Operating an Efficient District Cooling Plant in Water-Stressed Regions

Part 2: The System Design Options

WILL START ON THE HOUR

5:00 pm GST

8:00 am EST

1:00 pm GMT

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Welcome

- **Webinar Duration:** 1 hour 30 minutes

- **Panelists:** Please mute when not talking and silence /shut-off cell phones.

- **Questions to Presenters:** Please type in **Questions** in the **Q&A box** at the lower right hand corner of screen. **Questions will be answered after the end of the presentation.** (If you are just dialed in with audio, send questions to jill.h.woltkamp@jci.com)

- **Moderator** will hand **questions to presenters.** *Responses to unanswered questions will be provided by Jill Woltkamp after the webinar.*

- **Webinar (function) questions:** Please chat with Cheryl. Use the Chat box in the middle right hand section of the screen and choose - **"Chat privately to Cheryl."**

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- **Webinar Download:** Recording and Presentation slides will be available at www.districtenergy.org. Access to the first session presently available

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Operating an Efficient District Cooling Plant in Water-Stressed Regions

Part 2: The System Design Options

International District Energy Association
December 3, 2014
Tom Carter, P.E.
Johnson Controls, Inc.

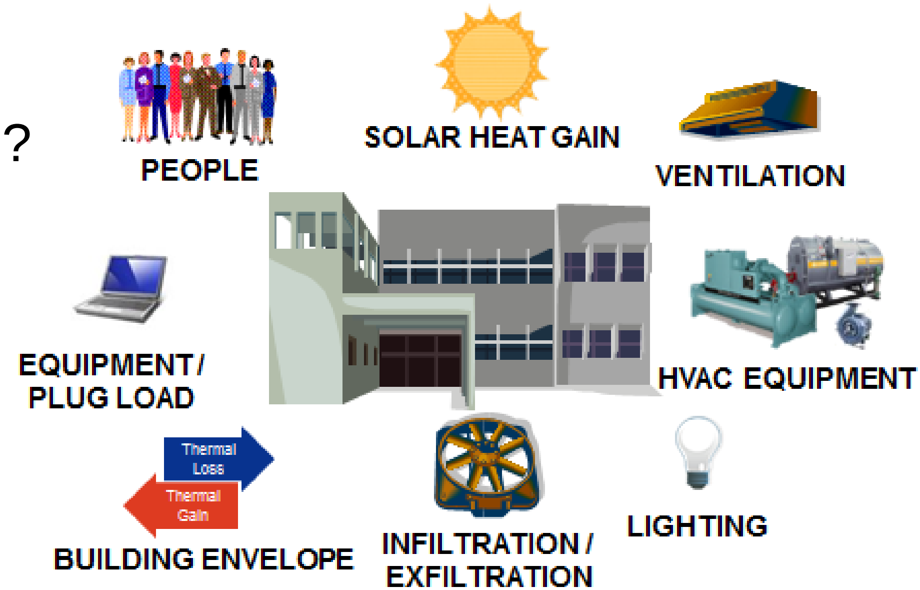
Agenda

- Review of the key points of Part 1: The Energy-Water Nexus
- Take a closer look at the metrics for the water-cooled and air-cooled systems
- Overview of several hybrid wet / dry technologies
- Take a detailed look at the design, control, and system performance of a thermosyphon cooler hybrid system

Summary of Part 1: The Energy Water Nexus

- Why do we need air conditioning?

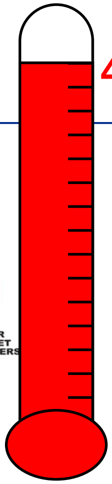
Allows building to be habitable.



- How does air conditioning work?

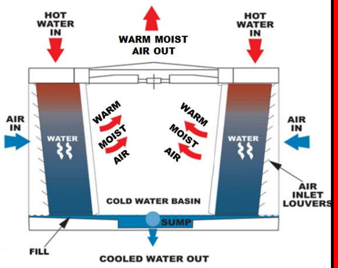
Move unwanted heat from one area (building) to a location less objectionable.

Summary of Part 1: The Energy Water Nexus



- How does water play a role in air conditioning?

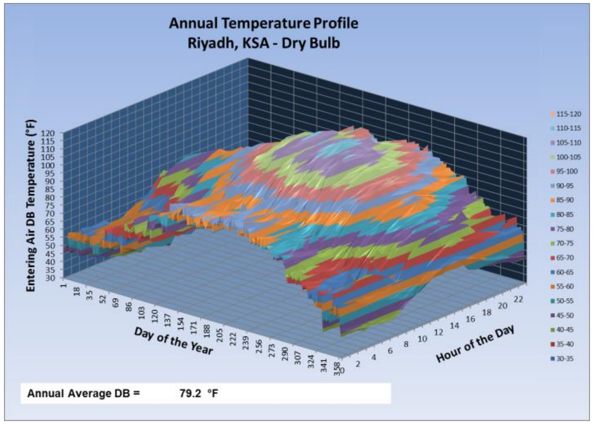
Evaporation of water allows for energy and cost efficient heat rejection to the atmosphere



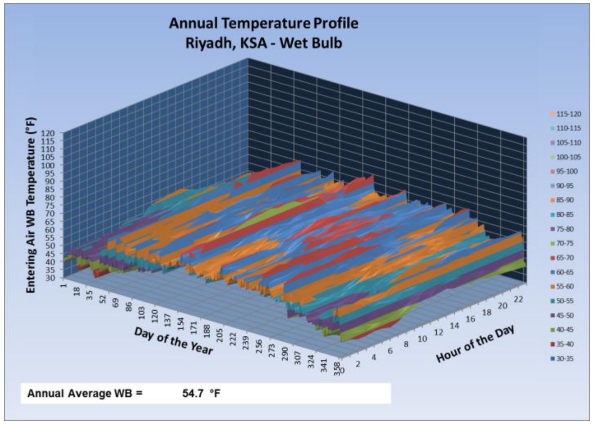
- What roles do weather and climate play in air conditioning?

Weather impacts both load and lift and thus energy consumption.

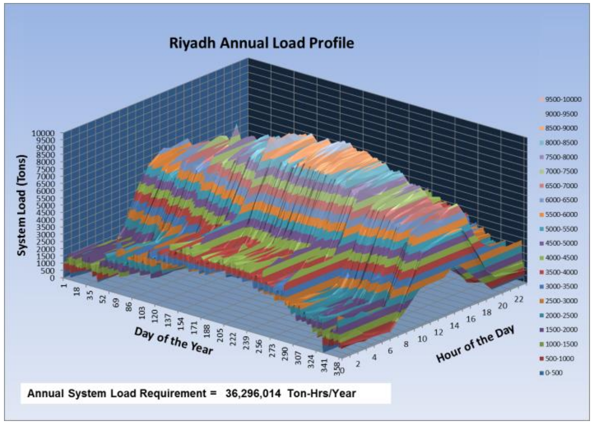
Dry Bulb



Wet Bulb



Load



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Summary of Part 1: The Energy Water Nexus

SAVING ENERGY = SAVING WATER = SAVING MONEY

Avoidance

- Insulation
- Low-E Glass
- Lighting

Conserve

- Night setback
- Isolate leaks
- Lighting
- CHW Reset

Design

- District Energy
- Highly Efficient and variable speed components, products and systems

Optimize

- Central Plant and System Optimization

Maintain

- Scheduled Service
- Measurement and Verification plan

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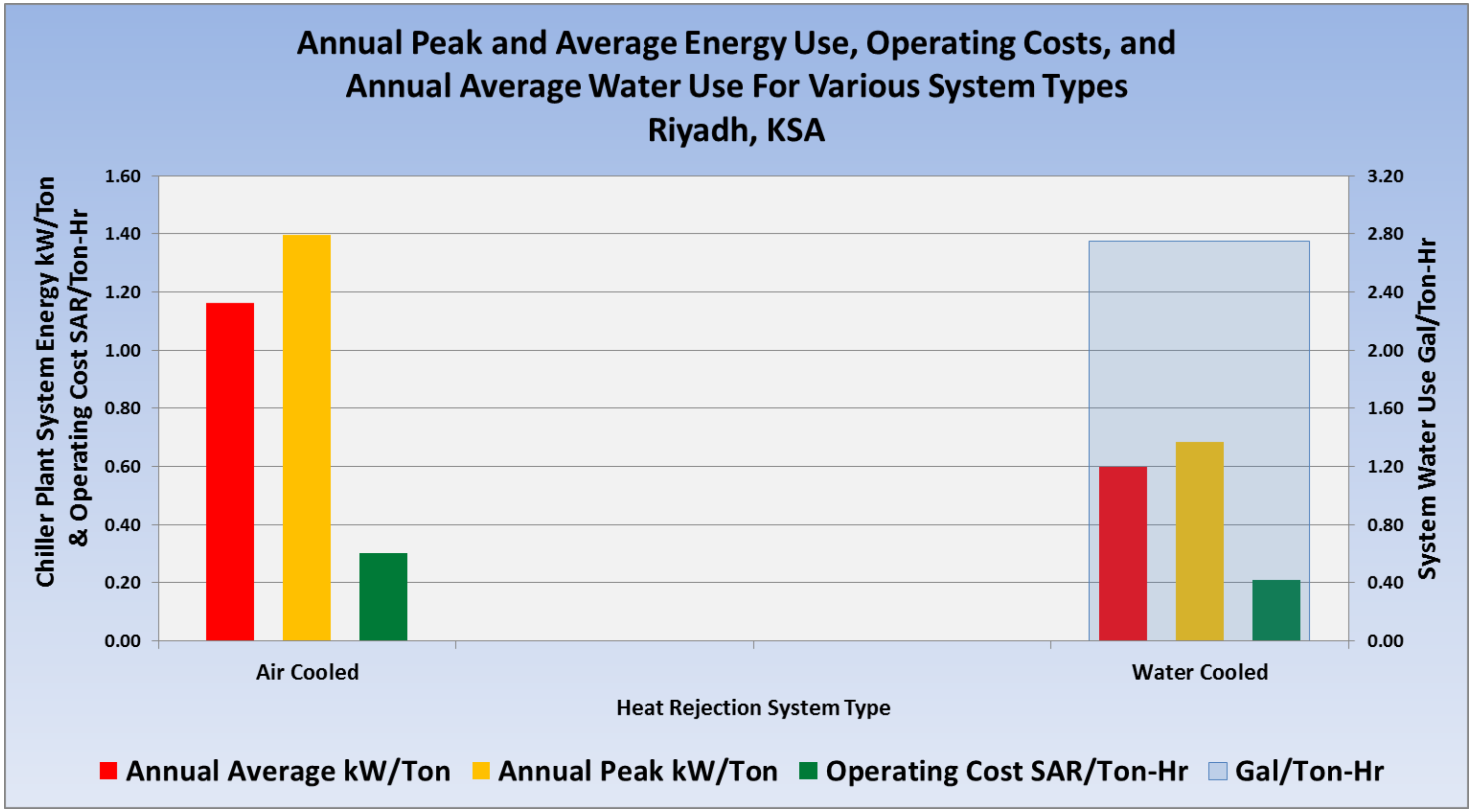
Summary of Part 1: The Energy Water Nexus

- What are the two main choices in air conditioning heat rejection systems?

Air-cooled systems and water-cooled systems



Assumptions

- Energy Evaluated at SAR 0.26/kWh
- Water Evaluated at SAR 4.00/m^3

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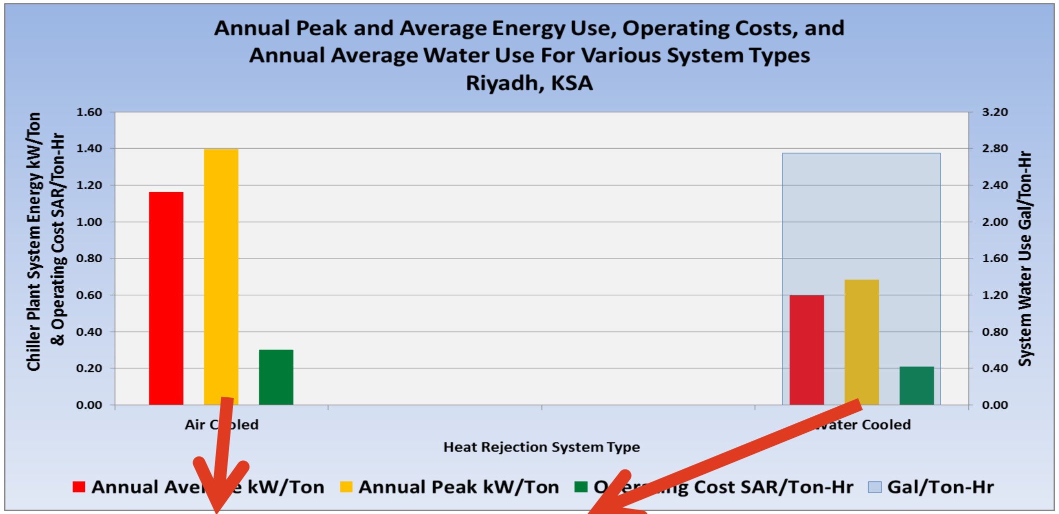
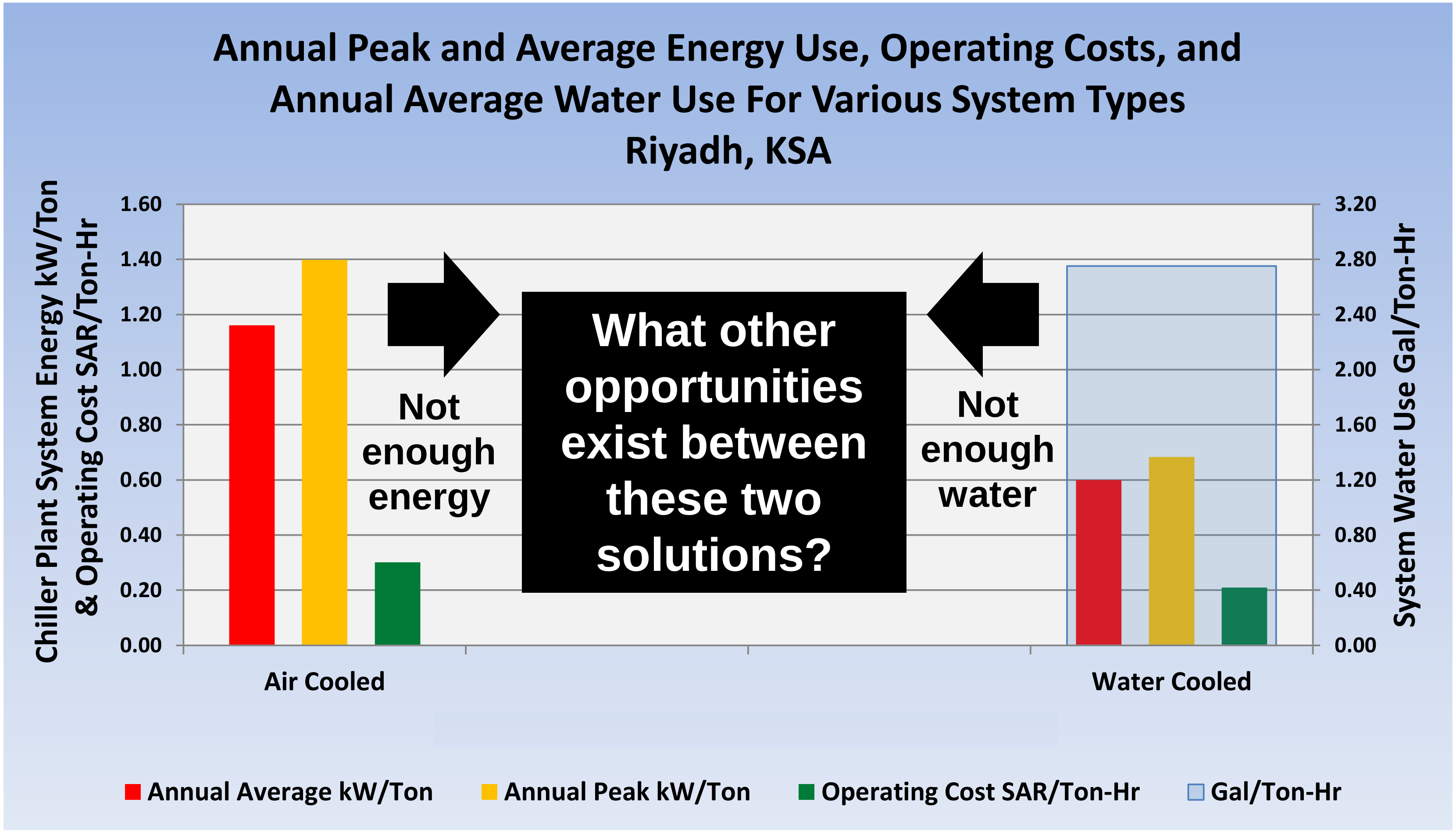
Air Cooled Vs. Water Cooled – A Closer Look

- **Condenser Water Loop Design**
  - **Design Flow Rate 3 gpm/ton**
  - **Cond. Wtr allowed to float down to 13°C**



System Metrics	Air Cooled System	Water Cooled System	Percent Difference
Average kW / Ton	1.161	.600	+93.5%
Peak kW / Design Ton	1.398	.683	+104.7%
Operating Cost SAR / Ton-Hr	.302	.21	+43.8%
Water Use Gal / Ton-Hr	0	2.751	-100.0%

Air-Cooled System vs Water-Cooled System - Riyadh, KSA



Assumptions

- Energy Evaluated at SAR 0.26/kWh
- Water Evaluated at SAR 4.00/m^3

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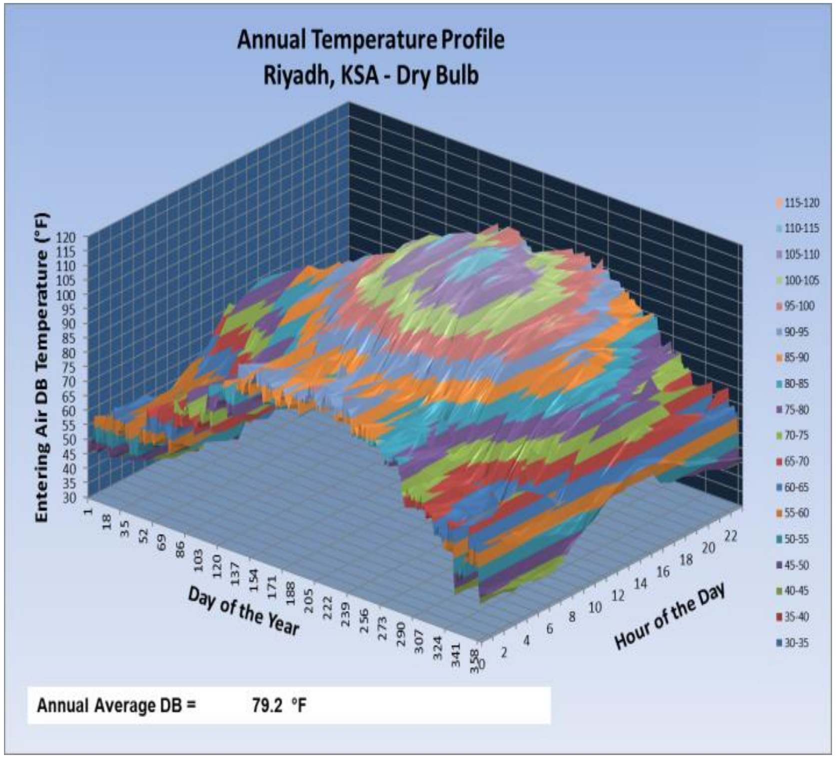
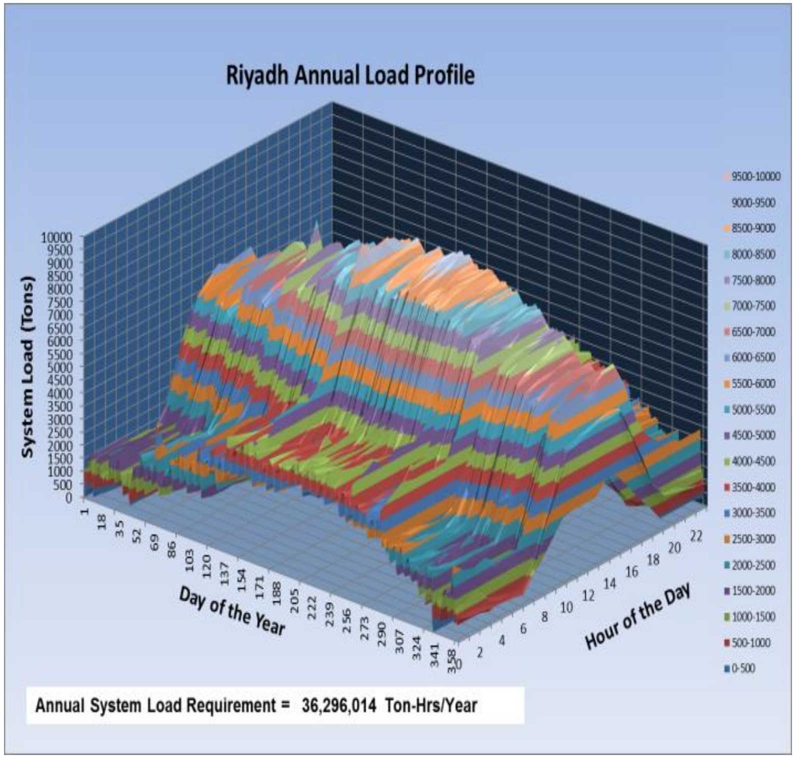
Weather and Load Variations Provide Opportunities

DB

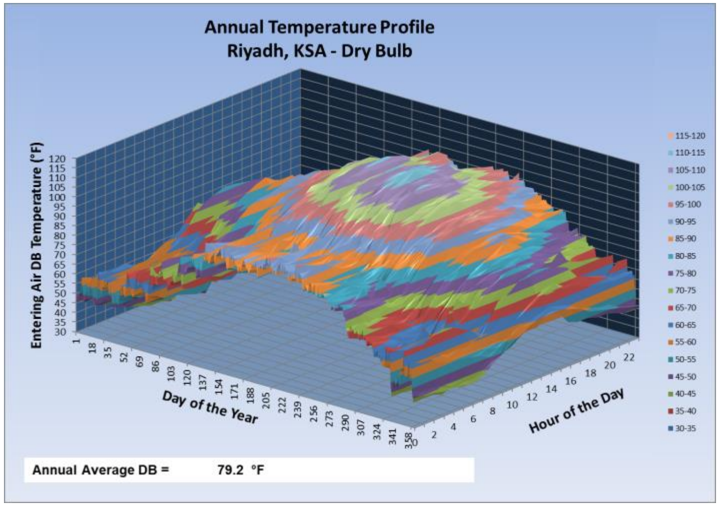
Thermal Load

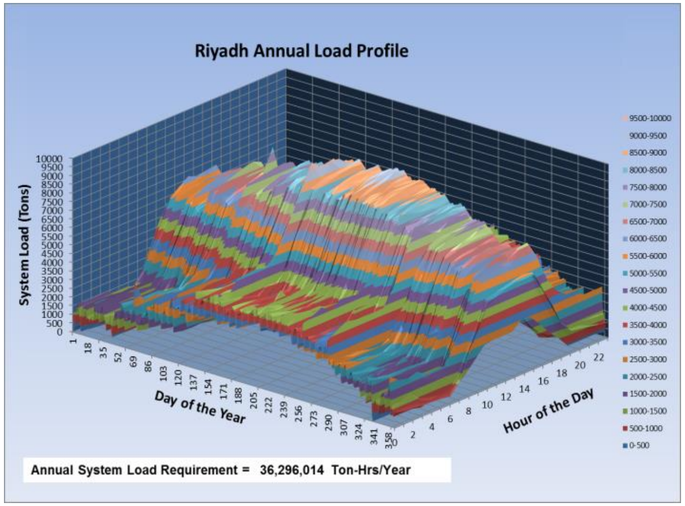




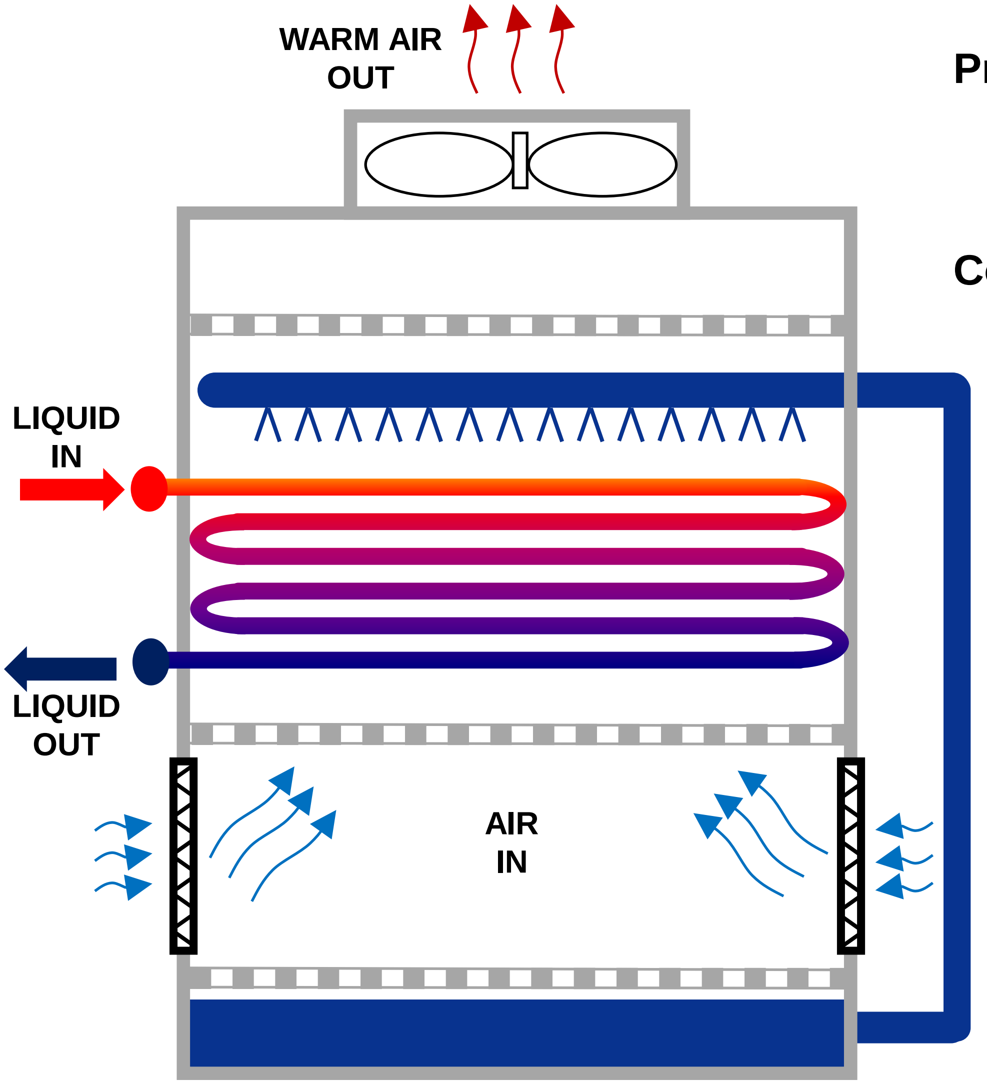
Hybrid Wet / Dry Solutions

- 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





Closed Loop Evaporative Products



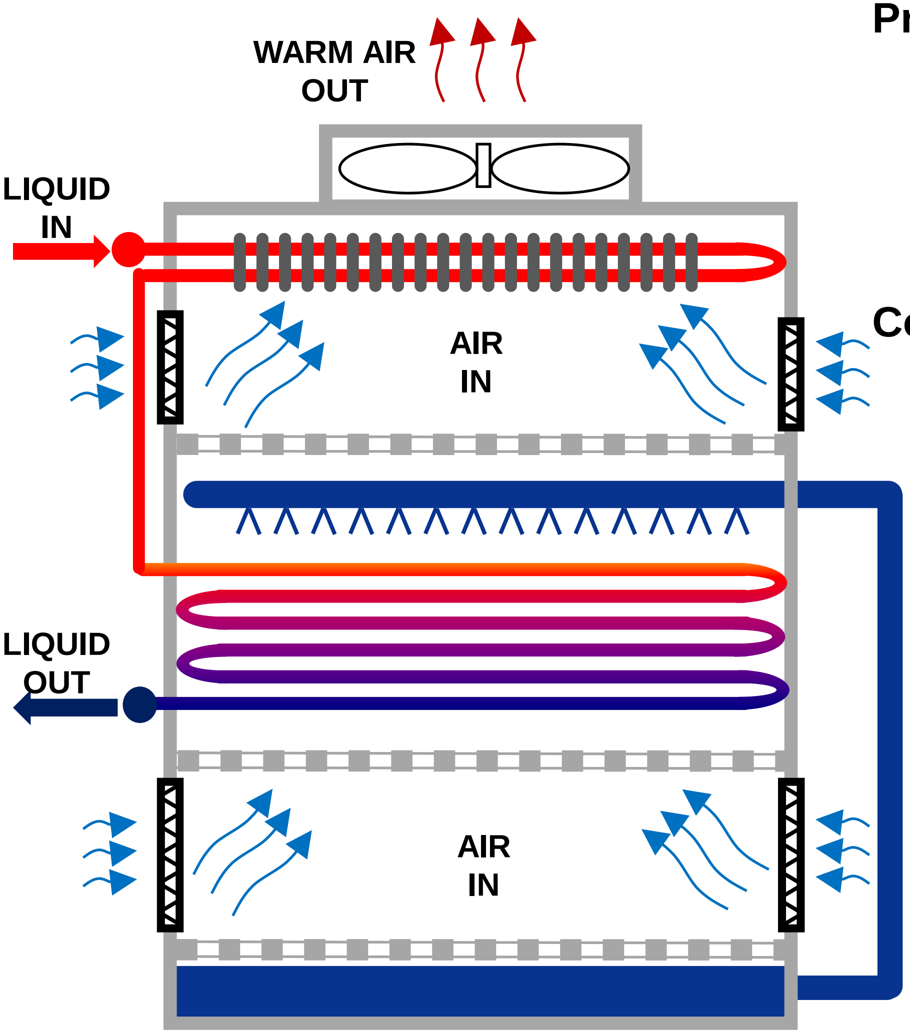
Pros re: Open Cooling Tower System

- Saves water when in the dry mode
- Clean closed loop system

Cons re: Open Cooling Tower System

- May require a glycol solution as the main circulating fluid if the location experiences sub-freezing ambient conditions
- On the design day, fan kW is 2-4 times higher
- Plan area is about 2 to 4 times higher
- Equipment costs are 7 to 10 times higher
- Typically can only operate as full wet or full dry mode

All in One Closed Loop Hybrid Systems



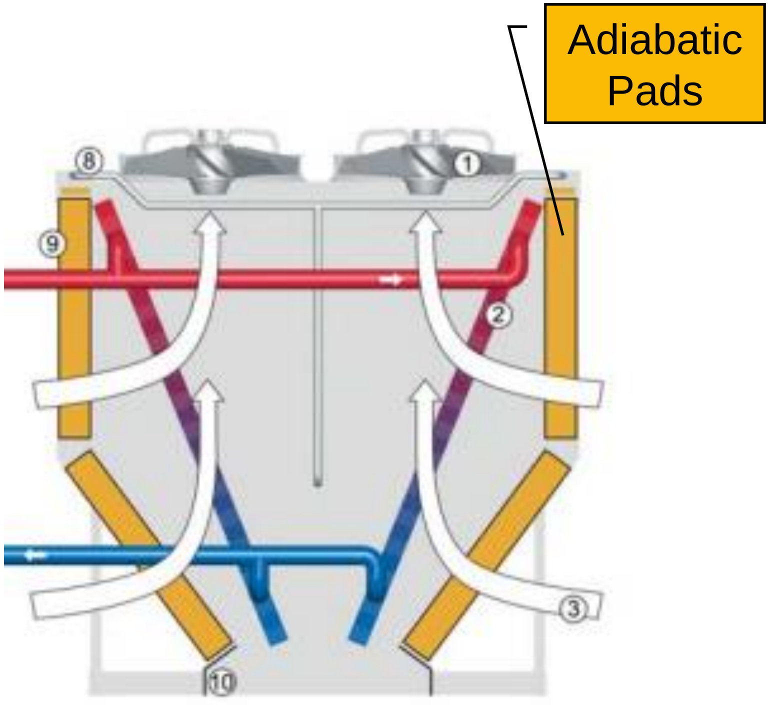
Pros re: Open Cooling Tower System

- Saves water – has the ability to save some water prior to shutting down the spray water pumps
- Closed loop system

Cons re: Open Cooling Tower System

- May require a glycol solution as the main circulating fluid if the location experiences sub-freezing ambient conditions
- Finned coil causes additional air resistance
- On the design day, fan kW is again about 2-4 times higher
- Plan area is about 2-4 times higher
- Equipment costs are 8 to 10 times higher

Dry System with Adiabatic Pre-cooler



Source: http://www.jaeggi-hybrid.ch/db/daten/dokumente/usa/2-US_Datasheet_HTK.pdf

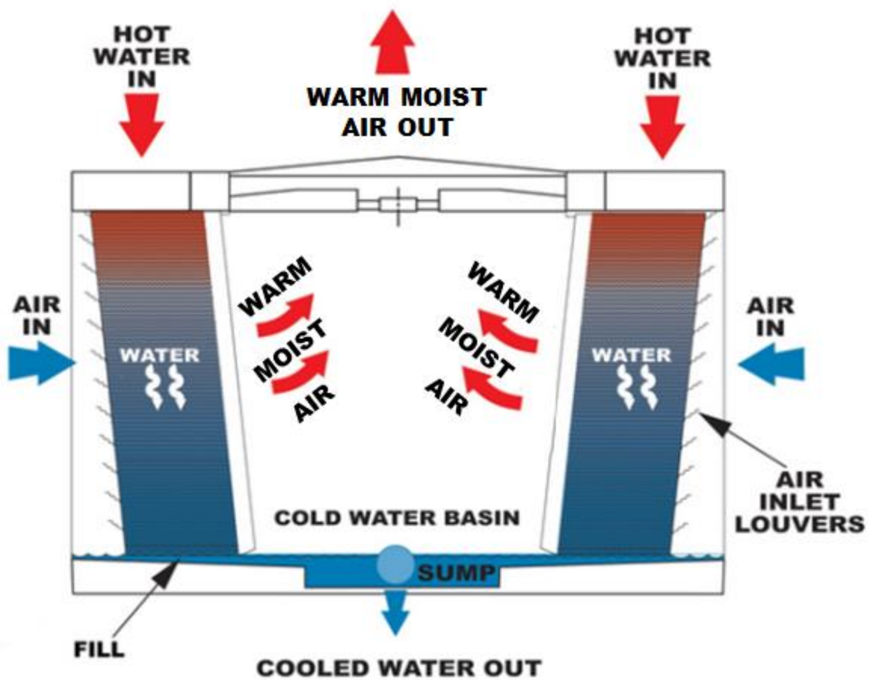
Pros re: Open Cooling Tower System

- Saves water
- Closed loop system

Cons re: Open Cooling Tower System

- May require a glycol solution as the main circulating fluid if the location experiences sub-freezing ambient conditions
- Adiabatic pads add air resistance even when they are providing no benefit and this might be 70% of the time
- Adiabatic pads may require periodic cleaning
- On the design day, fan HP is can be 3 to 10 times higher
- Plan area is about 5 to 10 times larger
- Equipment costs are 8 to 12 times higher

The Open Cooling Tower is Very Efficient and It's Desirable to Have it as Part of a Hybrid System



- Highly efficient – because it has the ability to saturate the exit air stream with moisture it can reject the same amount of heat as a dry system with about 80% less air… this leads to:
  - Significantly lower cost
  - Significantly smaller footprint
  - Significantly lower fan energy
- It can also operate against the lower WB temperature heat sink instead of the higher DB heat sink… especially important on those design days when the WB depression is typically the greatest

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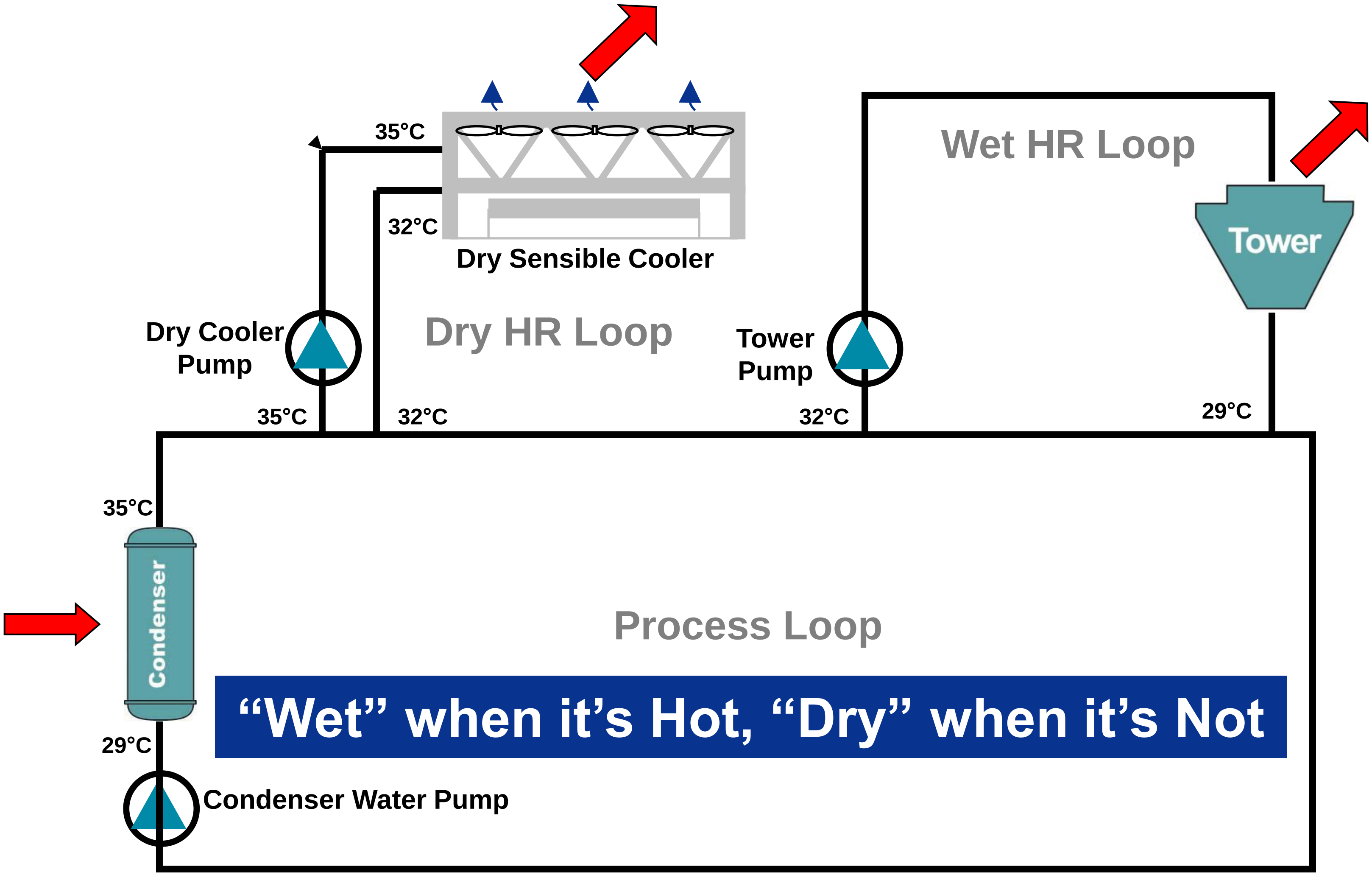
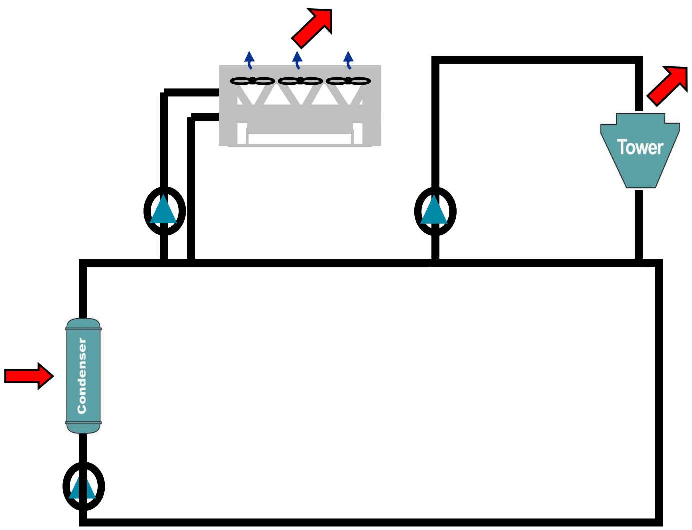
Series Flow Dry / Wet Hybrid Heat Rejection System

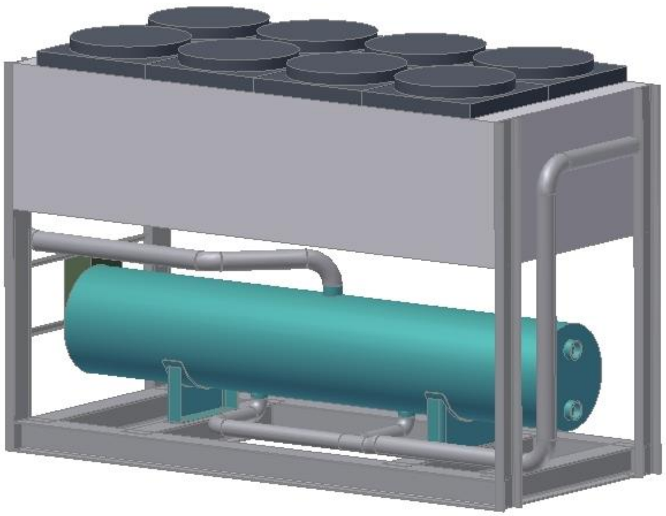


Dry Sensible Heat Exchanger Requirements



- Seems simple enough but there are several issues that need to be dealt with:
  - Open system – cleanability issues, material compatibility issues
  - Low pressure drop design
  - Control issues (how do you balance the fan energy between the two pieces of equipment and the condenser loop temperatures that impact the chiller energy to achieve the greatest system benefit?)
  - Freeze protection

Thermosyphon Cooler (TSC) - a Dry Sensible Cooling Device Specifically Designed for Application in Open Cooling Water Systems



- Cleanable heat exchanger
  - Enables efficient contact with open cooling water
- Low waterside pressure drop
  - 1 – 4 psi minimizes pumping energy
- No intermediate fluid pump required
  - Uses natural circulation of refrigerant
- Control system designed for <u>cost optimized</u> balance between water and energy use
- No need for antifreeze
  - Freeze protection accomplished by controlling refrigerant flow

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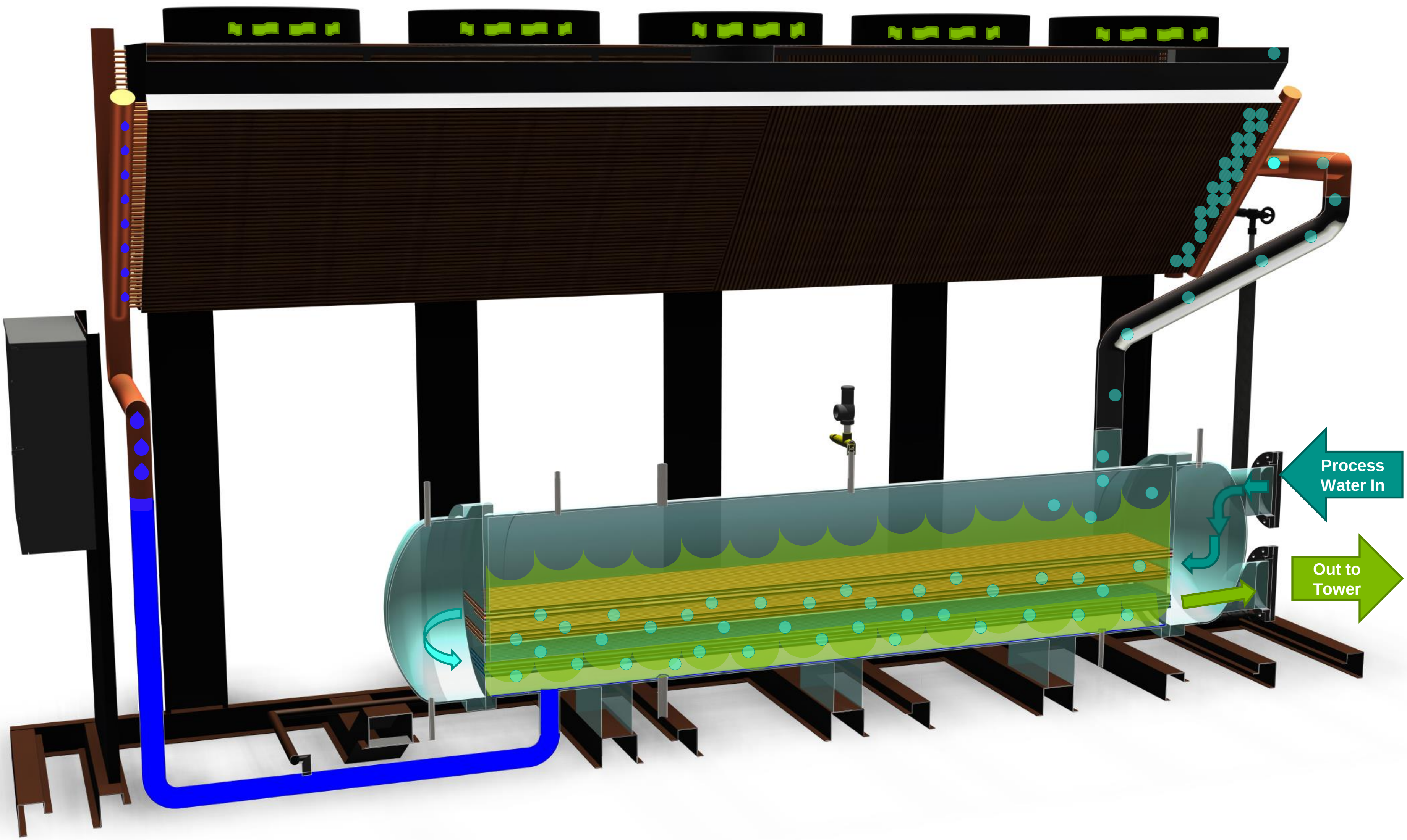
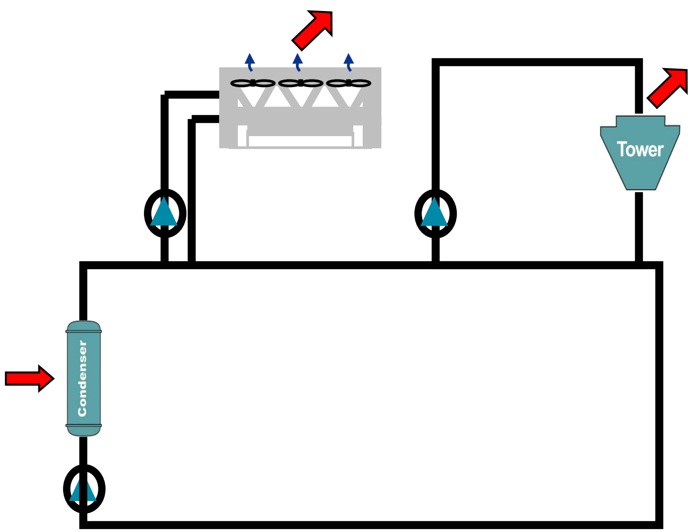
Thermosyphon Cooler – Conceptual Design



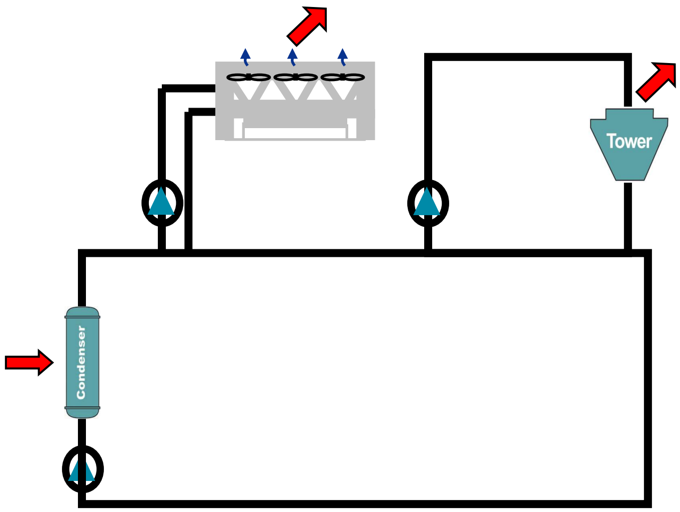
System Control Considerations for Operating Cost Optimization

■ **WECER** = **W**ater to **E**nergy **C**ost **E**quivalence **R**atio



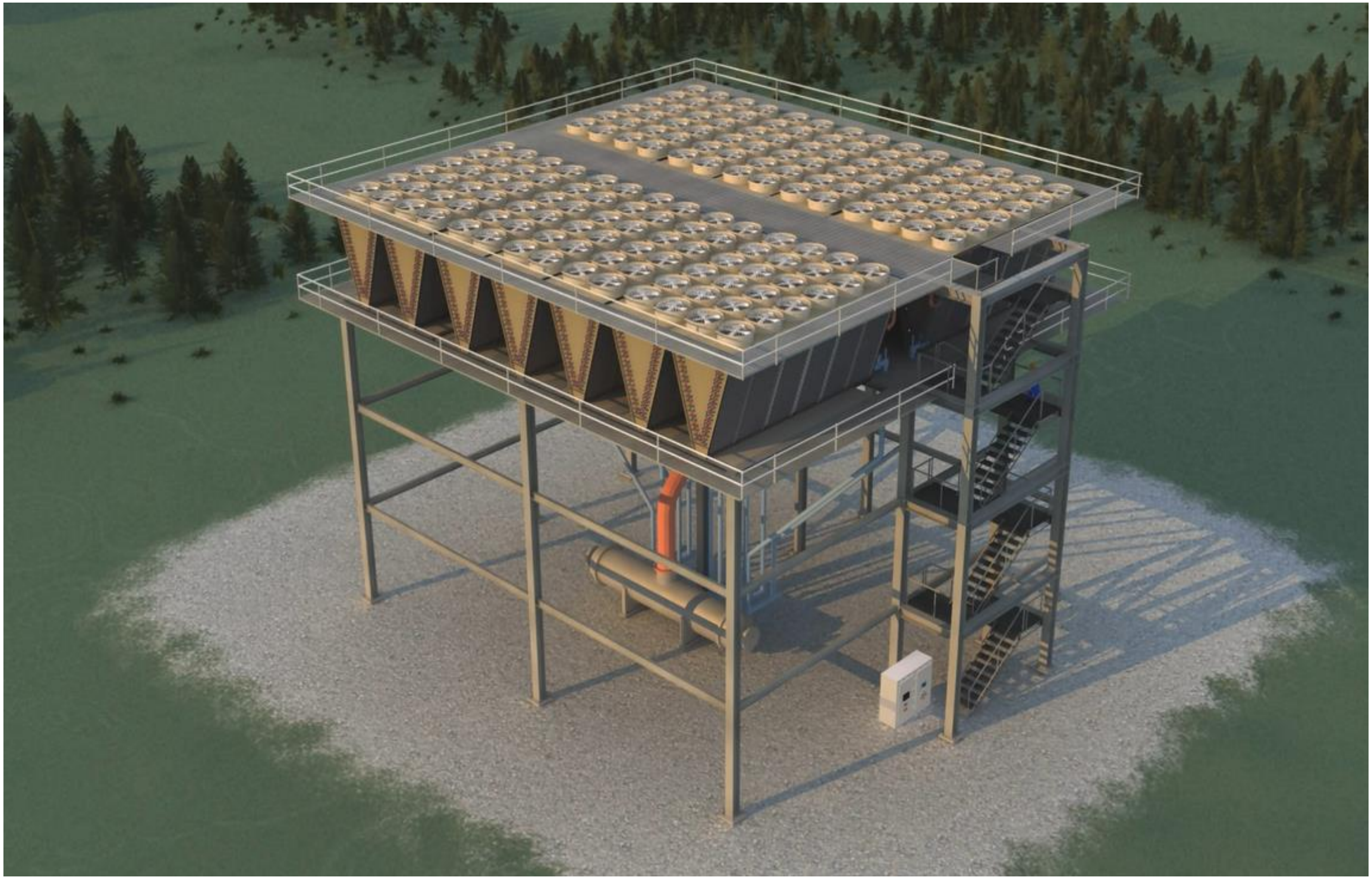
- **WECER = Additional Hybrid Heat Rejection System kWh / 1000's of Gallons of Water Saved**
- **WECER = Cost of Water / Cost of Electricity**
- **WECER = ($/1000 gal Water) / ($/kWh)**
- **WECER = kWh / 1000 gal**

System Control Considerations for Maximum Water Savings



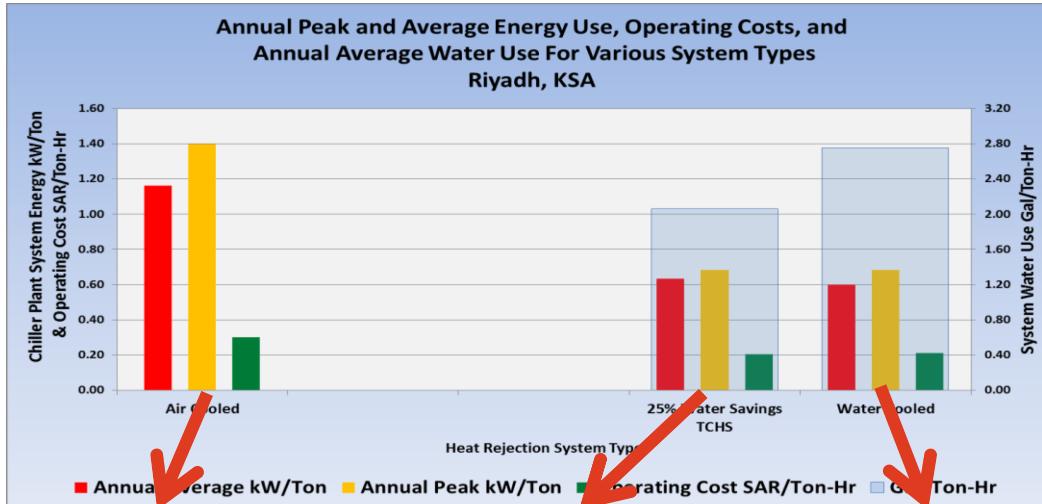
- **Run the dry cooler fans at their maximum speed**
- **Elevate the condenser water loop temperatures**

Larger Capacity 14 Condenser Unit TSC Module



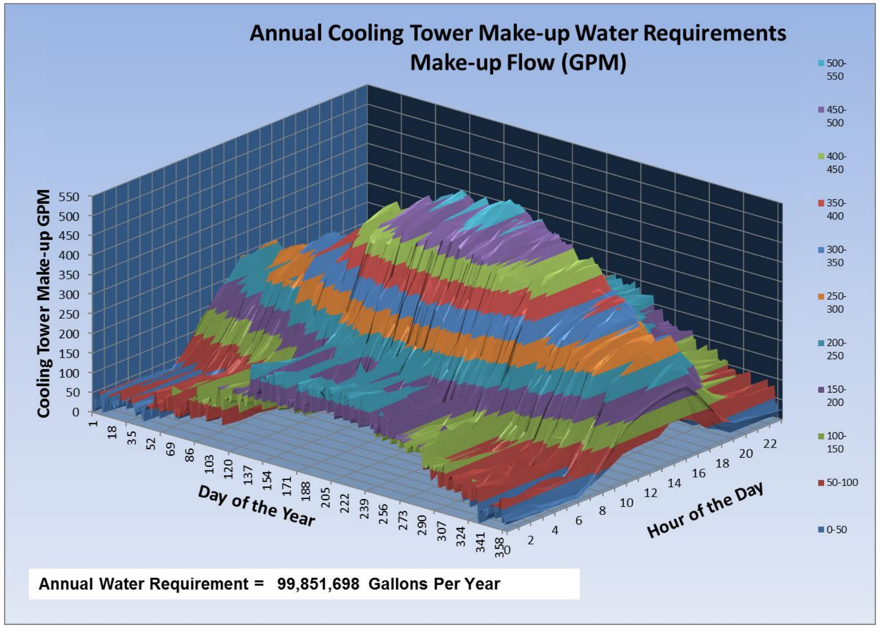
25% Water Savings TSC Hybrid System Example

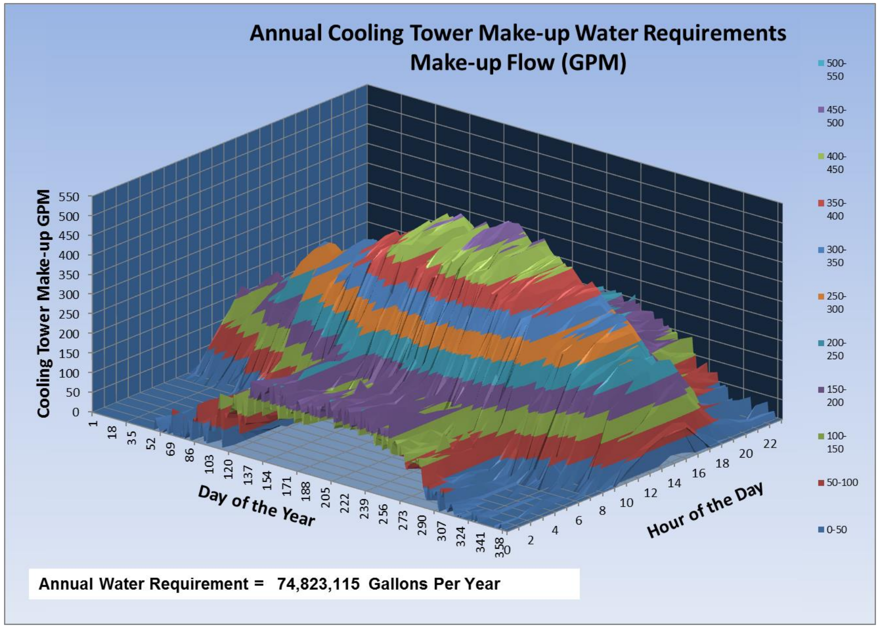
- **WECER Control**
- **Minimum Condenser Water Temperature = 27°C**



System Metrics	Air Cooled System	Compared to Water Cooled	25% TSC Hybrid System	Compared to Water Cooled	Water Cooled System
Average kW / Ton	1.161	+93.5%	.635	+5.8%	.600
Peak kW / Design Ton	1.398	+104.7%	.683	+0.0%	.683
Operating Cost SAR / Ton-Hr	.302	+43.8%	.205	-2.2%	.210
Water Use Gal / Ton-Hr	0	-100%	2.061	-25.1%	2.751

Cooling Tower Annual Make-up Water Requirements



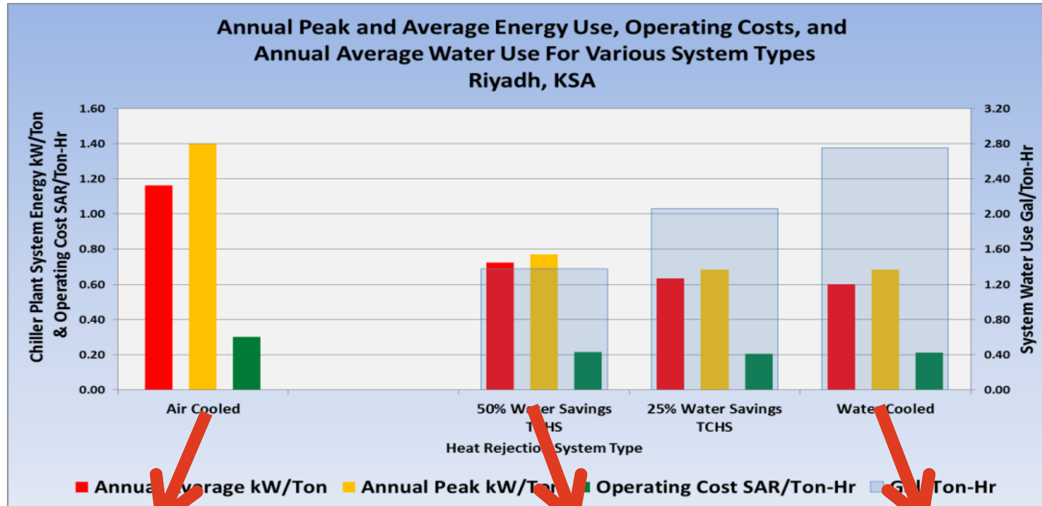


Cooling Tower Only System
Annual Water Use = 378,006 m^3

TCHS System 25% Savings
Annual Water Use = 283,256 m^3
Saving 94,750 m^3 / Year

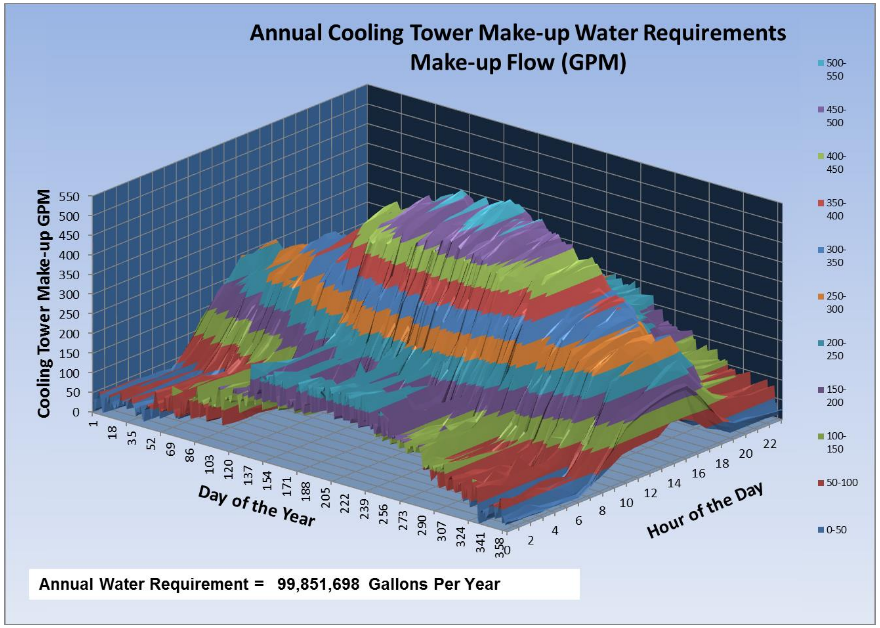
50% Water Savings TSC Hybrid System Example

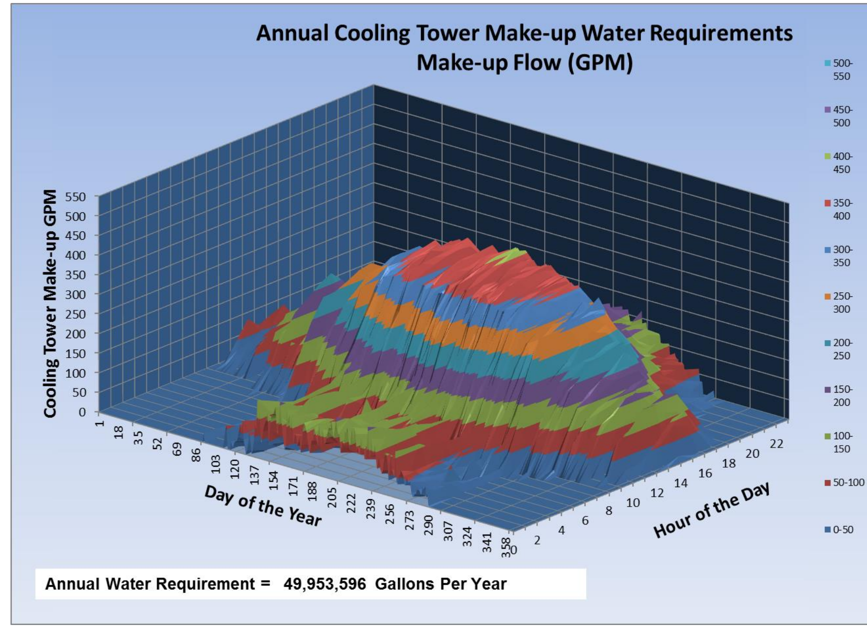
- **WECER Control**
- **Minimum Condenser Water Temperature = 36°C**



System Metrics	Air Cooled System	Compared to Water Cooled	50% TSC Hybrid System	Compared to Water Cooled	Water Cooled System
Average kW / Ton	1.161	+93.5%	.724	+20.7%	.600
Peak kW / Design Ton	1.398	+104.7%	.769	+12.6%	.683
Operating Cost SAR / Ton-Hr	.302	+43.8%	.215	+2.5%	.210
Water Use Gal / Ton-Hr	0	-100%	1.376	-50.0%	2.751

Cooling Tower Annual Make-up Water Requirements



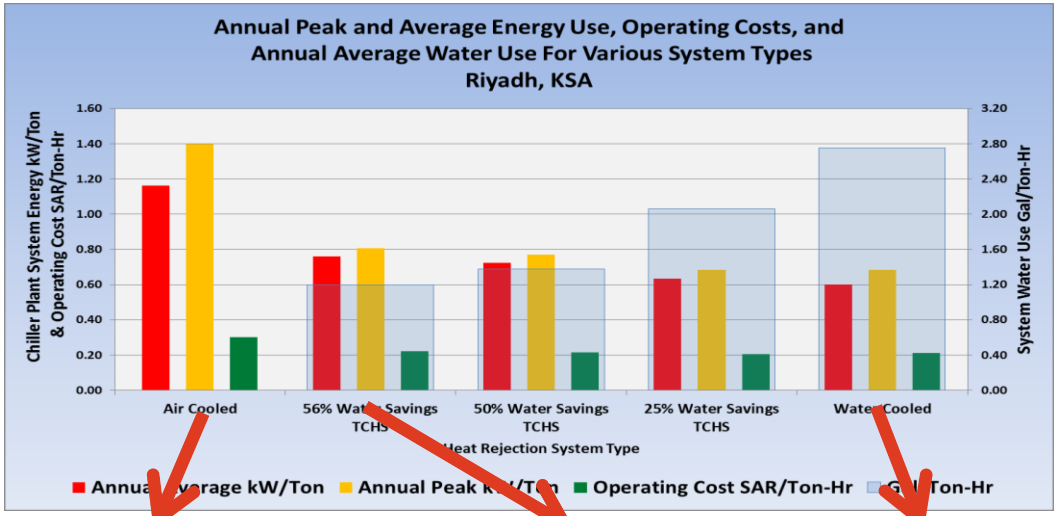


Cooling Tower Only System
Annual Water Use = 378,006 m^3

TCHS System 50% Savings
Annual Water Use = 189,108 m^3
Saving 188,898 m^3 / Year

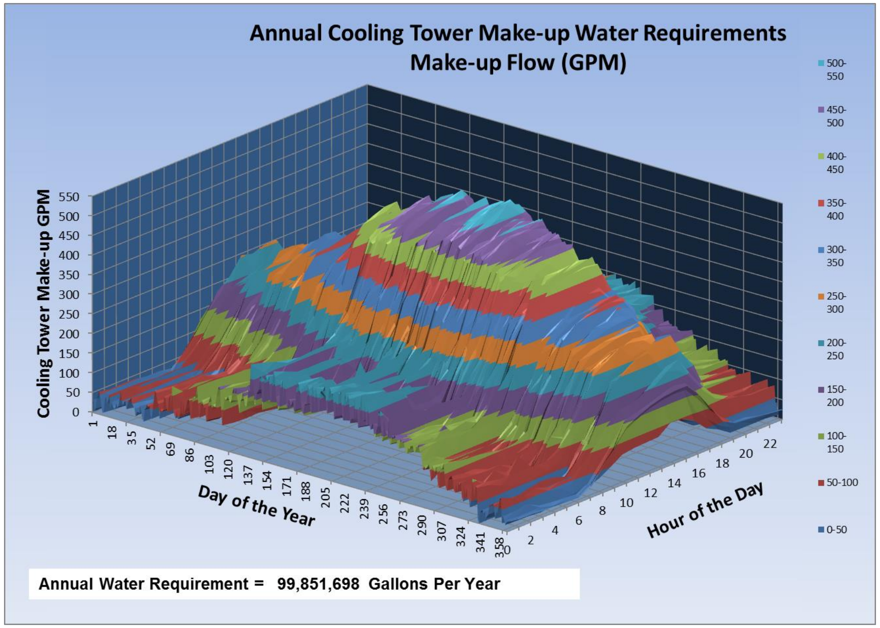
56% Maximum Water Savings TSC Hybrid System Example

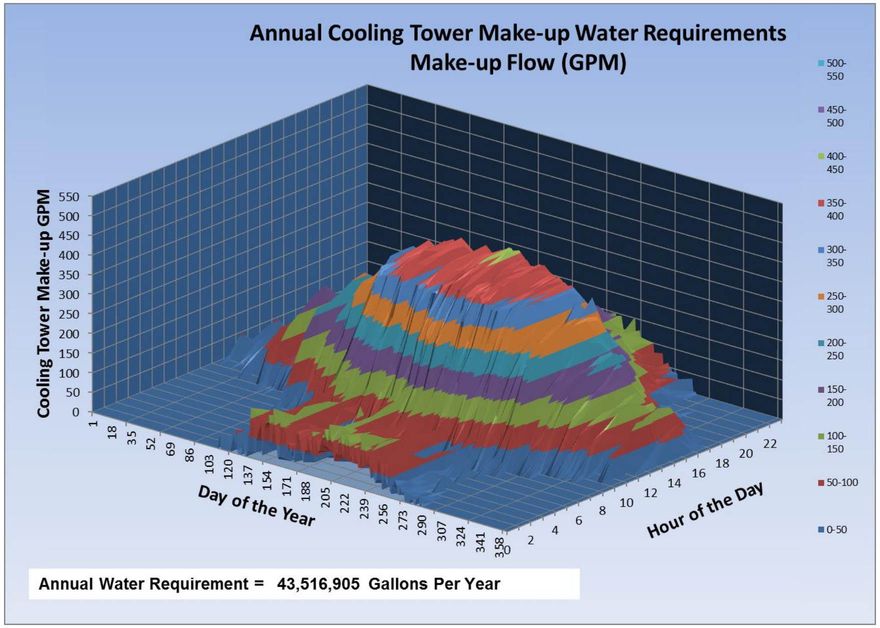
- **TSC Full Fan Speed**
- **Minimum Condenser Water Temperature = 36°C**



System Metrics	Air Cooled System	Compared to Water Cooled	56% TSC Hybrid System	Compared to Water Cooled	Water Cooled System
Average kW / Ton	1.161	+93.5%	.761	+26.8%	.600
Peak kW / Design Ton	1.398	+104.7%	.808	+18.3%	.683
Operating Cost SAR / Ton-Hr	.302	+43.8%	..221	+5.5%	.210
Water Use Gal / Ton-Hr	0	-100%	1.199	-56.4%	2.751

Cooling Tower Annual Make-up Water Requirements





Cooling Tower Only System
Annual Water Use = 378,006 m^3

TCHS System 56% Savings
Annual Water Use = 164,741 m^3
Saving 213,265 m^3 / Year

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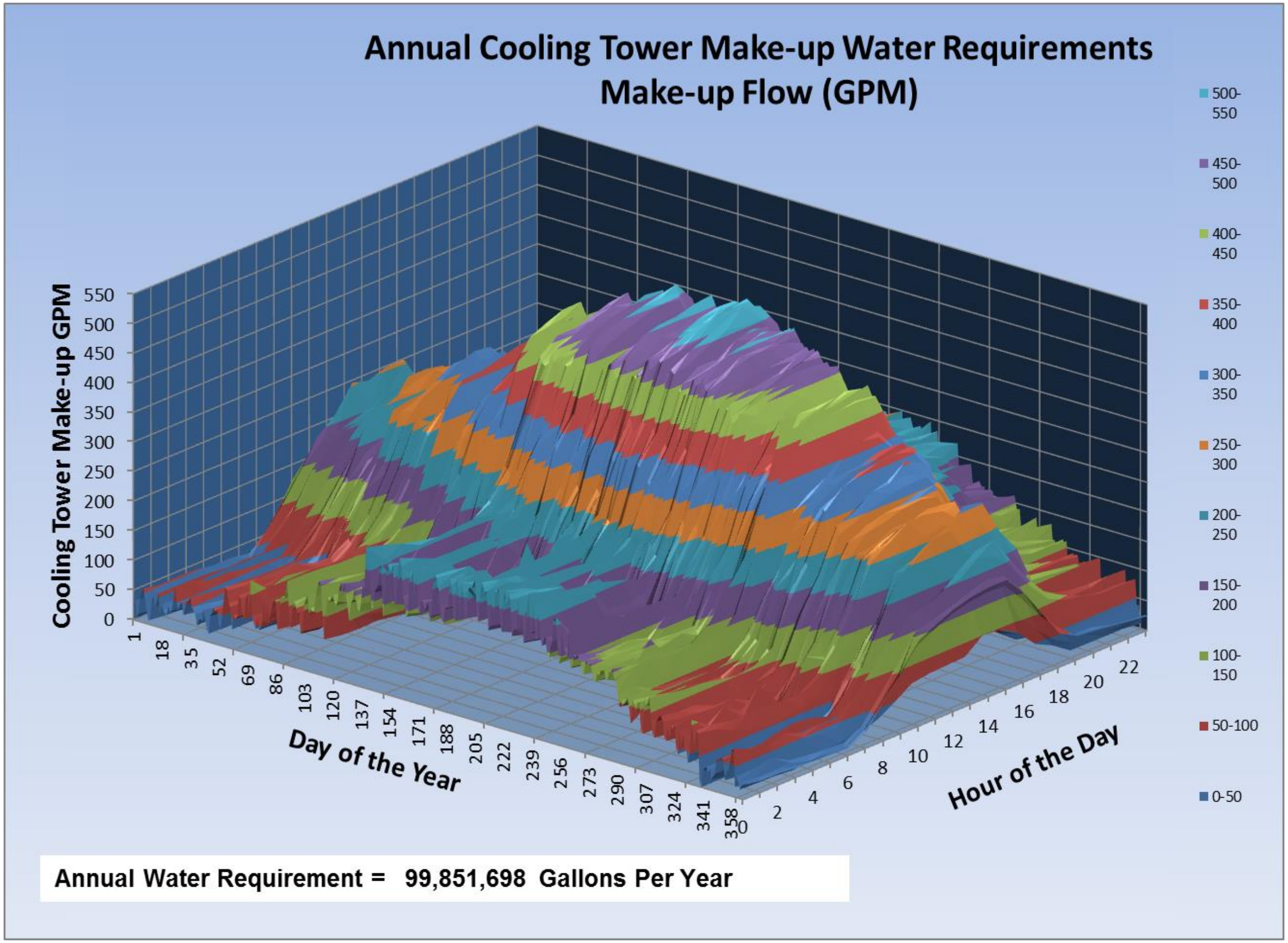
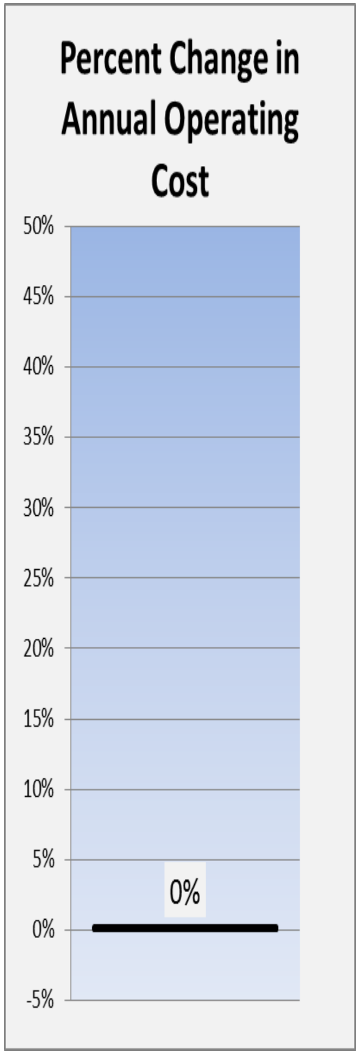
Cooling Tower Annual Make-up Water Requirements
Cooling Tower Only System





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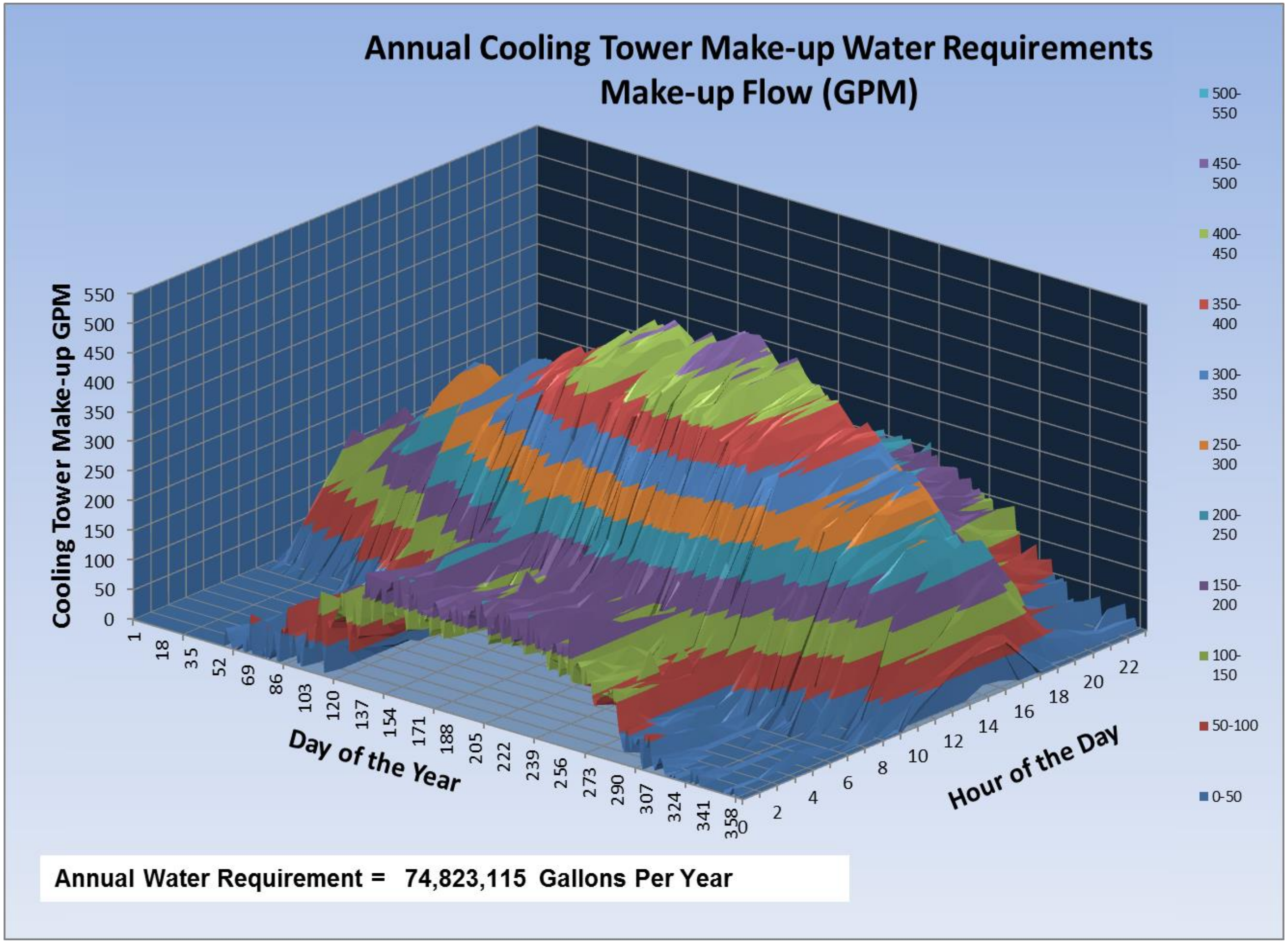
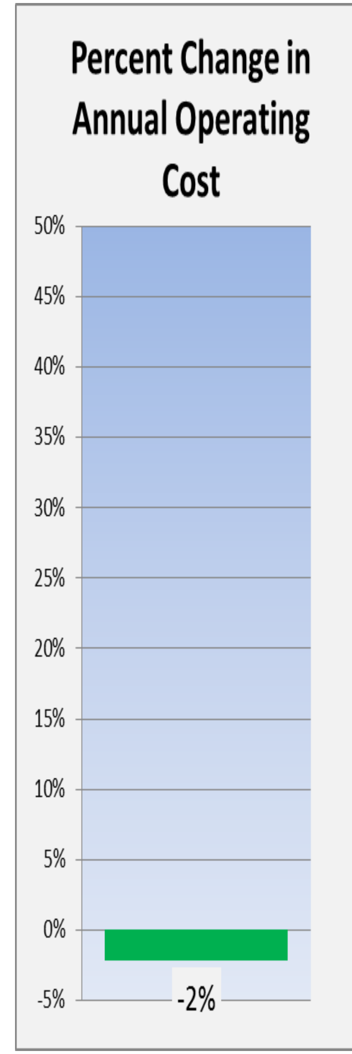
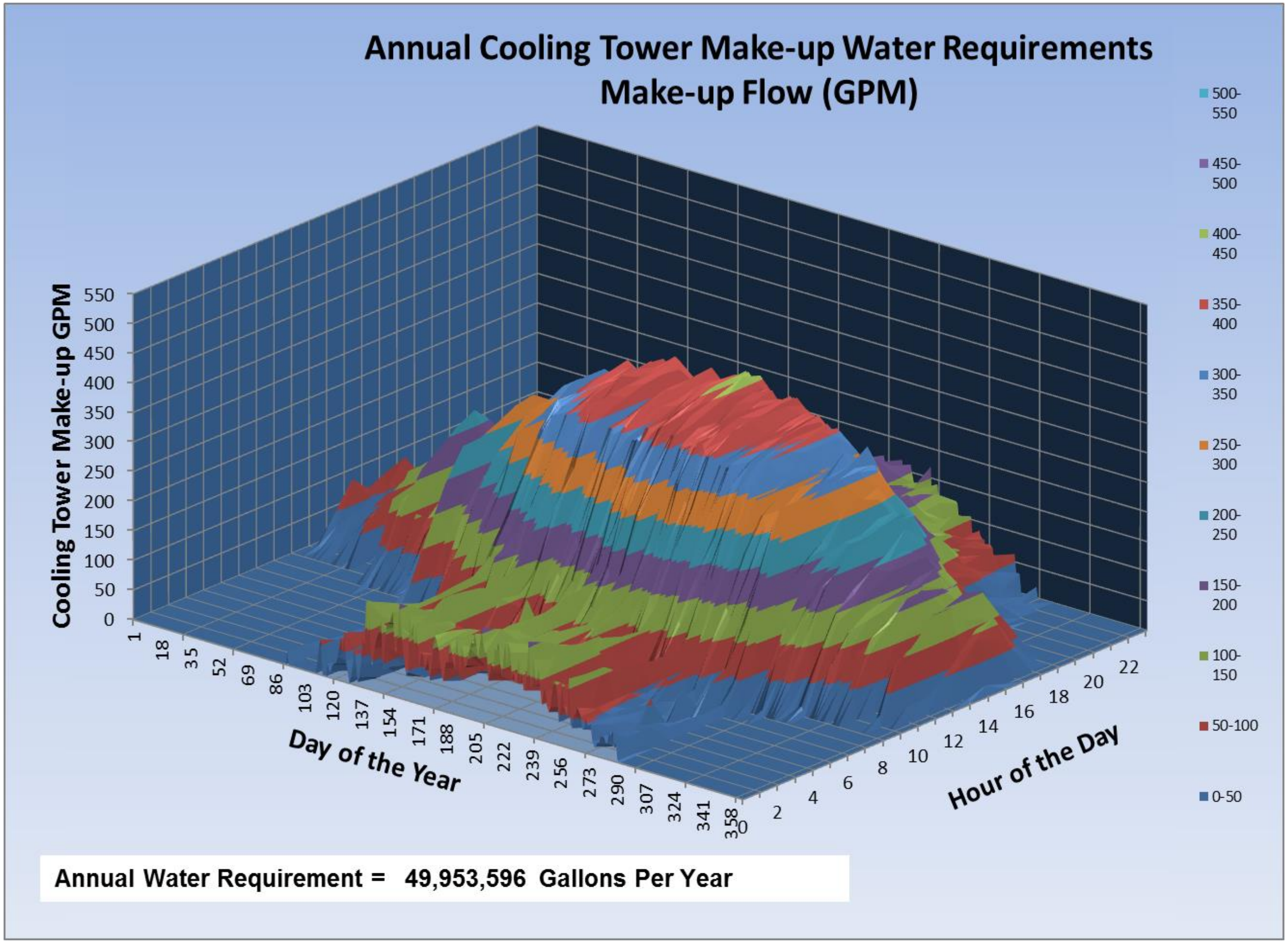
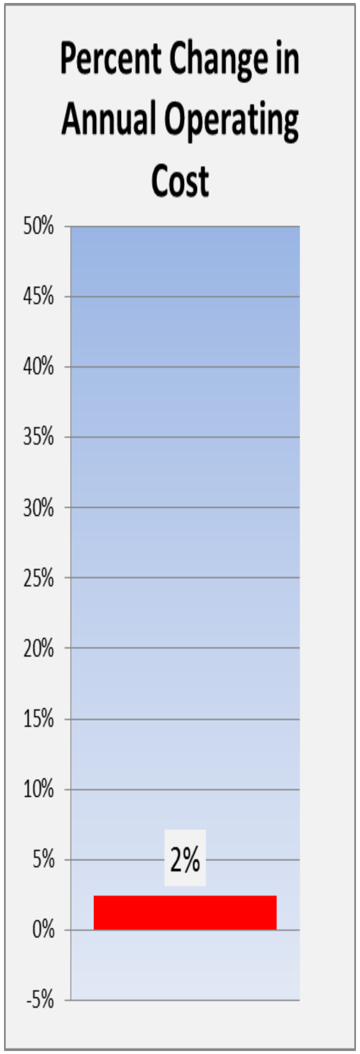
Cooling Tower Annual Make-up Water Requirements
25% Water Savings TSC Hybrid System



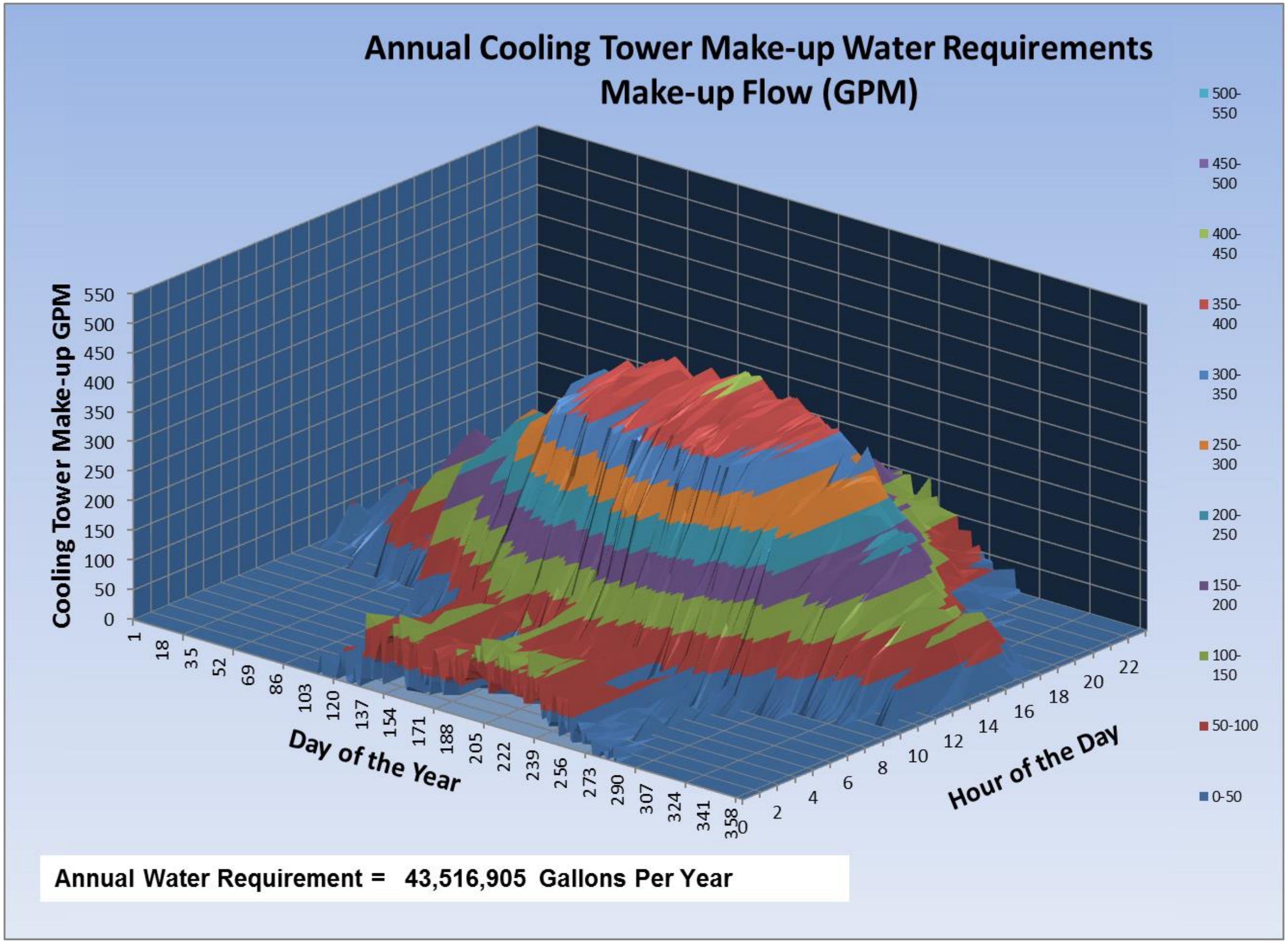


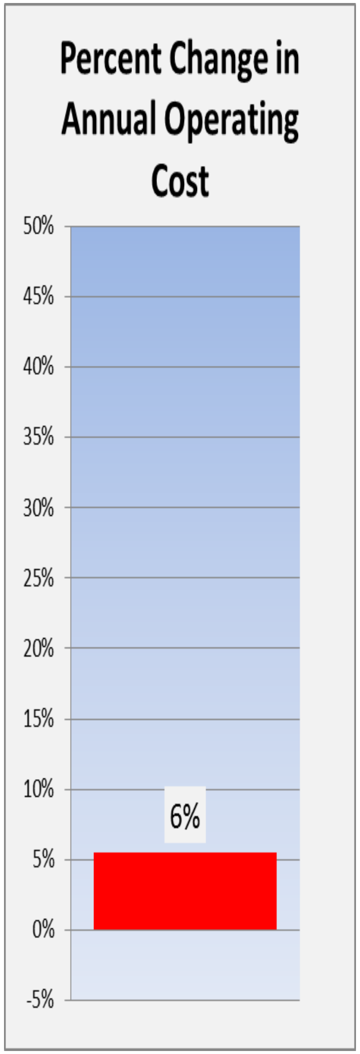
Cooling Tower Annual Make-up Water Requirements
50% Water Savings TSC Hybrid System



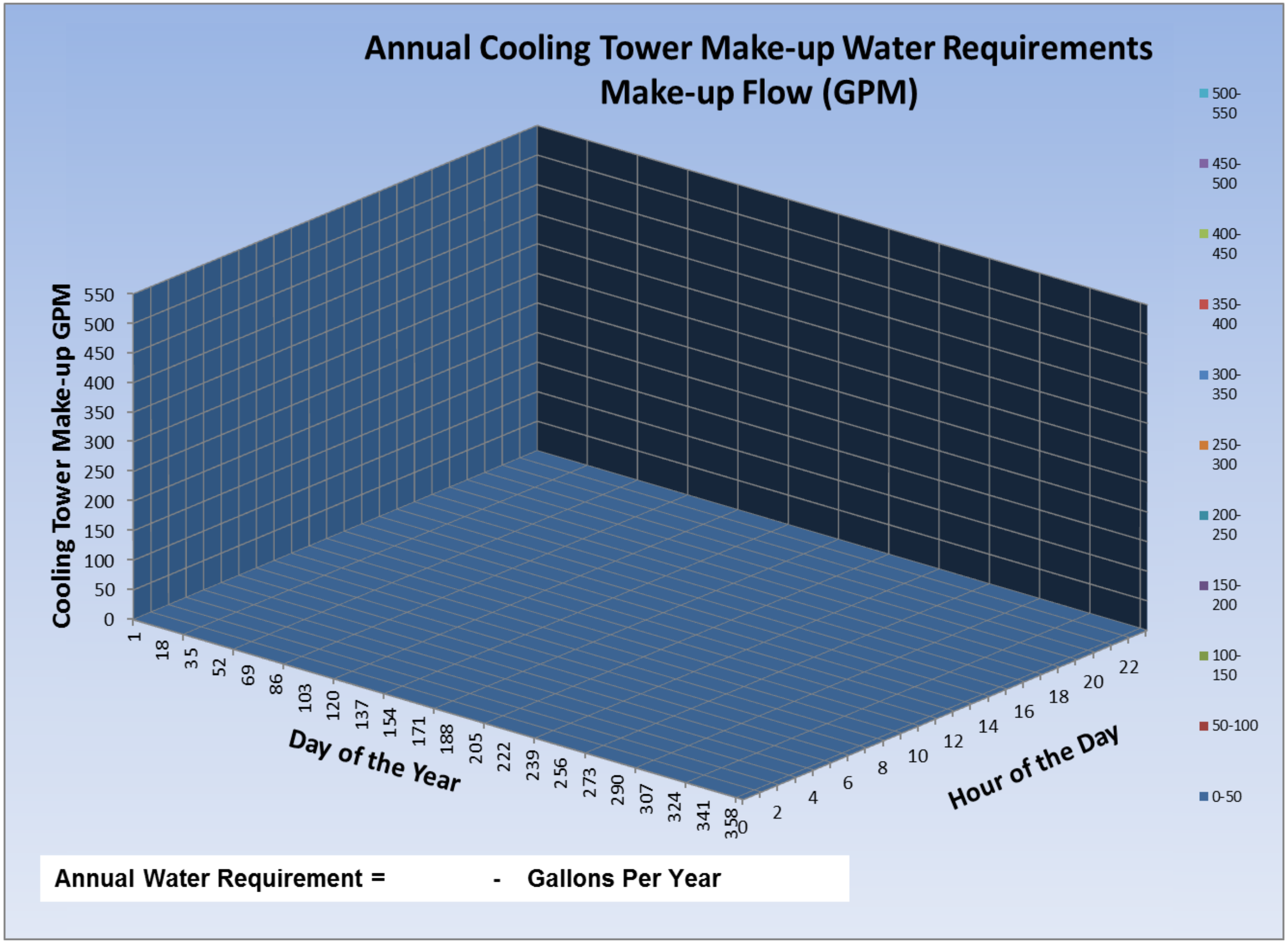


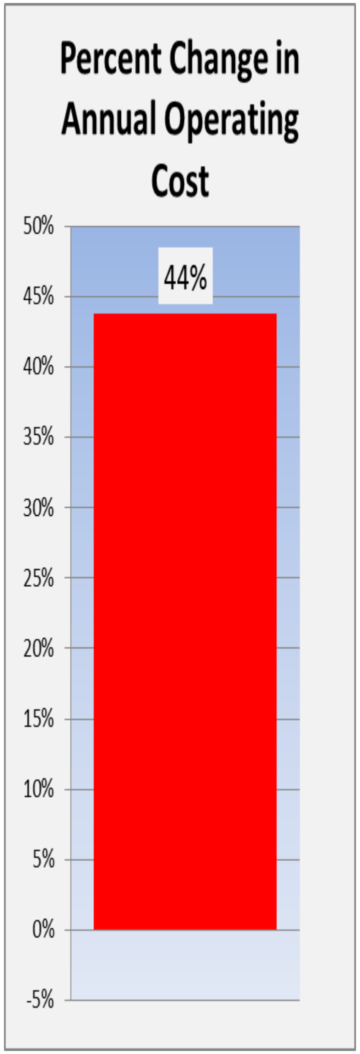
Cooling Tower Annual Make-up Water Requirements
56% Water Savings TSC Hybrid System





Cooling Tower Annual Make-up Water Requirements
Air Cooled Radiator System





Summary

- Concerns about the continuous assured availability and the escalating price of water are increasing
- If water is readily available and relatively inexpensive then evaporatively cooled water heat rejection systems provide the best system efficiencies
- Air-cooled heat rejection systems allow for zero water use but significantly increase both the annual average kWh and peak system kW
- Between these two traditional design choices exists a range of hybrid systems that offer significant water savings while minimizing the impact on energy
- The series flow dry sensible / wet cooling tower hybrid system allows for significant water savings while preserving the first cost and efficiency benefits of the open cooling tower

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