

Cooling Towers

HVACR Leadership Workshop by Eurovent Middle East

Eurovent Middle East

Association of the
Heating, Ventilation,
Air-Conditioning and
Refrigeration Industry
in the Middle East



Workshop Partners



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KEY PERSPECTIVES ON THE REGION'S HVACR INDUSTRY

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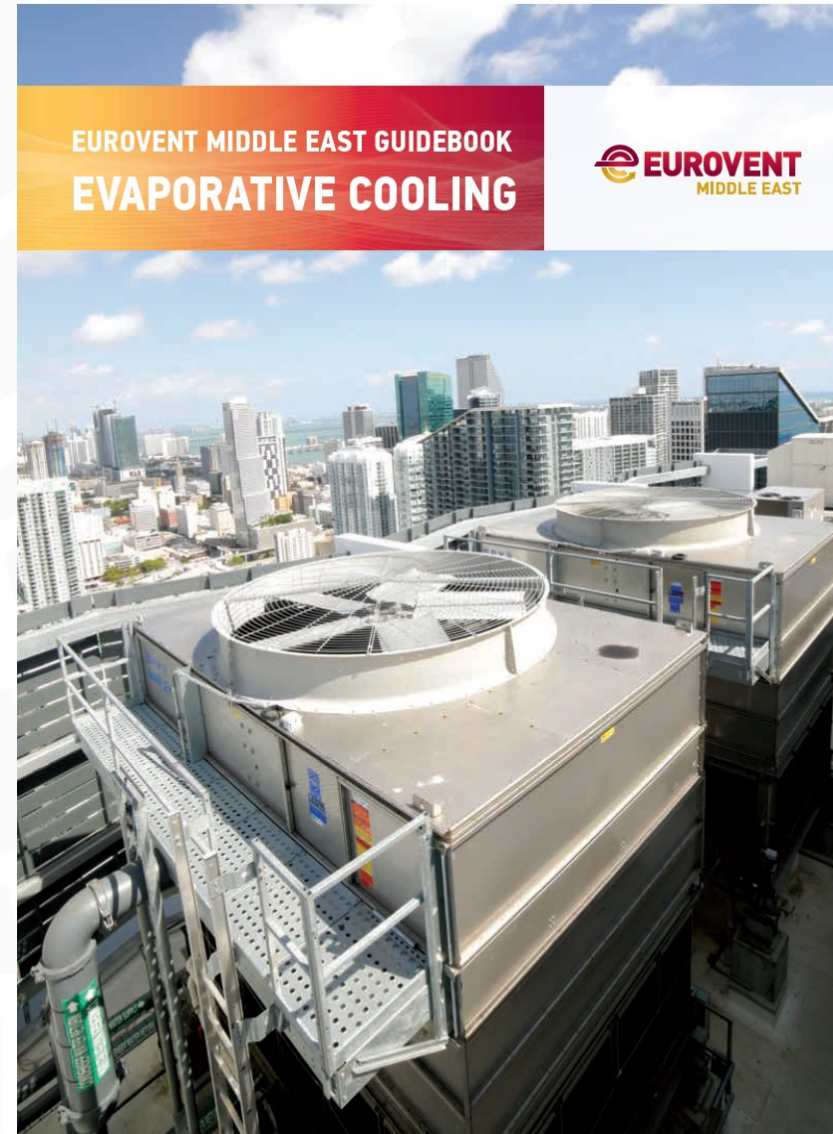
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Agenda

1. Introduction: Guidebook Evaporative Cooling
2. Overview of advantages
3. Working principles
4. Critical aspects of design, installation, and operation
5. Case Study: Total Cost of Ownership
6. Cooling Tower Certification
7. Moderated Discussion

Introduction: Guidebook Evaporative Cooling



Guidebook 'Evaporative Cooling'

3. COOLING TOWERS

3. COOLING TOWERS

A large variety of evaporative cooling equipment exists, with different design principles, sizes and construction materials. While natural draft cooling towers depend on the height of the tower, and the associated differential air pressure between the top and the bottom to naturally induce air through the structure, mechanical draft cooling towers work with the support of fans, to create a forced or induced draft. There are also many options in terms of materials of construction and flow arrangements as the designer can choose the best combination of performance, energy usage and product life for each particular application. Finally, evaporative cooling products are available with a broad range of accessories such as supply controls or sound attenuation packages.

3.1 OPEN CIRCUIT

Water from the heat source enters an inlet connection and is distributed over the fill path through a spray distribution arrangement. Simultaneously, ambient air is induced or forced through the tower, causing a small portion of the water to evaporate. This evaporation removes heat from the remaining water. The cooled water falls into the lower sump from where it is returned to the heat source. It is an open circuit as the water is cooled as it contacts with atmospheric air.

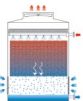


Figure 2: Open circuit cooling tower

3.2 CLOSED CIRCUIT

The fluid to be cooled is circulated inside the tubes of the heat exchanger coil. A secondary system circulates water over the tubes of the coil. Simultaneously, air is forced or drawn over the coil causing a portion of the secondary water

to evaporate. This evaporation removes heat from the fluid through the coil wall. The secondary water falls to the sump from where it is pumped over the coil again. This is called closed circuit as the fluid to be cooled is in a sealed loop and does not come into contact with atmospheric air. A combination of coil and fill is also frequently used in the market as latest technology to improve system efficiencies.

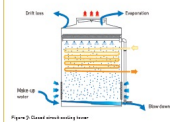


Figure 2: Closed circuit cooling tower

3.3 CROSS FLOW

Warm process water from the heat source enters the water distribution system at the top of the cooling tower where it is distributed over the fill or heat transfer media. At the same time air is drawn from the sides of the coil through the fill. Because the water is travelling vertically down, and the air is passing horizontally across the fill, it creates each other in perpendicular directions, hence the term cross flow.

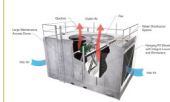


Figure 3: Cross flow cooling tower

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3.4 COUNTER FLOW

Warm process water from the heat source enters the spray system at the top of the cooling tower where it is distributed over the fill or heat transfer media. At the same time air is drawn or forced from below the fill. Because the water is travelling vertically down, and the air is passing vertically up through the fill, they are in counter directions to each other, hence the term counter flow.

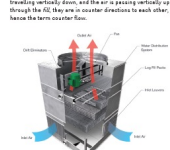


Figure 3: Counter flow cooling tower

While these technologies forms and counter flow are most common, equipment with parallel flow or a combination of different flow technologies also exist.

3.5 INDUCED DRAFT

These cooling towers are characterized by the fan located in the discharge air stream, therefore inducing the air through the tower.

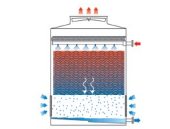


Figure 3: Induced draft, counter-flow cooling tower

2. ENERGY EFFICIENCY, WATER CONSUMPTION AND THE MIDDLE EAST ENVIRONMENT

2.1 ENERGY CONSUMPTION

Because more heat is removed by evaporation than by standard air-to-liquid transfer, evaporative cooling requires up to five times less airflow for a given heat transfer capacity compared to a conventional air-cooled process. This means that as little as a quarter of the electrical energy used in dry cooling is needed.

Using a cooling tower in HVAC systems not only reduces the energy consumption of the condenser water cooling loop, but also provides better returning water temperatures to the chiller to allow for much lower energy consumption on the chiller itself. The other benefit the most power consuming piece of equipment in the system.

Effective heat transfer combined with lower airflow through the coil makes evaporative cooling equipment a triple-winner when it comes to energy savings. Thus, by both application and design, evaporative cooling equipment saves energy and reduces emissions.

1 Evaporative cooling is always more energy efficient than dry cooling.

2.2 WATER CONSUMPTION

In any cooling system, there is a balance between usage of water and power to achieve the required cooling – this is sometimes referred to as the water-energy nexus. Evaporative cooling systems use the significant efficiency of latent cooling to dissipate large amounts of energy whilst using the lowest amount of energy.

In regions with scarce water resources like in some parts of the Middle East, using the water usage from evaporation at the end of higher power consumptions may seem preferable. However, in evaporative cooling systems, the water is recirculated and the water losses through evaporation are rather minimal. On the other hand, condensates must be given to the water that is required for the production of electrical power.



Figure 4: Water-Energy Nexus

A study published in 2012 by the National Renewable Energy Laboratory found that whilst some renewable power generation technologies such as solar and wind have zero water usage, more traditional methods such as nuclear and fossil fuel based, oil, and power plants consume 48,380 gallons (122) of water for each MWh of energy produced. The net overall water saving gained by switching evaporative cooling are therefore minimal, while the impact to the carbon footprint is a whole is negative.

For a recent study on water consumption and reduction methods, refer to the European Recommendations 102 – 206, which is available for free in our Document Library.



Therefore, as a rule of thumb, the industry on a global scale has tended to opt for water cooled systems whenever the cooling capacity required is over 200kW. In areas where there is a complete lack of water availability, larger heat loads can also be considered for air cooled systems. From a general carbon footprint case however, the approach should be where there is water available to use for cooling, use it.

1 Use evaporative cooling to projects over 200kW.

2.3 GREY WATER

Many water-cooled HVAC systems now also make use of grey water in the cooling loop, to reduce the burden on municipal water systems. The wastewater from processes or buildings can be treated to be suitable to pass through a cooling tower system, with the components being selected appropriately based on the quality of water supplied from the treatment process.

Check with manufacturers on the best options and design to reduce power electricity and water saving potential.

EUROVENT MIDDLE EAST

2.4 EVAPORATIVE COOLING IN THE MIDDLE EAST

2.4.1 LOCAL CONDITIONS AND CLIMATE DATA

As the cooling towers cool water by evaporation, the wet bulb temperature (WBT) is the critical design parameter. Typically, the WBT in the region is more than 10°C lower than the dry bulb temperature (DBT), making lower water outlet temperatures as compared to the air-cooled systems. The amount of evaporation is a function of the difference between DBT and WBT and the heat load.

The larger the difference between these two temperatures are, the bigger the efficiency gains by evaporative cooling. For example, this means that even on hot summer days in Riyadh with an ambient dry bulb temperature of 44.8°C, evaporative cooling equipment can easily cool water down to temperatures of 24°C. How is that possible? The wet bulb temperature in Riyadh for this period is shown to be 25.5°C. Certified evaporative cooling equipment can cool down to within 1.0°C of the given wet bulb temperature.

To understand the potential and requirements, it is important to look at the full climatic data of a specific location. Such data is provided by local meteorological agencies and is also published regularly by ASHRAE.

KEY TAKEAWAYS

- Cooling towers are designed for specific wet bulb temperatures. To establish the correct wet bulb temperature for any given location, refer to ASHRAE or local weather data.
- Evaporative cooling is always more energy efficient than dry cooling.
- Use evaporative cooling in projects over 200kW.
- Consult with manufacturers on the best plant layout.
- Incorrect plant design can lead to misreculation and significantly reduce plant's capacity.
- Not maintaining systems regularly results in a loss of money every day.
- Water treatment programmes are crucial to maintain performance and avoid harmful bacteria and chemical accumulation.
- Comprehensive maintenance programmes save money.
- Quality should never be compromised by questions of costs. Remember, cheap is always more expensive.
- Independent third-party certification is essential to avoid discrepancies between published performance data and actual performance.
- Factory assembled products with CE Eurovent certification do not require any further testing on site.
- Evacuation certificates shall be cross checked with an online database to ensure their validity.

DEFINITIONS

This Guidebook provides a comprehensive glossary on page 27, which contains all specific terminology used throughout the text, defining its meaning to promote a better understanding of the Guidebook contents. All terms within the text which are further explained in the glossary are printed in course letters.

Guidebook 'Evaporative Cooling'



Guidebook 'Evaporative Cooling'



**BALTIMORE
AIRCOIL COMPANY**



Guidebook 'Evaporative Cooling'

We appreciate your feedback!

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Evaporative Cooling Advantages

Mr Chukri Al Aani

Regional Sales Manager – MEA & Turkey
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What are your design goals?

- Comfort
- Efficiency
- Cost
- Reliability
- Sustainability
- All of the above

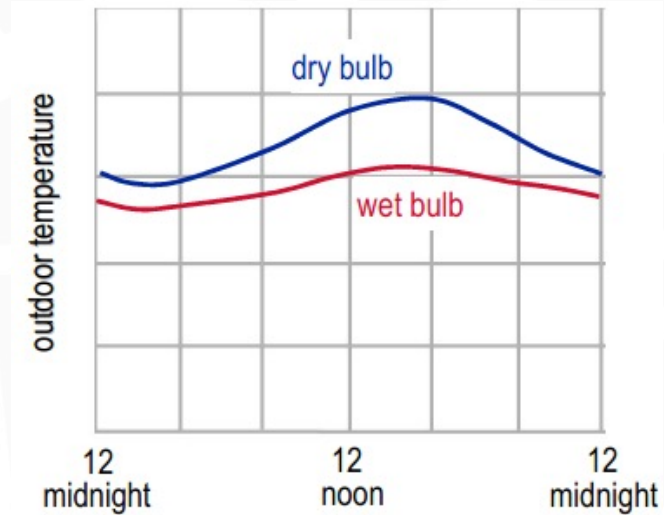
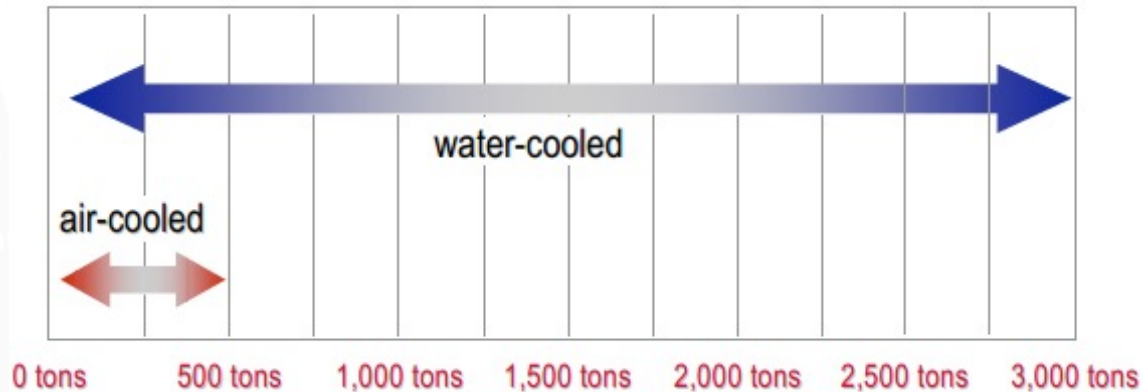


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Water-Cooled System Advantages

- Evaluated Cost (Energy Use)
- Capacity/Comfort/Control (Water-cooled chillers capacity)
- Noise and Maintenance Time (No. of Fans & equipment)
- Smaller Footprint (No. of Chillers)
- Total Water Usage (Power Generation)

System Definition: Water-Cooled Chiller vs. Air-Cooled Chiller



- **Water-cooled chiller has a larger capacity**
- **Utilisation of cooling tower requires extra piece of equipment, but allows us to cool below dry bulb temperature**

The Value of Evaporative Heat Rejection

Vs. Alternative Systems

Highest energy efficiency

- 50% less energy usage on typical application

Lower GHG Emissions

- Significantly lower; less than half of the CO₂ footprint

Comparable or lower water usage

- Up to 40% less water consumption (high water usage in power production)

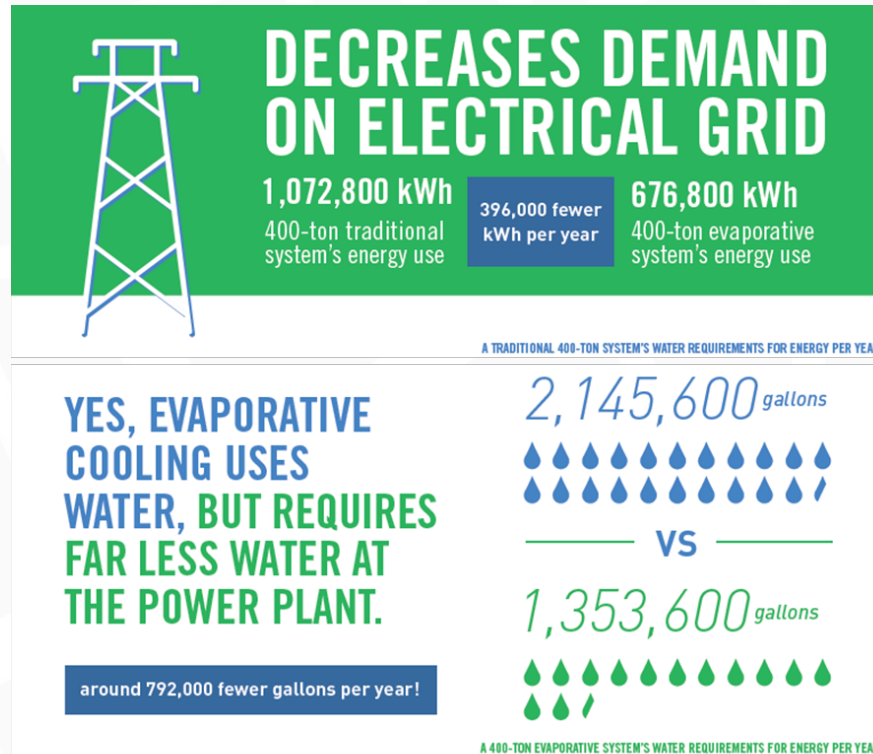
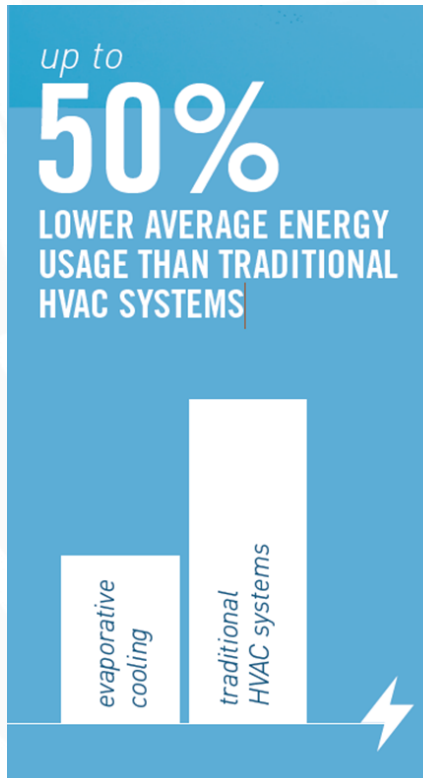
Other User Benefits

- Less noise – 2 fans vs. 20 fans, typical
- Environmentally friendly materials – recycled PVC, less metal usage
- Space – 2 - 5X less space for heat rejection

Evaporative Cooling is Sustainable with Significant Environmental and Water Usage Benefits

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Benefits of Evaporative Cooling



Source: Alliance to Prevent Legionnaires' Disease

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Evaporative Cooling: Working Principles

Mr Jai Kawrani

Application Manager – Middle East & India

Baltimore Aircoil Middle East LLC

Methods of Cooling

AIR COOLED

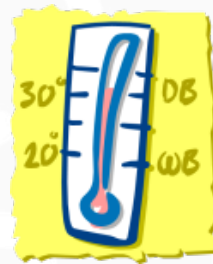


Dependent on ambient
(dry bulb)
temperature

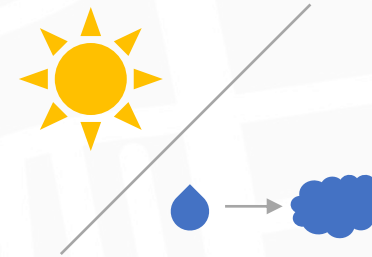
EVAPORATIVE COOLED



Evaporative cooling, dependent
on wet bulb temperature



HYBRID, WET/DRY, ADIABATIC

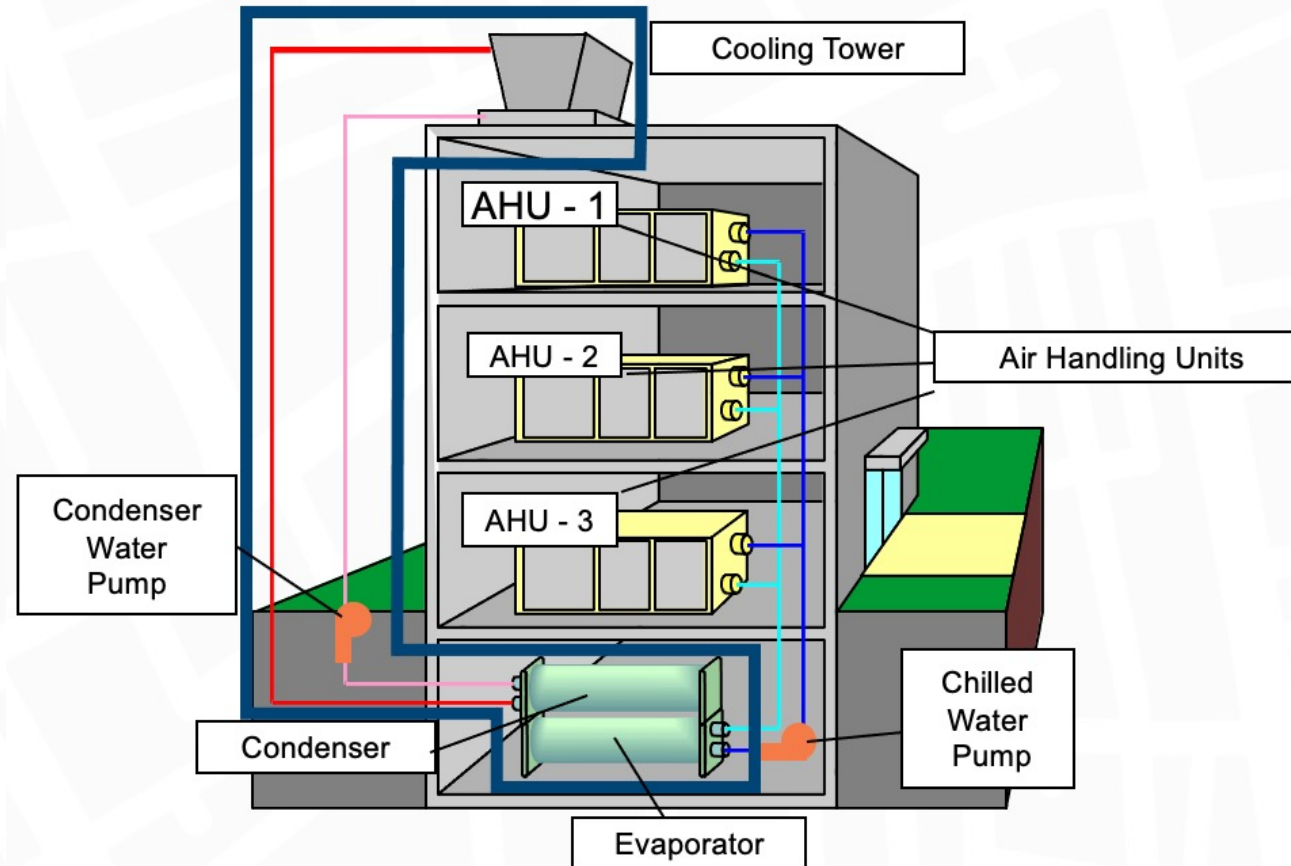


Dependent on both
dry bulb and wet bulb
temperatures

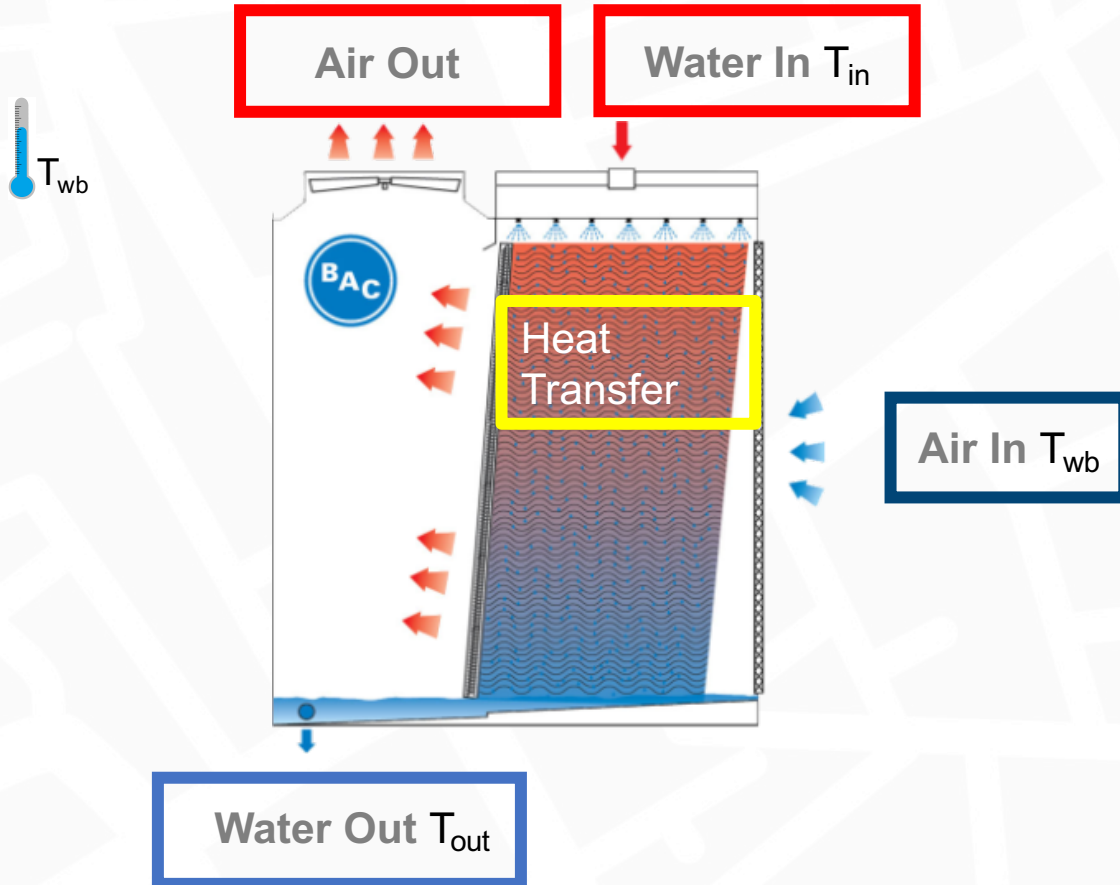


Typical $>10^{\circ}\text{C}$ difference between wet bulb and dry bulb

Traditional Water-Cooled HVAC System



Principles of Evaporative Cooling



T_{in} : Water Inlet Temperature ($^{\circ}\text{C}$)
 T_{out} : Water Outlet Temperature ($^{\circ}\text{C}$)
 T_{wb} : Wet Bulb Temperature ($^{\circ}\text{C}$)

Range = $T_{in} - T_{out}$

Approach = $T_{out} - T_{wb}$

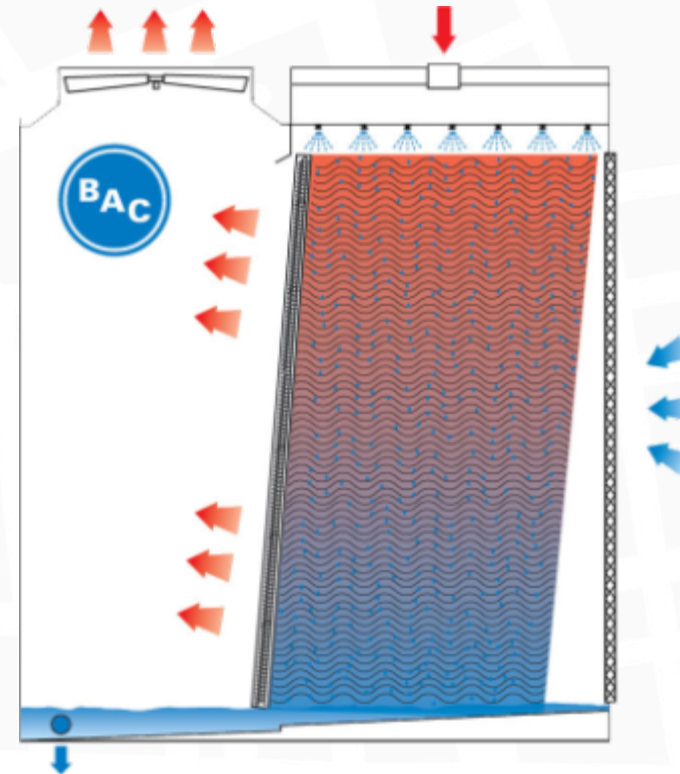
Principles of Evaporative Cooling

Heat transfer

- Sensible
- Latent

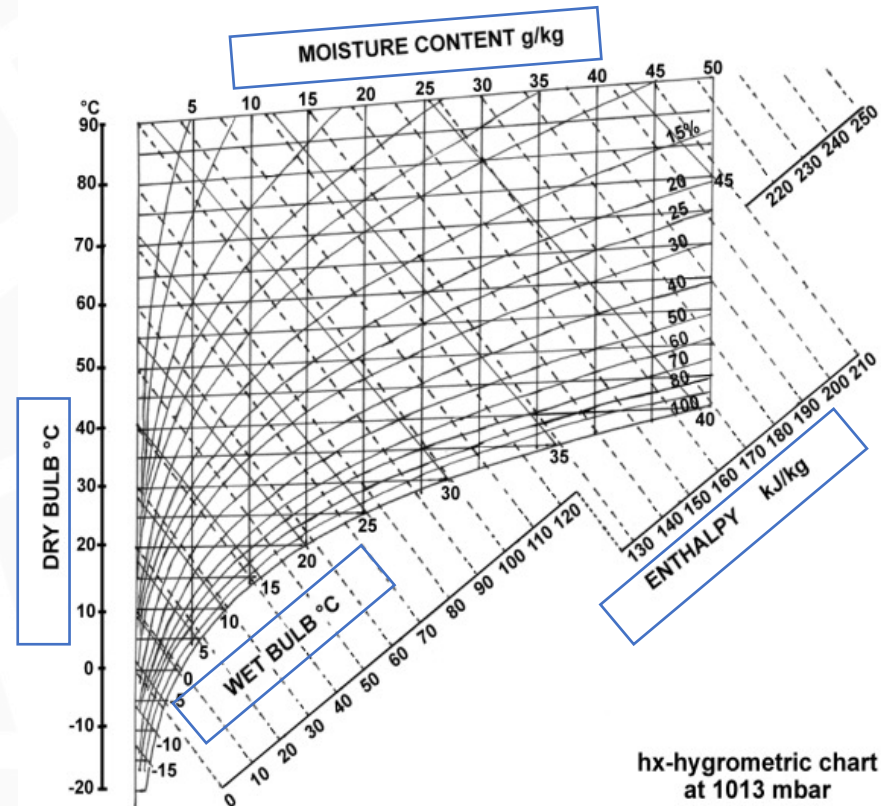


For every kilogram of water evaporated, 2256 kilo Joule of heat is removed from the water (whereas with 1 Kilogram of air, the heat removed is about 1 kilo Joule per deg C)



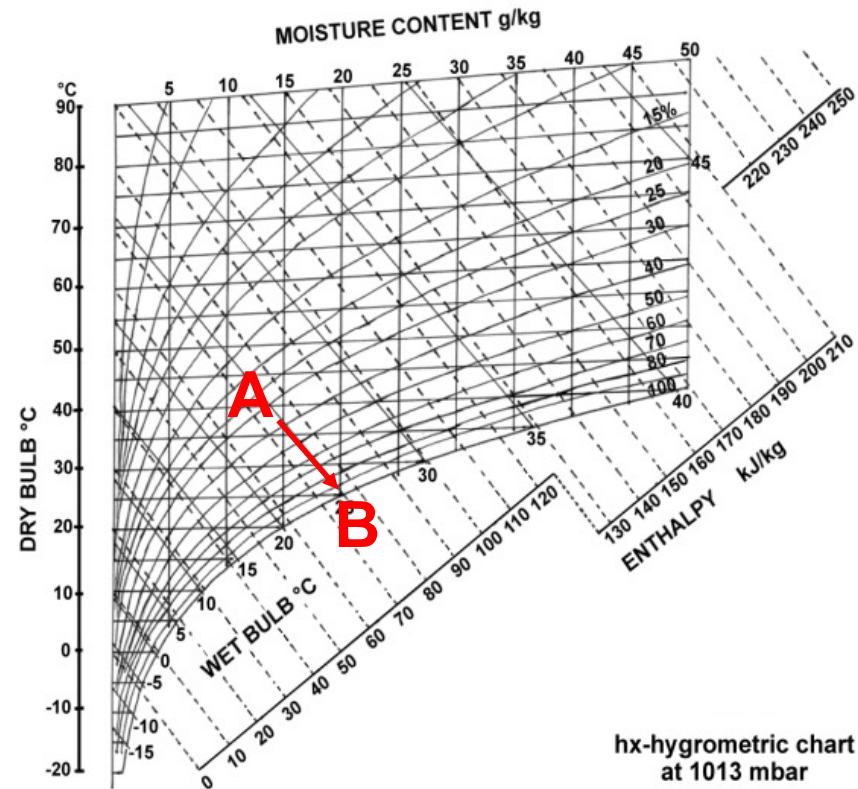
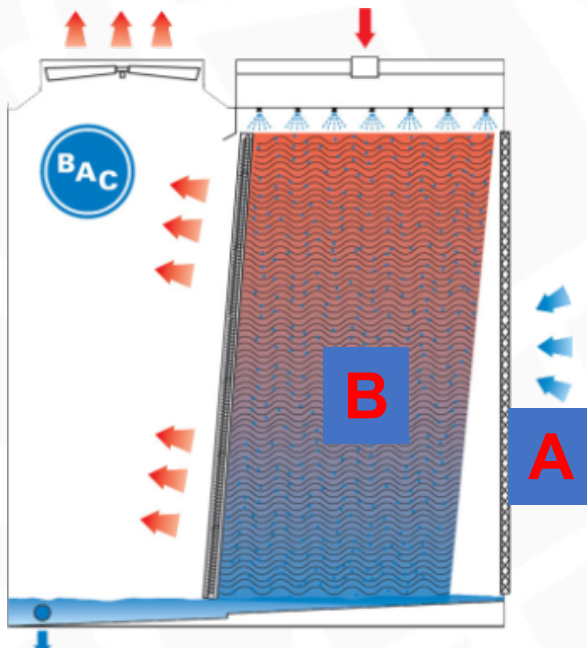
Principles of Evaporative Cooling

Dry Bulb
Wet Bulb
Enthalpy
Moisture Content



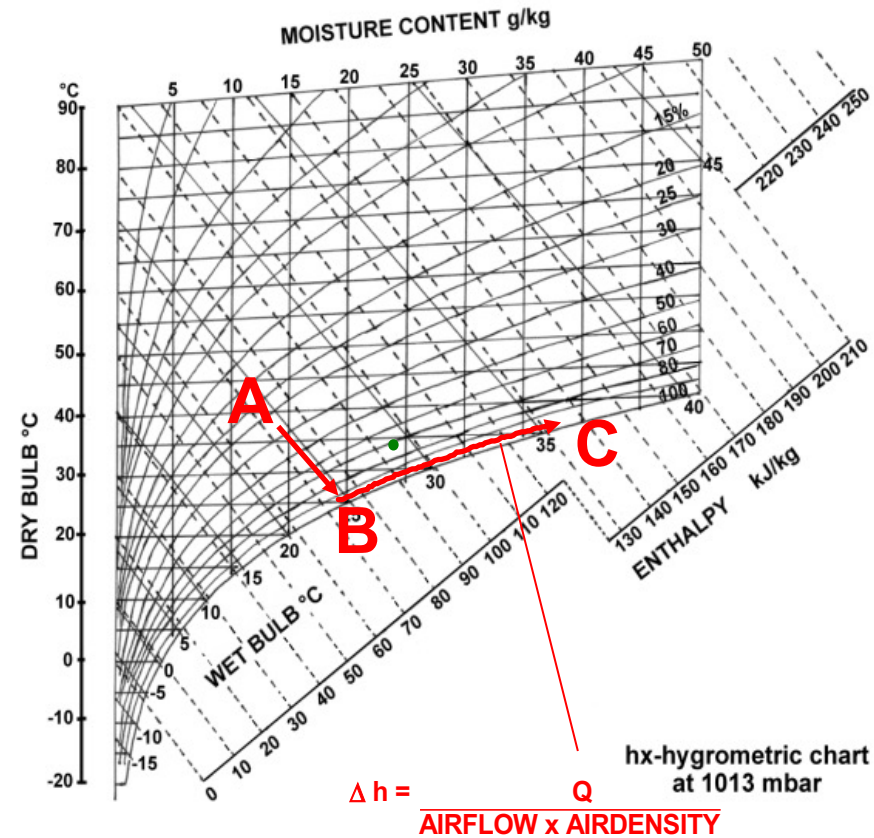
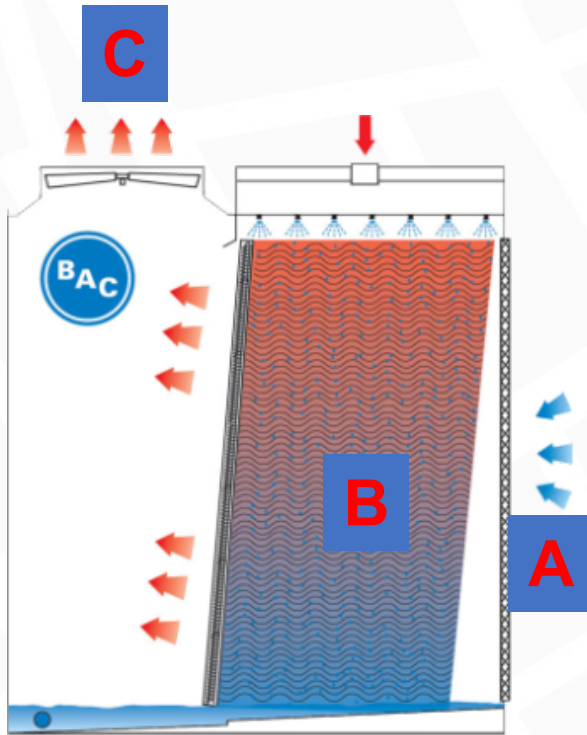
Principles of Evaporative Cooling

Air gets saturated



Principles of Evaporative Cooling

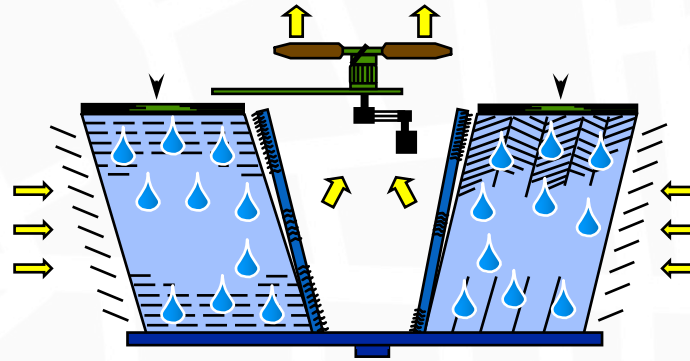
Air heats up



HVAC System

$$\text{kW} = \text{flow (lps)} \times \text{delta T} \times 4.186$$

- The cooling tower does not control the range or flow
- The cooling tower only controls the approach



HVAC System Optimisation

10°C Approach
10.1°C Range
4300kW

T_{in} = 41.1°C
T_{out} = 31.0°C

22kW Fan motor



6°C Approach
5°C Range
2100kW

T_{in} = 32°C
T_{out} = 27°C

22kW Fan motor



3.5°C Approach
2.5°C Range
1100kW

T_{in} = 27°C
T_{out} = 24.5°C

22kW Fan motor



Constant

- ♦ Flow: 100.9 l/s
- ♦ **Wet bulb: 21°C**

Variable

- ♦ Range

Same Cooling Tower can handle different capacities

HVAC System Optimisation

10°C Approach

$T_{in} = 36^{\circ}\text{C}$
 $T_{out} = 31^{\circ}\text{C}$

15kW Fan motor



6°C Approach

$T_{in} = 32^{\circ}\text{C}$
 $T_{out} = 27^{\circ}\text{C}$

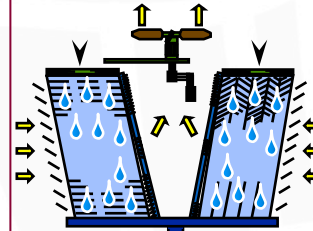
22kW Fan motor



2°C Approach

$T_{in} = 28^{\circ}\text{C}$
 $T_{out} = 23^{\circ}\text{C}$

45kW Fan motor



Constant

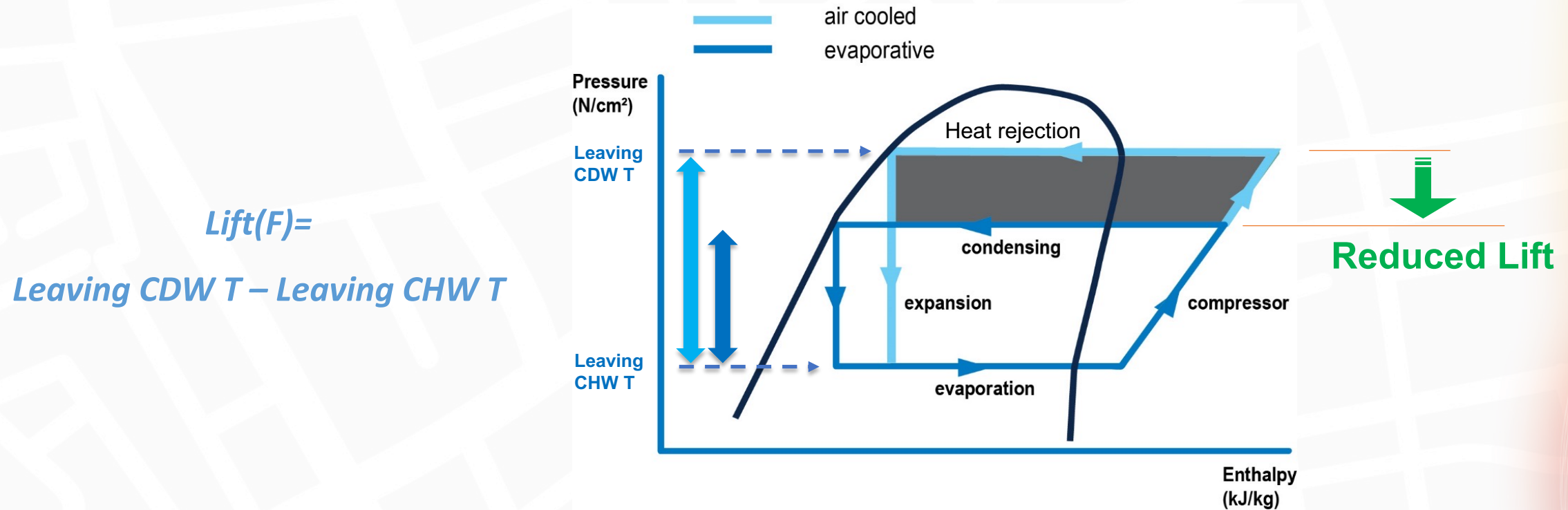
- ◆ Flow: 100 l/s
- ◆ Range: 5°C
- ◆ Heat rejection: 2100kW
- ◆ Wet bulb: 21°C

Variable

- ◆ Approach

Design for smaller Approach with a larger Cooling Tower → reduces the Chiller size

HVAC System Optimisation



For every 1°C decrease in condenser water → decreases the energy usage of the chiller by approx 3%

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Critical Aspects of Design, Installation and Operation

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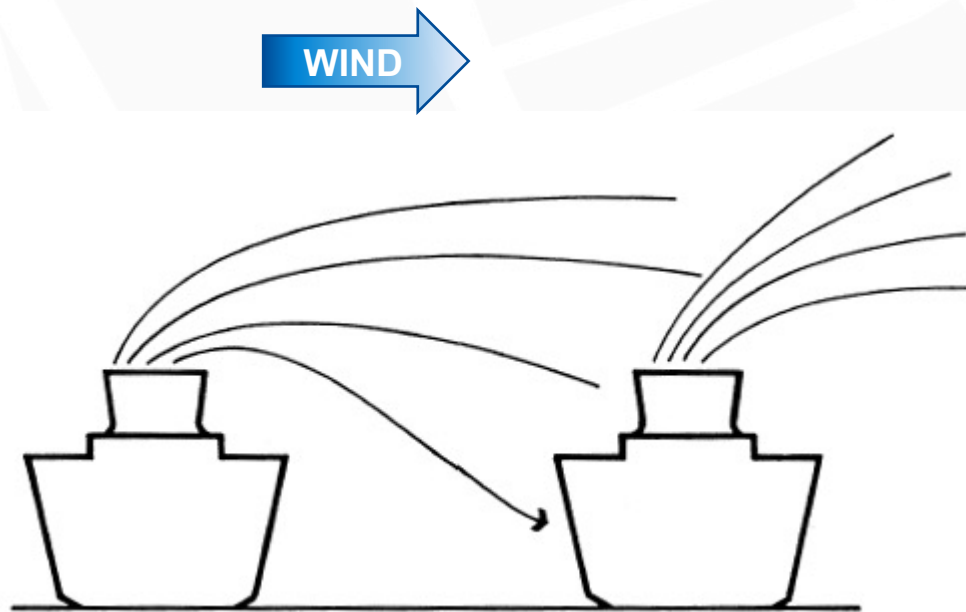
Cooling Towers Design

- **Space available**
- **Obstacles/other heat sources surround the site**
- **Noise requirements**
- **Plume**
- **Cooling tower maintenance**
- **Types of cooling towers**

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Interference

It is wet bulb at the tower air inlet that matters

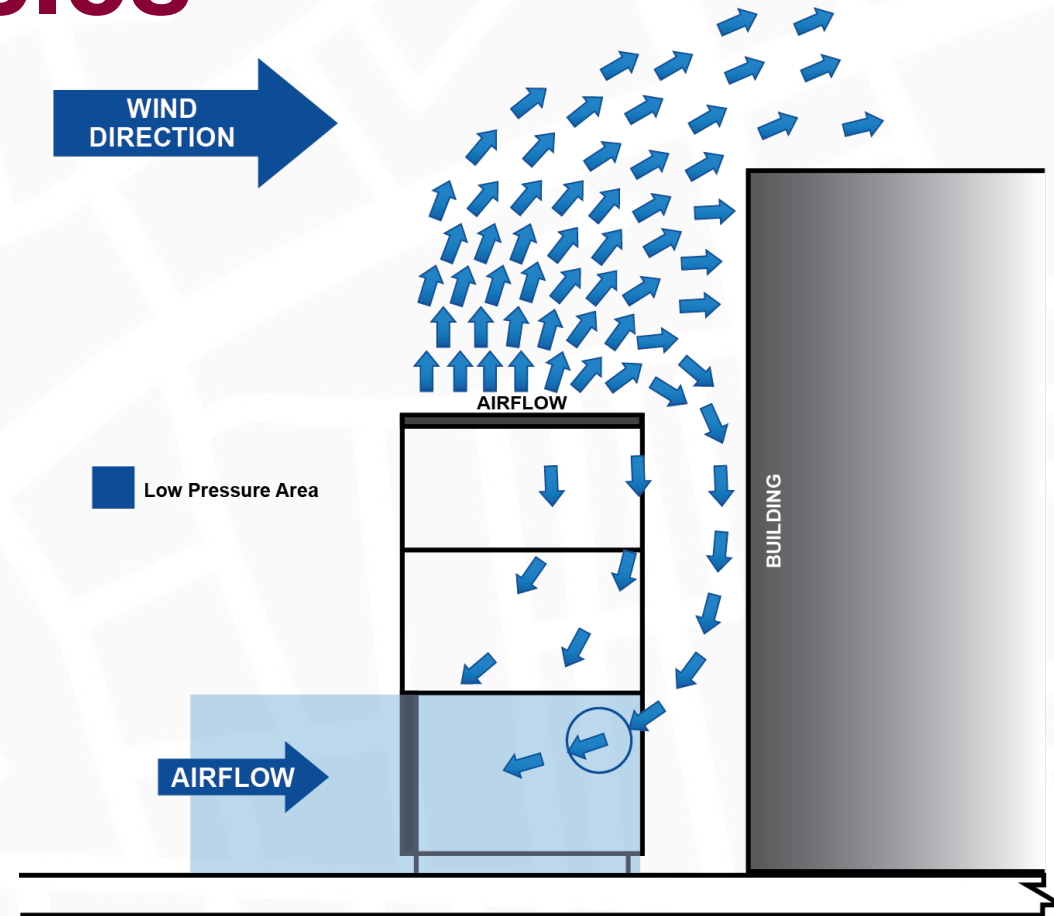


Local heat sources upwind of the cooling tower can elevate the wet bulb temperature of the air entering the tower, thereby affecting its performance. This could be an existing cooling tower, or another source of heat. This phenomenon is called “interference.”

Space & Obstacles

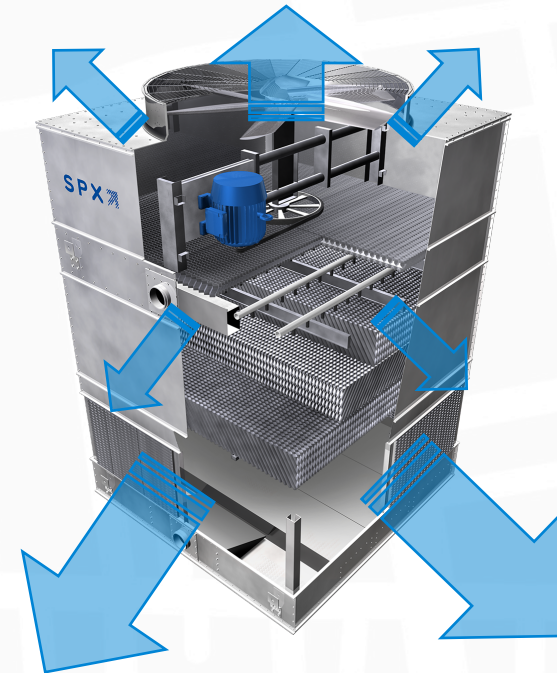
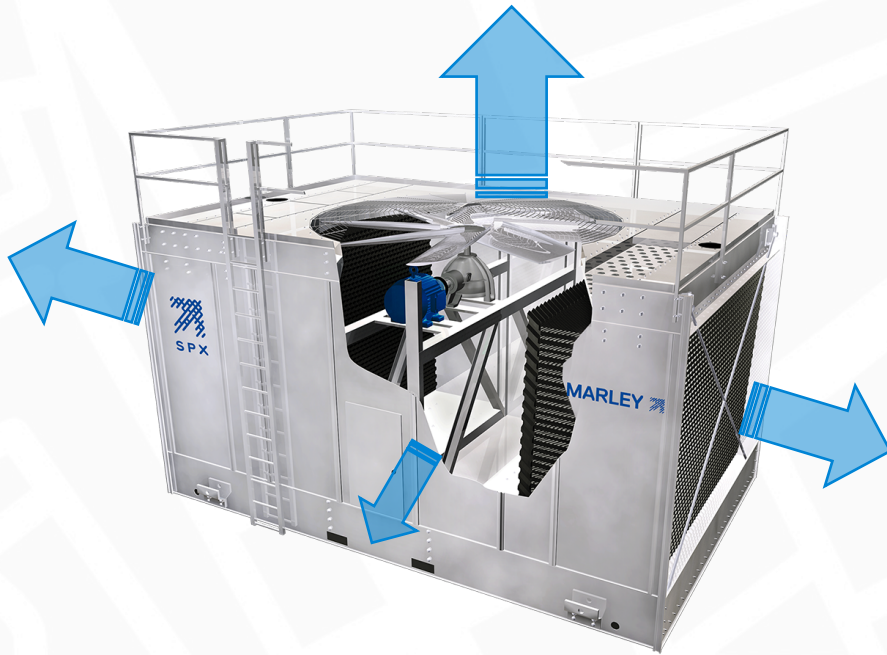
When siting a cooling tower next to a building, wind direction and discharge elevation need to be considered to avoid recirculation.

The higher building elevation, and low discharge velocity encourages the air back down towards the low-pressure area around the air inlet, created by the high inlet velocity of a forced draught configuration.



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Primary Measurement Locations/ Breakout Sources



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Primary Measurement Locations Breakout Sources

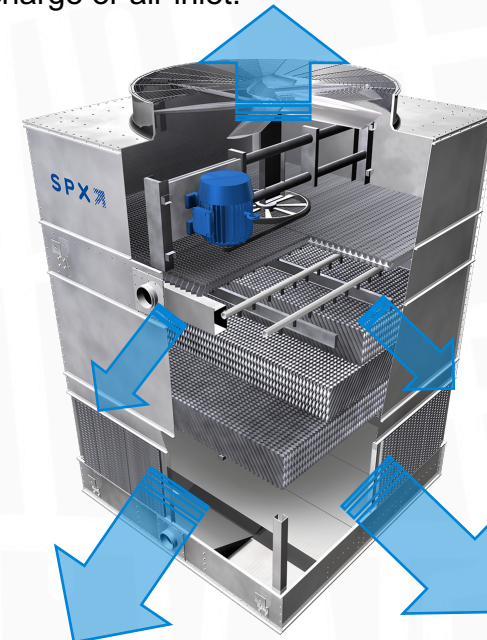


Counterflow

- Air inlets & fan discharge primary measurement locations
- Falling water noise produces higher frequencies at the air inlets, and on an induced draft tower this is typically on all 4 sides
- Again, noise breakout will also occur through the casing, although much less than fan discharge or air inlet

Crossflow

- Air inlets & fan discharge primary measurement locations.
- Because there is no falling water noise, air inlet noise is less prominent than a counterflow equivalent – lower frequency.
- Noise breakout will also occur through the casing, although much less than fan discharge or air inlet.



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Cooling Tower Noise

- Where is cooling tower sound important?
 - Where people will be to hear it!
 - Varies with every installation
 - Considerations
 - Near field: occupational safety
 - Far field: property line sound levels

Properly defining sound requirements is critical to making sound decisions.



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Sound Success Strategies

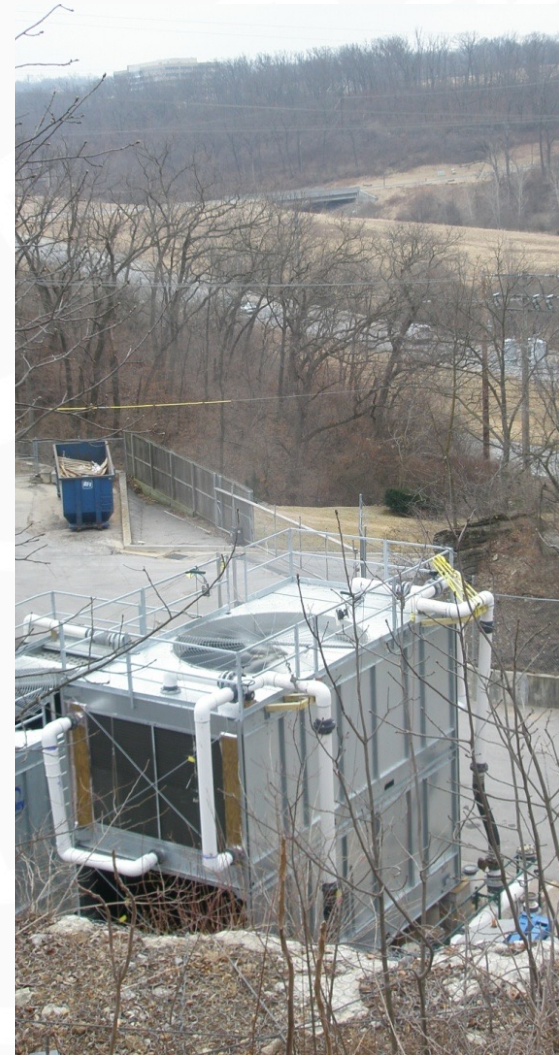
- Understand the project specific-requirements for noise
 - Where and what is the noise sensitive area
 - What options are there for where/how the tower can be oriented
 - Are there particular times of day that are more noise sensitive? – Running the fans at a lower speed at night will reduce noise
 - 50% speed = 12dB(A) approx
 - 66% speed = 8dB(A) approx

Cooling Tower Noise Treatment

- Re-orientation of tower
- Lower air inlet height (typically field erected only)
- Splash attenuation mats (counterflow only)
- Variable speed gearbox
- Incorporated and/or external barriers
- Low noise fan
- Inlet/outlet attenuators
- Ultra quiet fan, super low noise fan, ...

Consider options to reduce noise in order of cost

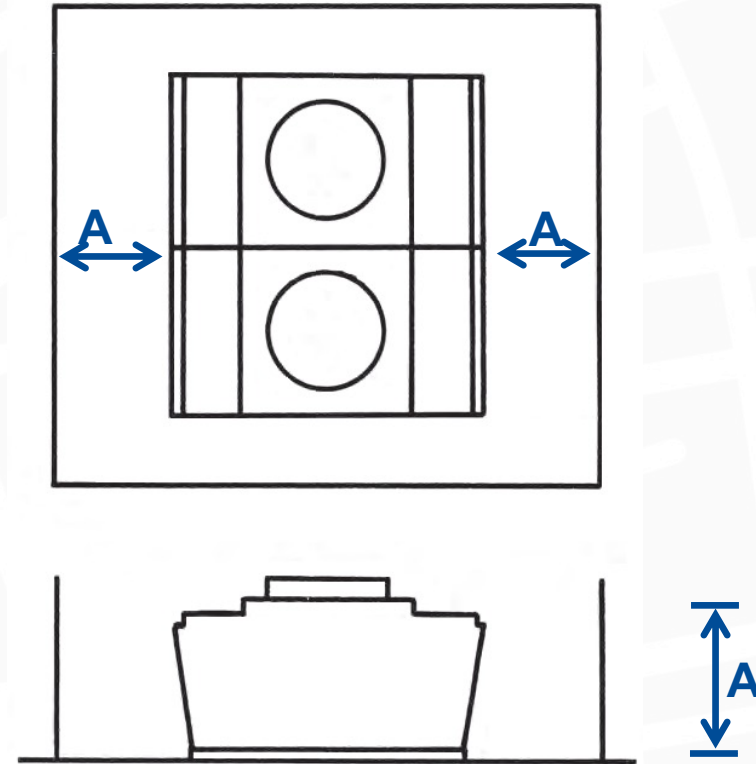
Plume



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Induced Draft Crossflow Tower

- Induced draft towers develop less total static pressure than forced draft towers.
 - more sensitive to the impact of external air losses
 - air inlet clearances must be governed by their potential to add system air losses***



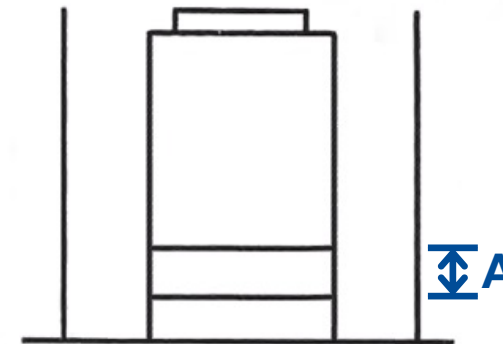
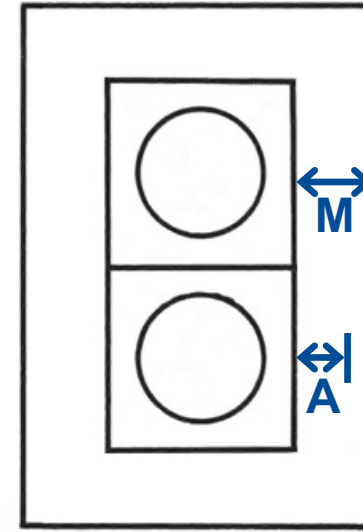
Rule applies to 1 or 2 cell towers only. For towers with more than 2 cells, add 15% to the dimension for every extra cell

Maintenance Access: Induced Draft Crossflow



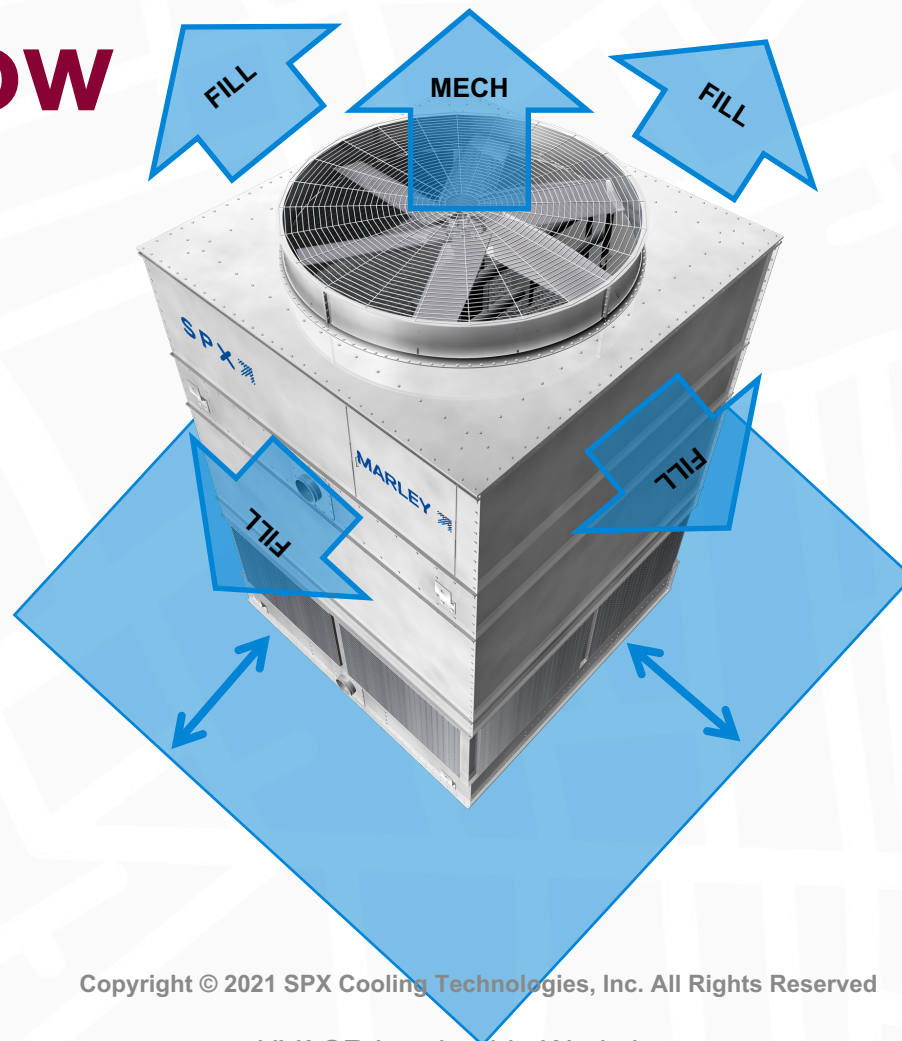
Induced Draft Counterflow Tower

- Because this distance is so much smaller typically on an induced draft counterflow, maintenance access becomes the deciding factor, not airflow.
- Typical maintenance access for this type of tower would be a minimum of 1000mm. Under normal circumstances, more than this would be given to allow for comfortable working.



Rule applies to 1 or 2 cell towers only. For towers with more than 2 cells, add 15% to the dimension for every extra cell

Maintenance Access: Induced Draft Counterflow



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Case Study: Total Cost of Ownership

Mr Rafael Van Eijcken

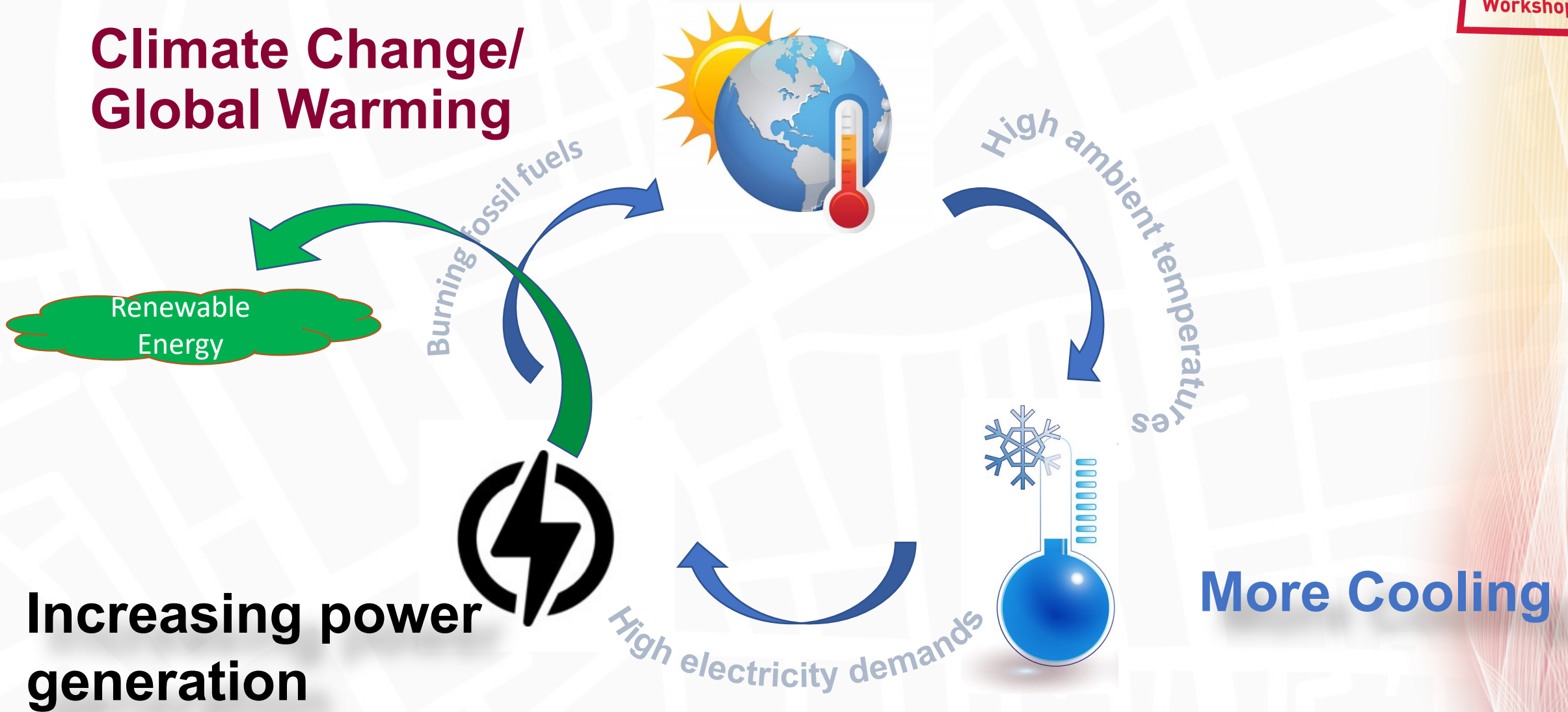
General Manager - Middle East, Turkey and India

Baltimore Aircoil Middle East LLC

***“If you want different results,
do not do the same things!”***

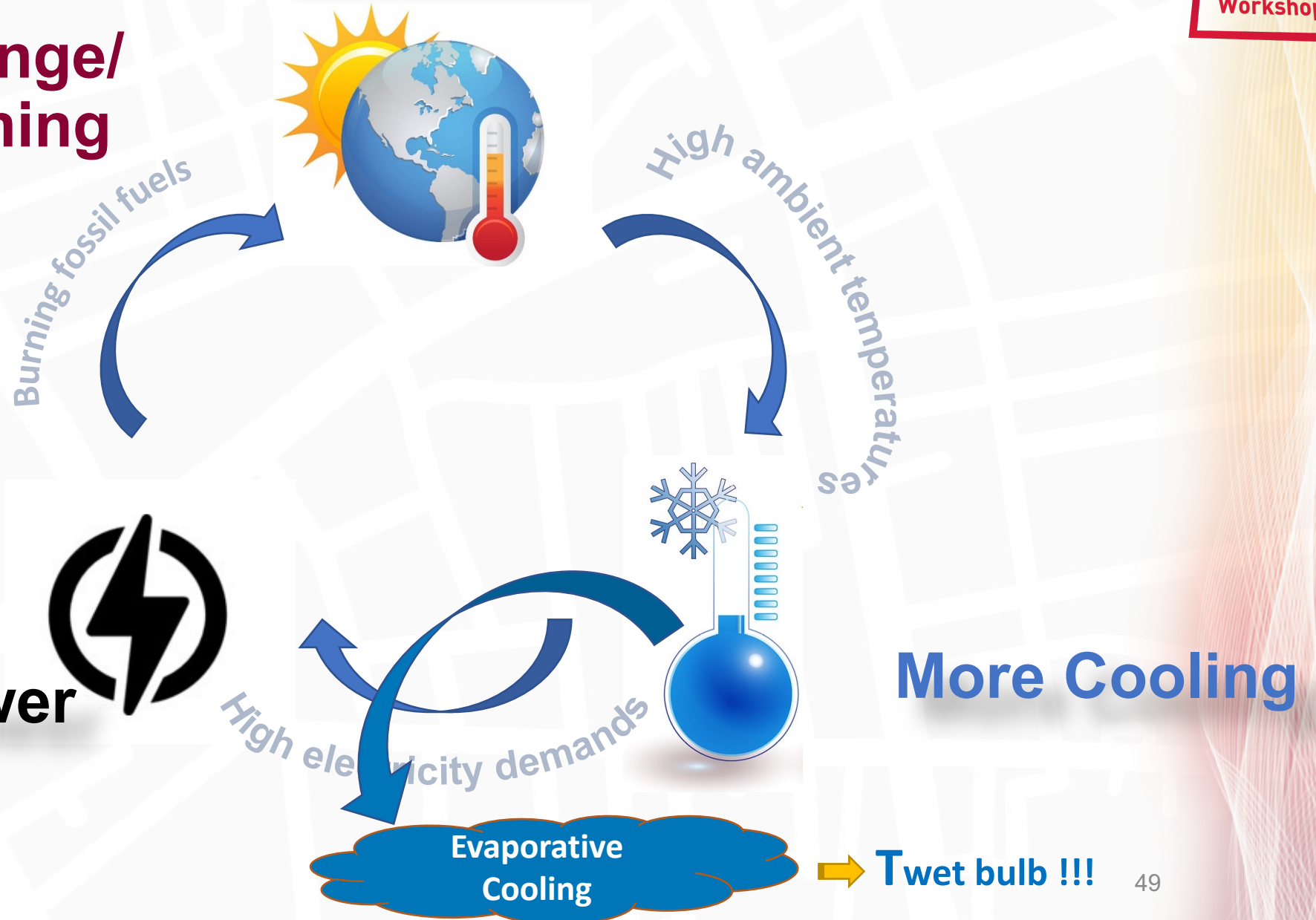
— Albert Einstein

Climate Change/ Global Warming



Climate Change/ Global Warming

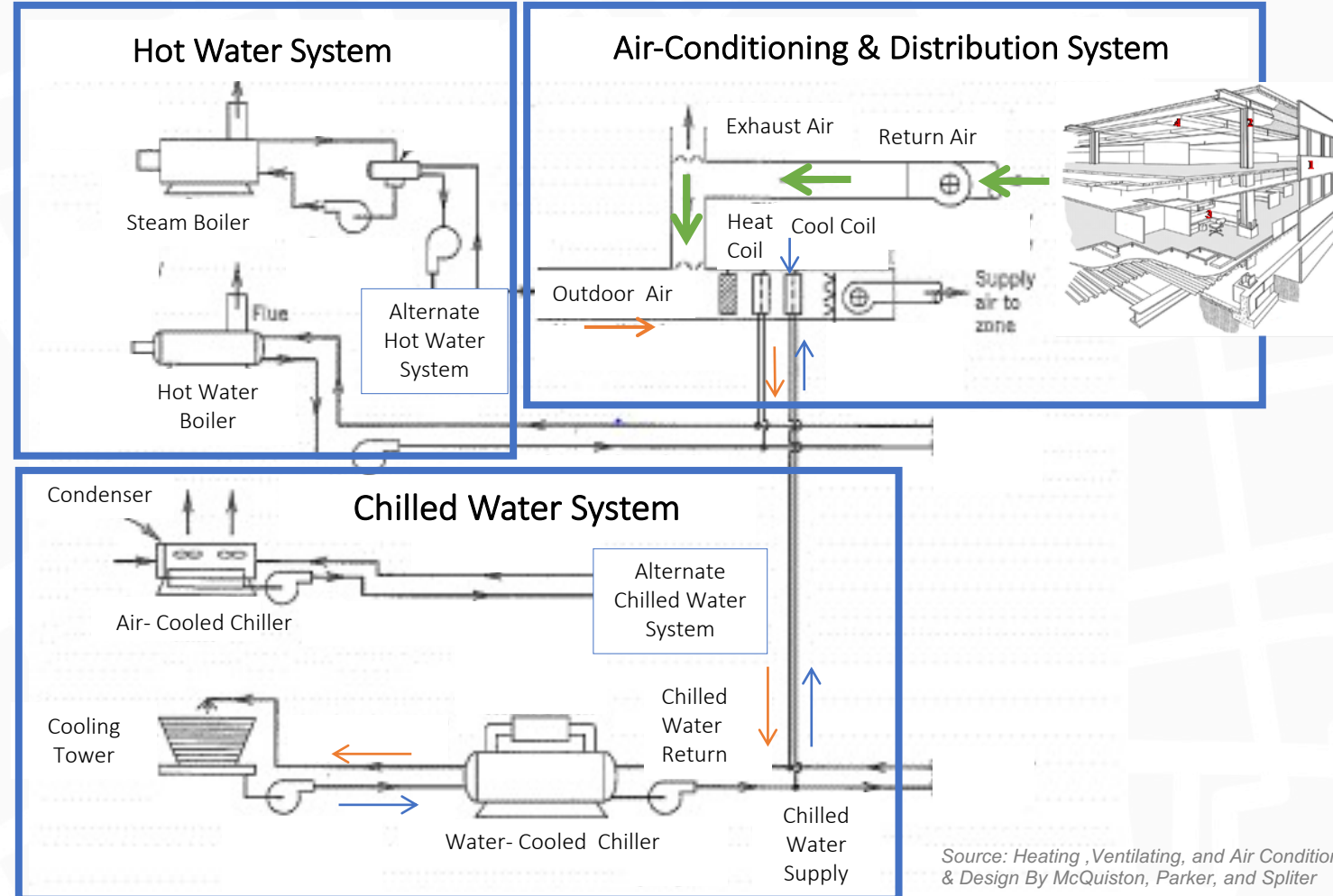
**Increasing power
generation**



Example: Typical HVAC System

Air-Cooled System →

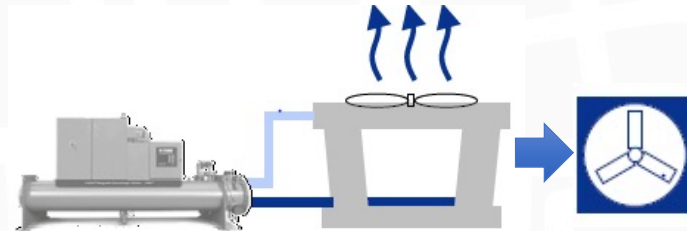
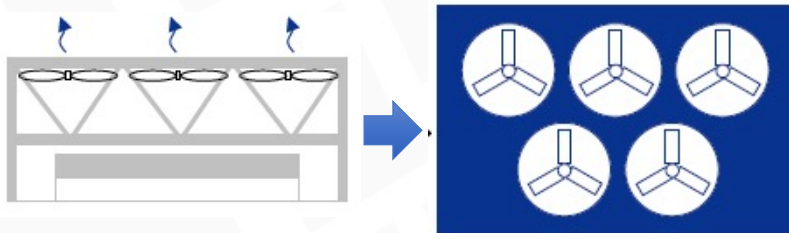
Water-Cooled System →



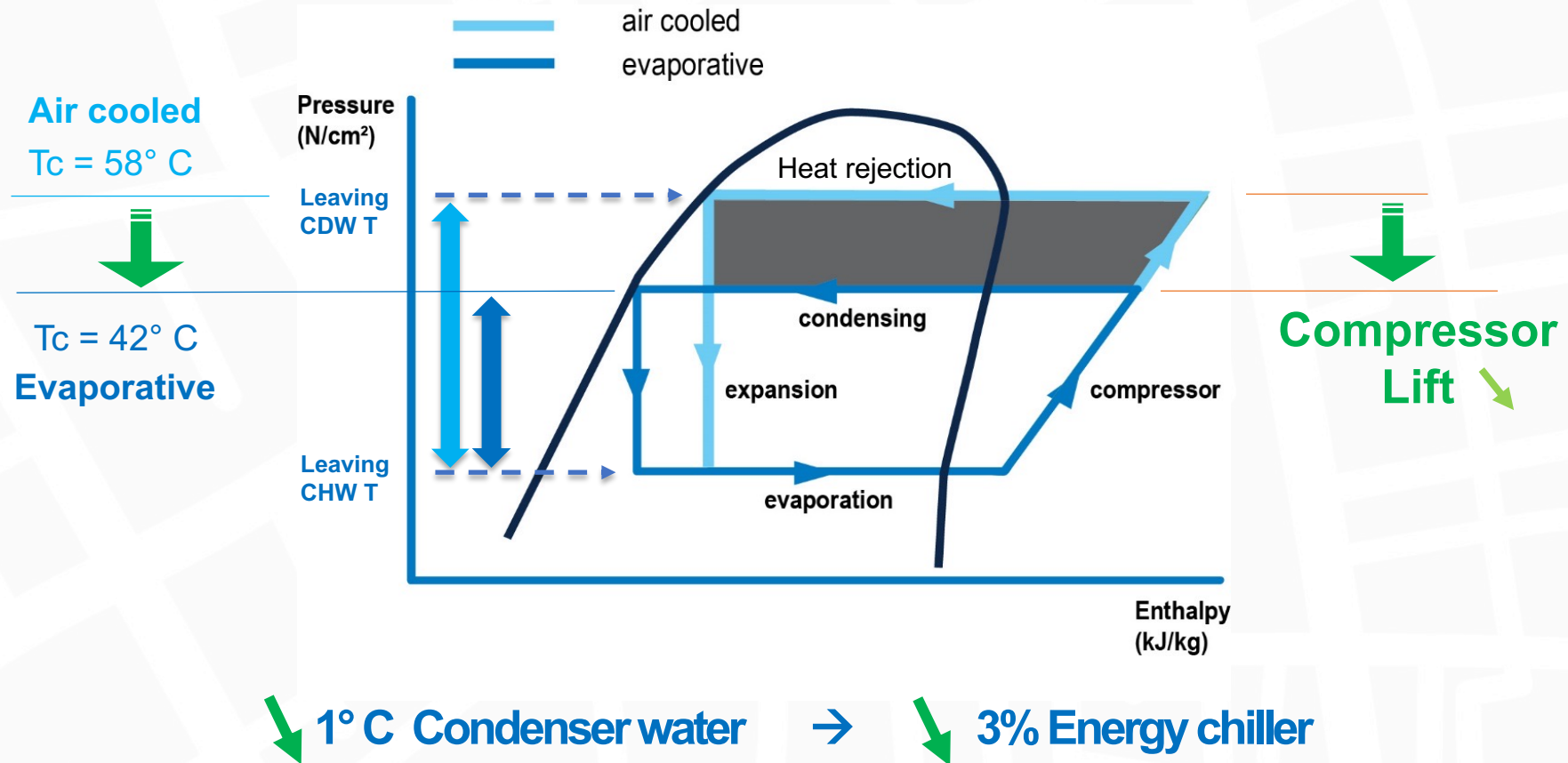
Source: Heating, Ventilating, and Air Conditioning Analysis & Design By McQuiston, Parker, and Splitter

Air-Cooled vs Water-Cooled Heat Rejection

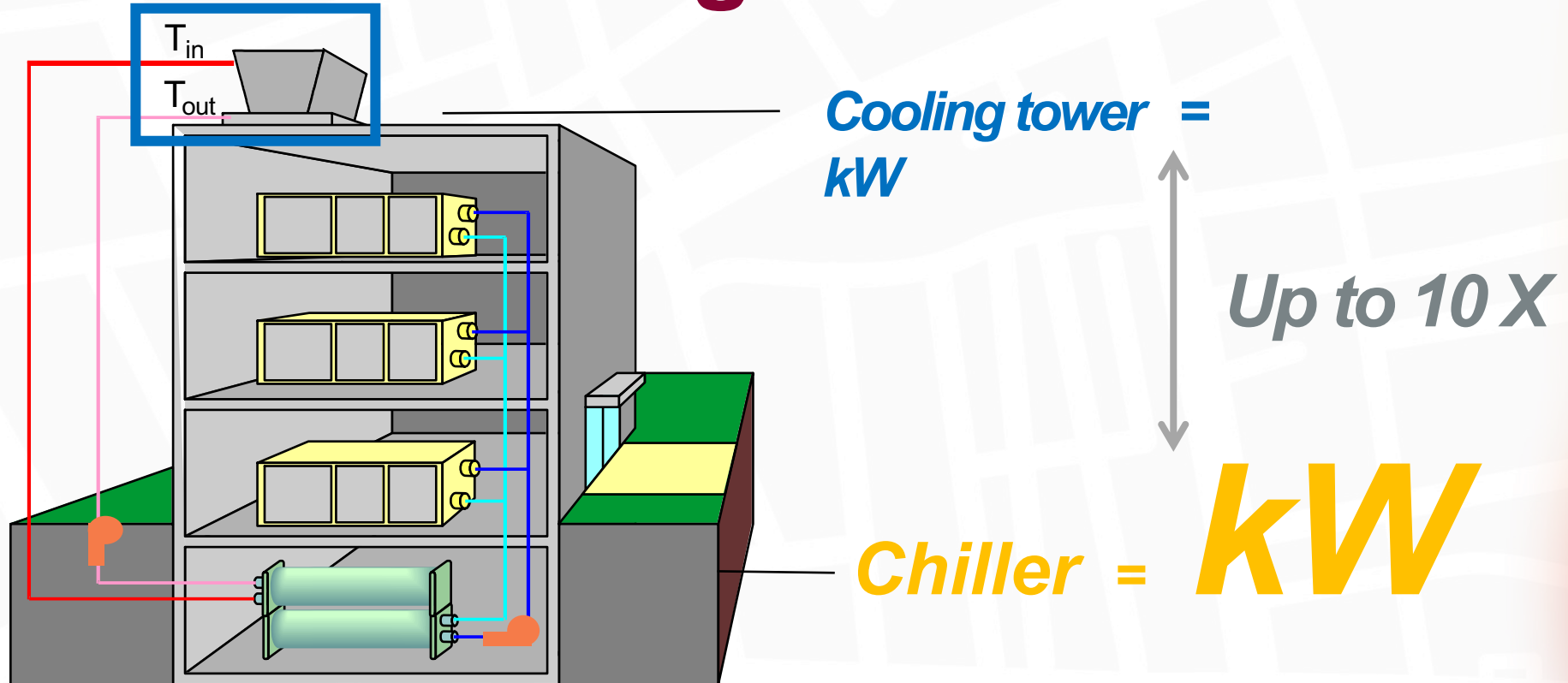
AIR-COOLED SYSTEM		WATER-COOLED SYSTEM	
1.	Design day is based on DRY bulb temperature		Design day is based on <u>WET Bulb</u> temperature
2.	Larger outdoor technical footprint (more surface area)		<u>Smaller</u> outdoor technical <u>footprint</u>
3.	Higher energy consumption		<u>Lower energy</u> consumption
4.	Higher noise emissions (many small fans)		<u>Lower noise</u> levels
5.	Consumes no water, at site (significant water usage at power plant)		Consumes water (Evaporative cooling) – TSE water



Air-Cooled vs Water-Cooled Heat Rejection

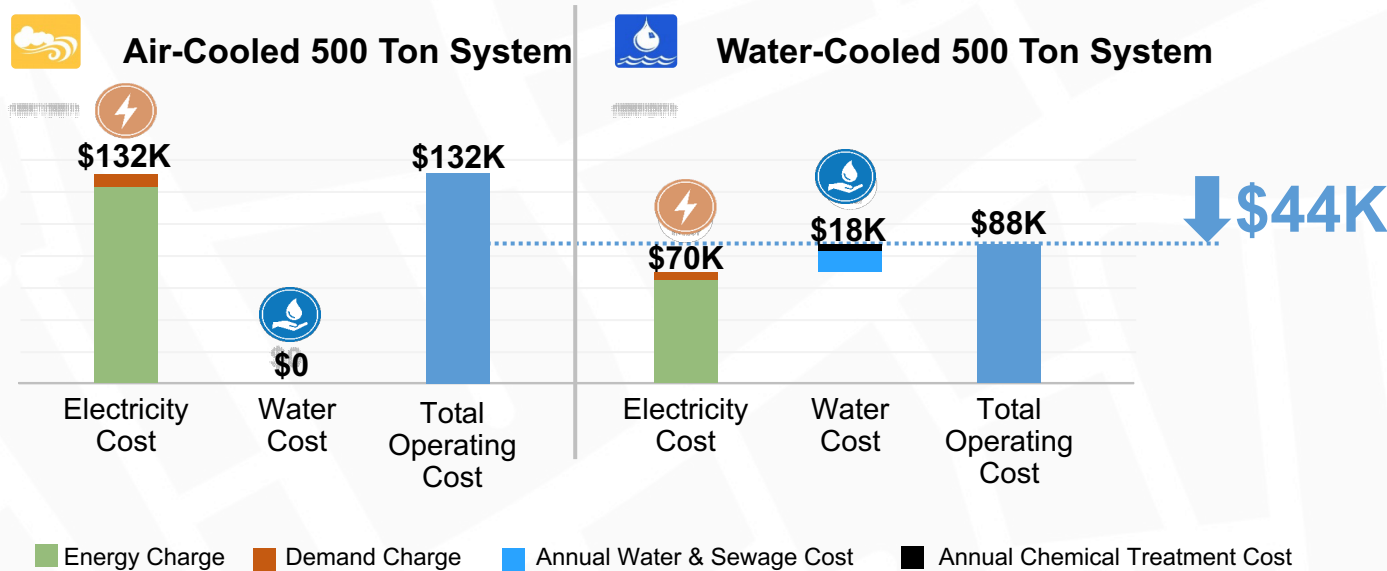


Evaporative Cooling in HVAC



Chiller is the **MAIN** energy consumer in an HVAC system

Annual Operating Cost



Assumptions:

Energy rate \$0.103/kWh. Demand Charge \$13.44/kW. Water rate \$2.9/1000gal.
Sewage rate \$5.3/1000gal. Hrs of Operation (IPLV) 4380.
Considered system cleaning equal for systems as both HEX open to atmosphere

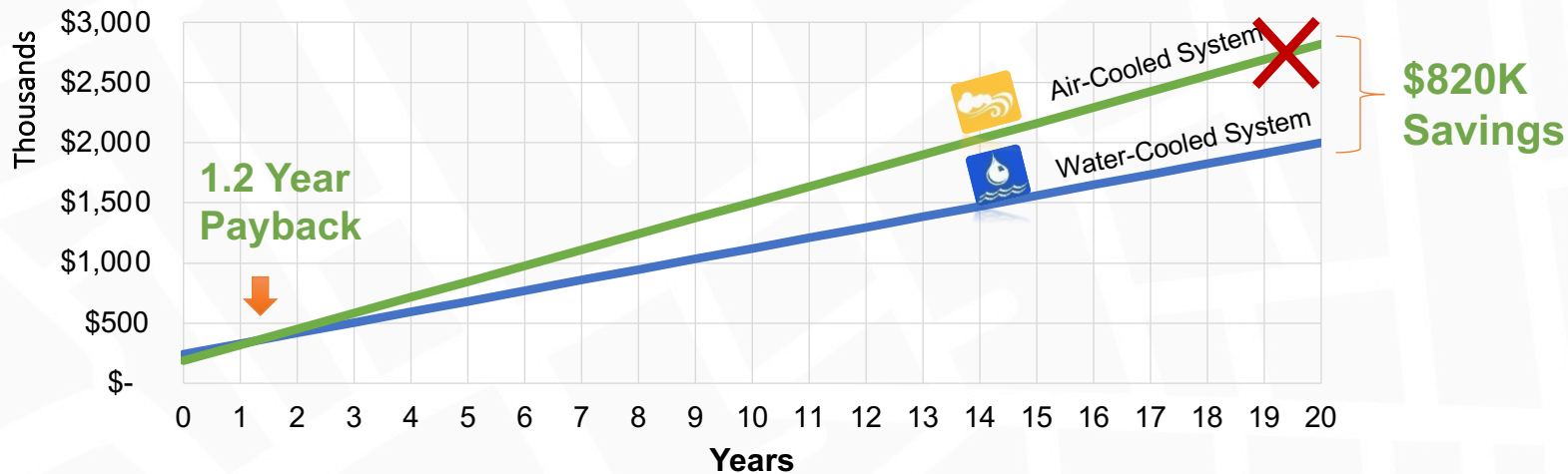
Water-Cooled Advantage:

- Savings of \$44,000 annually
- 48% Energy Savings
- 33% savings on annual operating costs

System Total Cost of Ownership

500 Ton System Cost	Equipment & Install	Annual Operating	Avg. Life*
Air-Cooled System	\$188K	\$ 132K	15-20 years
Water-Cooled System	\$ 242K	\$ 88K	20-30 years

* Selecting Chillers, Chilled Water Systems by David Grassl. <https://www.csemag.com>



Important Note:

Indirect costs linked to additional (valuable) spacing requirement and Sound reducing barriers/technologies can be very significant !!!

Water-Cooled Advantage:

- Payback Period of 1.2 years
- Life span of Water-Cooled > than Air-Cooled
- Total savings of ~\$820K at the end of 20 years

Benefits: Evaporative Cooling



Lowest
Energy Cost



Lowest
Operating Cost



Lowest
Installation Cost
&
Easy Transportation



Lowest
Environmental
Impact

Agenda

1. Introduction to Eurovent Middle East's Cooling Tower Guidebook
2. Evaporative Cooling: Overview of advantages
3. Evaporative Cooling: Working principles
4. Critical aspects of design, installation, and operation
5. Case Study – Total Cost of Ownership
- 6. Cooling Tower Certification**
7. Moderated Discussion

Cooling Tower Certifications

Mr Chukri Al Aani

Regional Sales Manager – MEA & Turkey
SPX Cooling Technologies Trading DMCC

Cooling Technology Institute (CTI)

The CTI establishes **standard testing and performance analysis systems and procedures** for cooling technologies. It also encourages and supports cooperative research to improve cooling technology and efficiency for the long-term benefit of the environment.

CTI STD-201

- The standard sets forth a program whereby CTI will certify that all models of a line of evaporative heat rejection equipment offered for sale by a specific manufacturer will perform thermally in accordance with the manufacturer's published ratings.
- Applies to Mechanical Draft Evaporative Heat Rejection Equipment such as Open Circuit Cooling Towers, Closed Circuit Cooling Towers and Evaporative Refrigerant Condensers.

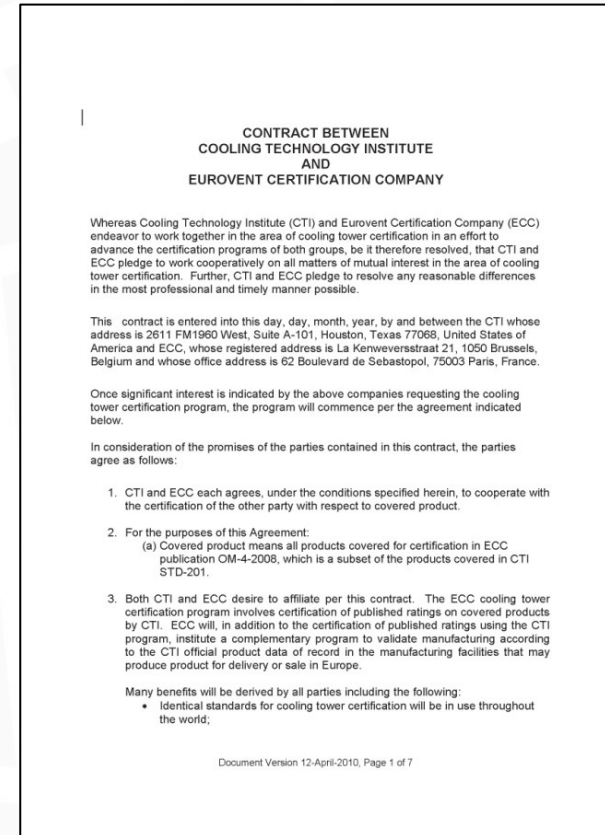


Eurovent Certification and CTI Partnership

ECC – CTI Memorandum of Understanding Mutual recognition Eurovent – CTI

“CTI and ECC endeavor to work together in the area of cooling tower certification in an effort to advance the certification programmes of both groups, be it therefore resolved, that CTI and ECC pledge to work cooperatively on all matter of mutual interest in the area of cooling tower certification.”

- Europe
- Middle East
- India



Scope of the Certification

General Purpose:

- Encourage honest competition
- Assure correctly rated equipment on the market
 - Separate and specific certification programmes for each product type
 - Product performance tests through an independent third-party
 - Application and participation open to all manufacturers

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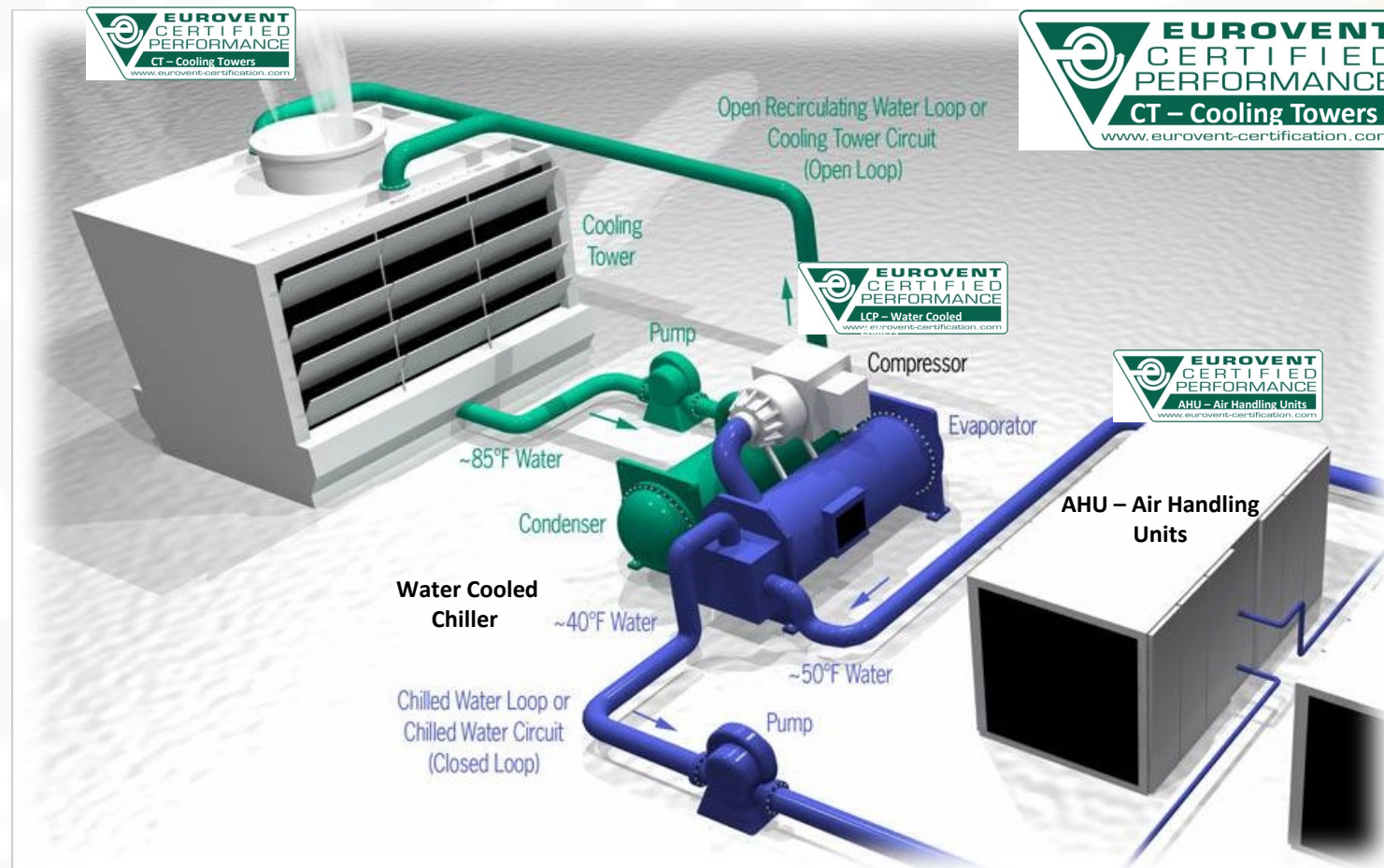
Initial Qualification Test

- **Thermal Performance Test per CTI ATC-105 Test Code**
 - Preparation per CTI FSP-156 Pretest Bulletin
 - Equipment Operation per CTI ATC-105 Test Code
 - Test Instrumentation per CTI ATC-105 Test Code
 - CTI owned flow measurement device
- **Capability Calculated Using Published Ratings**
 - Compares Measured Performance with Predicted Performance
 - 95% Minimum Capability Required to Pass Test
- **Verification of Physical “Data of Record”**
 - Inspection of Tower
 - Dimensional Comparison

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Adding to System Design Performance/ Efficiency

Cooling Towers Joins the
Certified Product
Performance Programme
from Eurovent Certita
Certification



Formula For Success: Certified Efficient Products, Optimised System Designs, & Professional Installations



Some key issues:

- Air Recirculation
- Noise Amplification
- Control Strategy
- Poor Installation
- Regular Maintenance
 - Cleaning!

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Verified performance:

