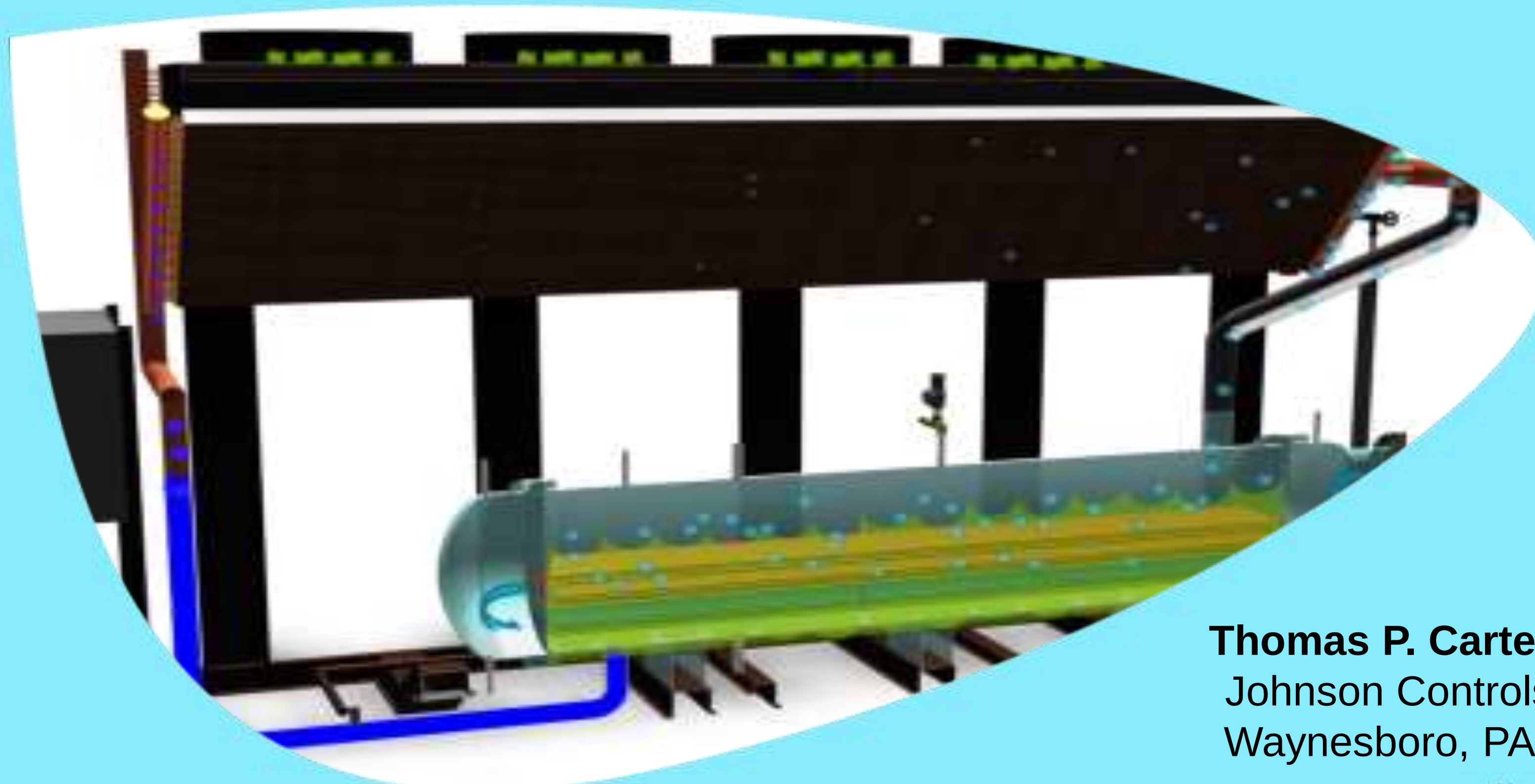
Water Savings Using The Thermosyphon Cooler Hybrid Heat Rejection System:

Case Studies From Atlanta, Phoenix, Seattle, and Boston



Thomas P. Carter, P. E.
Johnson Controls, Inc.
Waynesboro, PA, USA

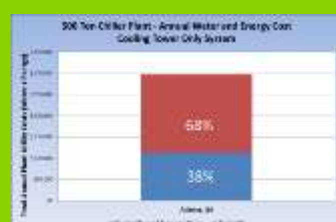
Johnson Controls

Four Key Points to Remember

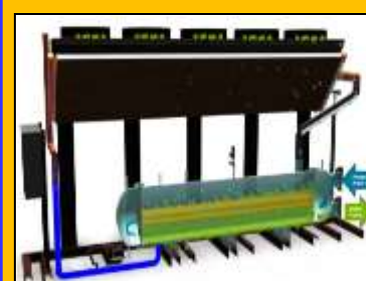
Evaporative Cooling is Efficient in Terms of:

- Energy
- Cost
- Space

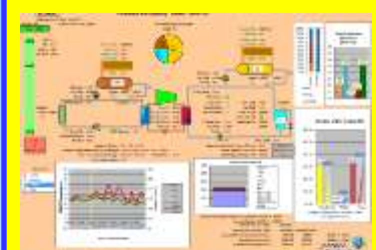
Lowering Chiller Plant Operating Costs Requires Focusing on Both Energy & Water



Hybrid Systems Increase The Water Resiliency & May Lower The Cost Of Operating The Chiller Plant



Evaluation of Alternatives Requires Detailed System Modeling



The Pros and Cons of Evaporative Heat Rejection

Evaporative Cooling is Efficient in terms of:

- Energy
- Cost
- Space

Pros:

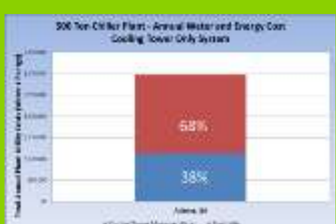
- Ability to reject heat to the cooler ambient WB versus DB
- Ability of evaporating moisture to pick up significantly more heat than dry air

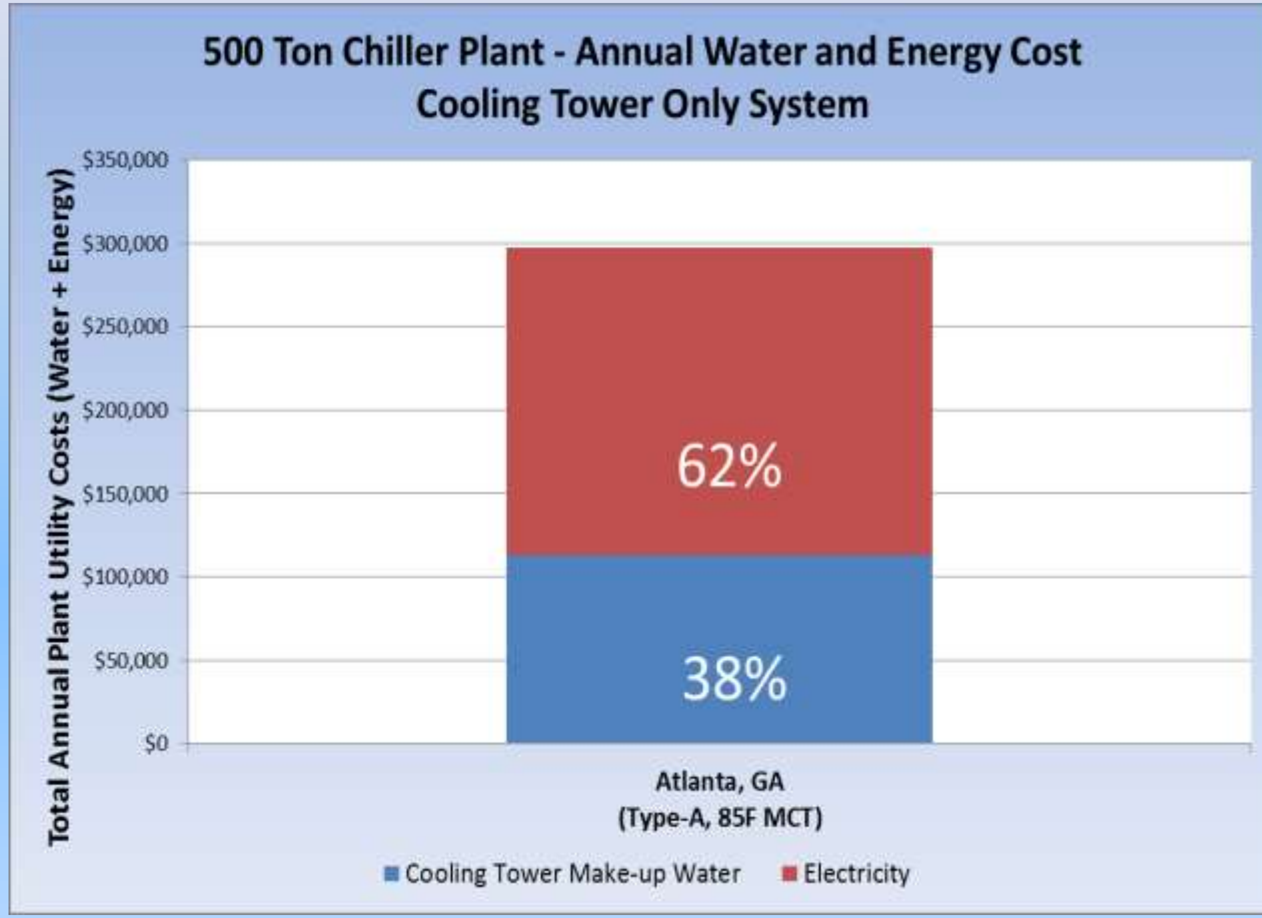
Cons:

- Consumes massive amounts of water
- Cooling tower blowdown may require additional special disposal requirements

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

Lowering Chiller Plant Operating Costs Requires Focusing on Both Energy & Water



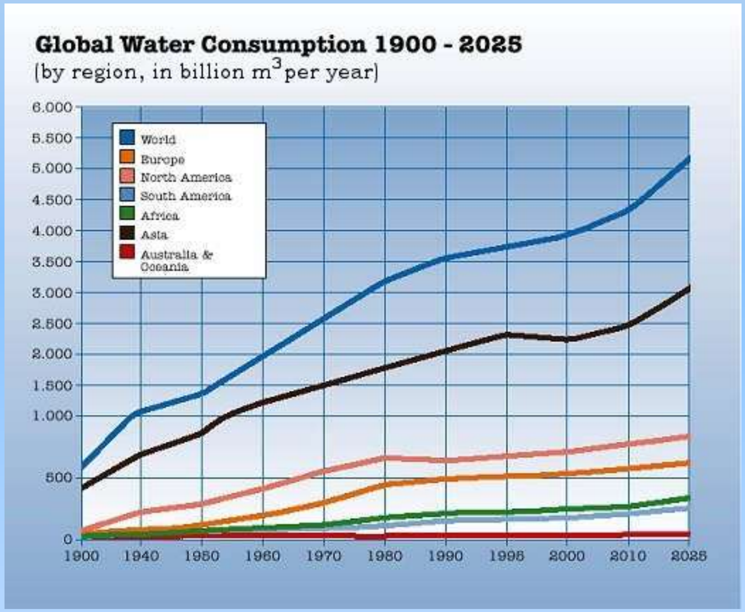


Freshwater Stress - The Global Perspective

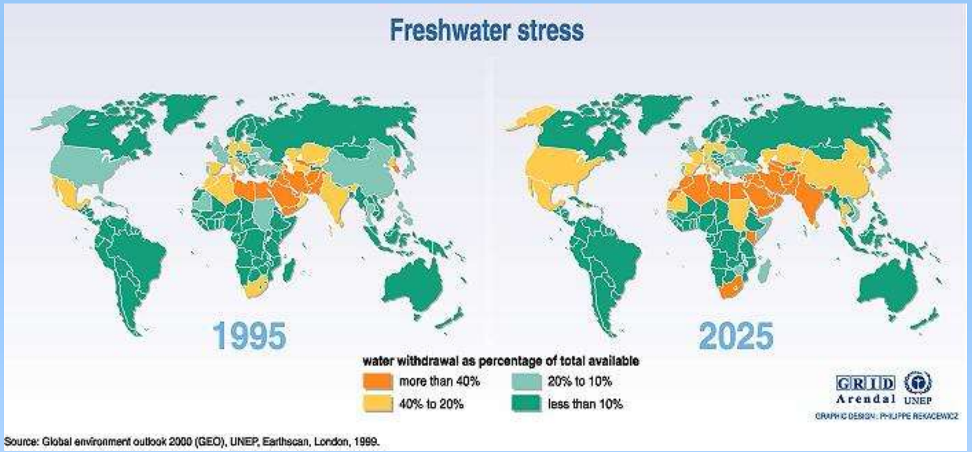
Forces Driving Fresh Water Consumption:

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

Consumption increases …



driving Freshwater Stress worldwide



Water & Sewer Prices Are Escalating Quickly

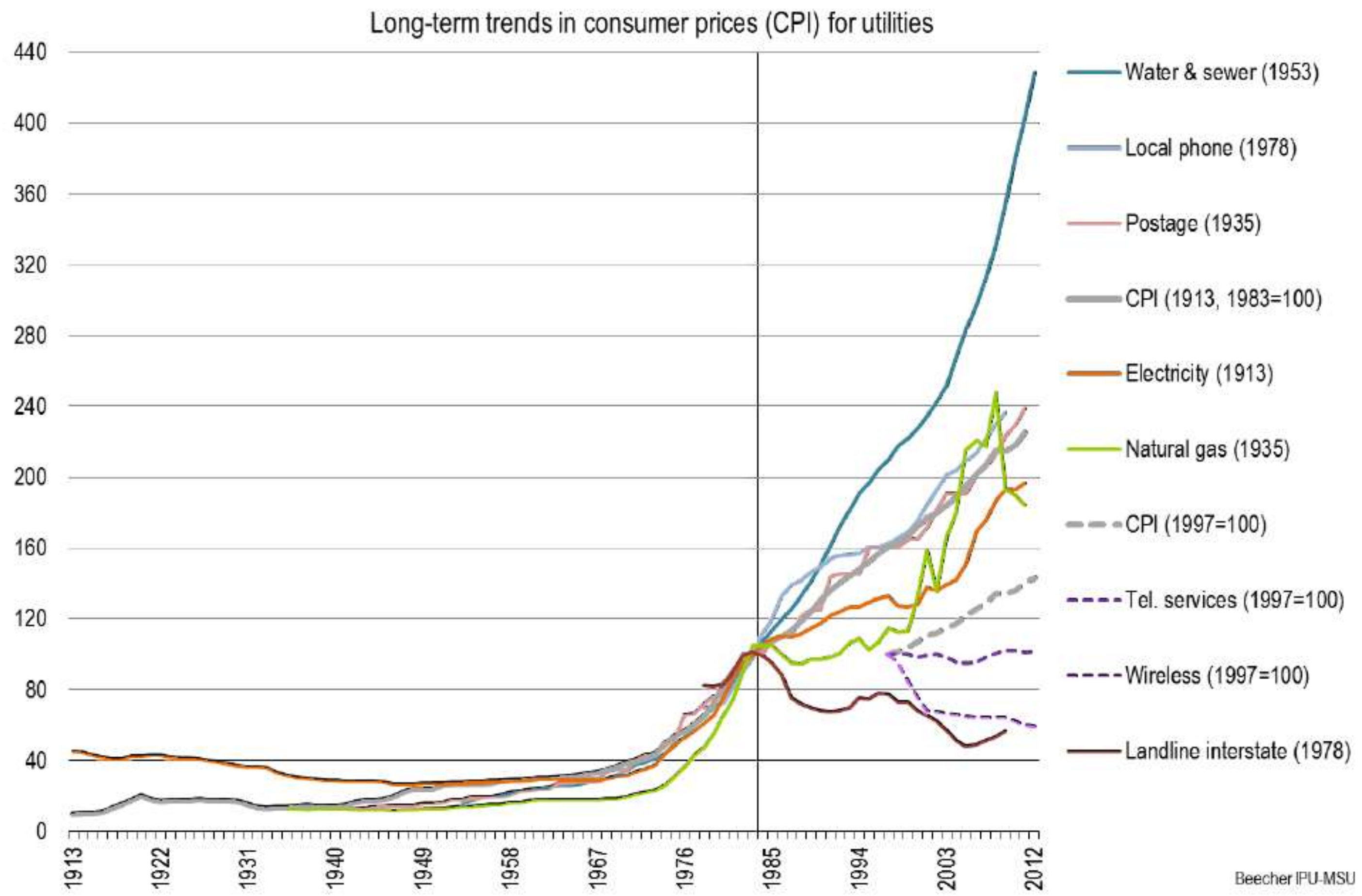


Exhibit 1. Long-term trends in the Consumer Price Index (CPI) for utilities (1913-2012).
The index is set to 100 for 1982-1984 except for telephone and wireless services, where the index is set to 100 for 1997. Date () indicates start of series.

Water and Sewer Rates From Selected Cities

(Rates Per 1000 Gallons)

City	Water	Sewer	Combined
Atlanta, GA	$8.19	$20.85	$29.04
Phoenix, AZ	$4.78	$3.35	$8.13
Seattle, WA	$6.87	$15.61	$22.48
Boston, MA	$6.86	$8.56	$15.42

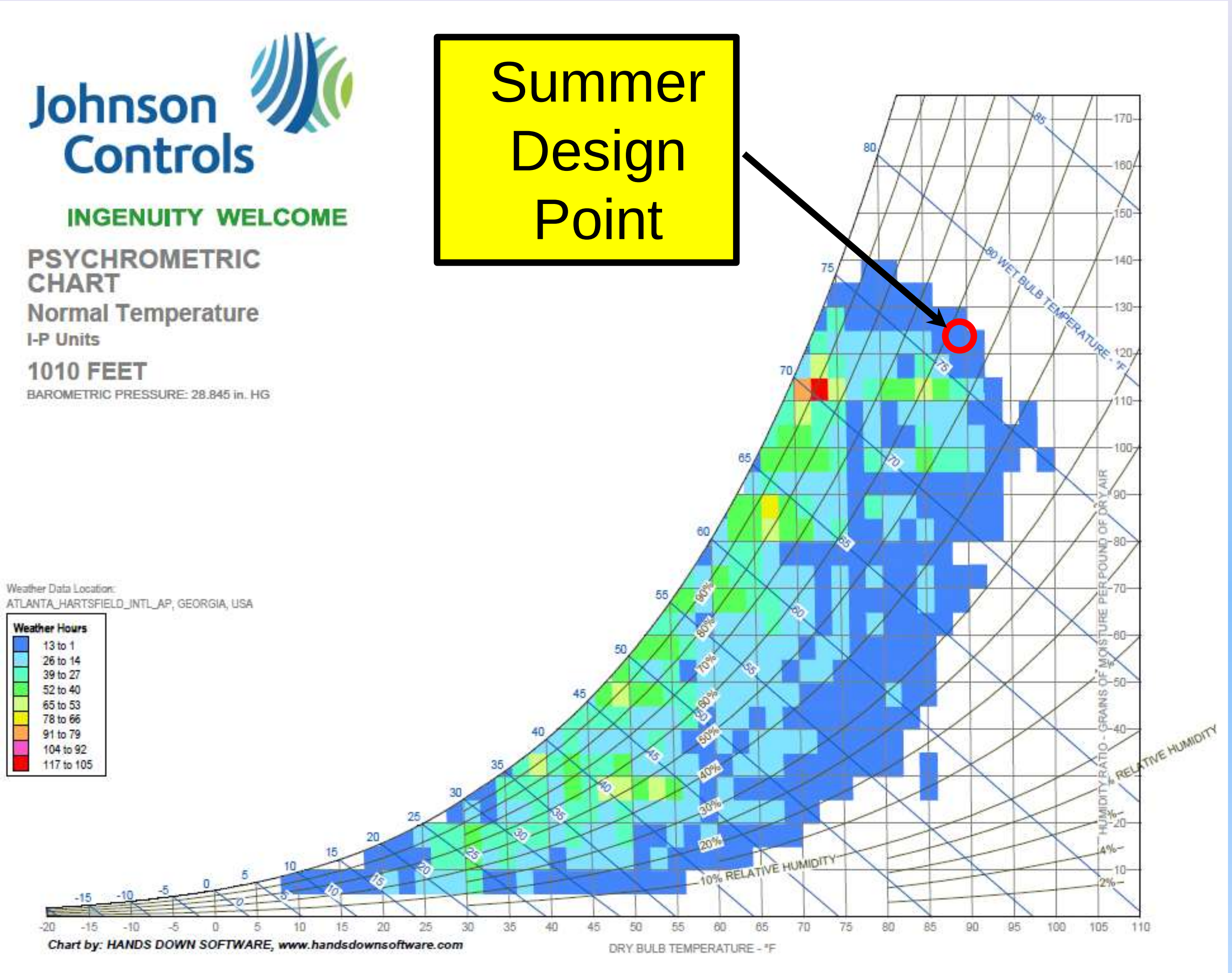
Source: "50 Largest Cities Water/Wastewater Rate Survey"
A Black & Veatch 2012/2013 Report"

Hybrid Systems

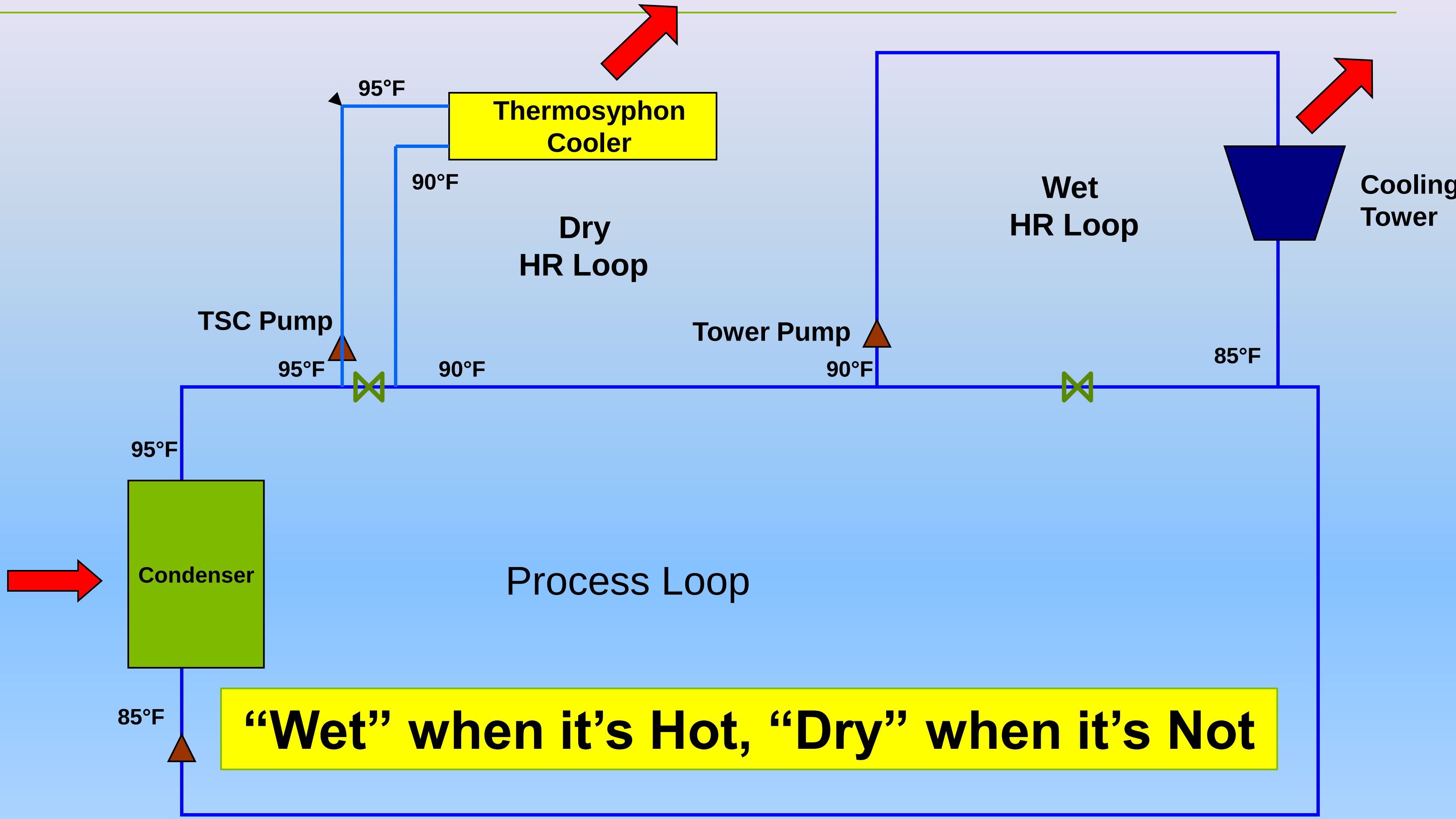
Hybrid Systems Increase The Water Resiliency & May Lower The Cost Of Operating The Chiller Plant

- **Adiabatic Dry Coolers**
- **Parallel or Series Dry Coolers**
- **Hybrid Wet/Dry Products**
- **Thermosyphon Cooler Hybrid System (TCHS)**

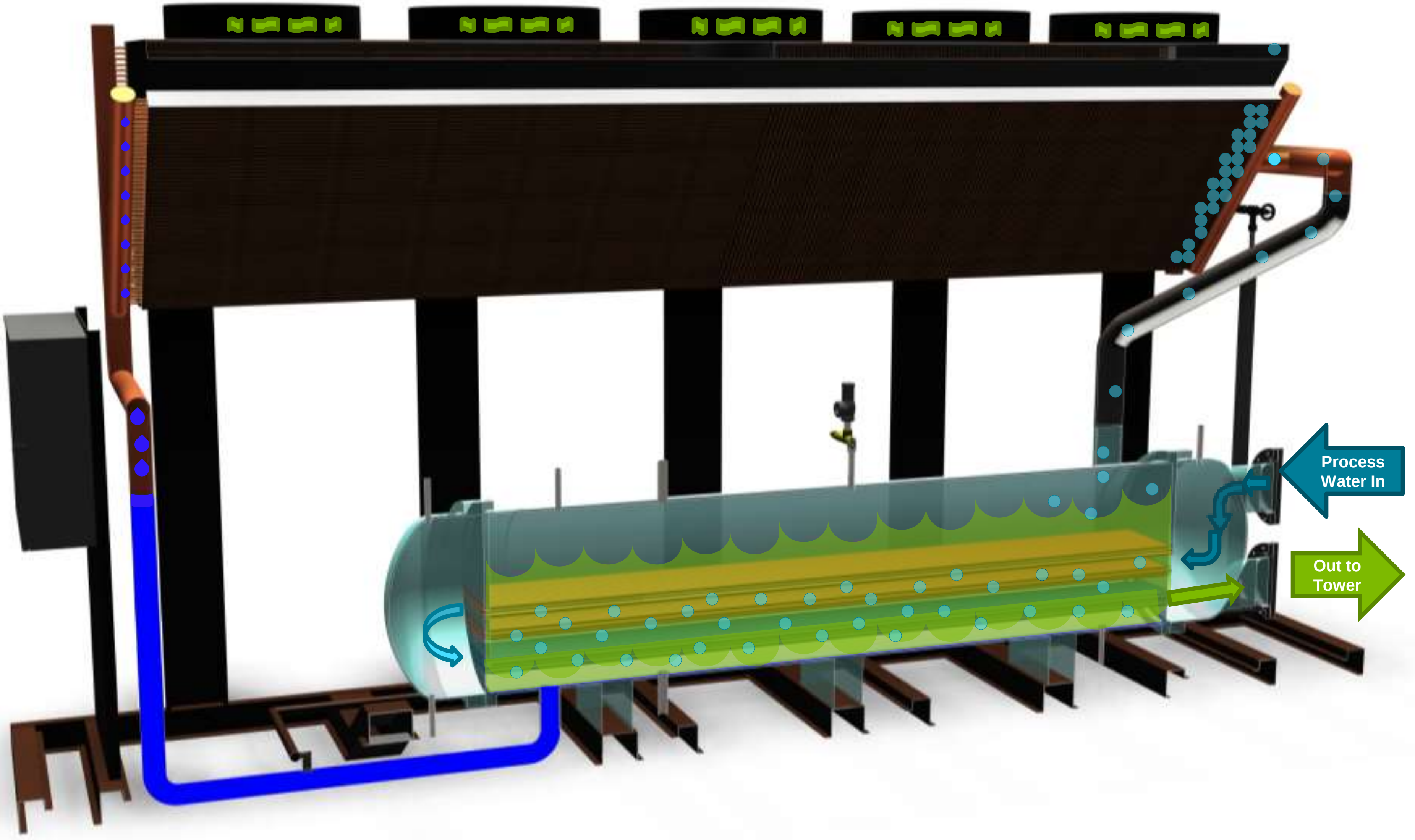
Psychrometric Chart For Atlanta, GA



Thermosyphon Cooler Hybrid System (TCHS)

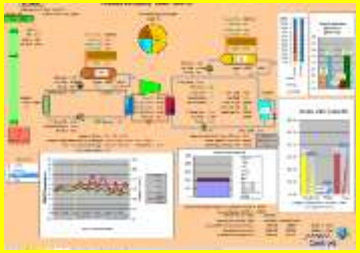


Thermosyphon Cooler (TSC) – Basic Conceptual Design



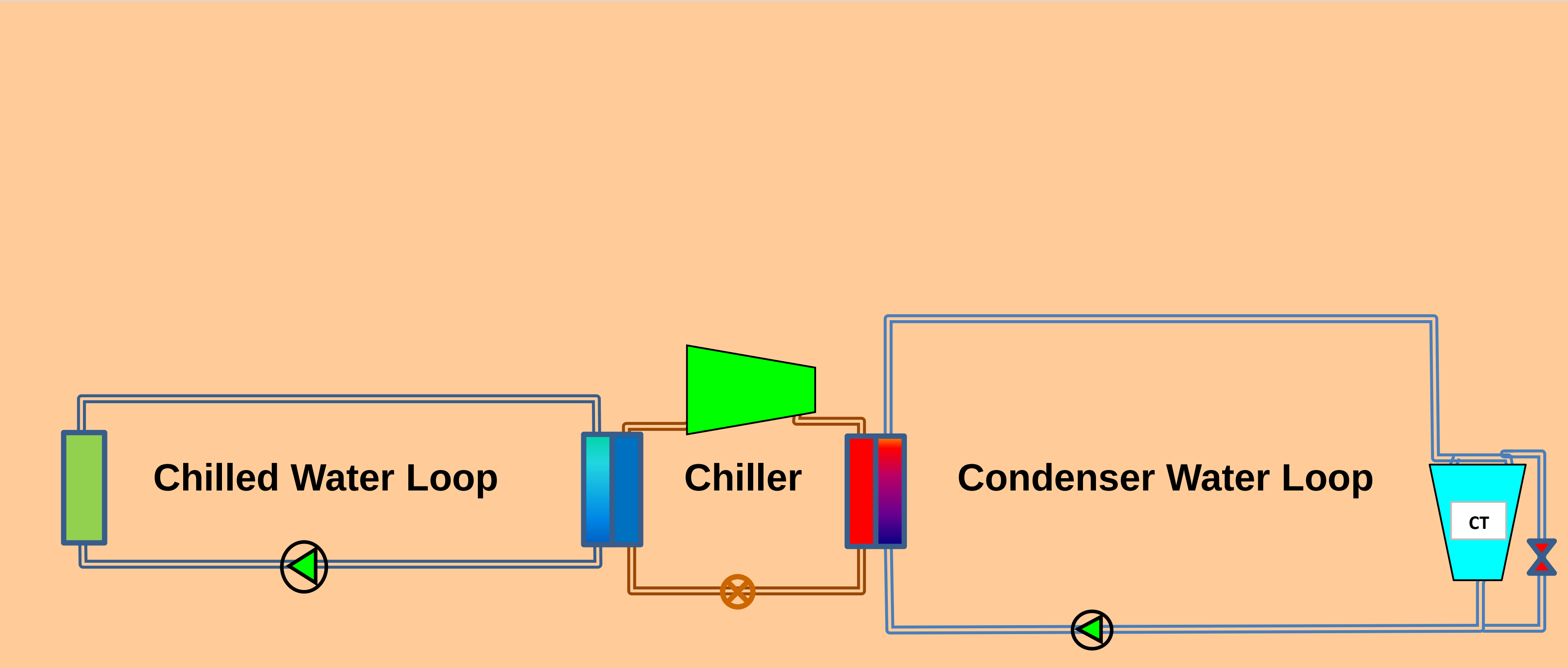
The Cooling System Interacts With Its Environment And The Rest of The Plant

Evaluation of Alternatives Requires Detailed System Modeling

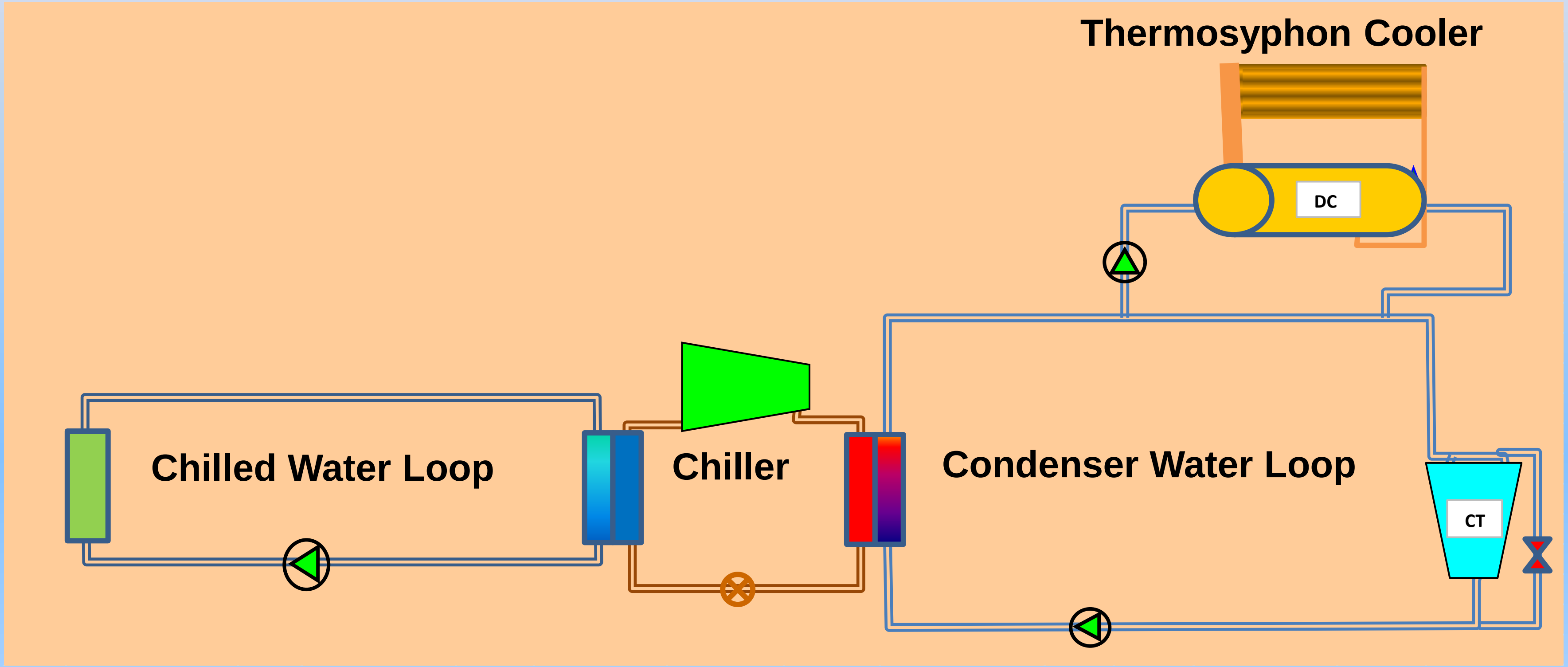


1. **Weather** ***f*(hour of the year)**
2. **Cooling Requirements** ***f*(Hr of Day, Day of Week, Month of Year, Weather)**
3. **Water Availability** ***f*(Hr of Day, Day of Week, Month of Year, Weather)**
4. **Energy and Water Costs** ***f*(Hr of Day, Day of Week, Month of Year, Weather)**
5. **Plant Efficiency** ***f*(Weather, Control Strategy, Equipment)**
6. **Heat Rejection Load** ***f*(Weather, Cooling Load, Plant Efficiency, Cooling Strategy)**
7. **Water Requirements** ***f*(Heat Rejection Equipment, Weather, Heat Load, Plant Operating Strategy)**

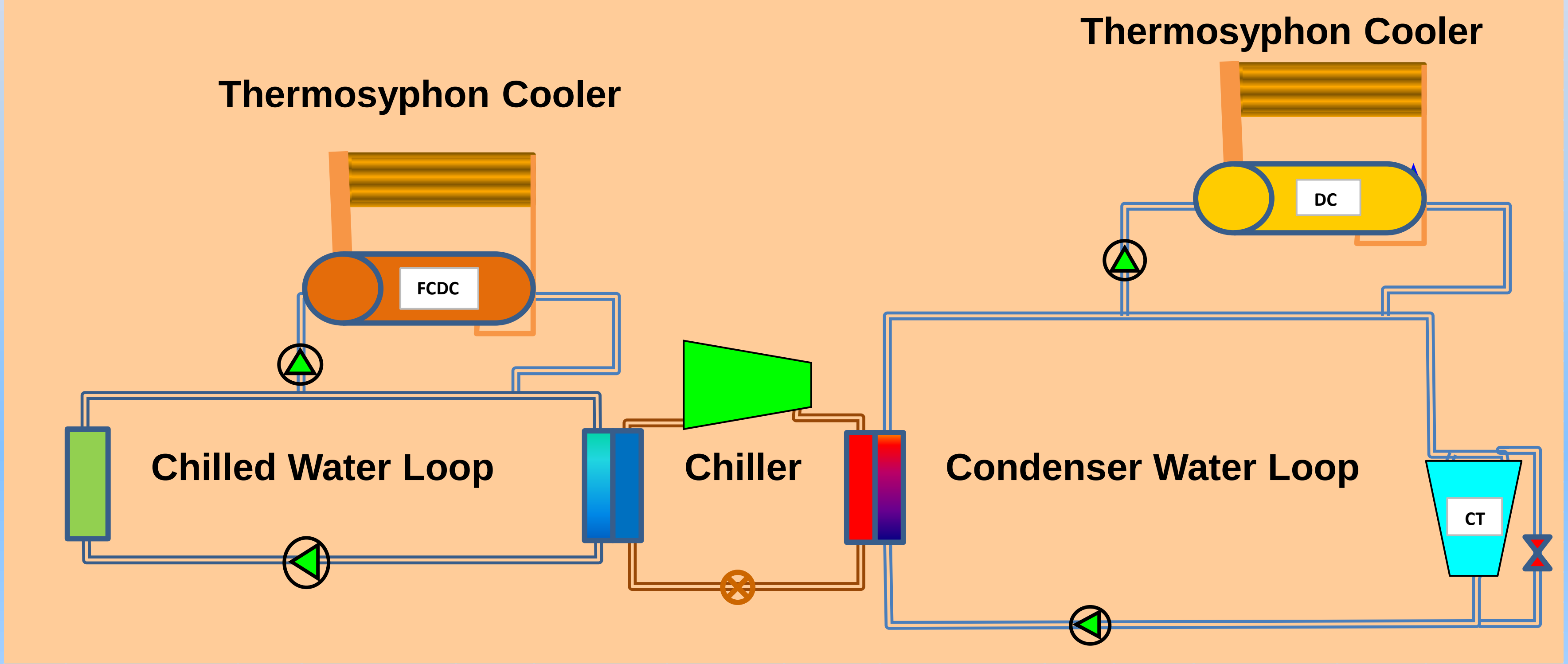
Simplified Chiller Plant Schematic
Cooling Tower Only System



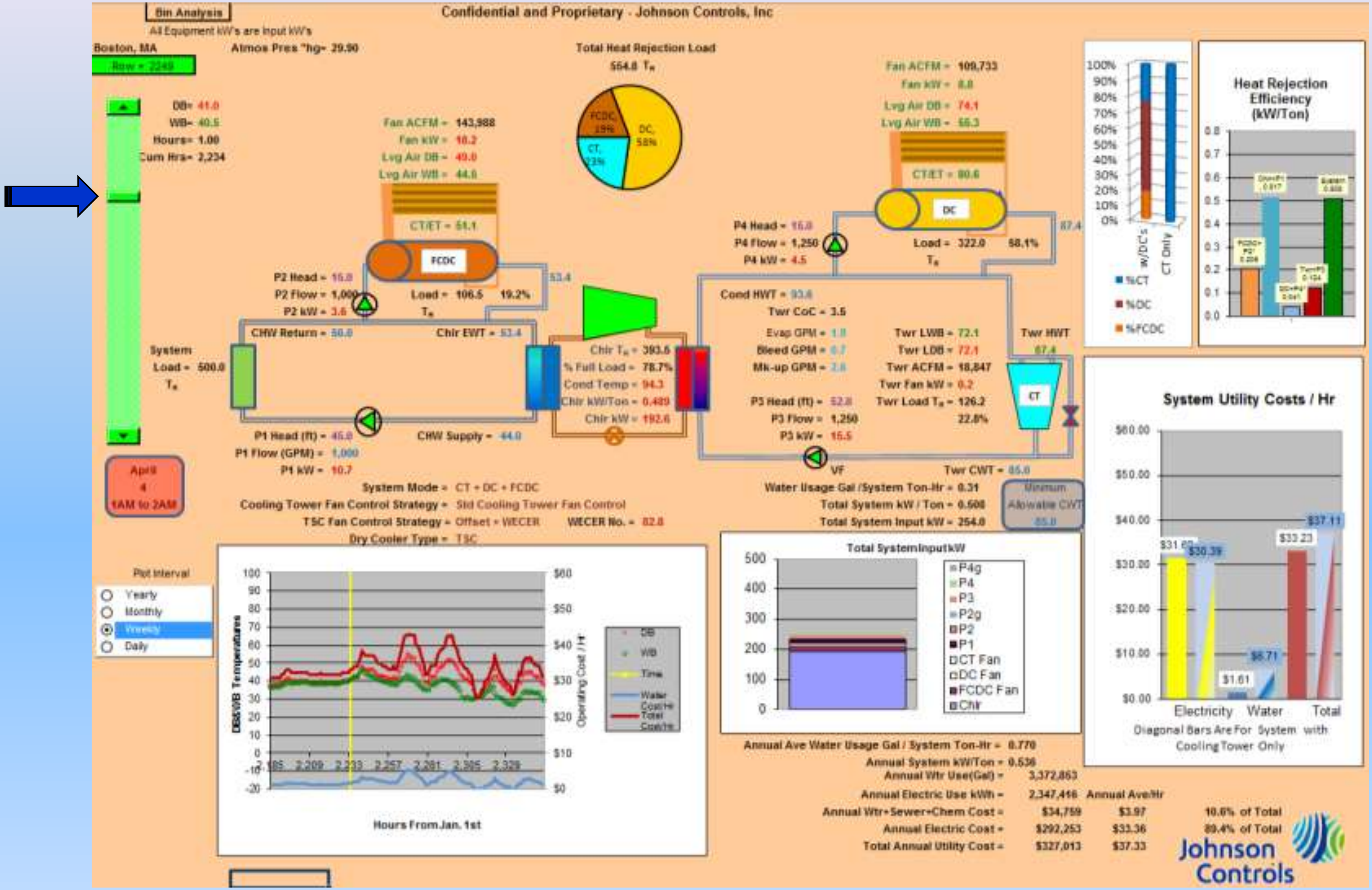
Simplified Chiller Plant Schematic
Thermosyphon Cooler Hybrid System – Type A



Simplified Chiller Plant Schematic
Thermosyphon Cooler Hybrid System – Type B



Interactive System Schematic From The Chiller Plant Simulation Program



Locations, Systems Modeled, and Assumptions

Locations / Energy Cost:

- Atlanta - $0.0783/kWh
- Phoenix - $0.0684/kWh
- Seattle - $0.0596/kWh
- Boston - $0.1245/kWh

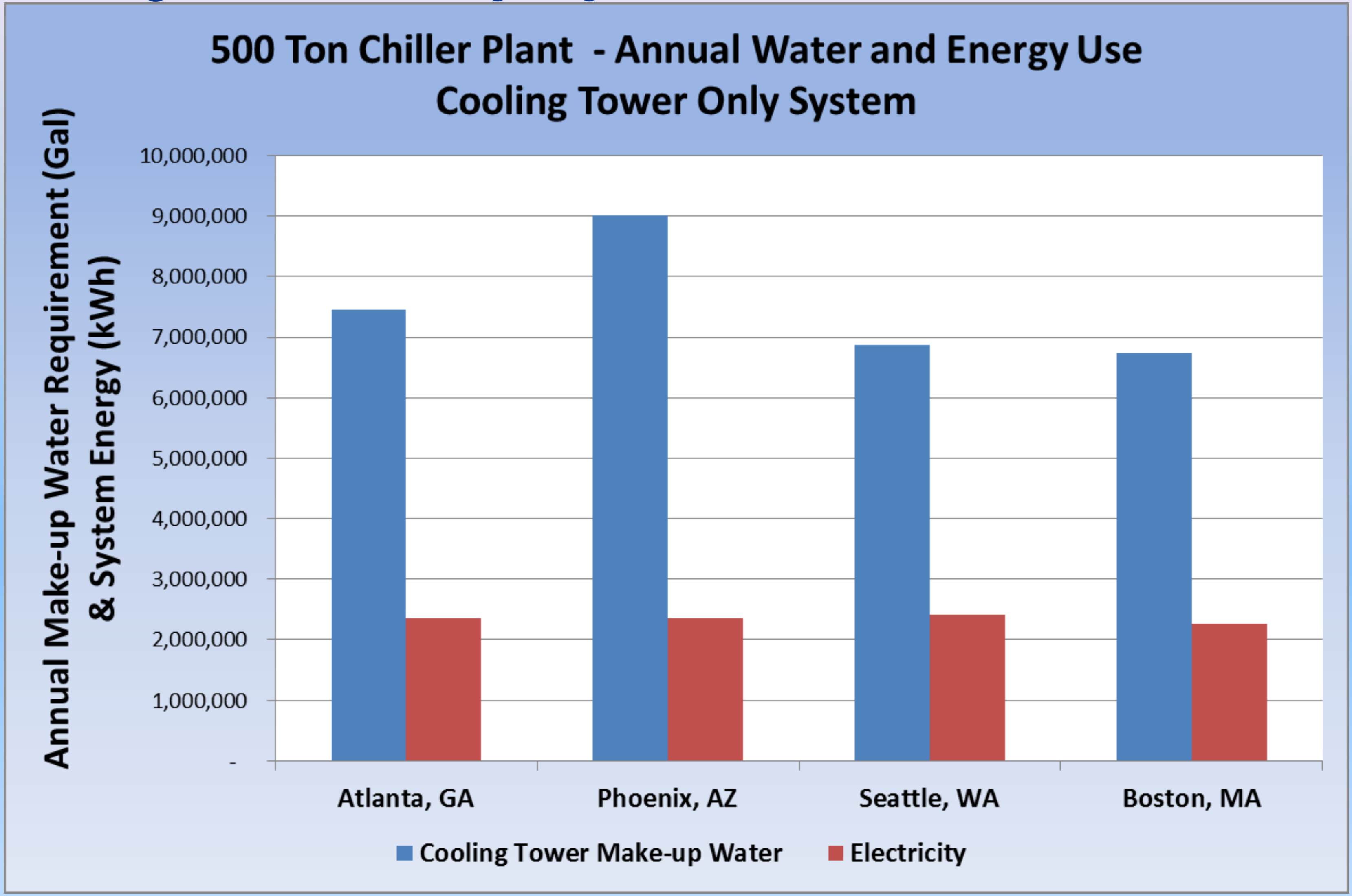
Systems:

- Cooling Tower Only with
  Min CWT = 65F
- TCHS (A) with Min CWT = 65F
- TCHS (B) with Min CWT = 65F
- TCHS (A) with Min CWT = 85F
- TCHS (B) with Min CWT = 85F

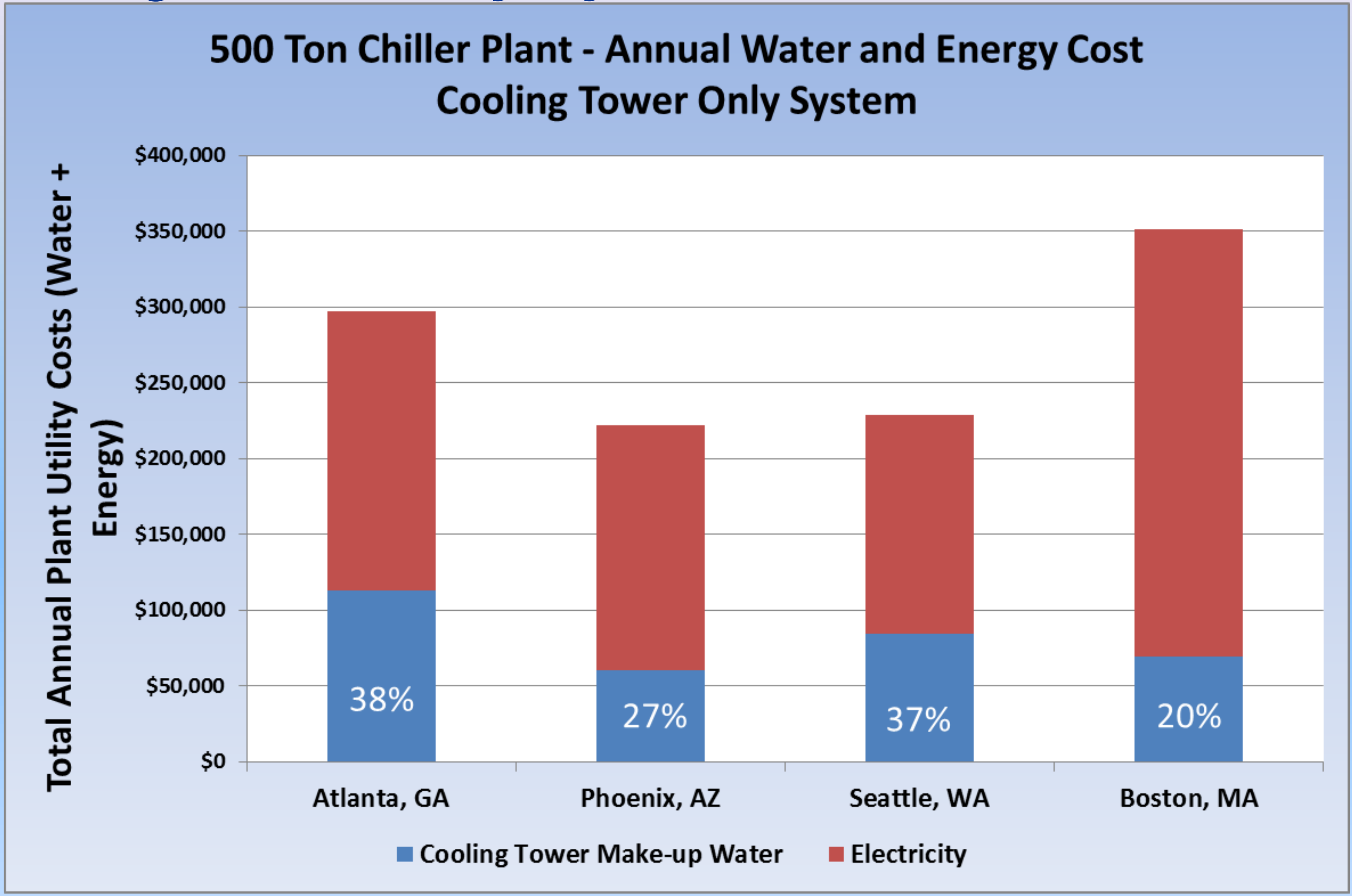
Assumptions:

- Constant 500 Tons Base Load
- 44°F Chiller Water Supply
- 2.0 GPM/Ton Chilled Water Flow Rate
- 2.5 GPM/Ton Condenser Water Flow Rate
- Cooling Tower Sized to Produce 85°F Condenser Water at the Summer Design WB
- 0.53 kW/Ton Chiller Efficiency at the Design Point
- Sewer Charges Only Applied to the Cooling Tower Bleed
- Chemical Treatment Costs = $3.50/1000 Gallons of Bleed
- 3.5 Cycles of Concentration

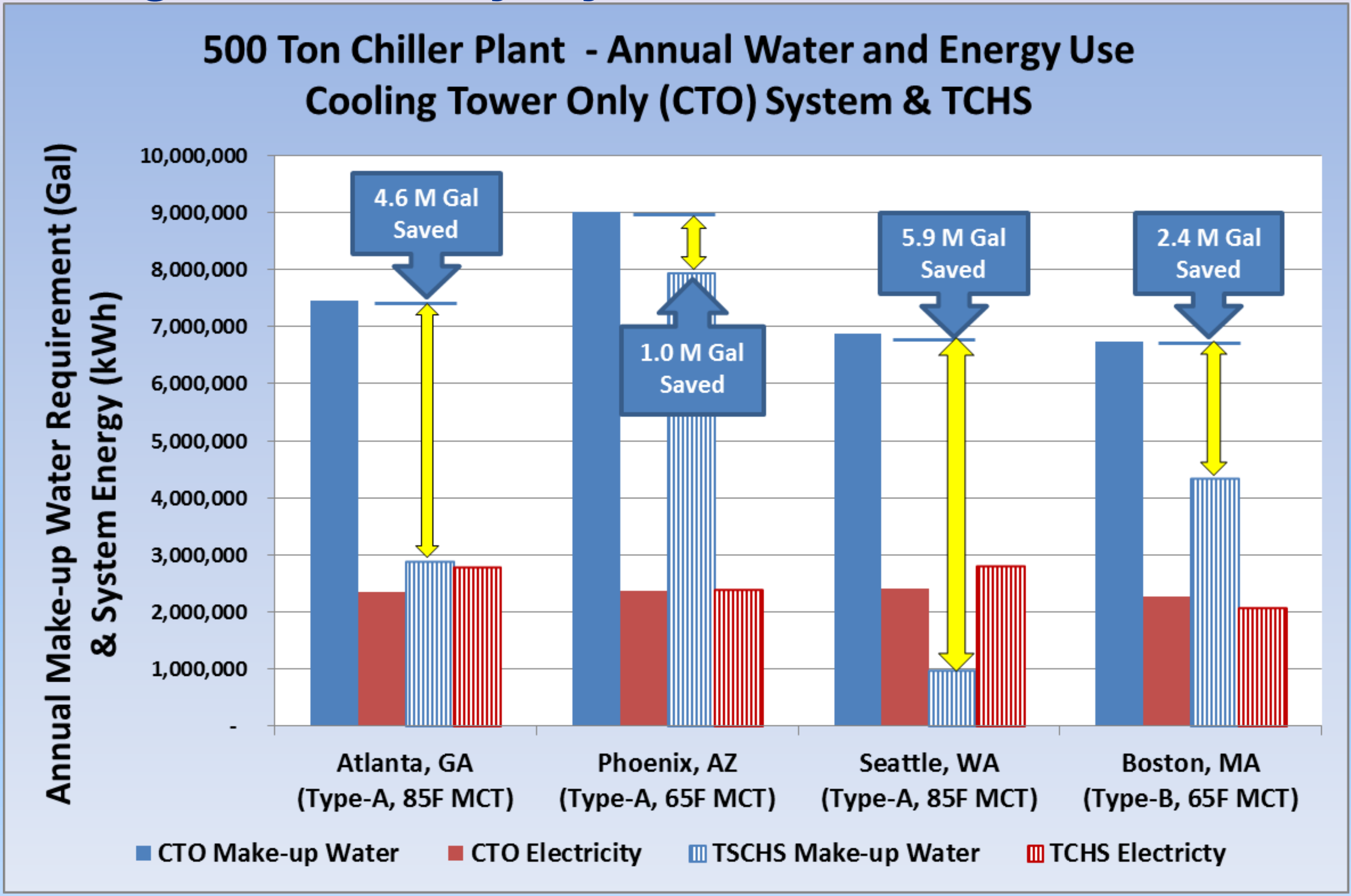
Annual Energy and Water Use – Cooling Tower Only System



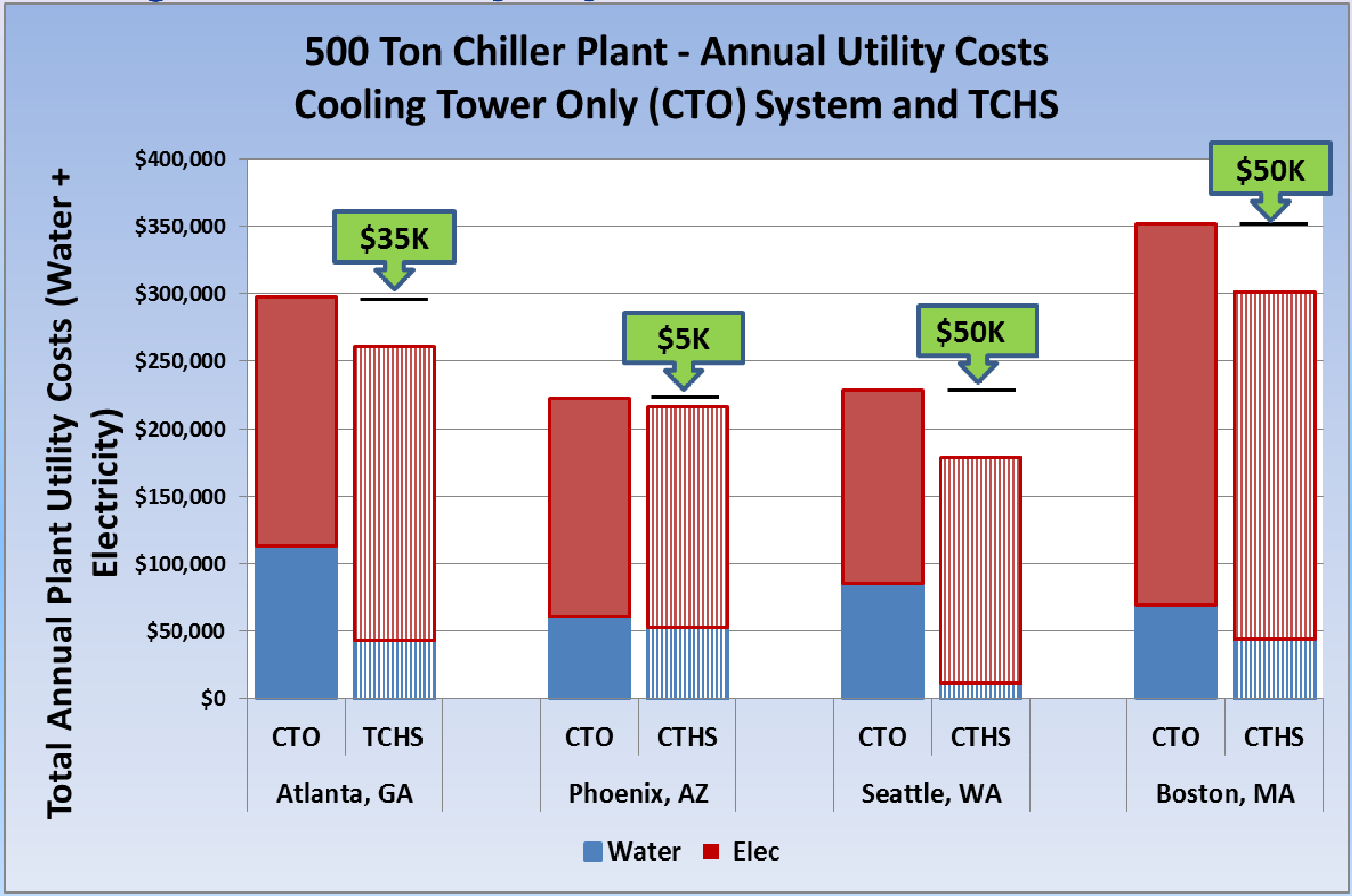
Annual Energy and Water Cost – Cooling Tower Only System



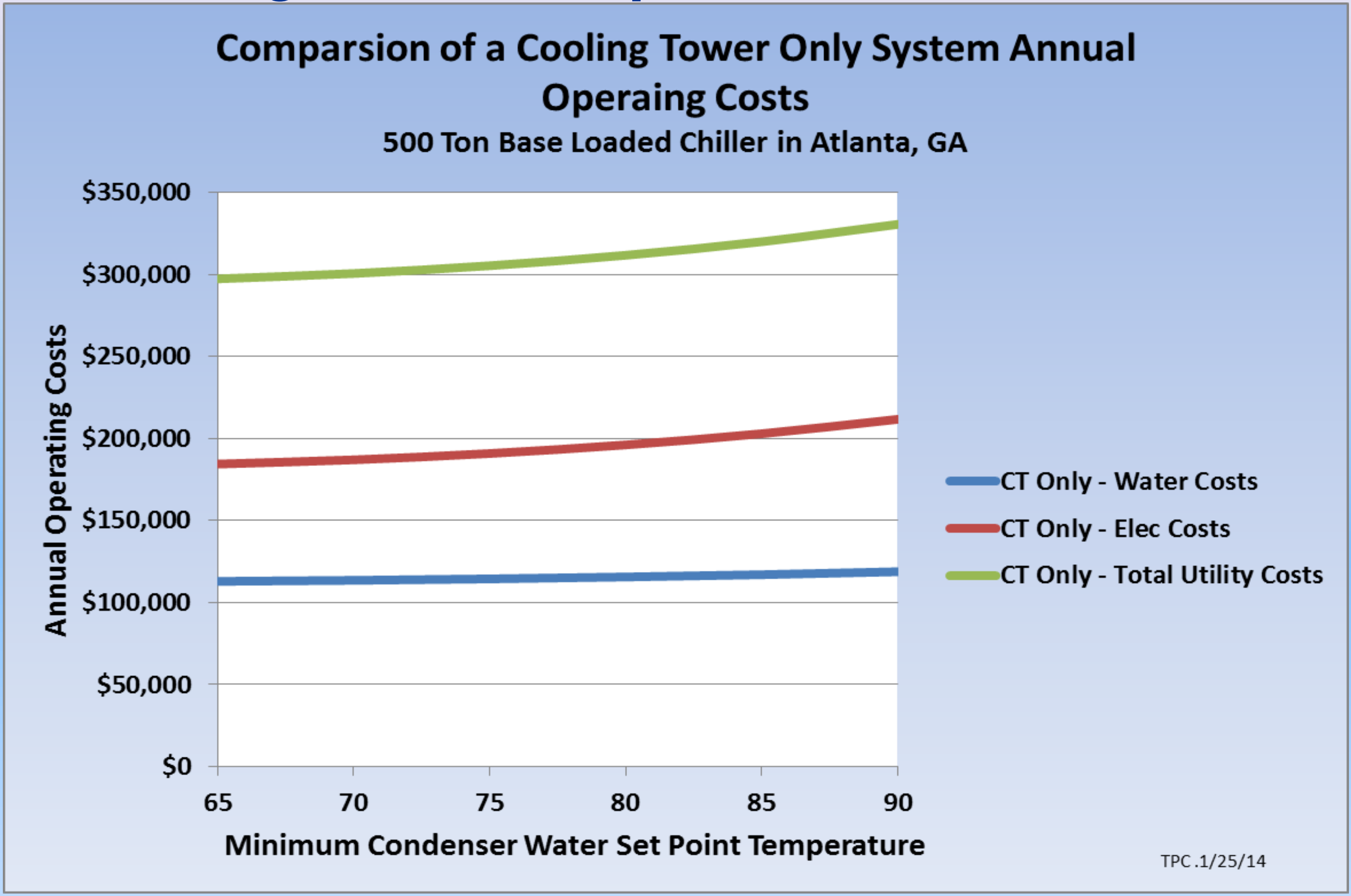
Annual Energy and Water Use –
Cooling Tower Only System & TCHS



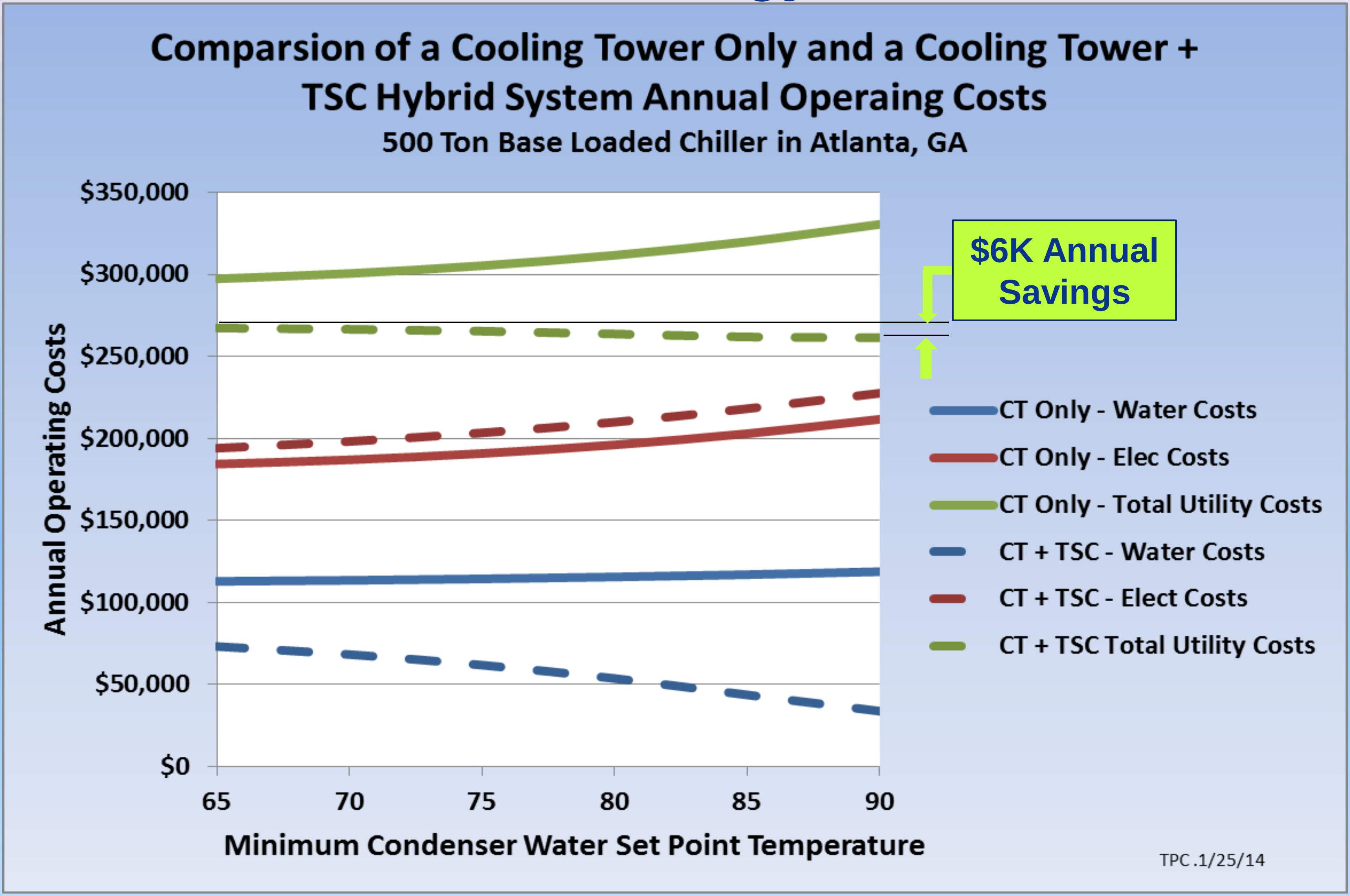
Annual Energy and Water Cost – Cooling Tower Only System & TCHS



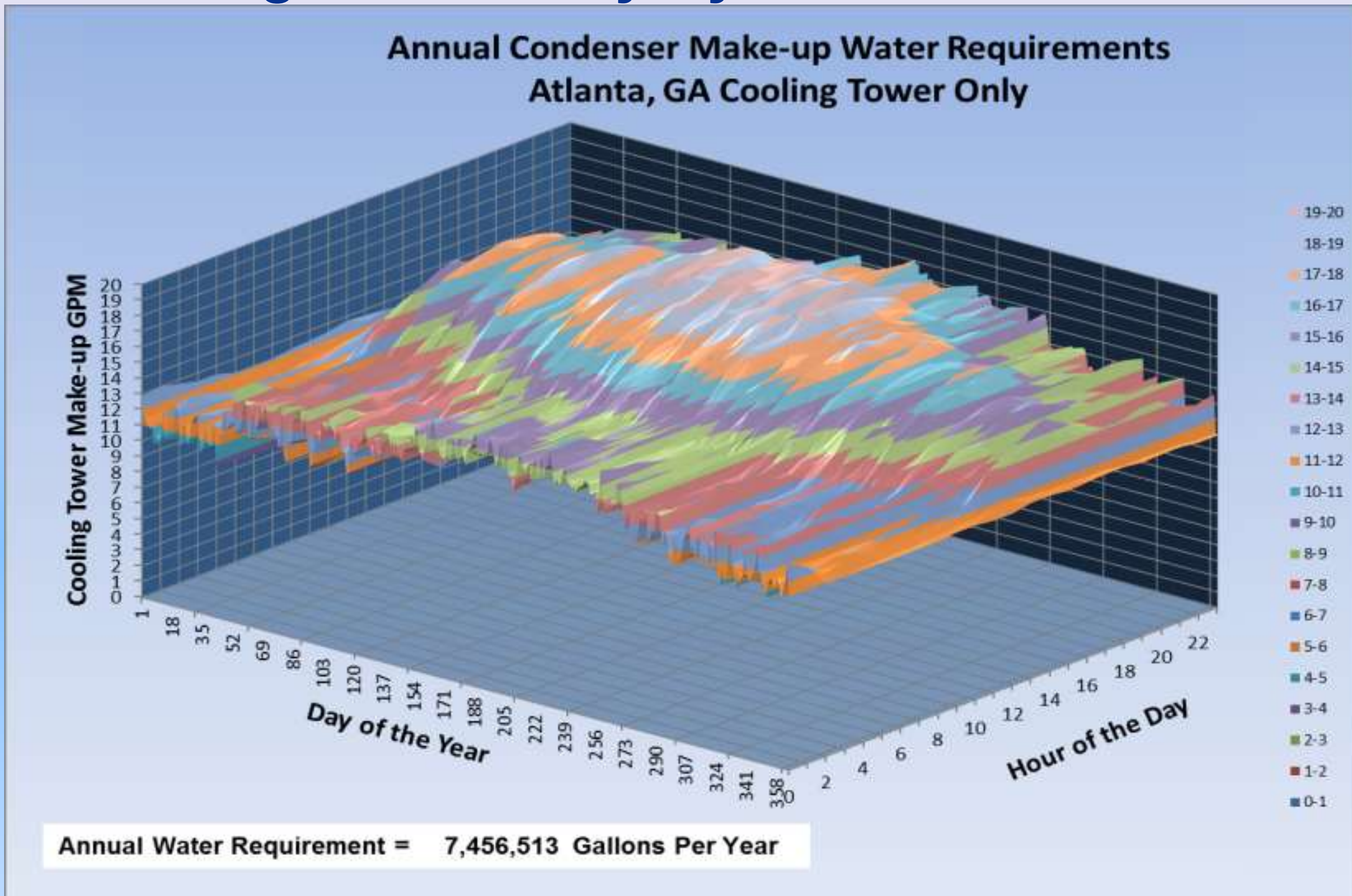
Change in Annual Operating Cost Vs. Minimum Condensing Water Temperature



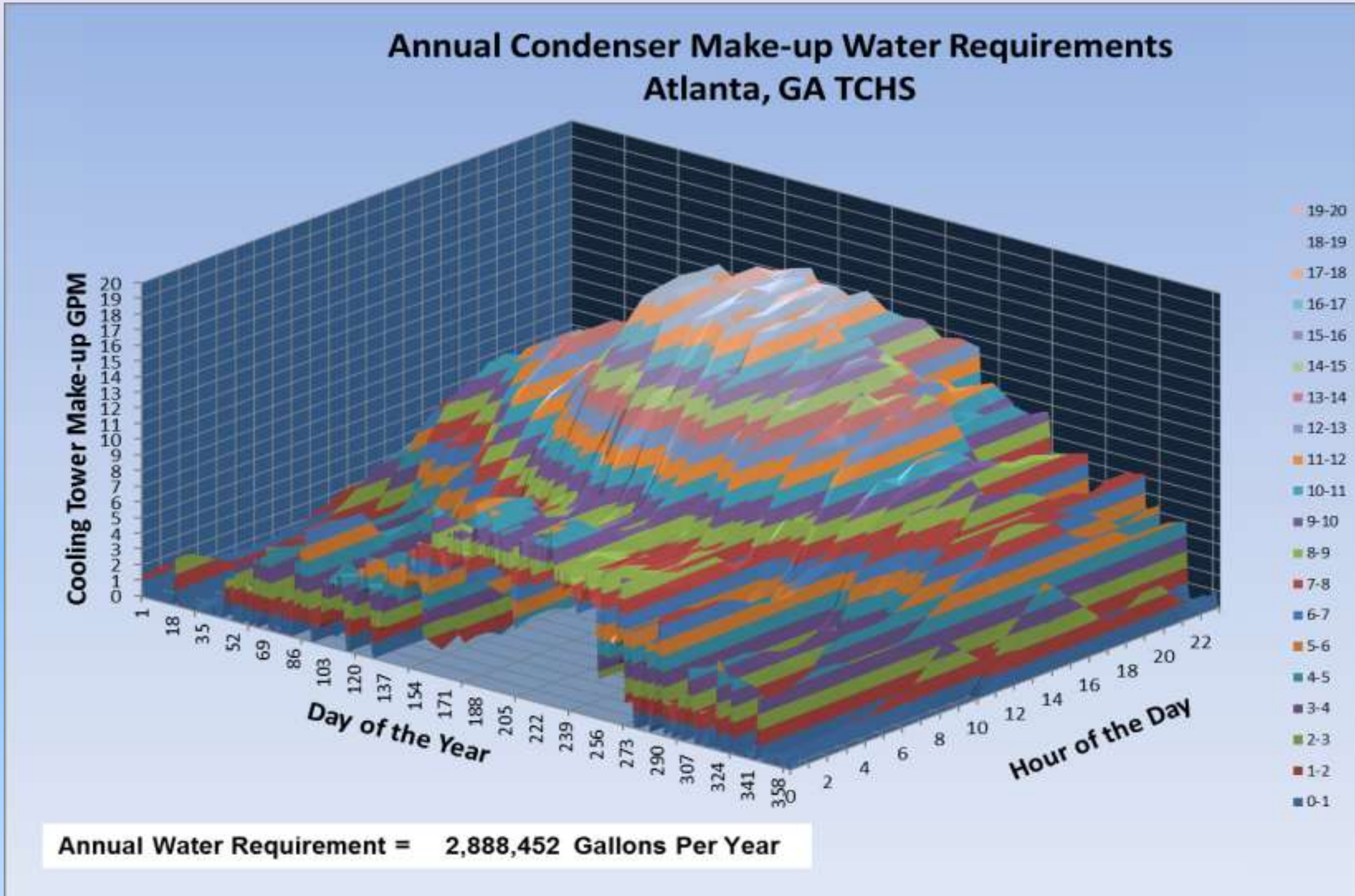
Lowest Operating Cost Doesn't Always Mean Lowest Energy Cost



Make-up Water Requirements
– Cooling Tower Only System



Make-up Water Requirements – TCHS



In Conclusion: Four Key Points to Remember

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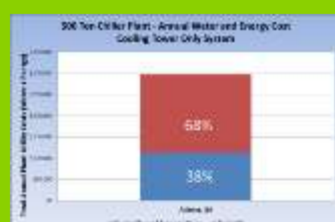

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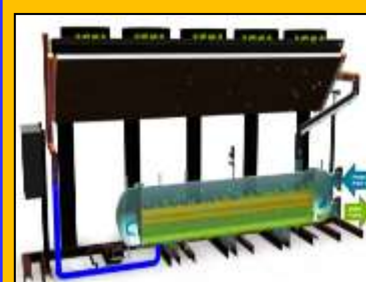

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