



HVACR
Leadership
Workshops

Event Introduction: Cooling Towers



Markus Lattner
Managing Director
Eurovent Middle East

Workshop Partners



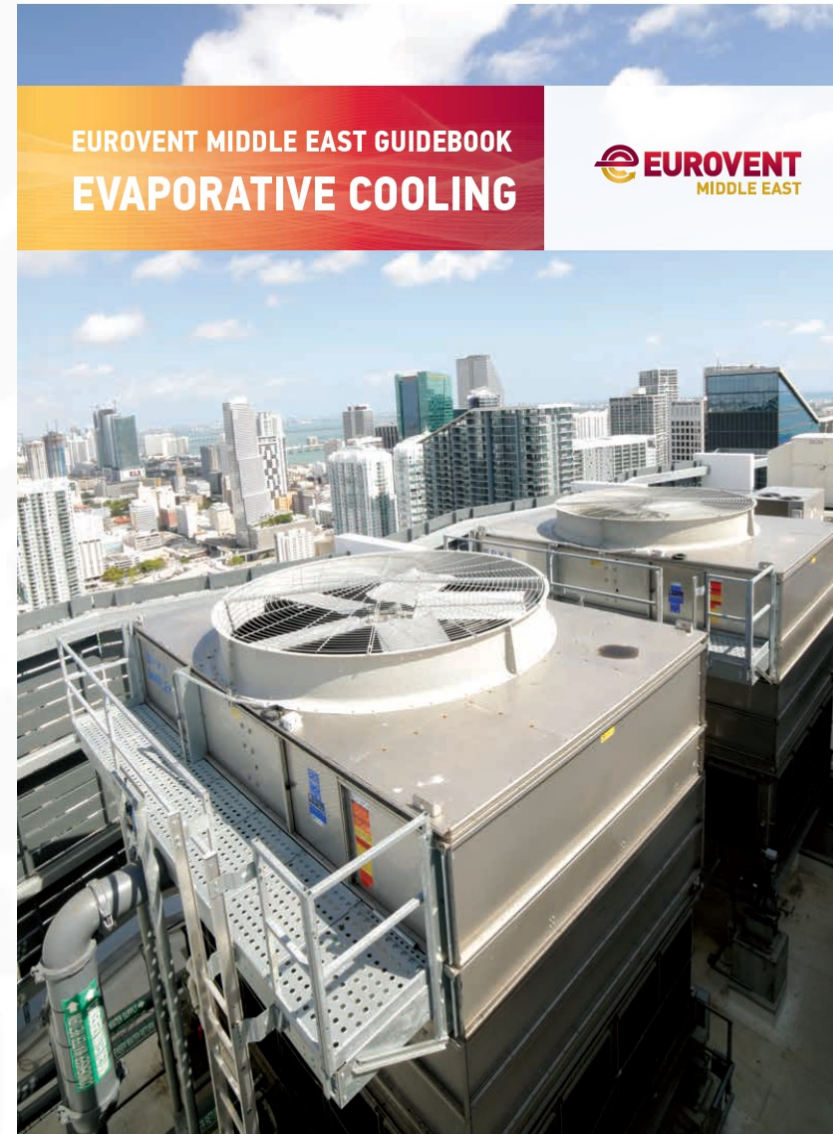
Media partner:

climate control MIDDLE EAST
KEY PERSPECTIVES ON THE REGION'S HVACR INDUSTRY

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

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 the 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 distribution and is distributed over the fill through a spray distribution arrangement. Simultaneously, ambient air is induced or forced through the tower, creating a small portion of the water to evaporate. This evaporator 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 not cooled or is cooled with atmospheric air.

3.2 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 unit through the fill. Because the water is travelling vertically down, and the air is passing horizontally across the fill, this cross each other in perpendicular directions, hence the term cross-flow.

3.3 COUNTER FLOW

Water from the heat source enters an inlet distribution and is distributed over the fill through a spray distribution arrangement. Simultaneously, ambient air is induced or forced through the tower, creating a small portion of the water to evaporate. This evaporator 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 not cooled or is cooled with atmospheric air.

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.

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

2.1 ENERGY CONSUMPTION

Because more heat is removed by evaporation than by sensible heat transfer, evaporative cooling requires up to four times less energy for a given heat transfer capacity compared to a conventional air-cooled process. This means that as little as a number 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 downstream cooling loop, but also provides better entering water temperatures to the chiller to allow for much lower energy consumption on the chiller itself. The chiller being the most power consuming piece of equipment in the system.

Effective heat transfer combined with lower water through the air and water evaporation cooling equipment a heat exchanger it serves to energy savings. Thus, by both application and design, evaporative cooling equipment saves energy and reduces emissions.

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 water.

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 consumption 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, condensation must be given to the water that is required for the production of electrical power.

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 include grey water and water saving products.

2.4 EVAPORATIVE COOLING IN THE MIDDLE EAST

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), enabling lower water outlet temperatures to be 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, the higher the efficiency gains by evaporative cooling. For example, this means that water in hot summer days in Riyadh with an ambient dry bulb temperature of 42.8°C, evaporative cooling equipment can easily cool water down to a temperature of 12.4°C, this is that possible? The wet bulb temperature is 12.4°C for the period of hours to be 12.4°C. Certified evaporative cooling equipment can cool down to within 1.5°C of the 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 stations and is also published regularly by AQHAQ.

KEY TAKEAWAYS

- Cooling towers are designed for specific wet bulb temperatures. To establish the correct wet bulb temperature for any given location, refer to AQHAQ or local weather data.
 - Evaporative cooling is always more energy efficient than dry cooling.
 - Use evaporative cooling in projects over 500kW.
 - Consult with manufacturers on the best plant layout.
 - Incorrect plant design can lead to misapplication and significantly reduce plant's capacity.
 - Not maintaining systems regularly results in a loss of money every day.
 - Water treatment programmes are critical to maintain performance and avoid harmful bacteria and biofouling 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.
 - For any awarded products with ISO9001 certification do not require any further testing on site.
 - Exhaust 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 terms used throughout the book. Defining its meaning to provide a better understanding of the HVAC systems. All terms used in the book which are further explained in the glossary are printed in normal letters.

23 November 2021

HVACR Leadership Workshops

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Guidebook 'Evaporative Cooling'



Guidebook 'Evaporative Cooling'



**BALTIMORE
AIRCOIL COMPANY**



Guidebook 'Evaporative Cooling'

We appreciate your feedback!

office@eurovent.me

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1. Introduction to Eurovent Middle East's Cooling Tower Guidebook
- 2. Evaporative Cooling: Overview of advantages**
3. Evaporative Cooling: Working principles
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6. Cooling Tower Certification

Evaporative Cooling: Overview of Advantages



Mr Chukri Al Aani

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

What are your design goals?

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



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Air-Cooled vs Water-Cooled Systems Comparison

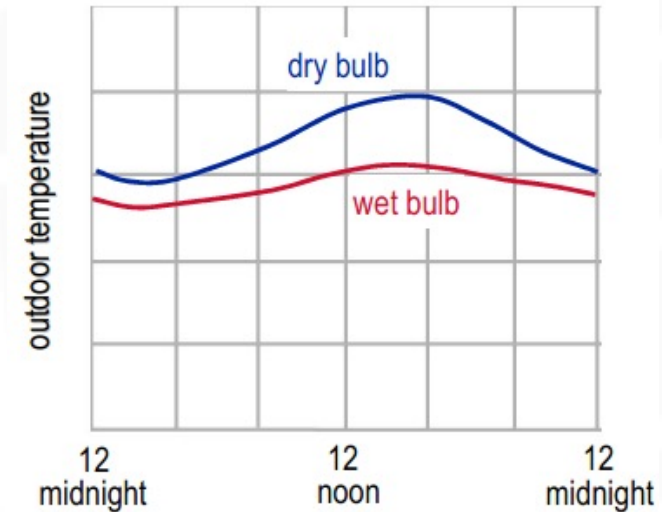
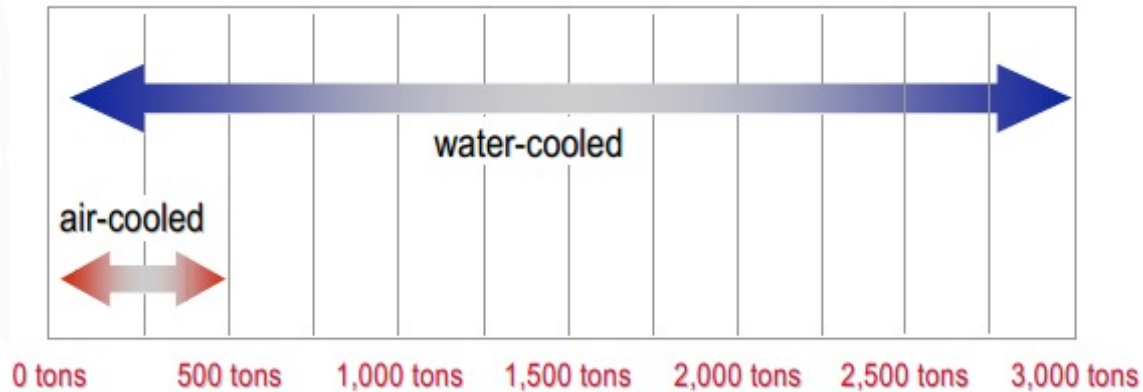
Air-Cooled Advantages

- Capital Cost
- Ease of Use/Maintenance Costs
- No Water
 - No Water Treatment
 - On-site water usage

Water-Cooled Advantages

- Evaluated Cost
 - Energy Use
- Capacity/Comfort/Control
- Noise and Maintenance Time
 - Fewer Fans
- Smaller Footprint
- Total Water Usage

System Definition: Water-Cooled vs Air-Cooled Chiller



- Air-cooled typically has lower upfront costs but are less efficient at rejecting heat therefore limiting their capacity.
- Utilisation of cooling tower requires extra piece of equipment but allows us to cool below the dry bulb temperature.

The Value of Evaporative Heat Rejection

Vs. Air-Cooled

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

Typical Application – 400 Ton

Annual	Air Cooled	Water Cooled	% Delta
Energy Consumption	440 MWH	190 MWH	(56.8%)
GHG Emission ⁽²⁾ lbs. of CO ₂	682,000	294,500	(56.8%)
Total Water Usage In 0000s Gallons (on-site ⁽³⁾ + power generation ⁽⁴⁾)	1,944	1,530	(21.3%)

1. Assumes \$0.1358/KWH.

2. Average US energy plant emits 1.55 lbs. of CO₂ for each KWH generated.

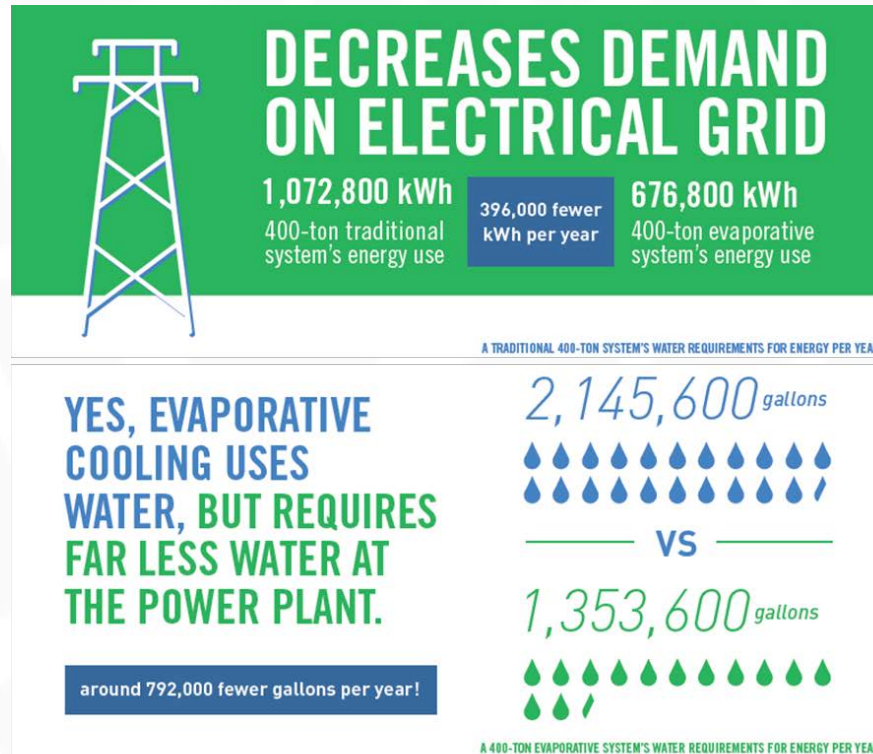
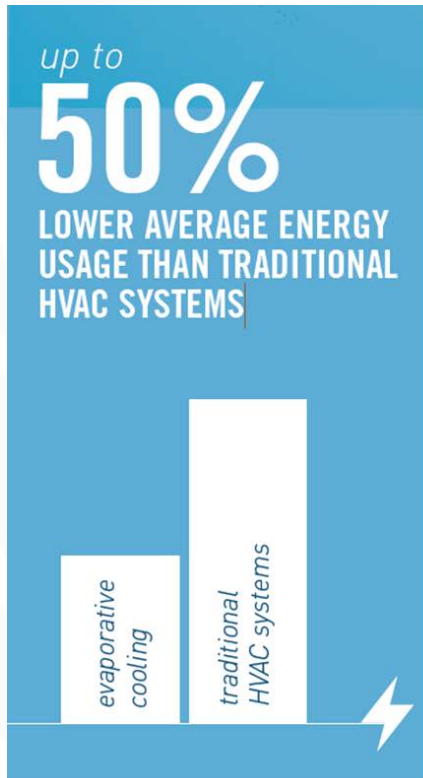
3. Site water includes water for blowdown, assuming 6 cycles of concentration, and make up.

4. In CA and many Western states each KWH produced consumes 4.42 gallons of water. On average in US each KWH produced consumes 2 gallons of water.

Source: Buildings Magazine 2008 quoting Pacific Gas & Electric Co. study including NREL data.

Evaporative Cooling is Sustainable with Significant Environmental and Water Usage Benefits

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

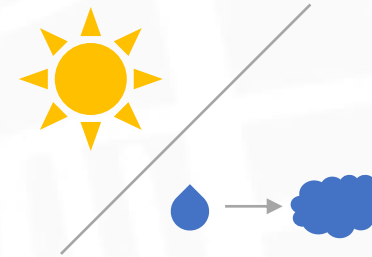
EVAPORATIVE COOLED



Evaporative cooling, dependent
on wet bulb temperature



HYBRID, WET/DRY, ADIABATIC

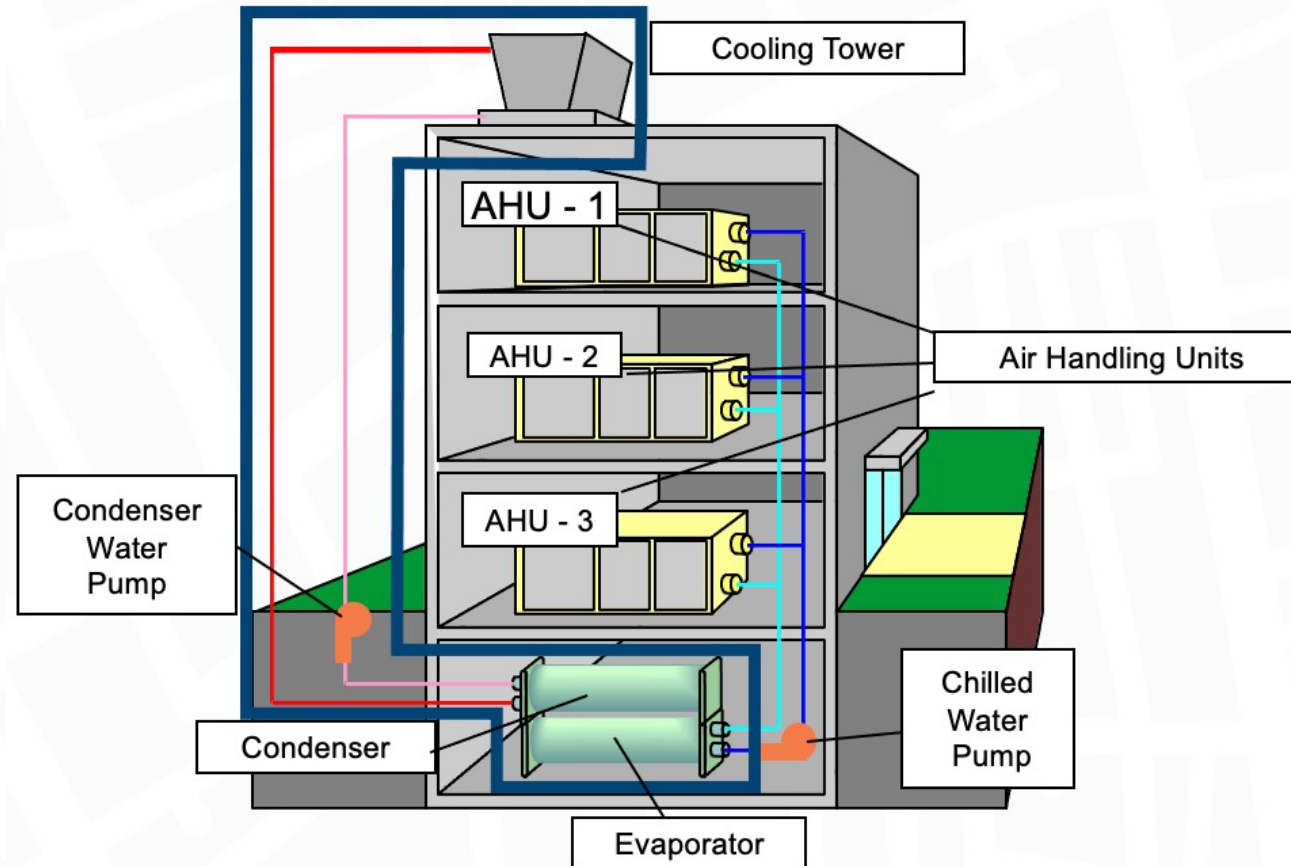


Dependent on both
dry bulb and wet bulb
temperatures

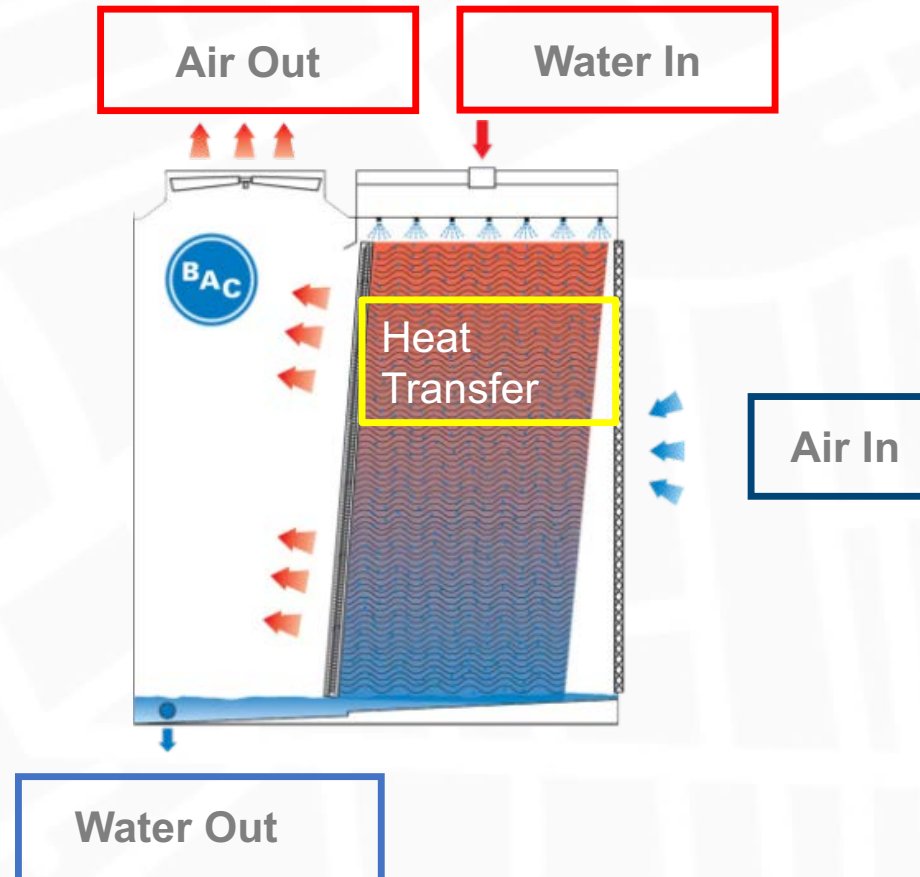


Typical $>10^{\circ}\text{C}$ difference between wet bulb and dry bulb

Traditional Water-Cooled HVAC System



Principles of Evaporative Cooling



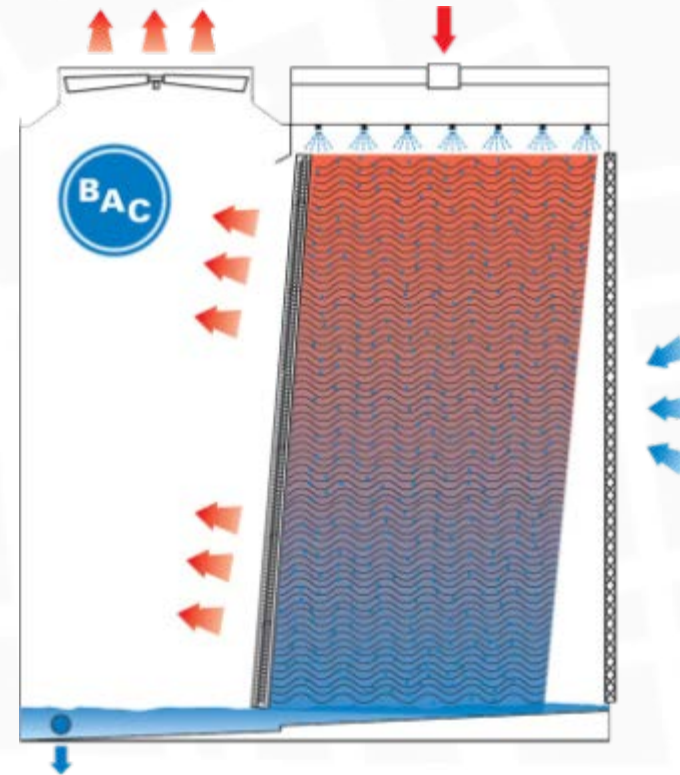
Principles of Evaporative Cooling

Heat transfer

- Sensible
- Latent

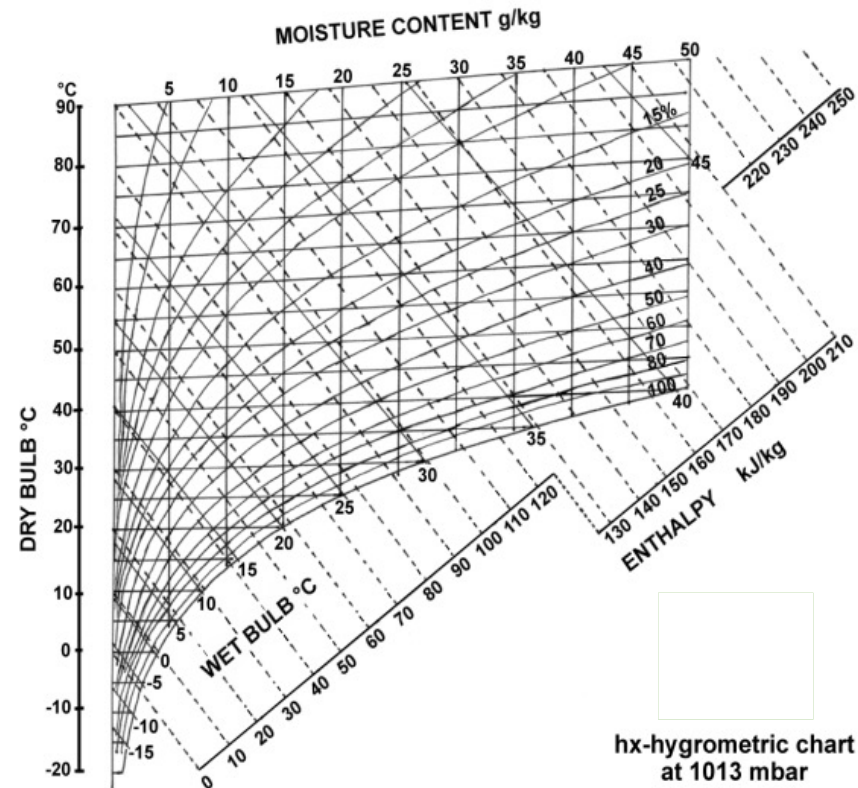


For every kg of water evaporated, 2256 kJ of heat is removed from the water



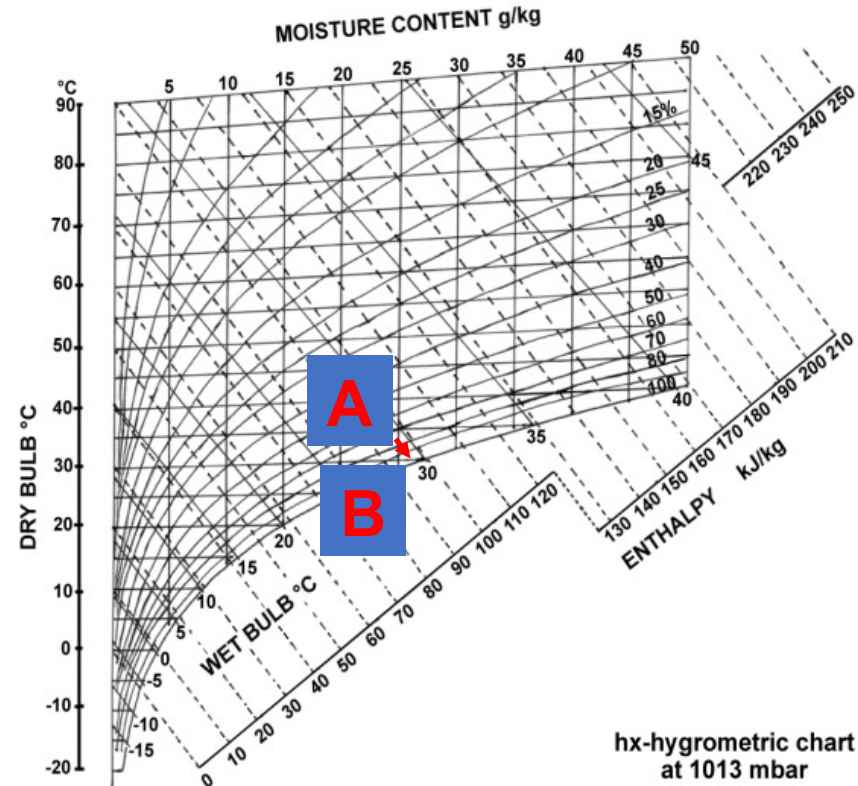
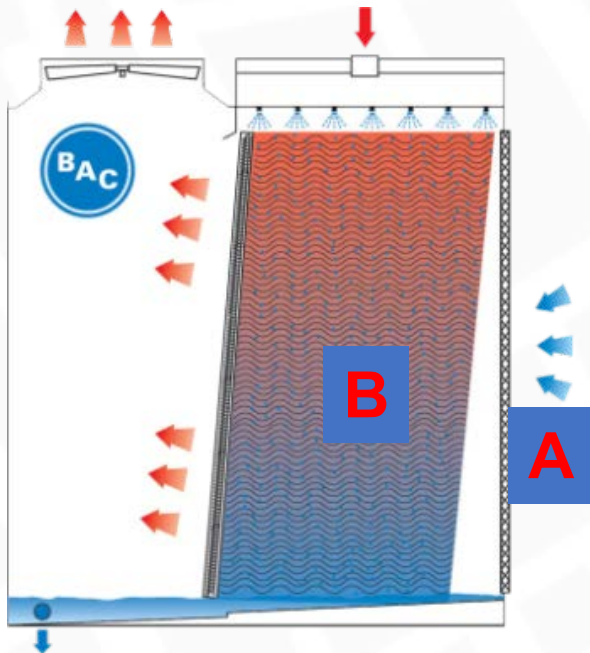
Principles of Evaporative Cooling

Dry Bulb
Wet Bulb
Enthalpy
Moisture Content



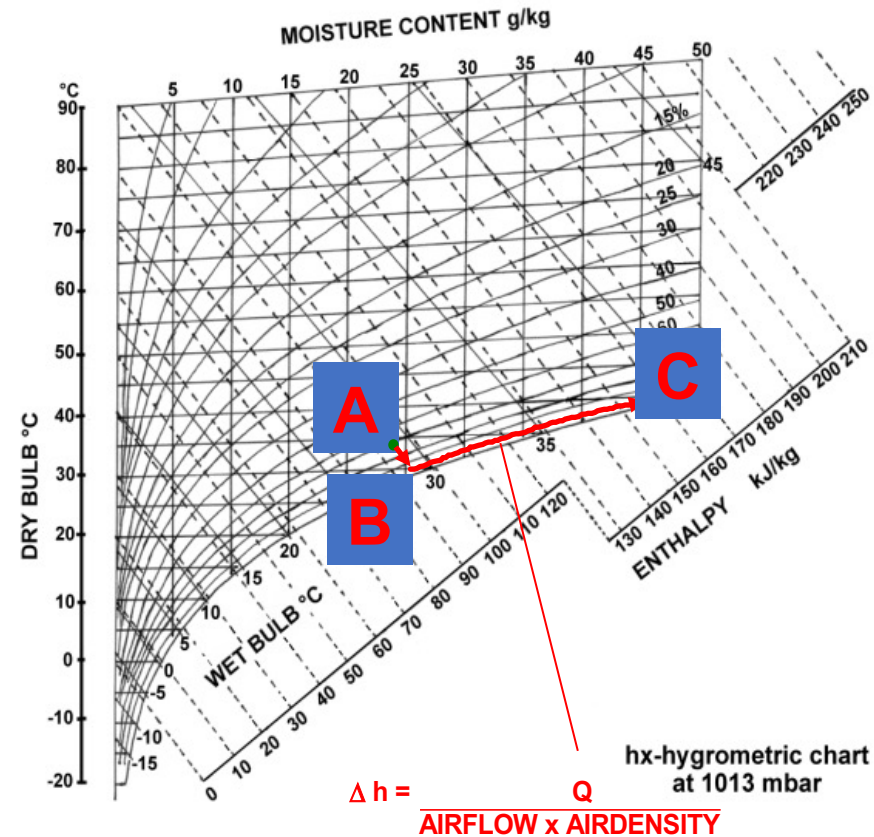
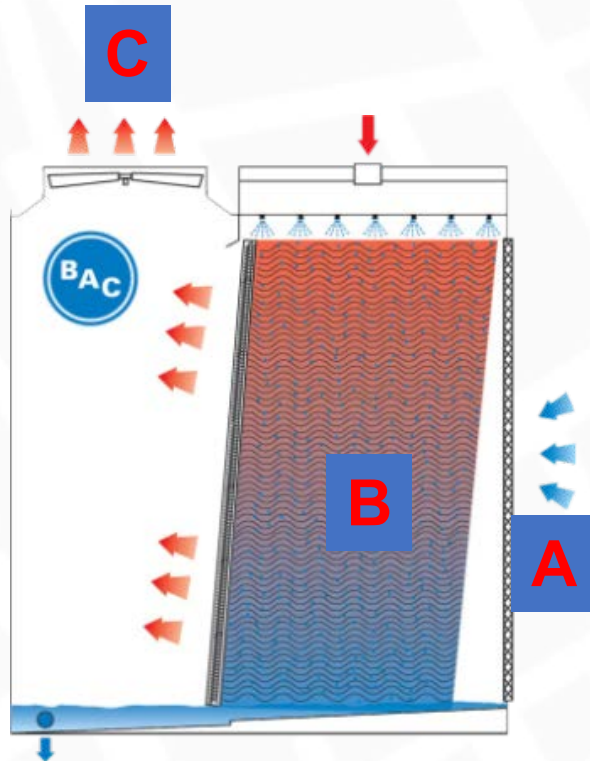
Principles of Evaporative Cooling

Air gets saturated

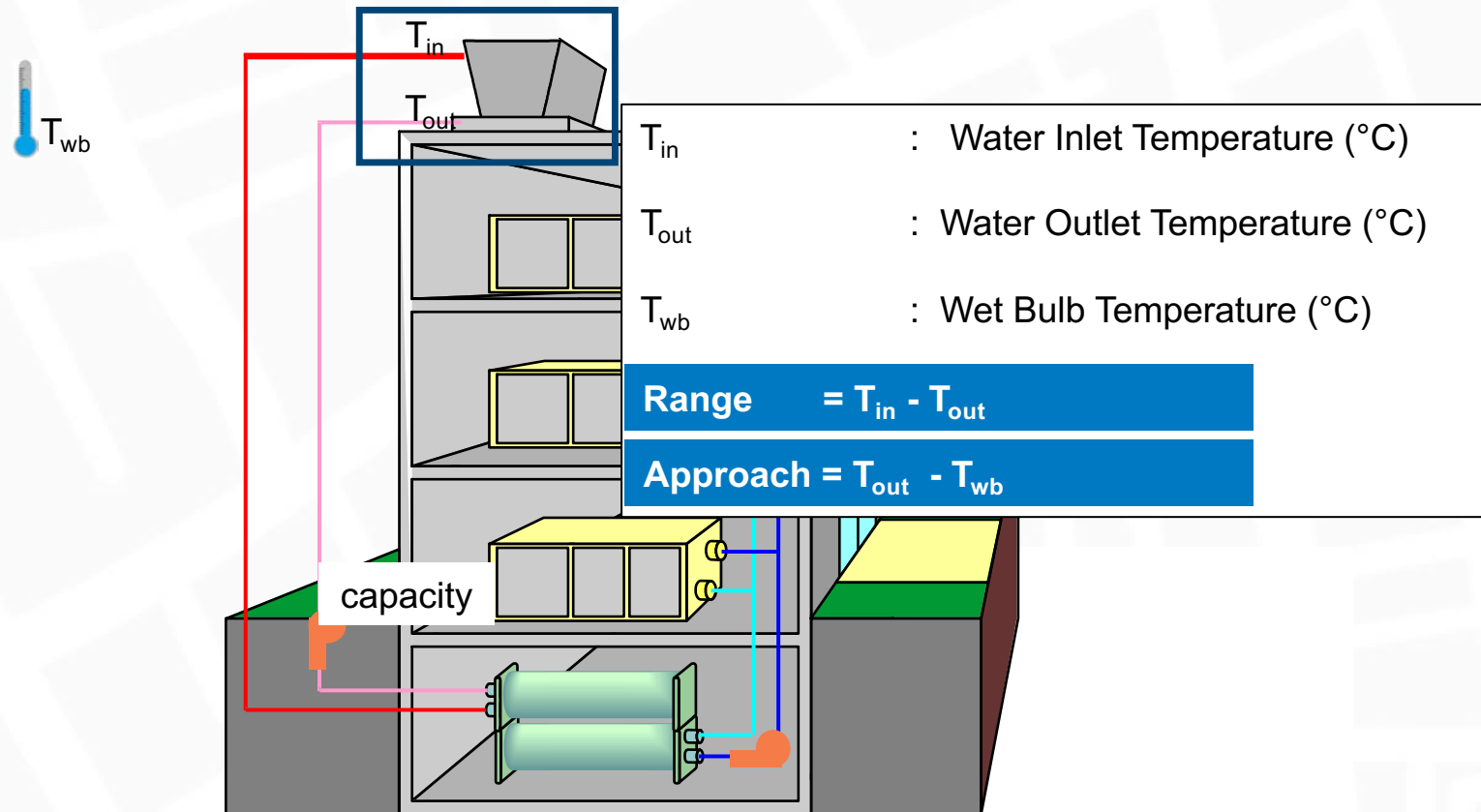


Principles of Evaporative Cooling

Air heats up



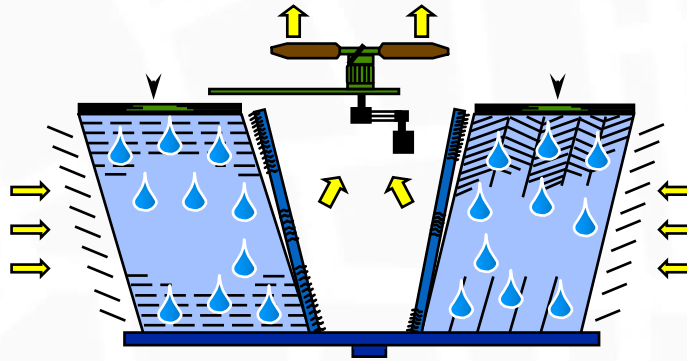
Principles of Evaporative Cooling



HVAC System

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

- The cooling tower does not control the range (assumes constant condenser water flow)
- The cooling tower controls only the approach



HVAC System

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

Multiple Cooling Towers can meet these conditions.
System Energy?

HVAC System

10°C Approach

T_{in} = 36°C
T_{out} = 31°C

15kW Fan motor



6°C Approach

T_{in} = 32°C
T_{out} = 27°C

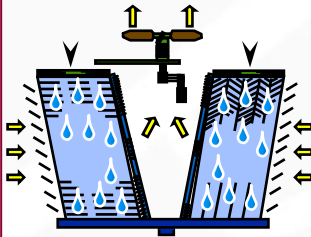
22kW Fan motor



2°C Approach

T_{in} = 28°C
T_{out} = 23°C

45kW Fan motor



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

Constant Wet Bulb Larger Cooling Tower for Smaller Approaches

HVAC System

10°C Approach Wet Bulb 8.2°C

Tin = 23.2°C
Tout = 18.2°C

22kW Fan motor



6°C Approach Wet Bulb 21°C

Tin = 32°C
Tout = 27°C

22kW Fan motor



3.5°C Approach Wet Bulb 31.5°C

Tin = 40°C
Tout = 35°C

22kW Fan motor



Higher Wet Bulb
Easier for Smaller
Approaches

Chiller duty is still related
to Tout temperature

- ♦ Flow: 101,9 l/s
- ♦ Range: 5°C
- ♦ Heat rejection: 2100kW
- ♦ **Wet bulb: varies**

HVAC System

10°C Approach
10.1°C Range
4300kW

Tin = 41.1°C
Tout = 31.0°C

22kW Fan motor



6°C Approach
5°C Range
2100kW

Tin = 32°C
Tout = 27°C

22kW Fan motor



3.5°C Approach
2.5°C Range
1100kW

Tin = 27°C
Tout = 24.5°C

22kW Fan motor



- ◆ Flow: 101,9 l/s
- ◆ Range: varies
- ◆ **Wet bulb: 21°C**

If using same cooling tower, higher heat loads require a larger approach

The diagram is a Pressure-enthalpy (P-h) plot. The vertical axis is labeled 'Pressure (N/cm²)' and the horizontal axis is labeled 'Enthalpy (kJ/kg)'. A legend at the top indicates that light blue lines represent 'air cooled' systems and dark blue lines represent 'evaporative' systems. The evaporative cycle (dark blue) consists of four main processes: 'compression' (upward sloping line), 'condensing' (horizontal line at high pressure), 'expansion' (vertical line down), and 'evaporation' (horizontal line at low pressure). The air-cooled cycle (light blue) follows a similar path but with a higher condensing pressure. The area between the two condensing lines is shaded grey and labeled 'Heat rejection'. A red double-headed vertical arrow between the two condensing lines is labeled 'Reduced lift'. Two horizontal dashed lines indicate 'Leaving CDW T' (top) and 'Leaving CHW T' (bottom). The evaporative cycle's condensing line is positioned between these two temperatures, while the air-cooled cycle's condensing line is above the 'Leaving CDW T' line.

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Critical Aspects of Design, Installation and Operation



Mr Chukri Al Aani

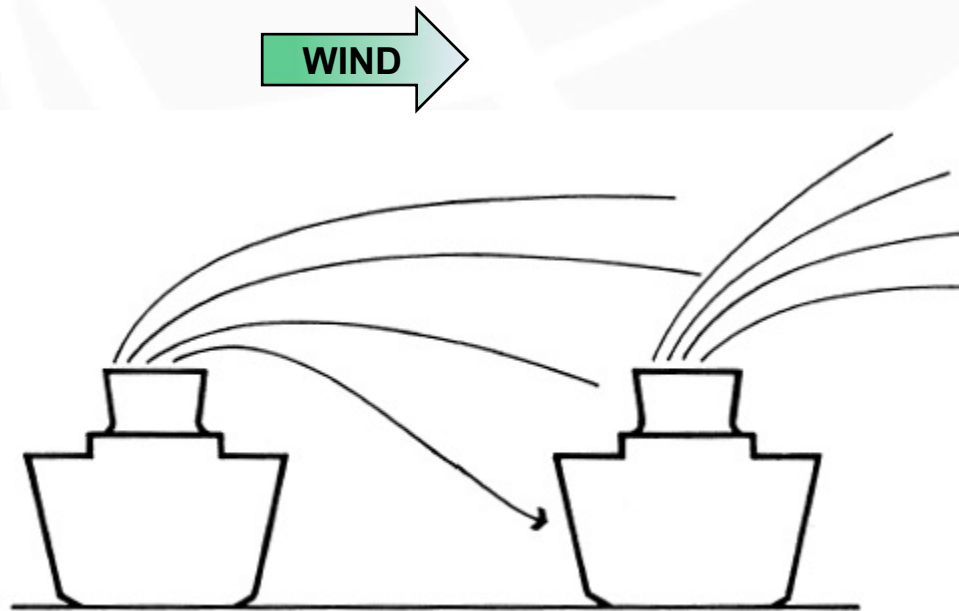
Regional Sales Manager – MEA & Turkey
SPX Cooling Technologies Trading DMCC

Cooling Towers Design

- **What space is available?**
- **What obstacles/other heat sources surround the site?**
- **What noise requirements are there?**
- **What plume requirements are there?**
- **What existing/new infrastructure do the cooling towers have to link into?**
- **How will the cooling towers be maintained?**
- **What types of cooling towers are possible to use?**

Interference

It is wet bulb at the tower air inlet which matters

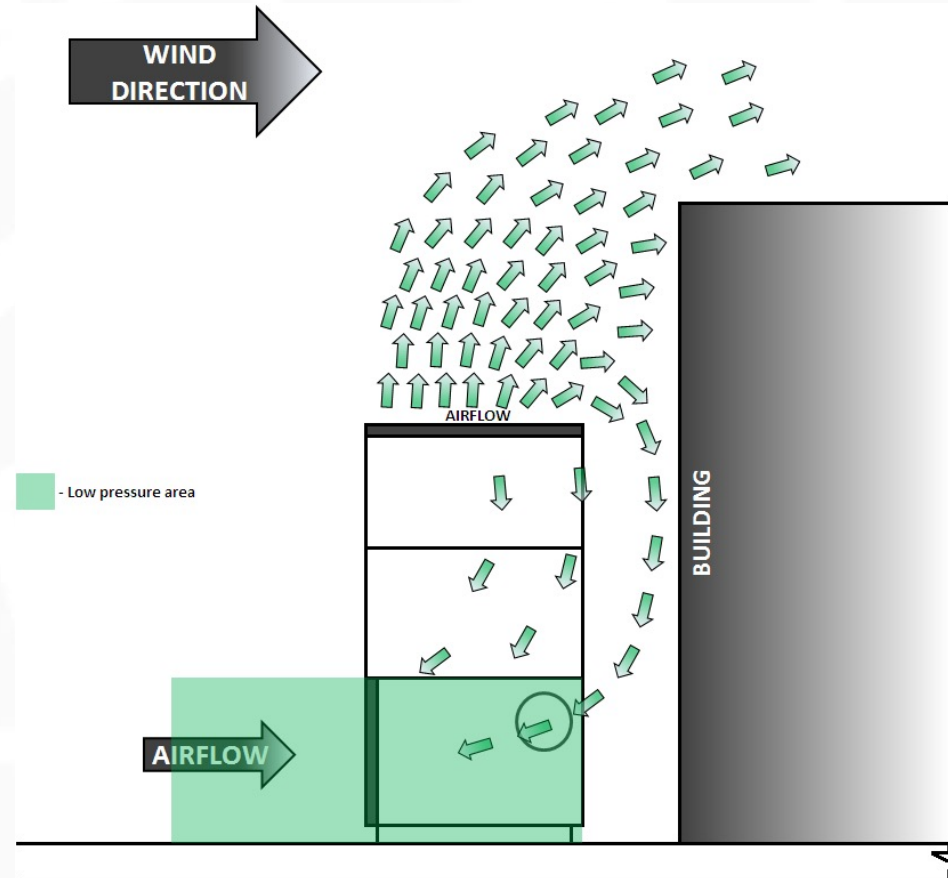


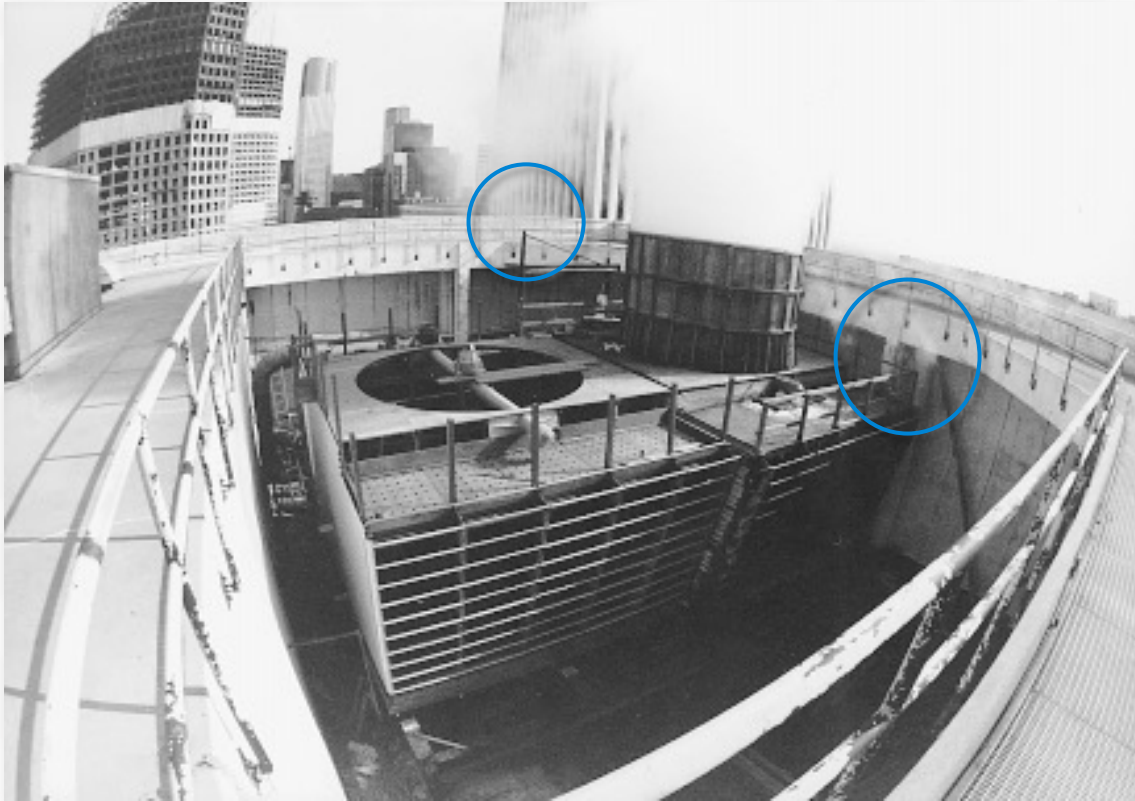
Local heat sources up wind of the cooling tower can elevate the wet bulb temperature of the air entering the tower, thereby affecting its performance. This could be an existing cooling tower, or another source of heat. This phenomenon is called “interference”.

Space and 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

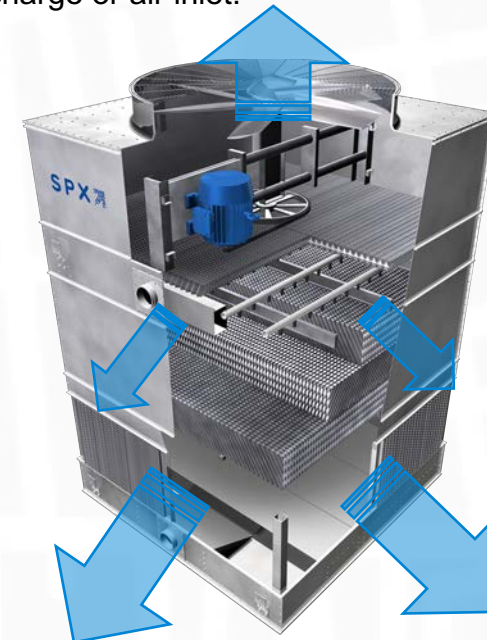


Counterflow

- 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.



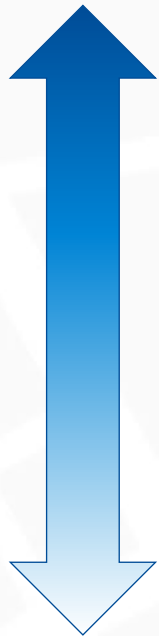
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Sound Success Strategies

- 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

LOWEST
COST

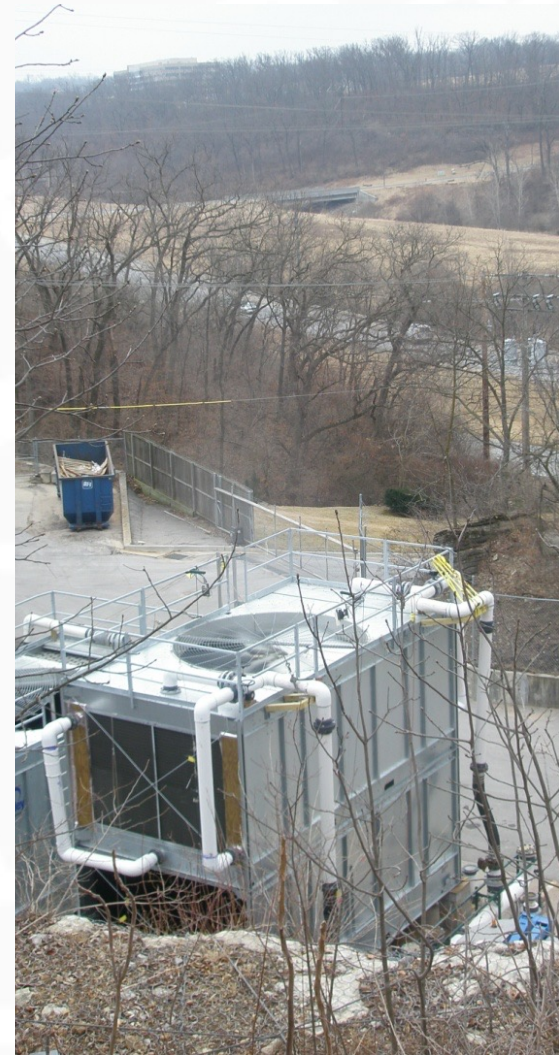


HIGHEST
COST

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

Consider options to reduce noise in order of cost

Plume



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Concrete/Supporting Steels: Decision Factors

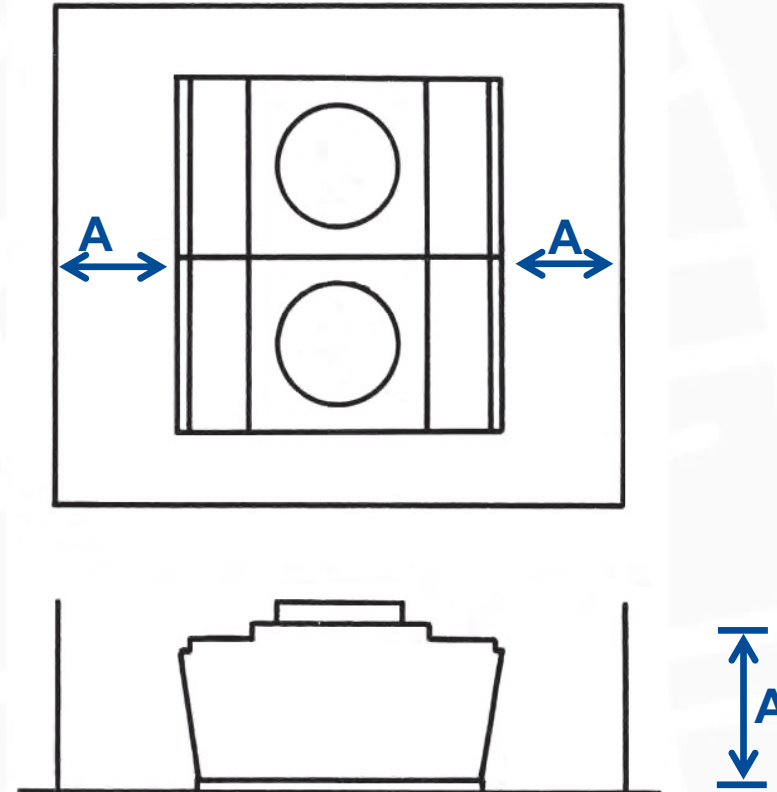
- Existing concrete basin installation
- Pipework/pumping requirements
- Location load-bearing capabilities
- Size of duty – package/field erected
- Project lead time
- Available downtime
- Water storage requirements
- Customer budget
- Water quality



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Rules of Thumb: Induced Draft Crossflow Tower

- In approximate terms, the distance from air inlet to nearest enclosure wall should be the same dimension as the air inlet height of the 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

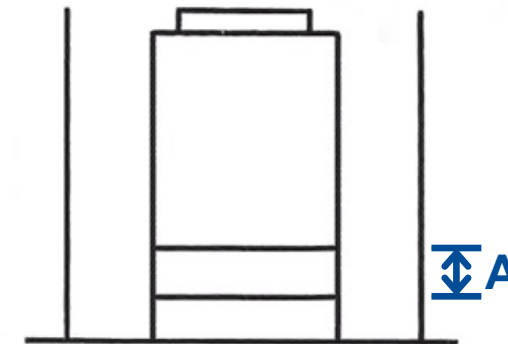
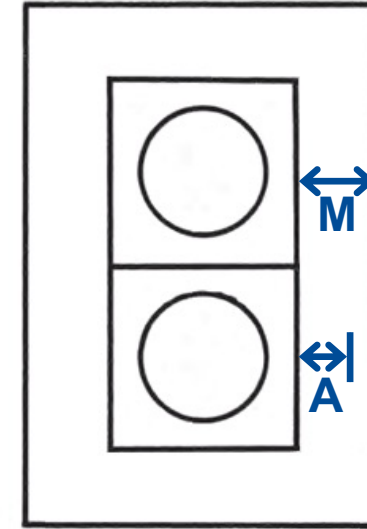
- If hanging fill pack needs to be cleaned in between sheets, or removed, it must come out through the side casing panels.
- Just the end panel at each end of the side casing can be removed, but typically the next one in will be removed for improved access.
- 908mm is a standard fan deck bridging plate dimension – this forms the minimum distance possible to perform this task.



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Rules of Thumb: Induced Draft Counterflow Tower

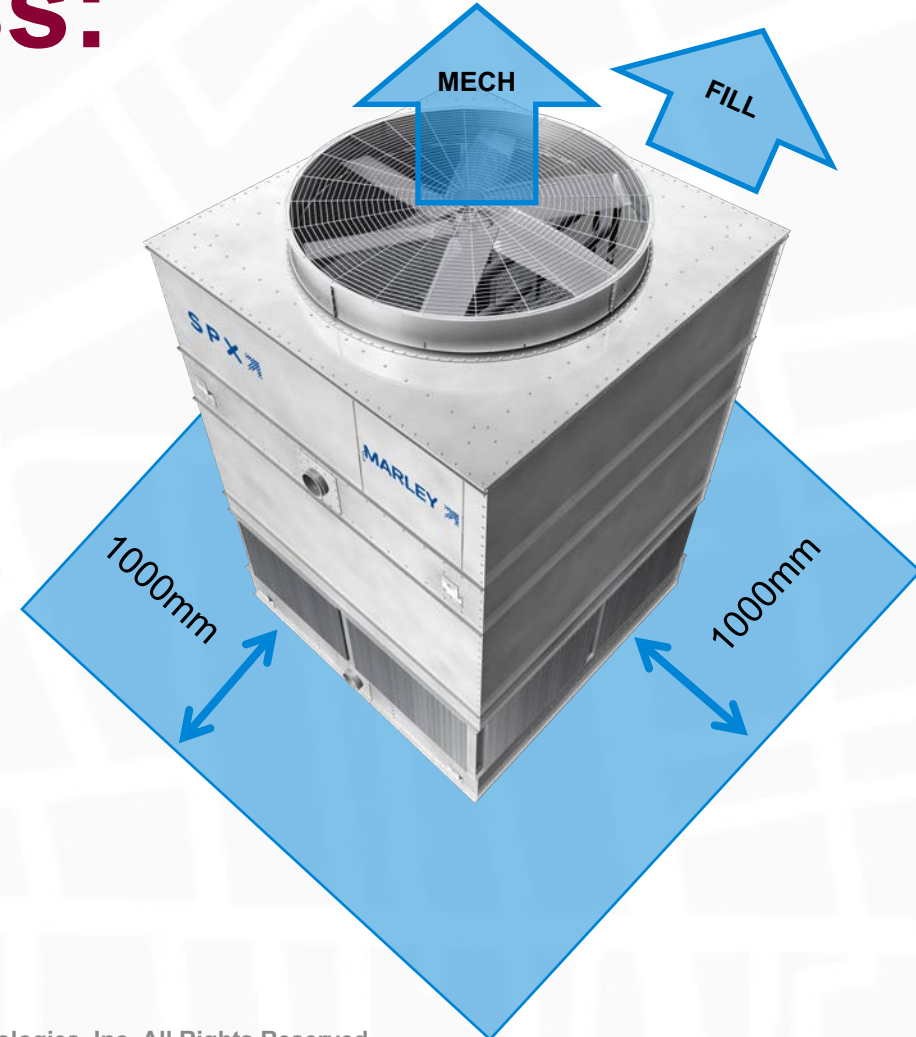
- In theory, the same rule applies as per an induced draft crossflow – distance to nearest wall should be equal or greater than air inlet height.
- Because this distance is so much smaller typically on an induced draft counterflow, maintenance access becomes the deciding factor, not airflow.
- Typical 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

- Tower requires minimum of 1000mm from each air inlet face to enable access through the air inlet to the basin.
- Fill pack removal and distribution inspection are possible through the access door on the side face of the tower.
- Mechanical equipment can be removed through the top of the tower, so consider crane locations when siting the tower.



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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

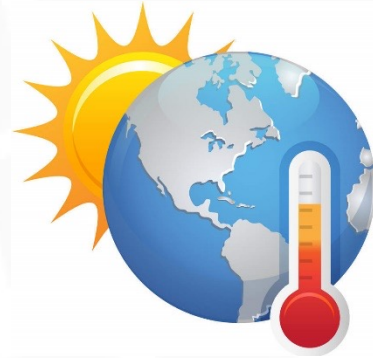
***“If you want different results,
do not do the same things!”***

— Albert Einstein

Climate Change/ Global Warming

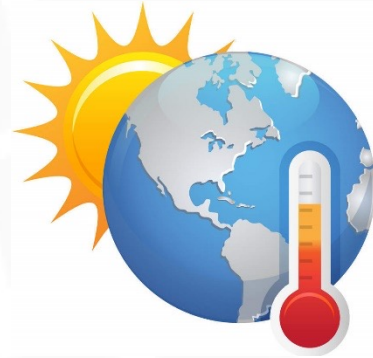


Climate Change/ Global Warming



High ambient temperatures

Climate Change/ Global Warming



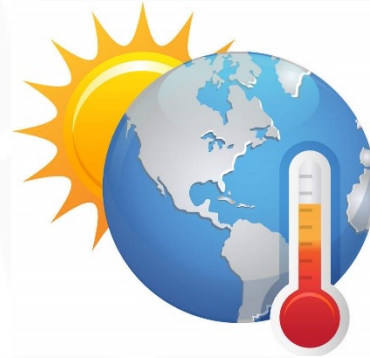
High ambient temperatures



More Cooling

Climate Change/ Global Warming

**Increasing power
generation**



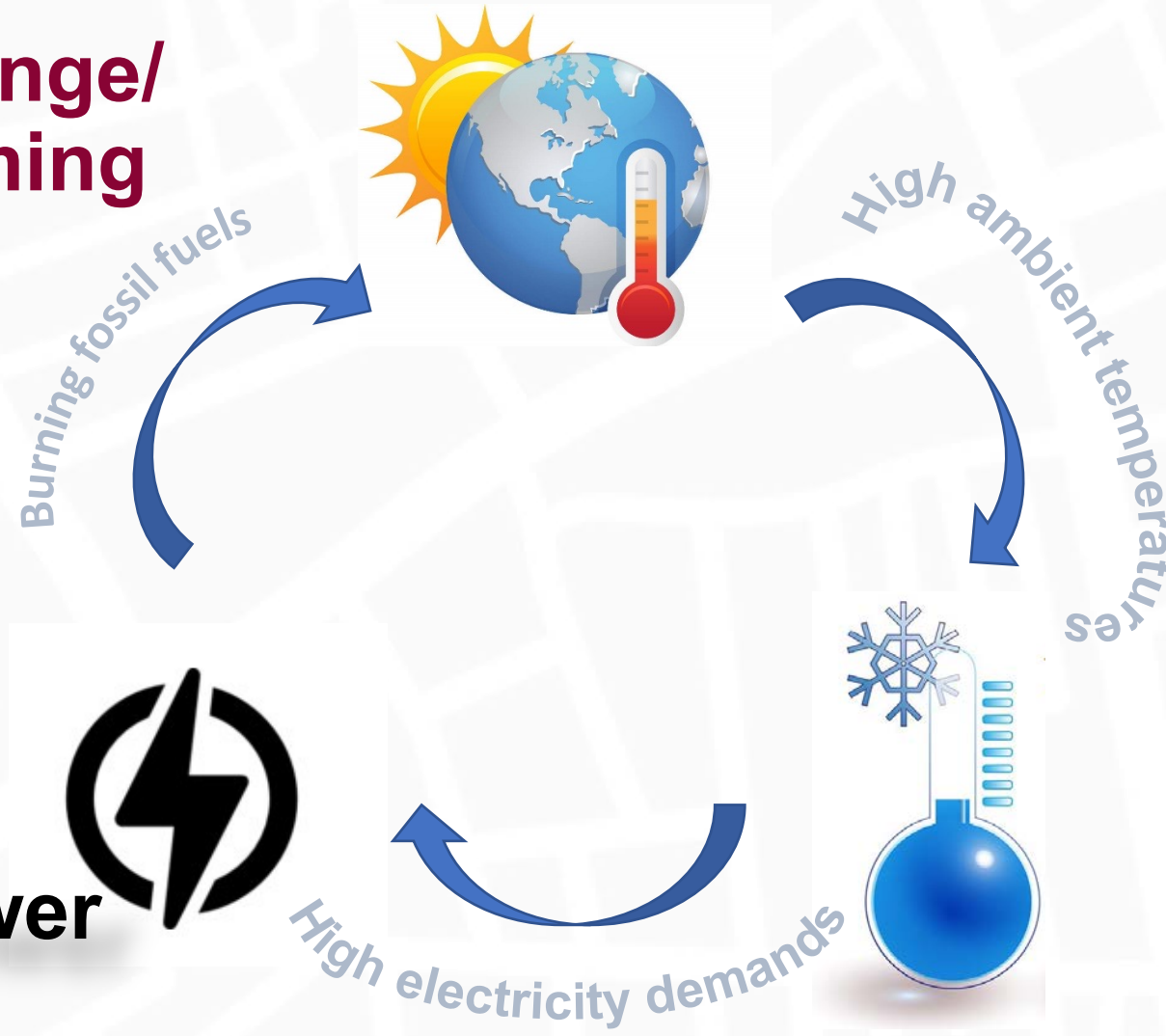
High ambient temperatures



More Cooling

High electricity demands

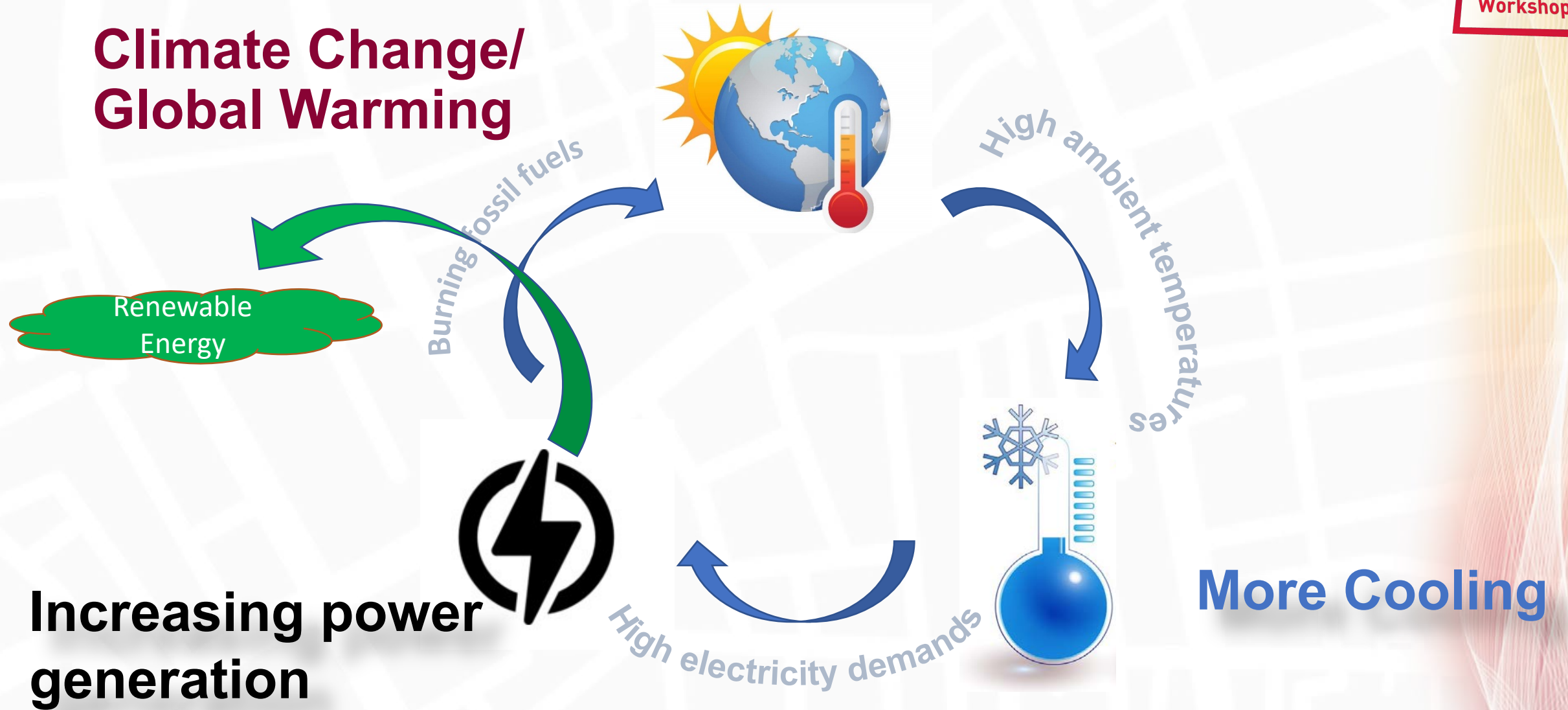
Climate Change/ Global Warming



**Increasing power
generation**

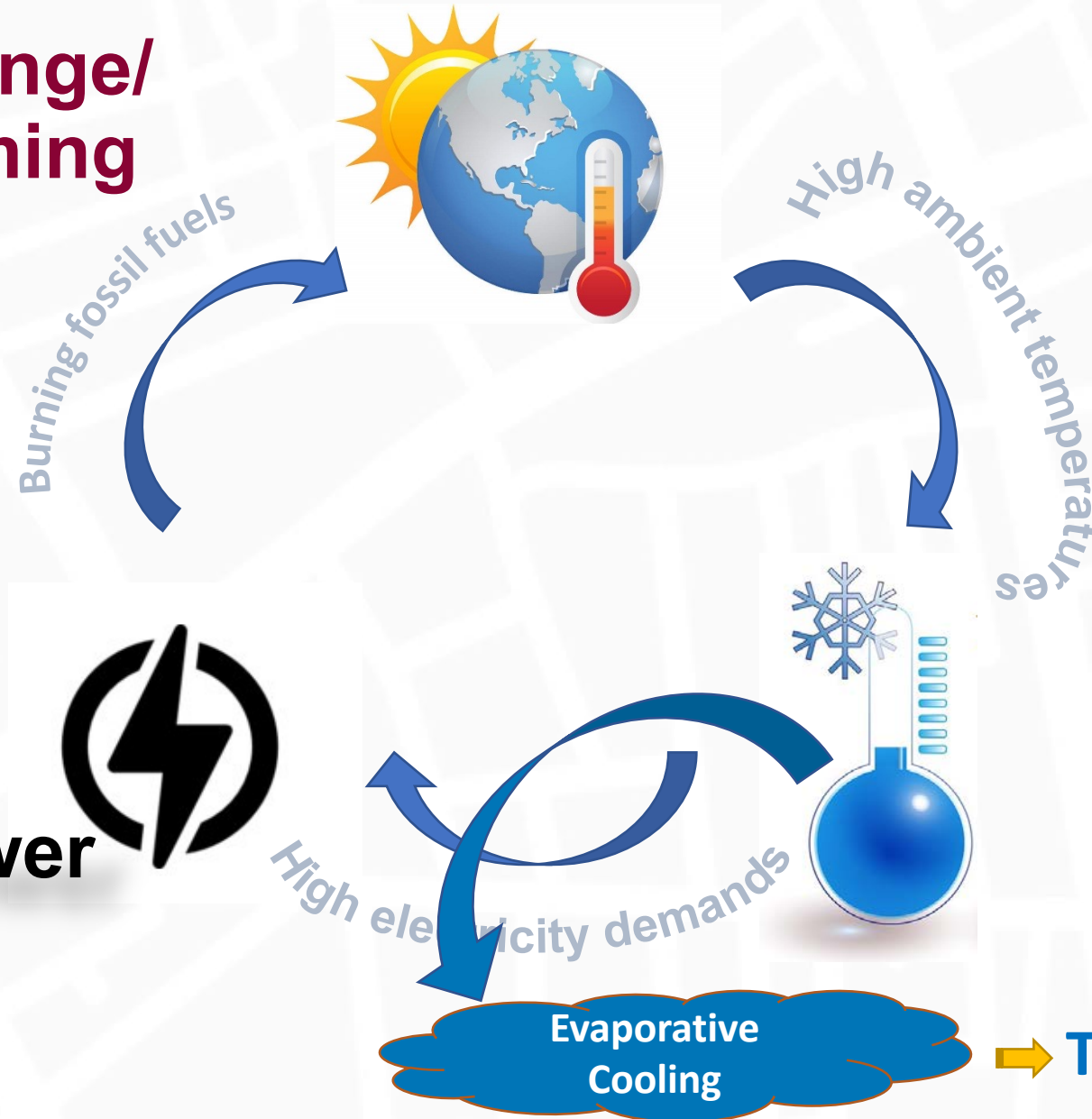
More Cooling

Climate Change/ Global Warming



Climate Change/ Global Warming

**Increasing power
generation**

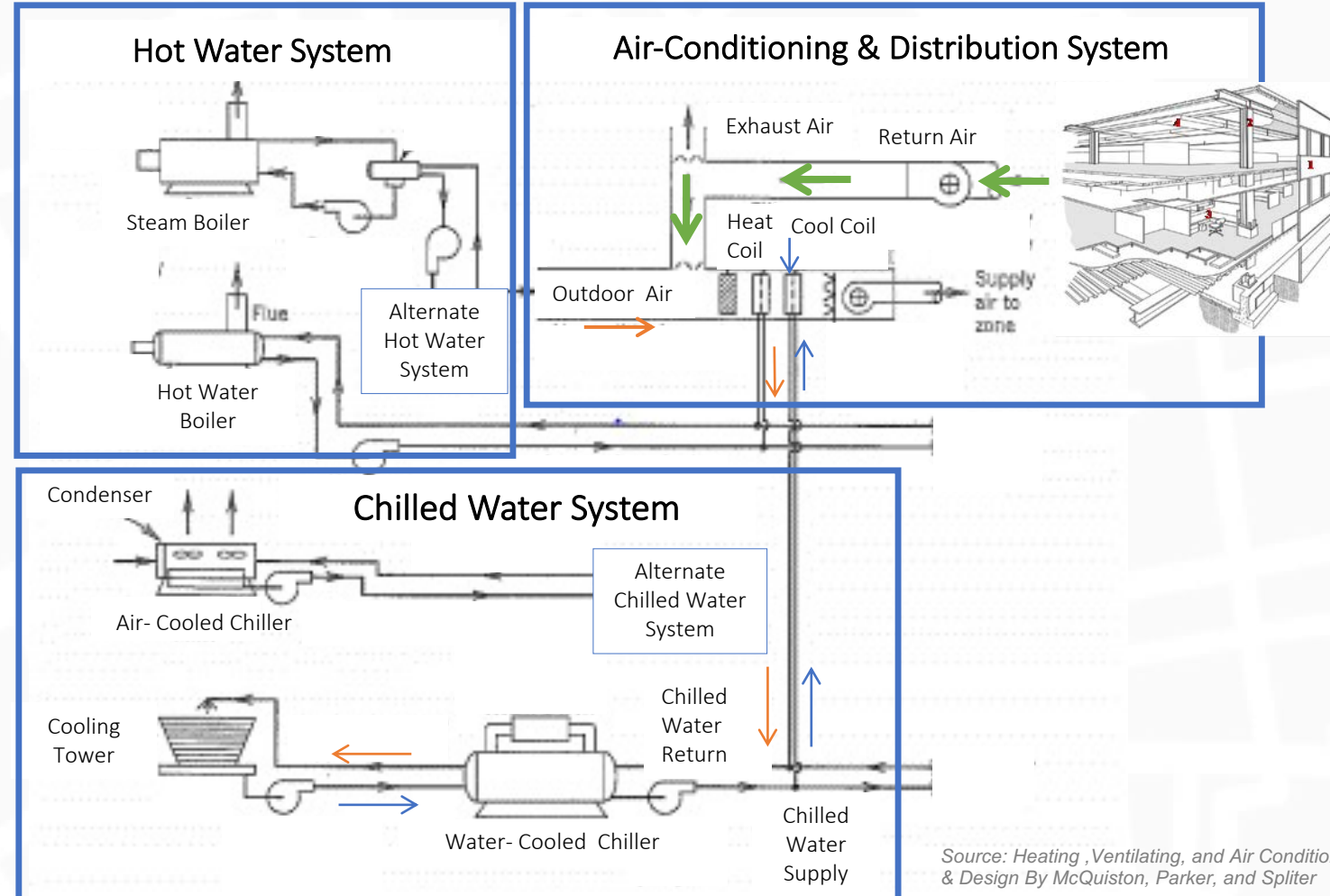


More Cooling

Example: Typical HVAC System

Air-Cooled System →

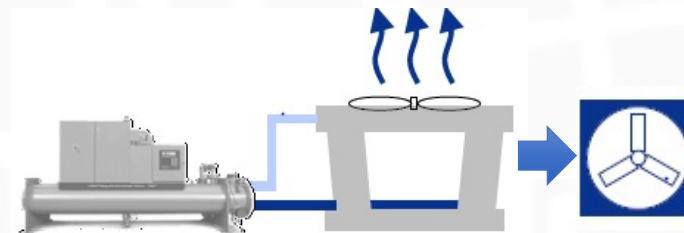
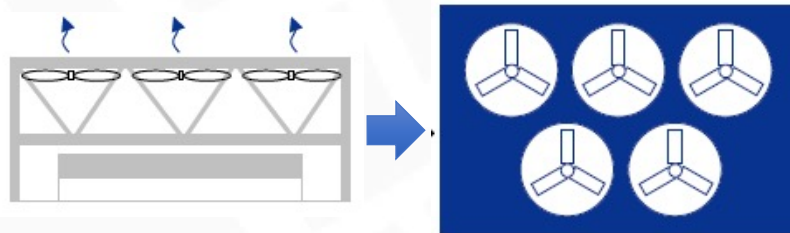
Water-Cooled System →



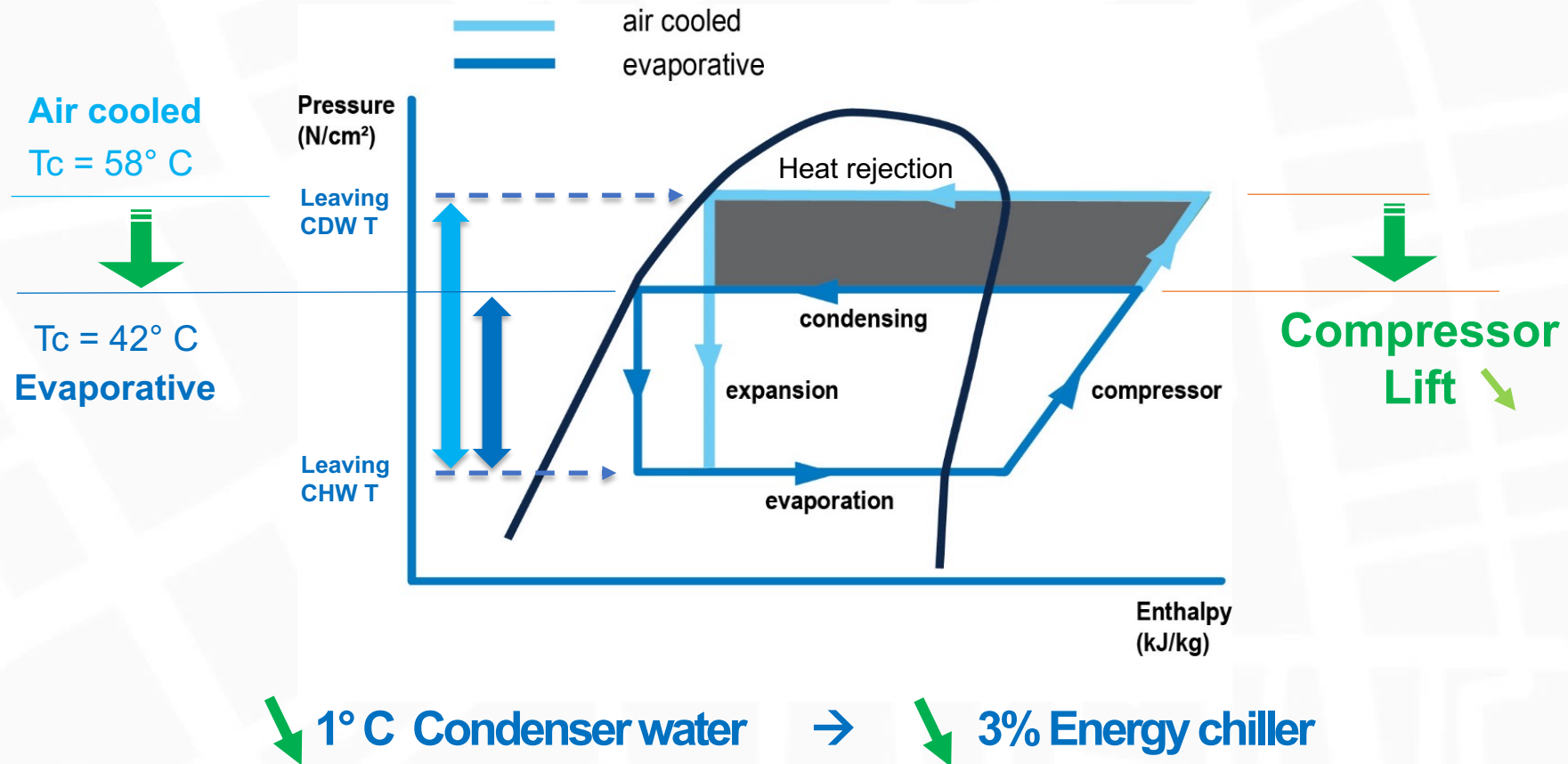
Source: Heating, Ventilating, and Air Conditioning Analysis & Design By McQuiston, Parker, and Spitzer

Air-Cooled vs Water-Cooled Heat Rejection

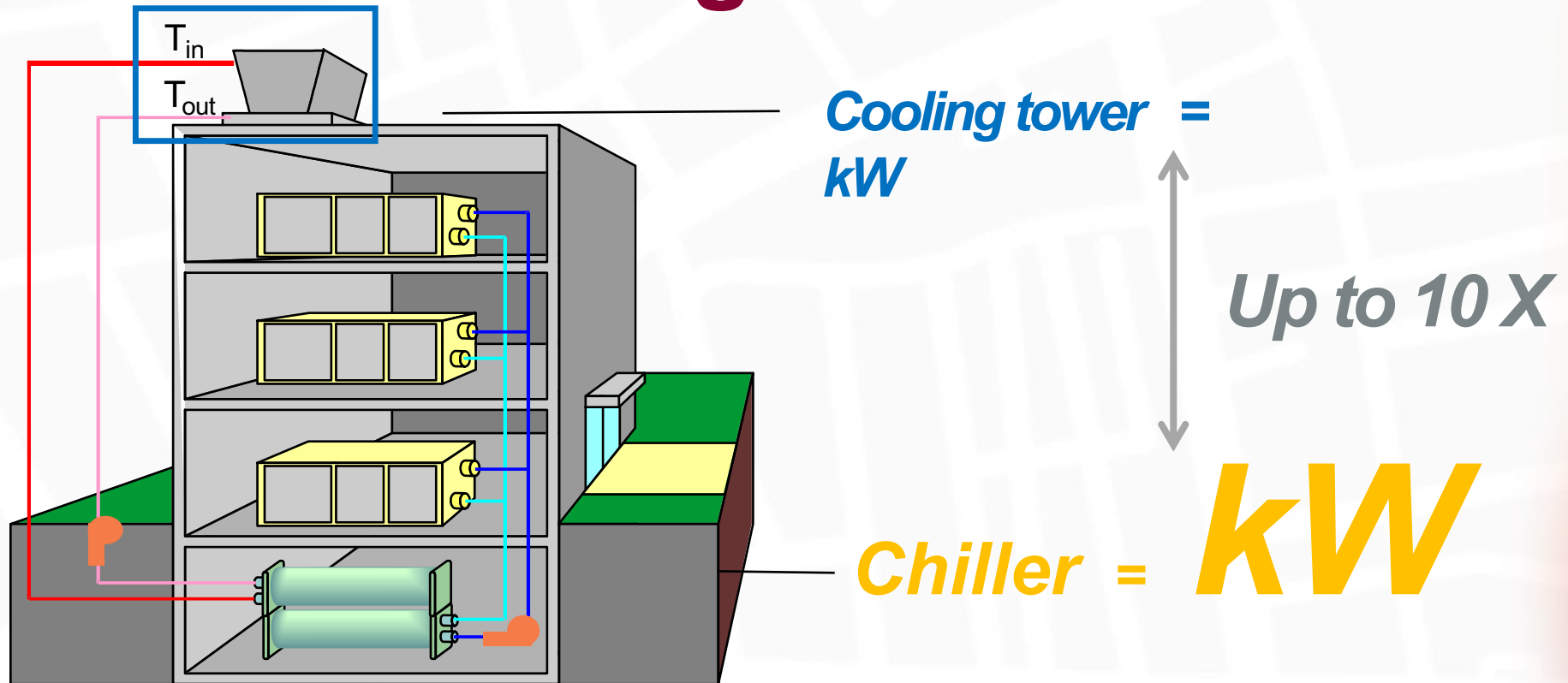
AIR-COOLED SYSTEM		WATER-COOLED SYSTEM	
1.	Design day is based on DRY bulb temperature		Design day is based on <u>WET Bulb</u> temperature
2.	Larger outdoor technical footprint (more surface area)		<u>Smaller</u> outdoor technical <u>footprint</u>
3.	Higher energy consumption		<u>Lower energy</u> consumption
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

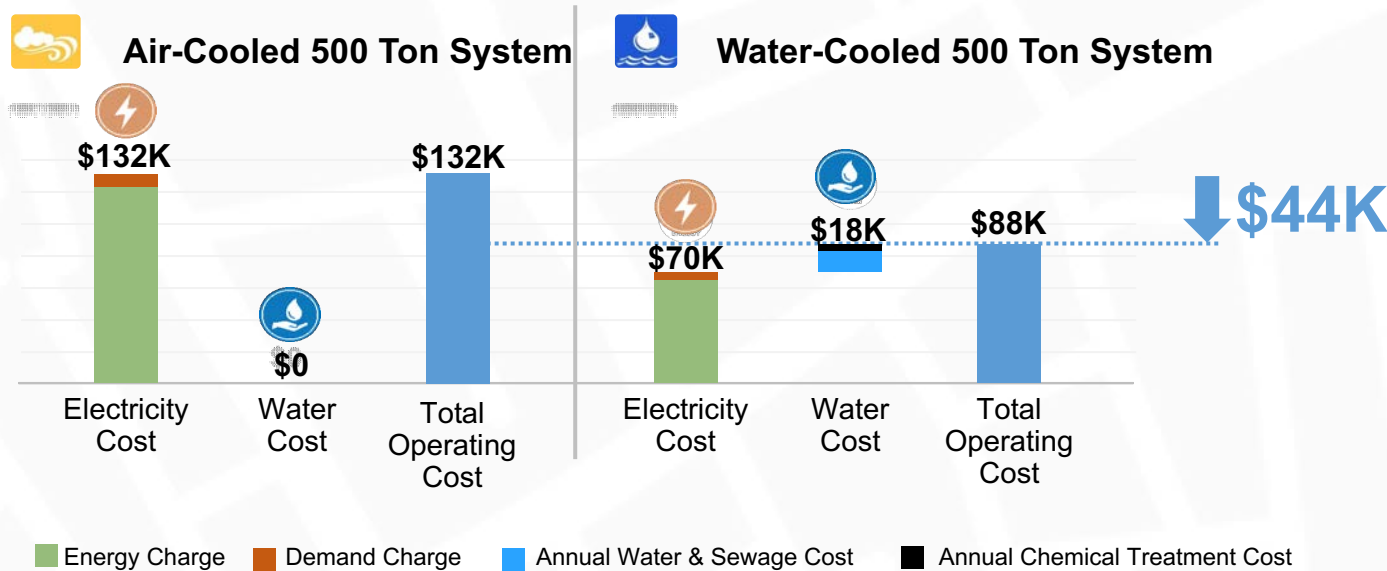


Evaporative Cooling in HVAC



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

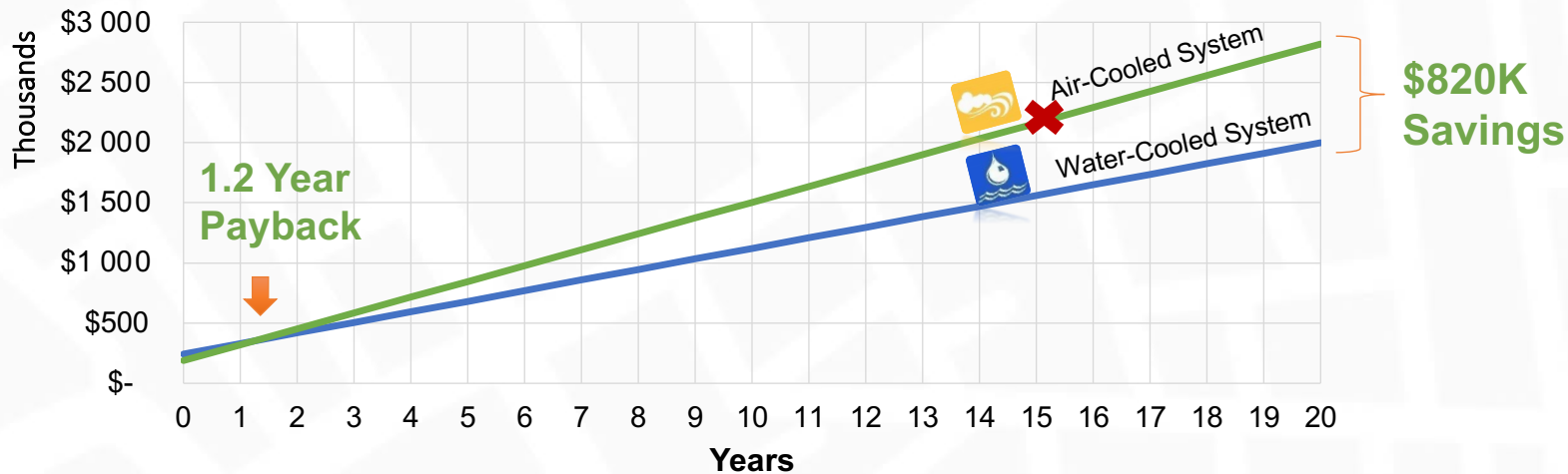
Water-Cooled Advantage:

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

Annual Operating Cost

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>



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

Important Note:

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

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.

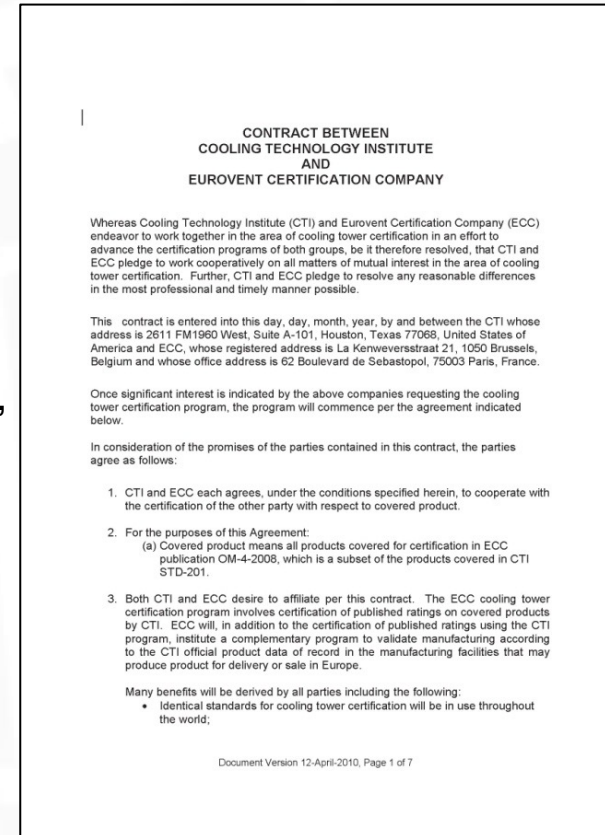


Eurovent Certification and CTI Partnership

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:

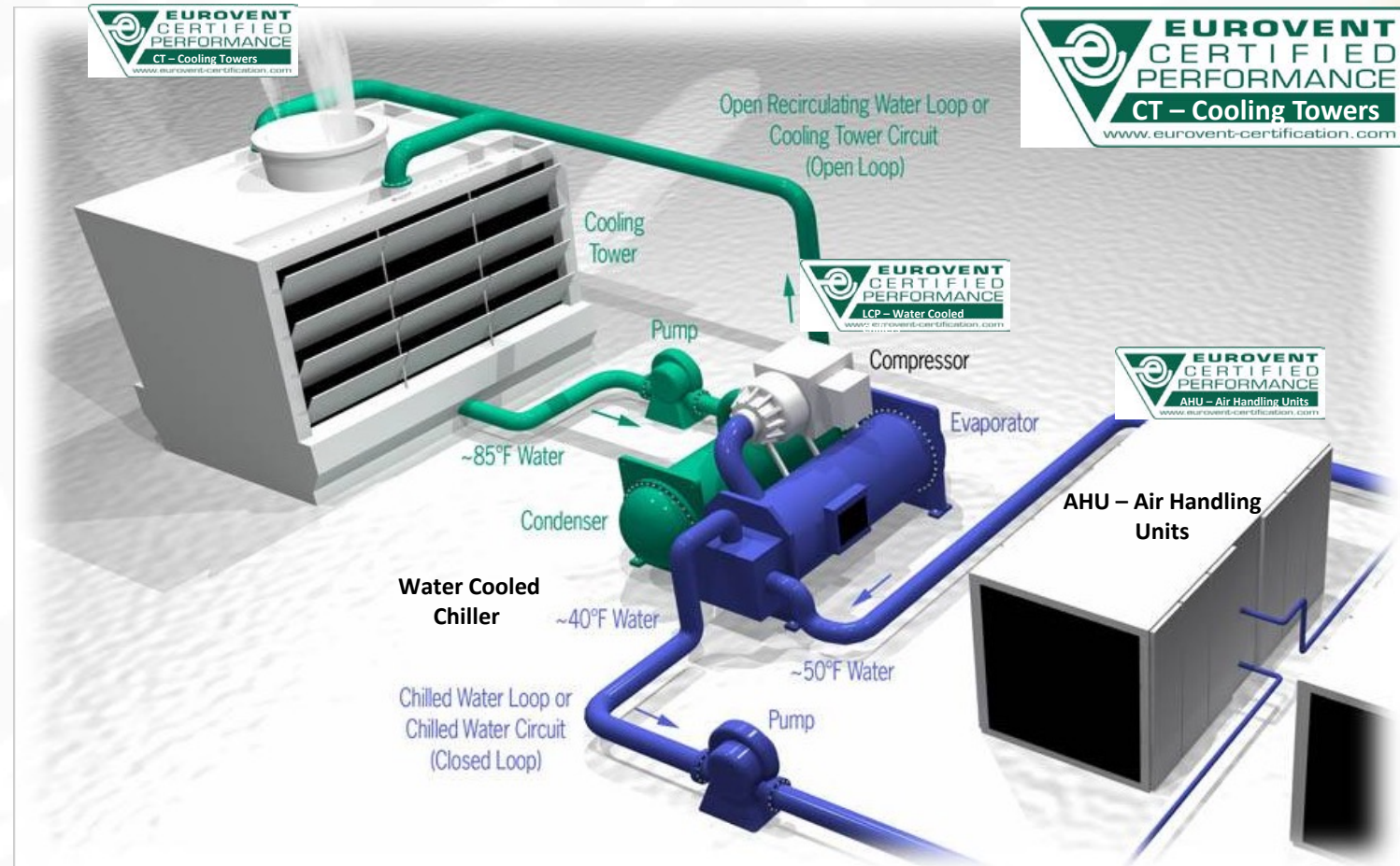
- To encourage honest competition
- Assure correctly rated equipment on the market
 - Separate and specific certification programmes for each product type.
 - Product performance tests through an independent third-party.
 - Application and participation open to all manufacturers.

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 – CTI Joins ECC



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:



Moderated Discussion

Final Remarks

Workshop Partners



Media Partner

climate control^{MIDDLE EAST}

KEY PERSPECTIVES ON THE REGION'S HVACR INDUSTRY



Thank You!