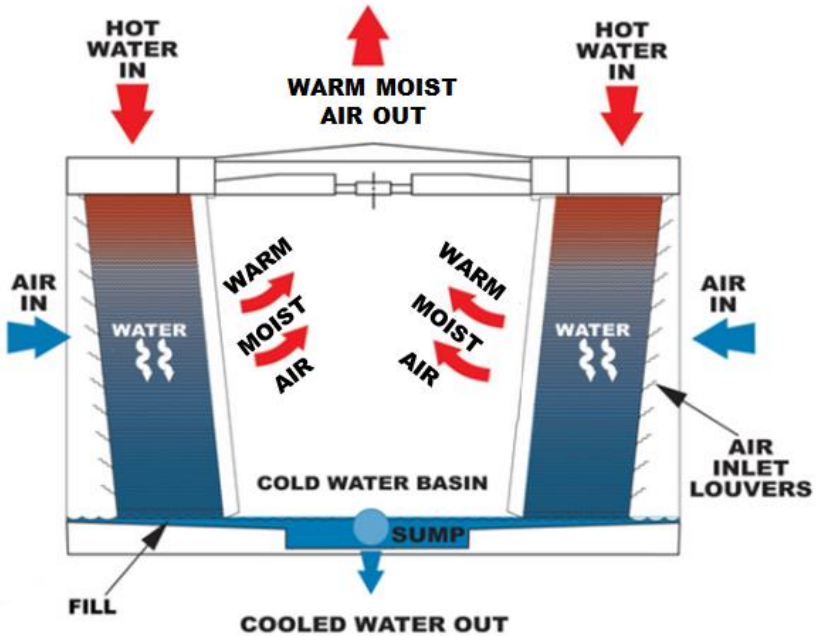
Basic Principles:

- Operates **wet** during peak design periods to save energy (high temperatures and loads)
- Operates **dry** during low design periods to save water (lower temperatures and loads)
- Depending on the system design may either operate as **wet** or **dry** or may be able to operate both **wet** and **dry**





The Open Cooling Tower is Very Efficient and It's Desirable to Have it as a Key Component of a Heat Rejection System

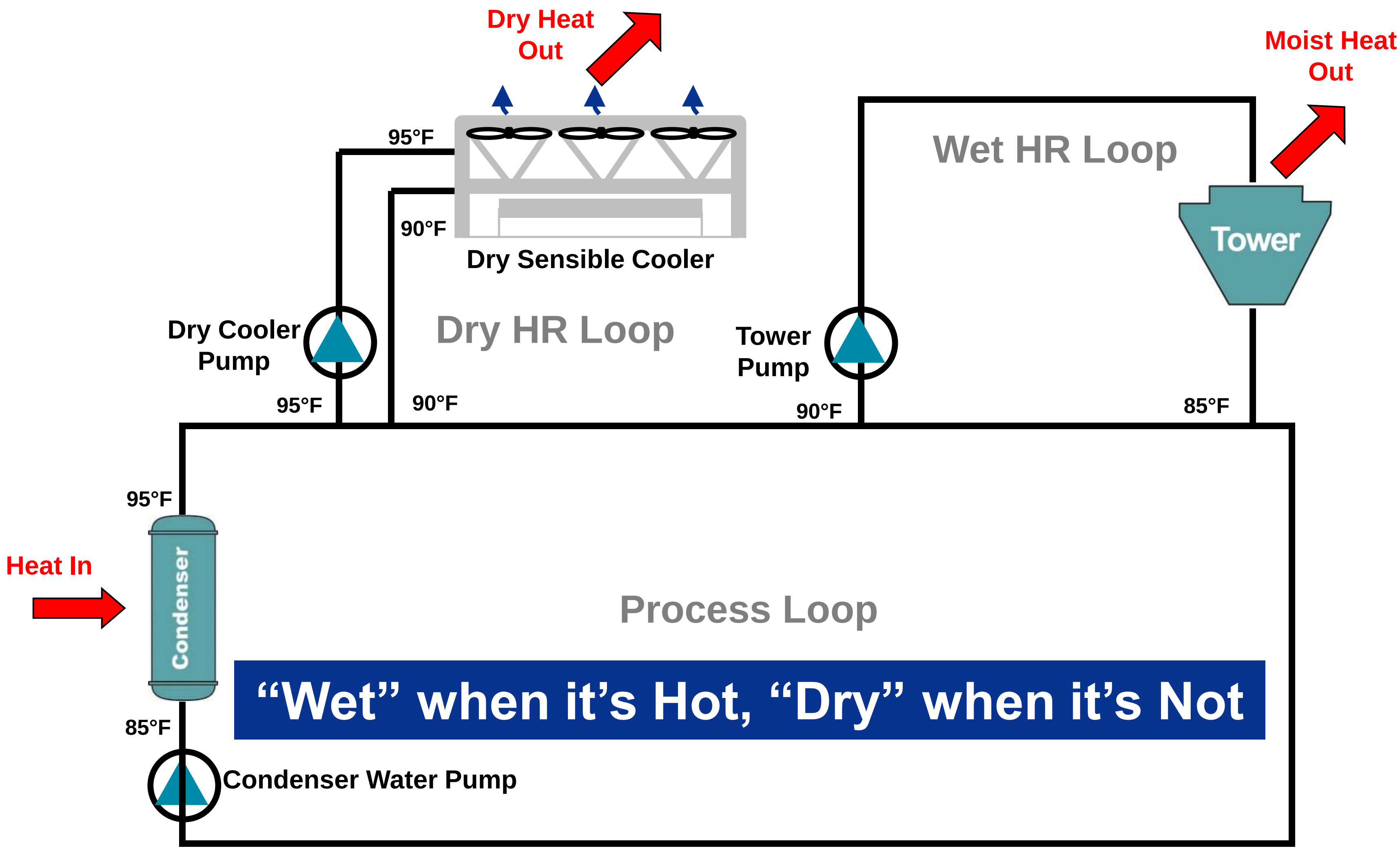


- Highly efficient – has the ability to saturate the exit air stream with moisture
  - Uses about 80% less air
  - Significantly lower cost
  - Significantly smaller footprint
  - Significantly lower fan energy
- Operates against the lower WB temperature sink

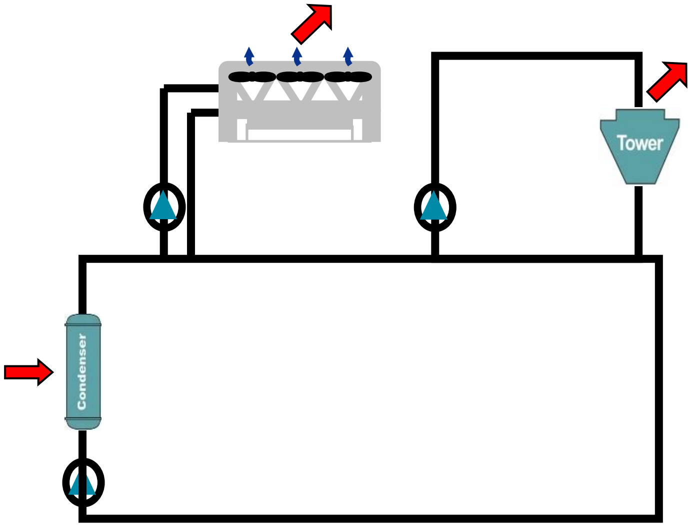
The Challenge:

How can the efficiency and capacity advantages of Evaporative Heat Rejection be delivered with far less water consumption?

Series Flow Dry / Wet Hybrid Heat Rejection System

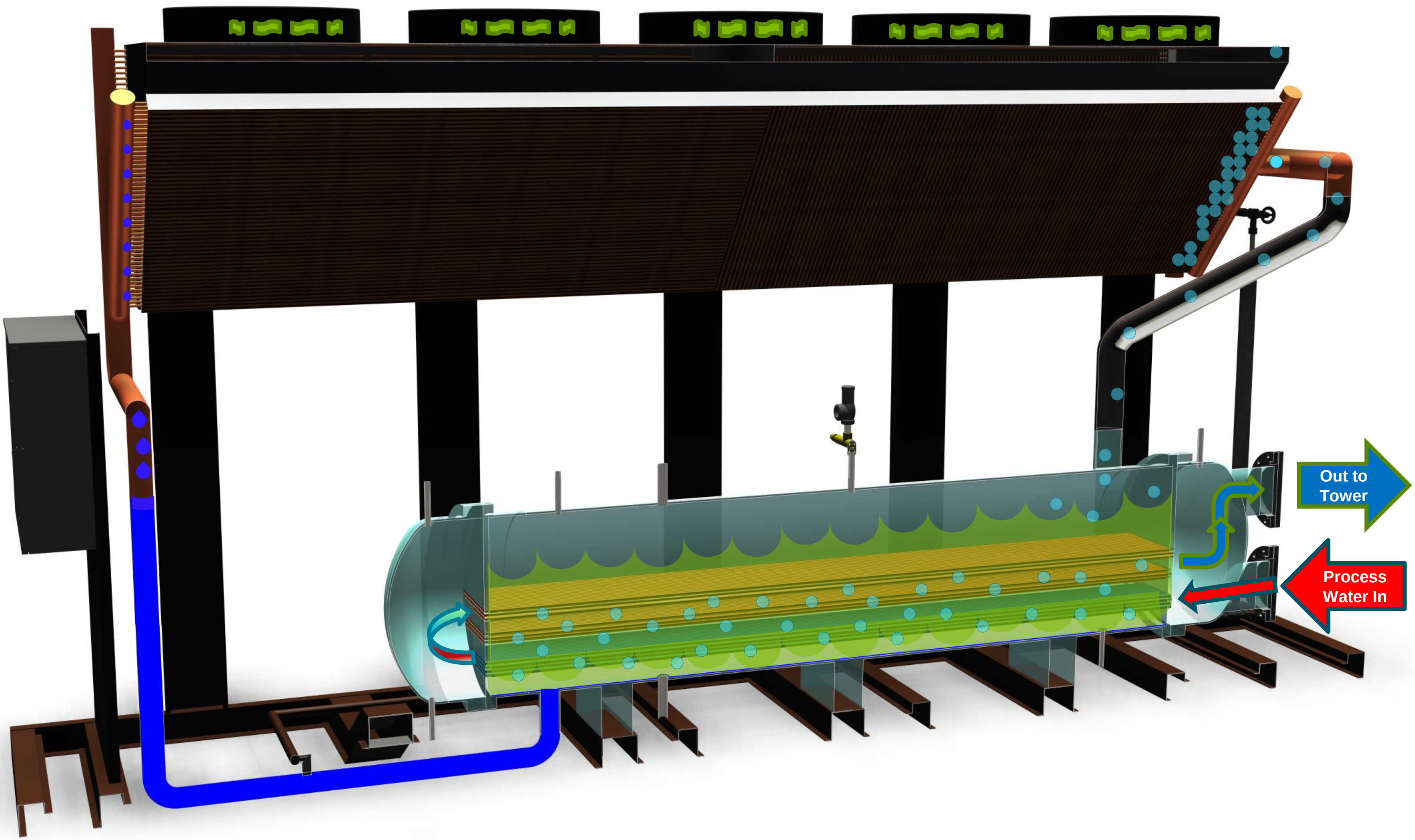


Dry Sensible Heat Exchanger Requirements



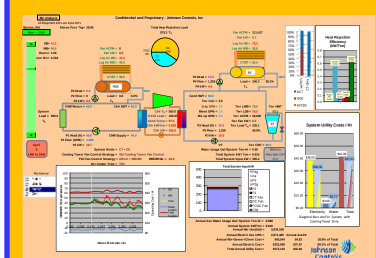
- Seems simple enough but …
  - Open system – cleanability issues, material compatibility issues
  - Requires low pressure drop design
  - Control issues:
    - Percentage of cooling by each device
    - Optimum condenser entering water temperature
  - Freeze protection

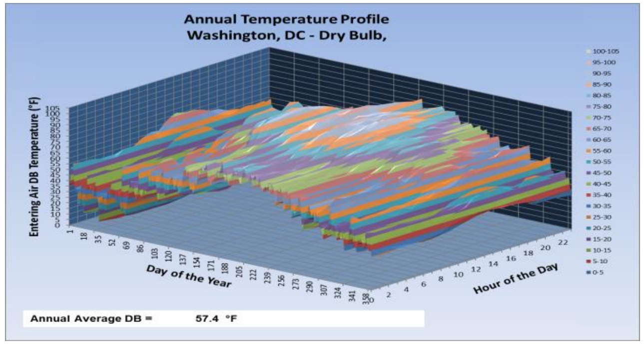
Thermosyphon Cooler – Conceptual Design

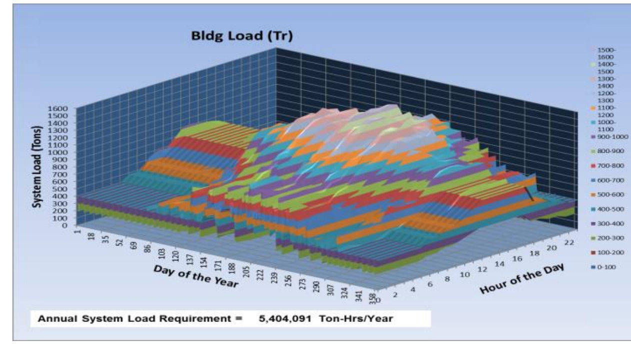


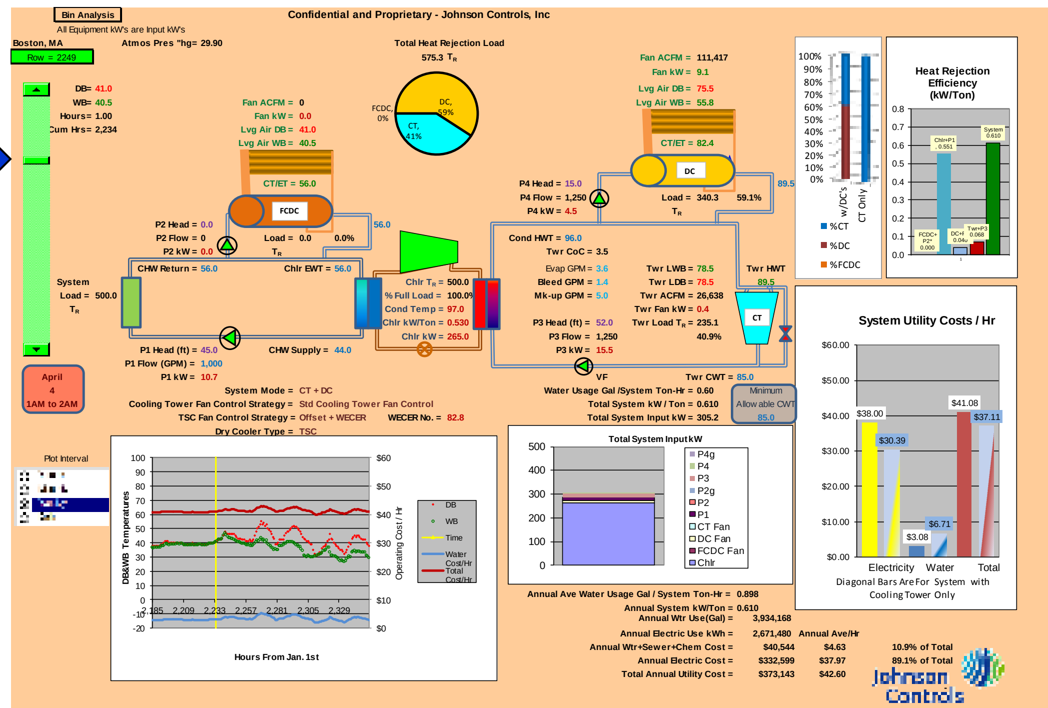
Interactive System Schematic From The Chiller Plant Simulation Program

Analysis of Alternatives Requires a Thorough Annual System Evaluation



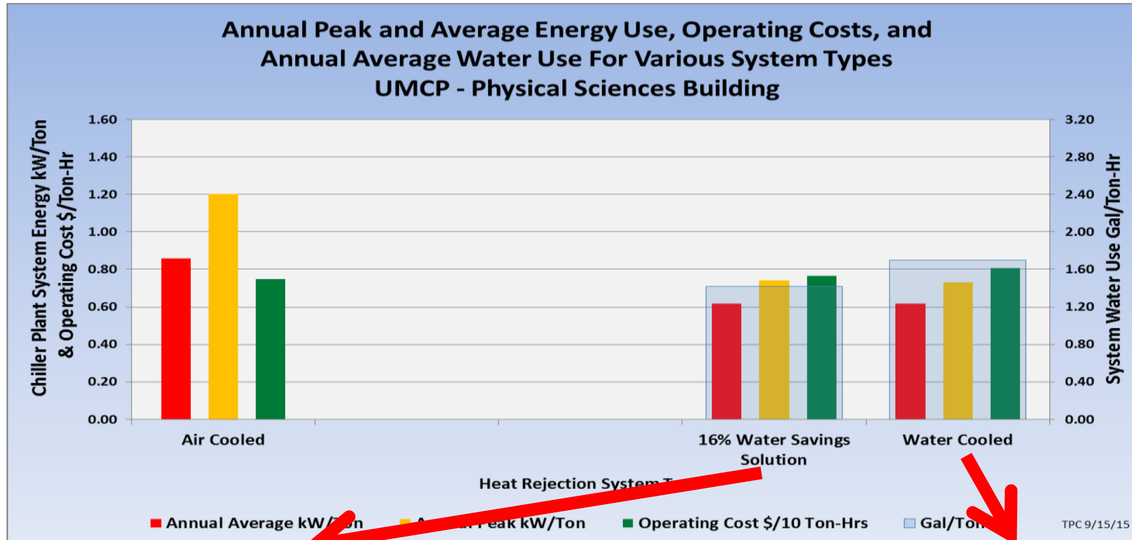






16% Water Savings TSC Hybrid System Example

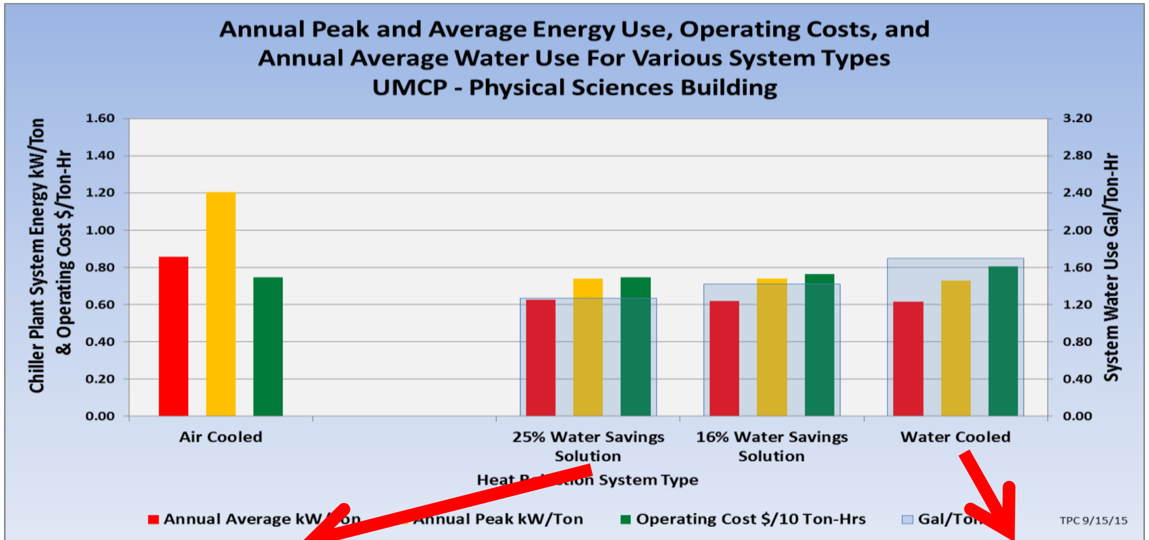
- One TSC Unit
- WECER Control
- Minimum Condenser Water Temperature = 55°F



System Metrics	16% TSC Hybrid System	Compared to Water Cooled	Water Cooled System
Average kW / Ton	.618	+0.2%	.617
Peak kW / Design Ton	.740	+1.5%	.729
Operating Cost $ / 10 Ton-Hrs	$.765	-5.2%	$.806
Water Use Gal / Ton-Hr Gal / Year	1.420 7,675,826	-16.3% **-1,495,934**	1.697 9,171,760

25% Water Savings TSC Hybrid System Example

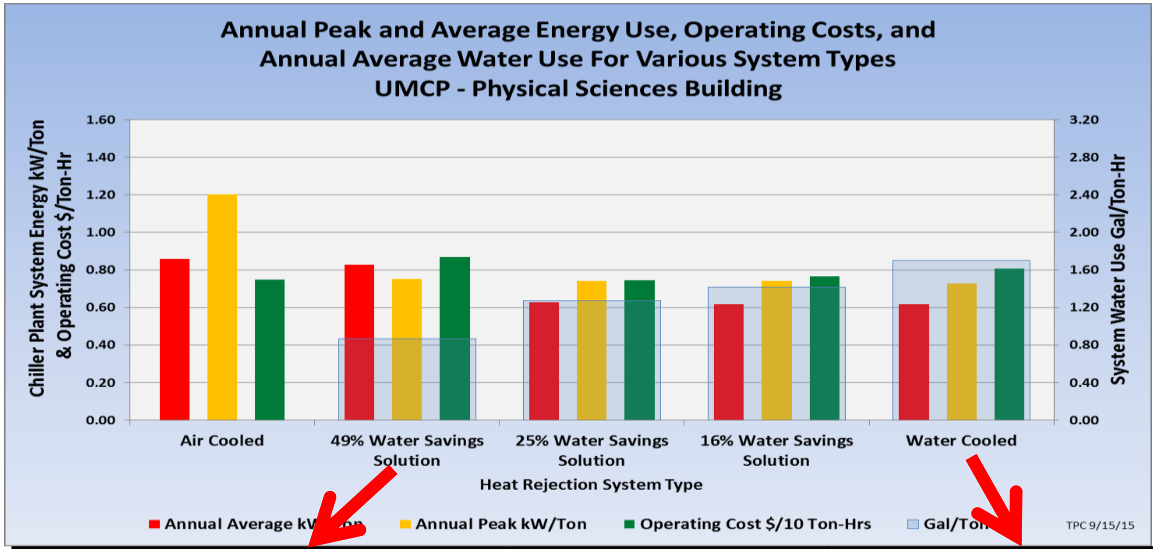
- **Two TSC Unit's**
- **WECER Control**
- **Minimum Condenser Water Temperature = 55°F**



System Metrics	25% TSC Hybrid System	Compared to Water Cooled	Water Cooled System
Average kW / Ton	.628	+1.8%	.617
Peak kW / Design Ton	.740	+1.5%	.729
Operating Cost $ / 10 Ton-Hrs	$.746	-7.4%	$.806
Water Use Gal / Ton-Hr Gal / Year	1.271 6,869,141	-25.1% **-2,301,819**	1.697 9,171,760

49% Water Savings TSC Hybrid System Example

- Two TSC Unit's
- Max Water Savings Control Mode
- Minimum Condenser Water Temperature = 85°F



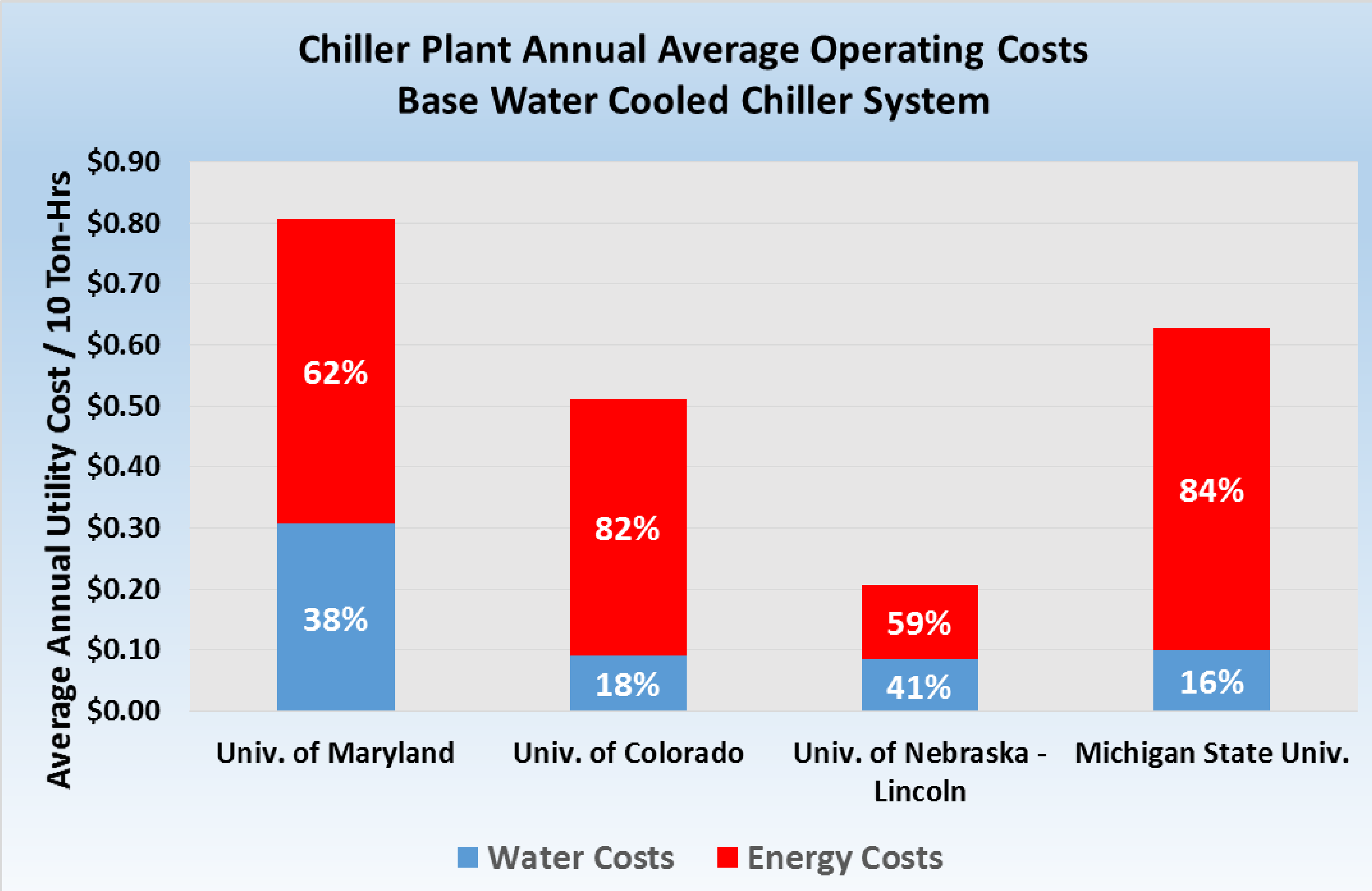
System Metrics	49% TSC Hybrid System	Compared to Water Cooled	Water Cooled System
Average kW / Ton	.827	+34.0%	.617
Peak kW / Design Ton	.751	+3.0%	.729
Operating Cost $ / 10 Ton-Hrs	$.867	+7.6%	$.806
Water Use Gal / Ton-Hr Gal / Year	0.867 4,686,357	-48.9% **-4,485,403**	1.697 9,171,760

Comparisons Among Several Universities

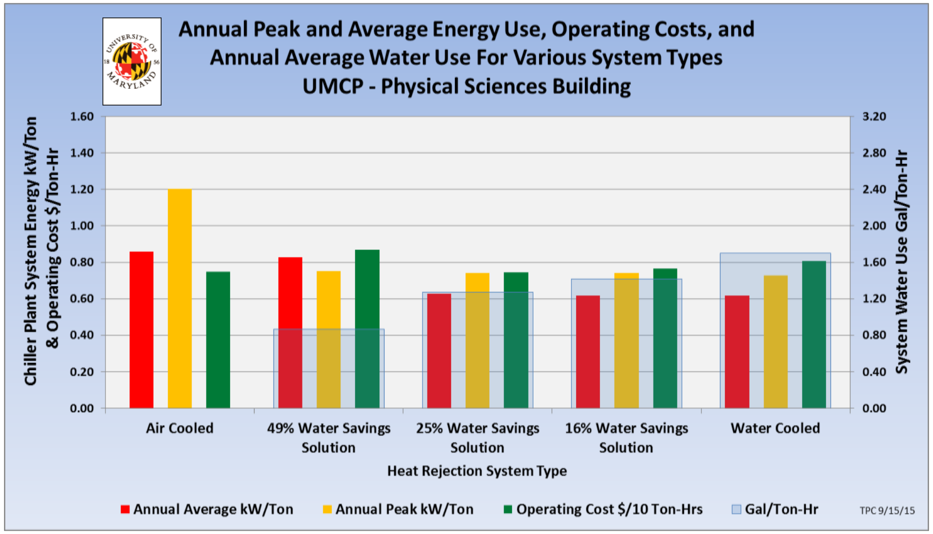
Location	Annual Average DB (°F)	Annual Average WB (°F)	Annual Cooling Ton-Hrs*	Blended Electrical Energy Rate ($/kWh)**	Fully Burdened Water Costs*** ($/1000 gal of Make-up)	Cooling Tower CoC
UMCP	57.4	51.1	5,404,091	$0.0809	$18.11	4.5
U. of CO - Boulder	50.5	40.1	4,474,109	$0.0790	$ 5.76	8.0
U. Nebraska - Lincoln	52.2	46.4	5,210,070	$0.0204	$ 5.29	5.0
Michigan State Univ.	47.7	43.3	4,928,143	$0.0921	$ 5.98	3.3

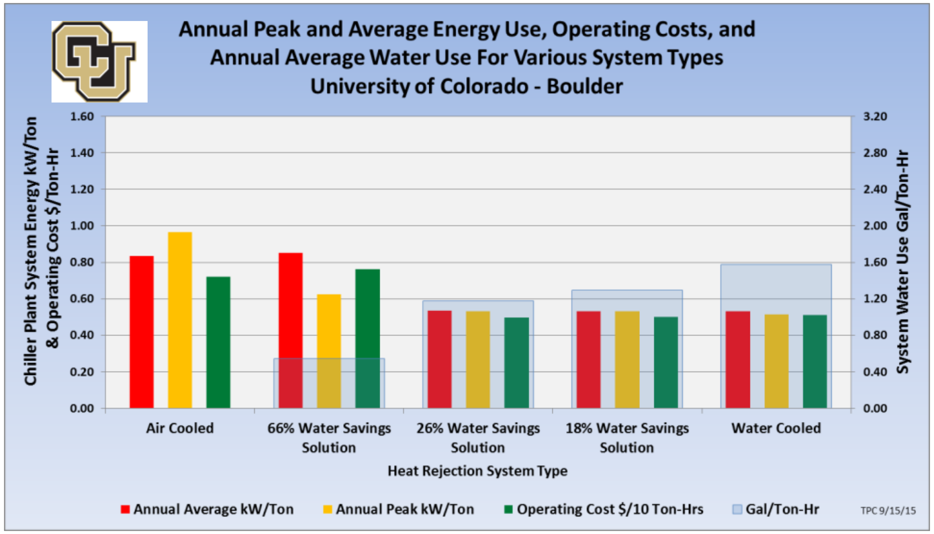
* Load profiles generated based on 1600 ton peak load, 200 ton minimum load
** An additional demand charge of $5.28/kW per month was applied to all systems that exceeded the peak monthly kW of the base water cooled system.
*** Includes water, wastewater, and chemical treatment costs

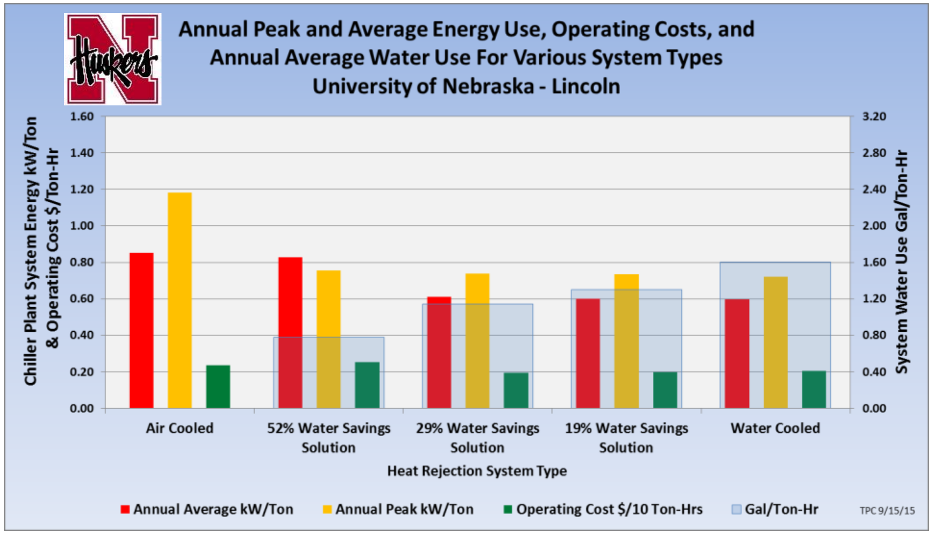
Chiller Plant Average Annual Operating Cost Comparison

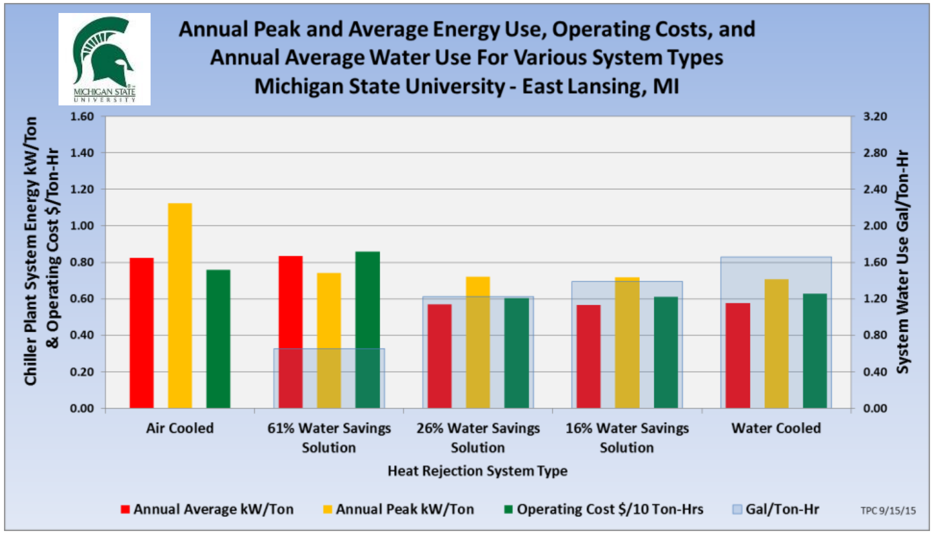


Summary Across Four Universities







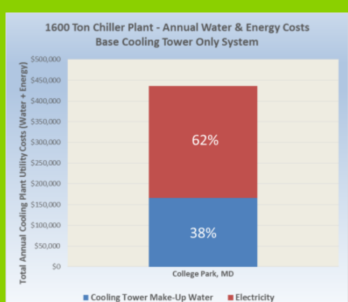


Key Points From The Analysis:

- Across a wide range of climates and utility rates, hybrid heat rejection systems can save **both** water and annual utility costs.
- Water and utility operating cost savings are related to the number of dry cooling units installed.
- Using the same quantity of installed dry cooling equipment, a range of water savings can be achieved based on the operating strategy employed.
- As water related costs increase, the traditional operating cost advantage of water cooled systems compared to air cooled systems decreases.

In Conclusion

Water Costs Are Becoming An Increasing Larger Component of a Chiller Plant's Total Operating Cost



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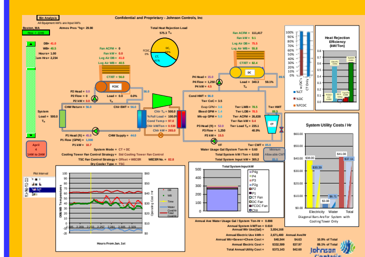

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