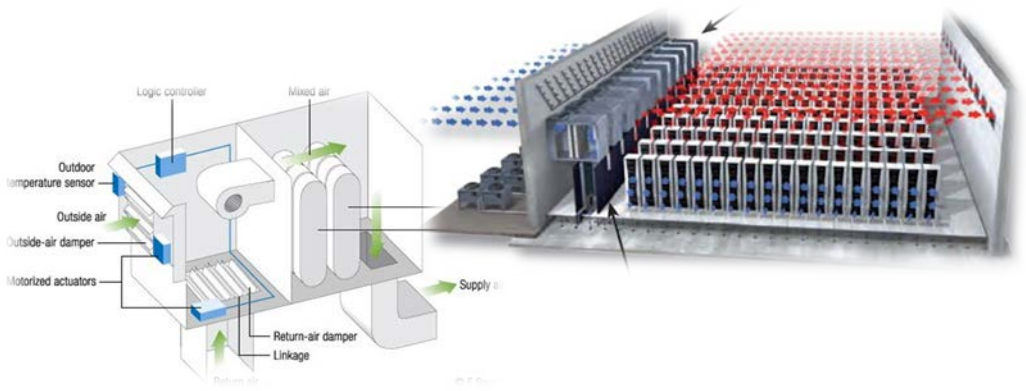
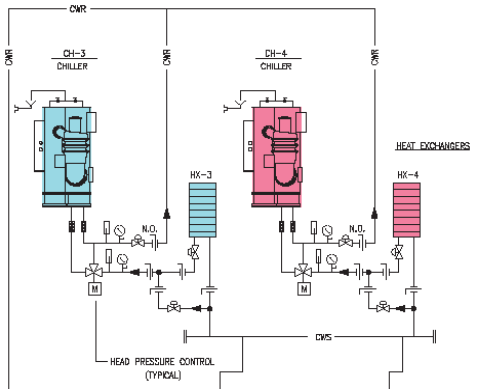
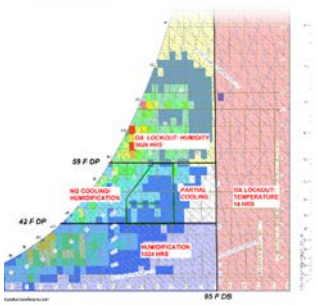
# Objectives

- Increase awareness of the types of economizers currently used for data centers
- Provide designers/owners with an overview of the benefits and challenges associated with each type
- Outline some commonly overlooked aspects and important items to consider during design
- Provide an operational cost comparison of common air-side and water-side economizer strategies for various climatic conditions

# Agenda



- Introduction and examples of several airside and waterside economizer options
- Description of the technology
- Pros and cons of each type of economizer system
- Energy and water use comparison for a typical data center in various climates

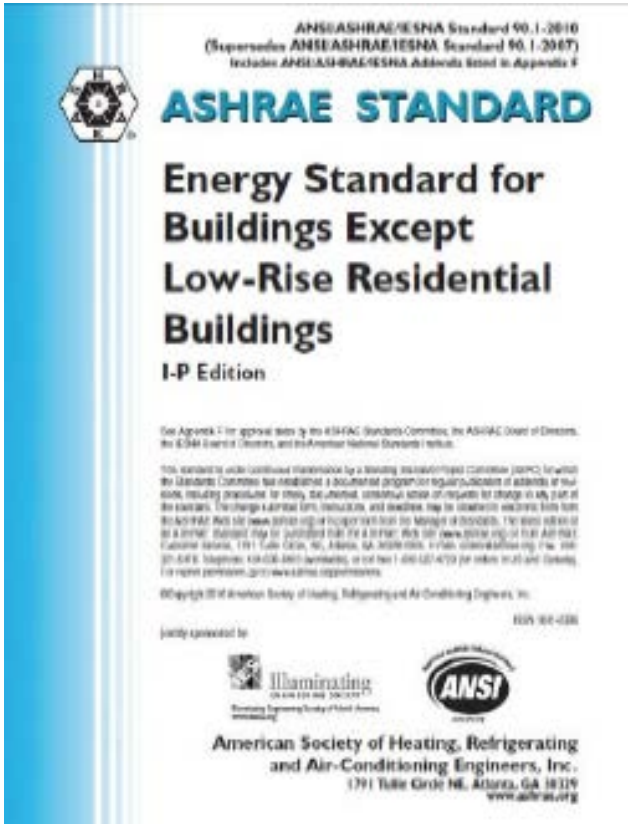
# Why use an Economizer?

- Required by energy code
  - ASHRAE 90.1-2010 and 2013
  - IECC 2012
- Maximize energy savings
- Increase life of cooling equipment
- More reliable for extreme cold weather conditions
- There are disadvantages
  - First cost
  - Increased complexity
  - Risks associated with change of state

# Energy Code Requirements

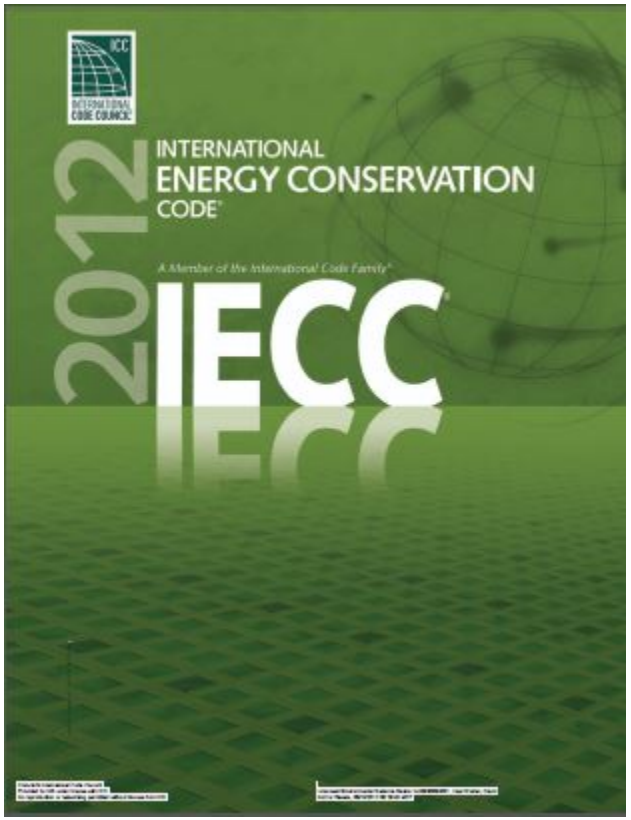
## ASHRAE 90.1- 2010

- Required for LEED projects
- Can be used in-lieu of IECC




## IECC – 2012

- Adopted by eight states and many local jurisdictions (according to ICC)
- Not as many data center exceptions



# Energy Code Requirements – ASHRAE 90.1-2010

**6.5.1 Economizers**. Each Cooling System that has a fan shall include either an air or water economizer meeting the requirements of Sections 6.5.1.1 through 6.5.1.4.

*For data centers, economizers are not required for:*

- *Small fan-cooling units less than 135,000 Btu/hr or 65,000 Btu/hr, depending on climate zone*
- *Extremely hot and humid climate zones*
- *Buildings with no central CHW plant, in which the total computer room cooling capacity is less than 250 tons*
- *Buildings with a central CHW plant, and the computer room cooling load is less than 50 tons*
- *Where cooling towers are not allowed*
- *Addition of less than 50-ton computer room capacity to existing building*

# Energy Code Requirements – ASHRAE 90.1-2010

## 6.5.1.2 Water Economizers

**6.5.1.2.1 Design capacity.** Water economizer systems shall be capable of cooling supply air by indirect evaporation and providing up to 100% of the expected system cooling load at outdoor air temperatures of 50°F dry bulb/ 45°F wet bulb and below

- *For data centers, the requirement is relaxed slightly to allow 100% economizer cooling at 40°F dry bulb/ 35°F wet bulb and below*
- *The code also allows dry-coolers for data centers, but they must provide 100% economizer cooling at 35°F dry bulb*
- *For ASHRAE 90.1-2013, the temperature requirements listed above will be specific to each climate zone*

# Energy Code Requirements – IECC-2012

**C403.4.1 Economizers.** Economizers shall comply with Sections C403.4.1.1 through C403.4.1.4

*This section requires either an air or water economizer*

**C403.4.1.1 Design capacity.** Water economizer systems shall be capable of cooling supply air by **indirect evaporation** and providing up to 100 percent of the expected system cooling load at outdoor air temperatures of 50°F dry bulb / 45°F wet bulb and below.

- *Exception for small systems below 33,000 Btu/h*
- *Unlike ASHRAE 90.1, IECC has no specific exceptions for data centers which allow lower dry-bulb/wet-bulb temperatures or even allow dry-coolers to be used.*

# Types of Economizers

Generally, we can define an economizer as any system that uses outdoor ambient conditions to reduce the amount of mechanical cooling required. The four types of economizers compared in this analysis were:

**Air-side Economizers**:

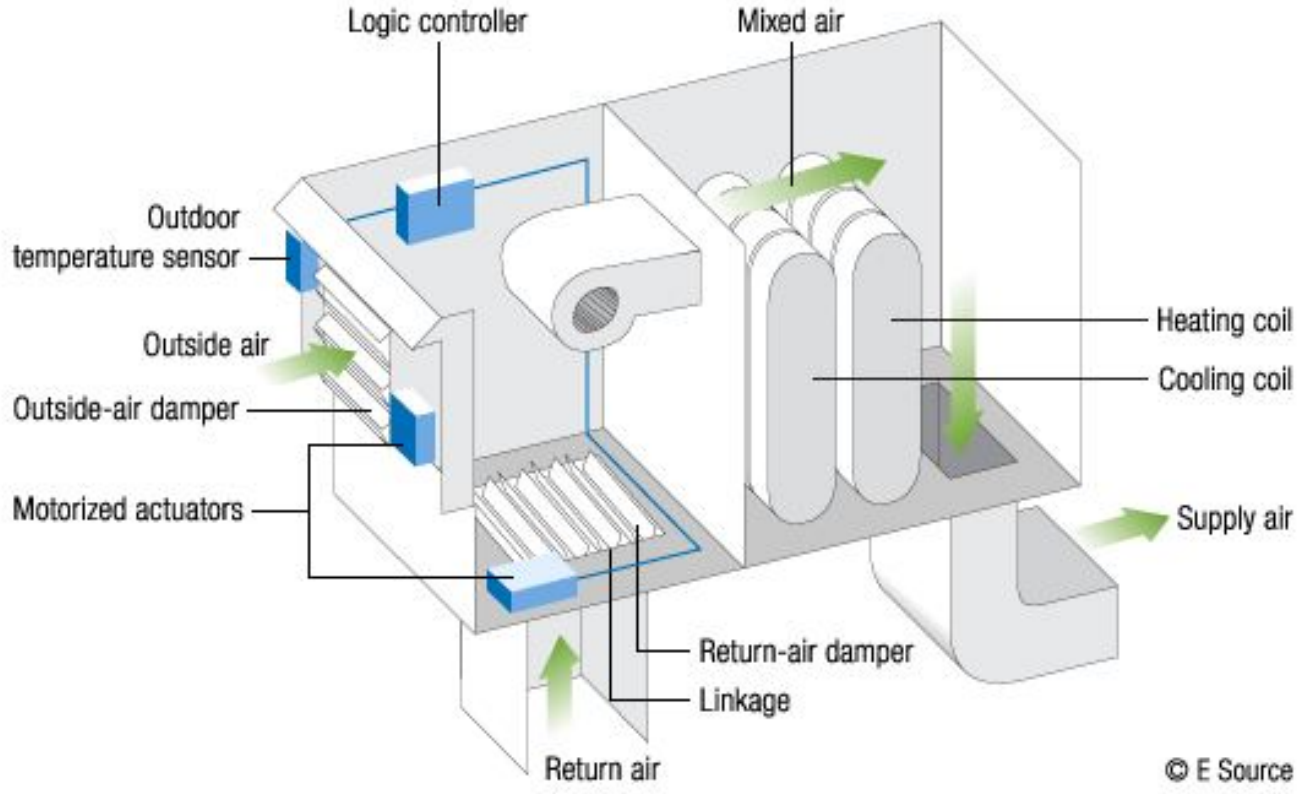
- **Direct Outside Air Economizer**: Outside air is directly supplied to the data center space if conditions are favorable.
- **Indirect Evaporative Air-side Economizer**: Outdoor air is cooled evaporatively and cools data center air indirectly through a heat exchanger. No outdoor air enters space.

**Water-side Economizers**:

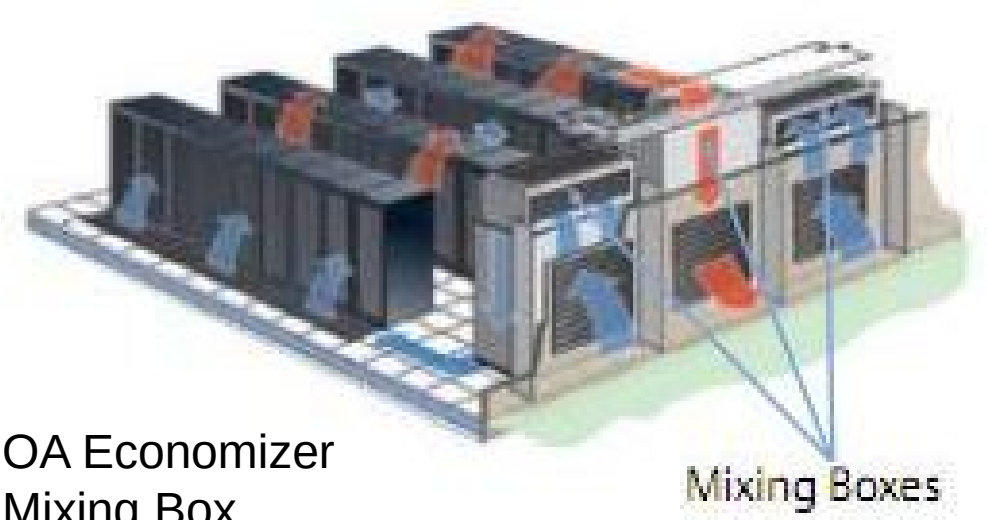
- **Water-cooled Chillers and Cooling Towers**: Cooling towers provide free evaporative cooling when wet-bulb temperature is favorable.
- **Air-cooled Chillers and Dry Coolers**: Dry coolers provide free cooling when outdoor dry-bulb temperature is favorable.

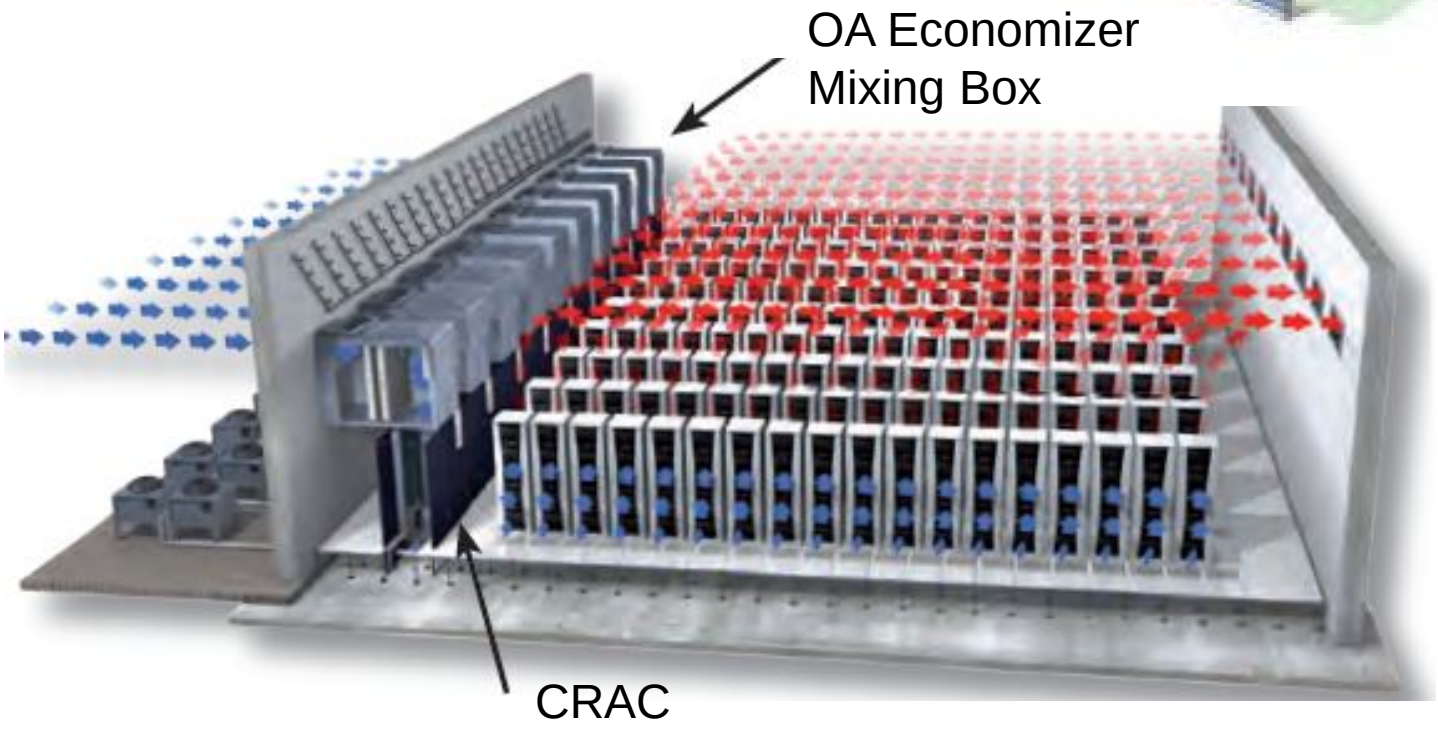
# Direct Outside Air (OA) Economizer – Technology Description

When outside air conditions are favorable, outside air is supplied directly into the data center. To avoid over-pressurization, a proportional amount of exhaust is also required.



# Direct OA Economizer – CRAC Based Options



# Direct OA Economizer – Example

Yahoo “Chicken Coop”

- Located in favorable climates
- Utilizes temperature/humidity ranges beyond ASHRAE recommendations

# Direct Outside Air Economizers – Pros and Cons

## Advantages

- **Eliminates heat exchanger inefficiencies**
- **Reduced water use for cooling**
  - Important where water is highly regulated
  - Cost of water may rise drastically in many areas
  - Water quality concerns
  - Minimizes cost of water treatment to prevent fouling of equipment

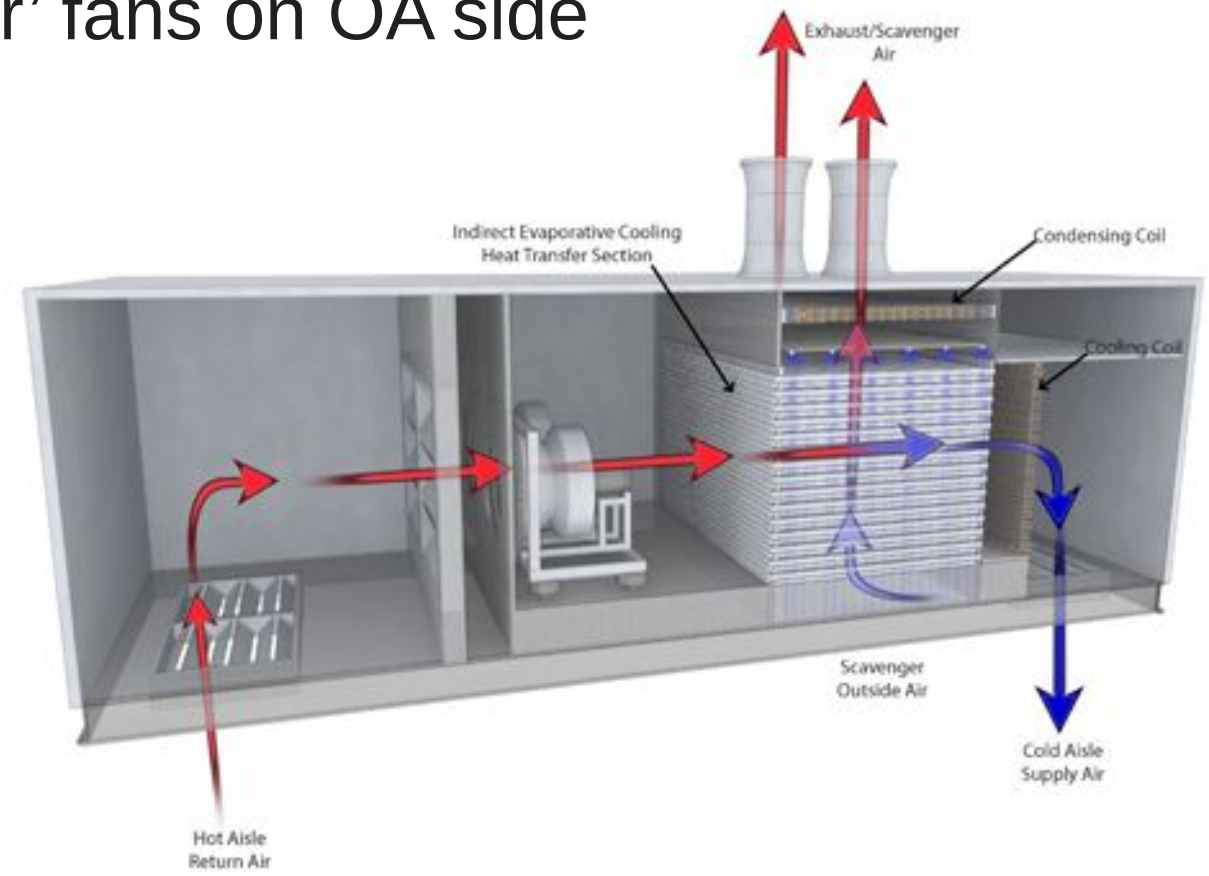
# Direct Outside Air Economizers – Pros and Cons

## Disadvantages

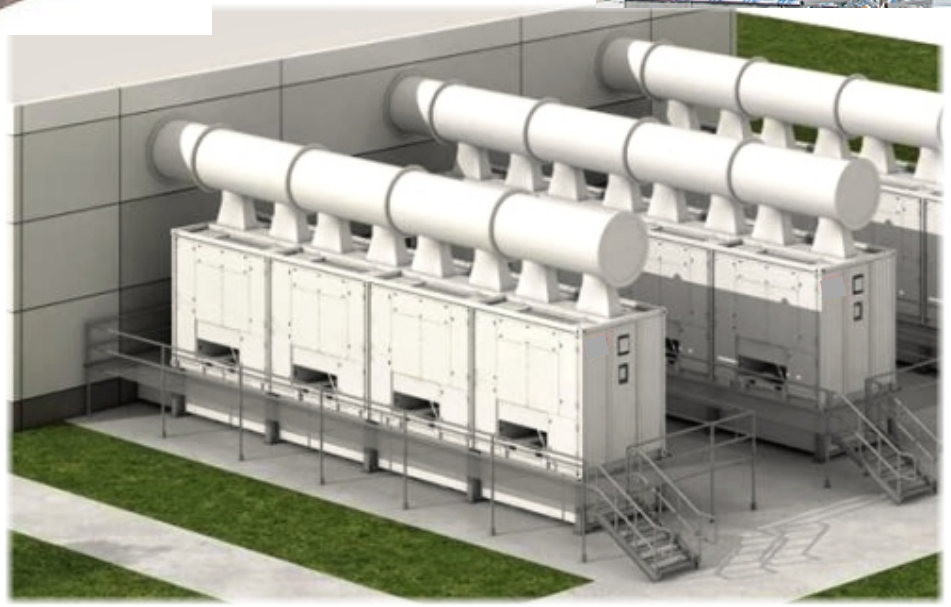
- **Air quality concerns**
  - Intel proof-of-concept studies say OA doesn't increase server failures
  - Further research required
  - Intentional or accidental outdoor air contamination events
- **Additional air filtering requirements**
  - Higher filter pressure drop
  - Increased operational costs due to filter replacements
- **Humidity control issues**
  - OA damper leakage
  - Variable outdoor conditions
- **Economizer hours limited by OA humidity and temperature**
- **High power requirement at peak times**

# Indirect Evaporative Economizer - Technology Description

- No outside air enters data center
- Air-to-air heat exchanger with evaporative cooling
- ‘Scavenger’ fans on OA side



# Indirect Evaporative Economizer – Various Configurations



# Indirect Evaporative Economizers – Pros and Cons

## Advantages

- **Maximizes available economizer hours**
  - Based on outdoor wet-bulb temperatures
  - Partial economizer even at peak times
- **Lower peak and overall energy use in most climates**
- **Better air quality**
  - No risk of contamination from outside events
  - No need for high efficiency filtration
- **Stable temperature and humidity conditions**
  - Weather variations do not directly affect indoor conditions
  - Simple humidification controls

# Indirect Evaporative Economizers – Pros and Cons

## Disadvantages

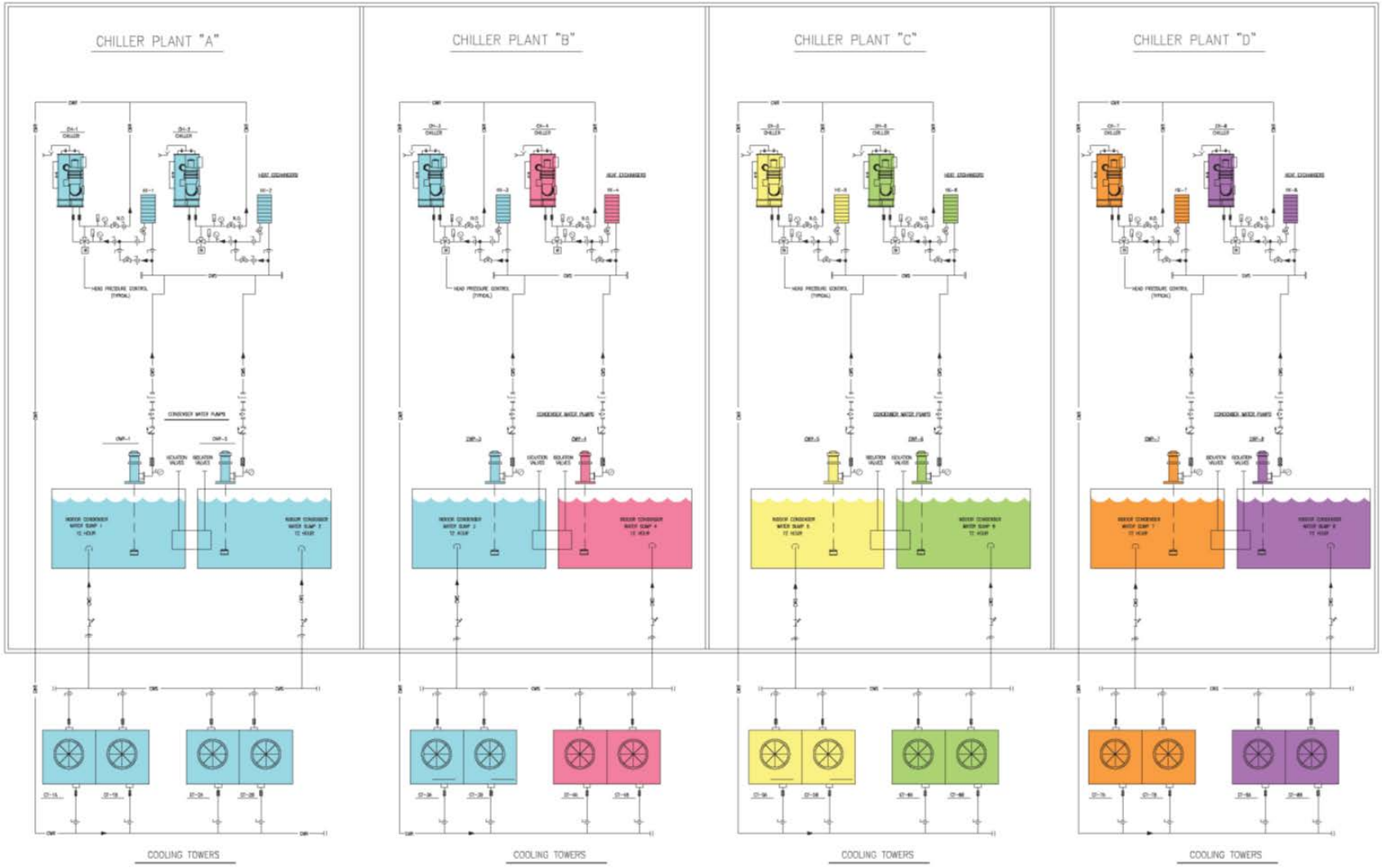
- **High water use**
  - May not be economical in areas with high water costs or use restrictions
  - Susceptible to future water regulations
  - Water storage required for reliability and Tier requirements
- **Water treatment may be required**
  - Local water quality may foul air-to-air heat exchangers
  - Increased operational costs
- **May have higher space requirements**
- **High fan energy use**

# Water-side Economizer: Cooling Towers - Description

- Indoor water-cooled chillers with cooling towers
- Cooling towers operate to provide coldest water possible and maximize economization
- Chillers do not run during cold weather


# Water-side Economizer: Cooling Towers - Description

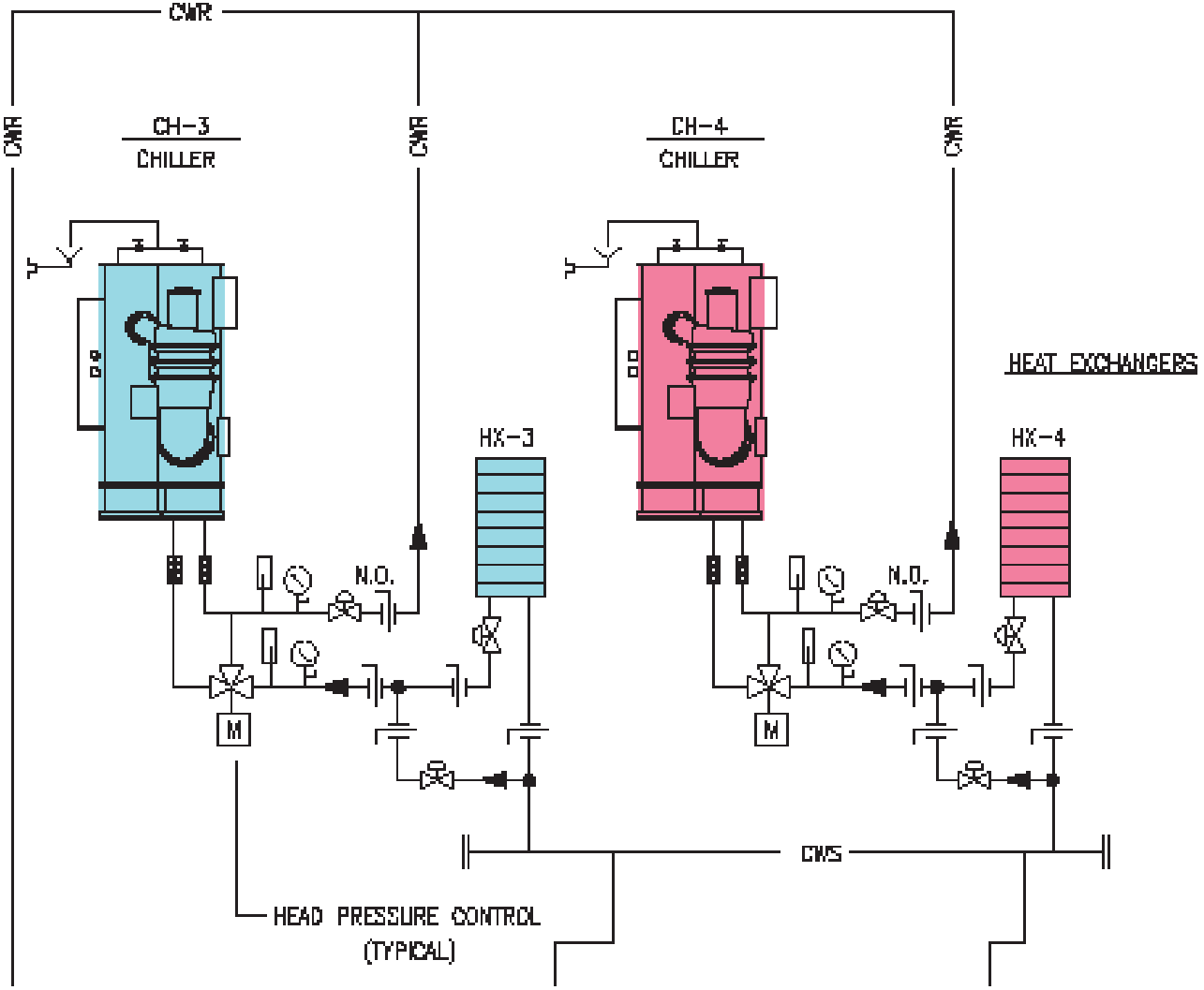
## Chilled water plant - Condenser water piping diagram



# Water-side Economizer: Cooling Towers - Description

## Detailed view of economizer piping:

- When cooling towers can supply water at a temperature lower than chilled water return temp, heat exchangers are activated.
- Cold condenser water flows through heat exchanger for free cooling of chilled water, then thru chiller if needed.



# Water-side Economizer: Cooling Towers – Pros and Cons

## Advantages

- **Chilled water distribution**
  - Generally more flexible and efficient than moving air long distances
  - For data centers with no direct access to outside
- **Low fan energy due to minimal filtering requirements and shorter air distribution**
- **Better air quality**
  - No risk of contamination from outside events
  - No need for high efficiency filtration
- **Stable temperature and humidity conditions**
  - Weather variations do not directly affect indoor conditions
  - Simple humidification controls

# Water-side Economizer: Cooling Towers – Pros and Cons

## Disadvantages

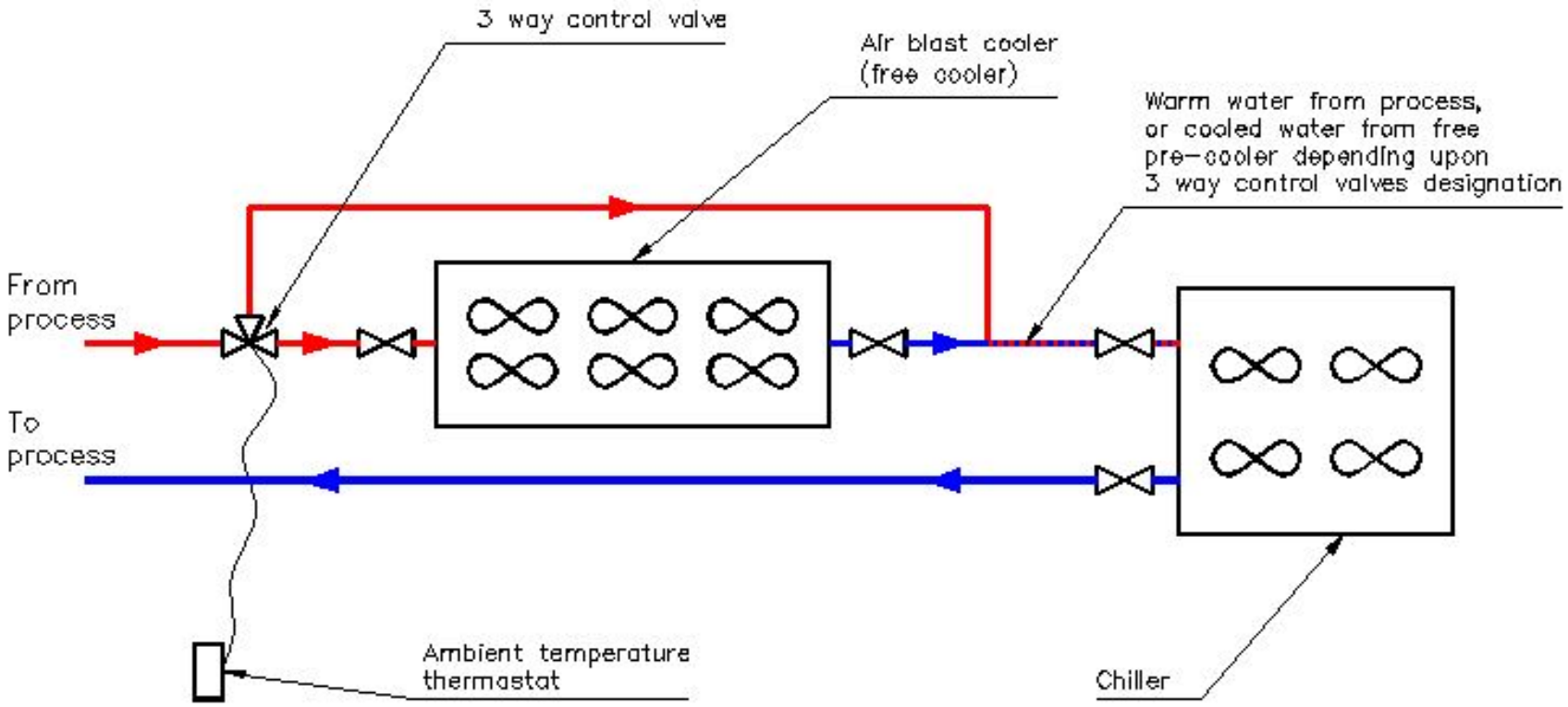
- **First Cost of Central Piping Distribution**
  - Piping generally sized for ultimate load
  - High on-site labor costs
- **Cooling tower maintenance and water treatment**
- **Water in or near IT equipment**
  - CRAH units and piping typically within data center
  - Leakage monitoring
- **Designing for reliability is difficult and costly**
  - Multiple isolation valves in common system to meet Tier III
  - Complicated controls to account for many failure modes
- **Thermal energy storage required for chiller restarts**

# Water-side Economizer: Air-Cooled Chillers/Dry Coolers- Description

- Outdoor air-cooled chillers with dry cooler economizers
- Chilled water/glycol is diverted to dry-coolers for partial and full cooling to maximize free cooling
- Chillers do not run during cold weather

# Water-side Economizer: Air-Cooled Chillers/Dry Coolers- Description

Air-cooled chiller with dry-cooler piped in series



# Water-side Economizer: Air-Cooled Chillers/Dry Coolers- Pros and Cons

## Advantages

- **Same advantages of previous chiller option**
  - Chilled water distribution flexibility
  - Low fan energy
  - Better air quality
  - Stable temperature and humidity conditions
- **No cooling tower maintenance or water treatment issues**
- **Minimal indoor space required**

# Water-side Economizer: Air-Cooled Chillers/Dry Coolers- Pros and Cons

## Disadvantages

- **Same disadvantages of previous chiller option:**
  - First Cost of Central Piping Distribution
  - Water in or near IT equipment
  - Designing for reliability is difficult and costly
  - Thermal energy storage required for chiller restarts
- **Large equipment footprint**
- **High energy use**
- **High peak load requirements**
- **Chiller noise may be a problem**

# Energy / Water Use Comparison

## Bin Data Energy Use Analysis

- **Design Criteria**
  - Typical Enterprise / Colocation Data Center Load
    - 10,000 sq. ft.
    - 200 W/sf
    - 2 MW of total IT load
  - **Within ASHRAE ‘Recommended’ Conditions**
    - Supply temperature = 75°F
    - Return temperature = 95°F
    - Space dew-point temp between 42°F and 59°F
    - Efficient adiabatic humidification used for analysis

# Energy / Water Use Comparison

- **Comparison of Five Different Climates**
  - Charlotte, NC
  - Phoenix, AZ
  - Chicago, IL
  - Denver, CO
  - Sacramento, CA
- **Annual Utility Costs for Two Different Scenarios**
  - High Electricity Cost, Low Water Cost
  - Low Electricity Cost, High Water Cost

# Energy / Water Use Comparison

## Four Systems Analyzed and Compared:

## Air-side Economizer Options:

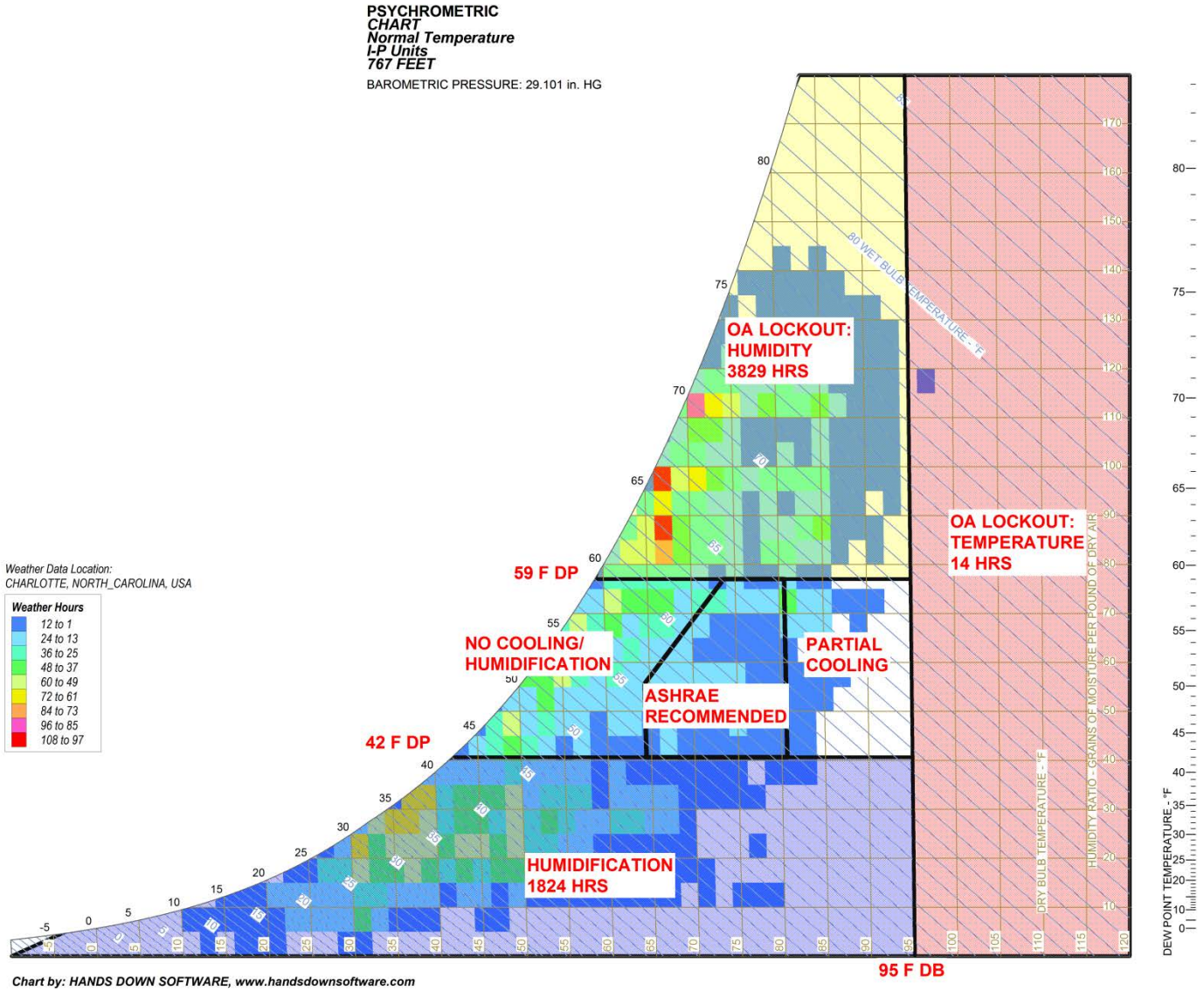
1. **Direct Outside Air**
   - Multiple 500 kW capacity rooftop supply/exhaust AHUs
   - Merv 13 Filters
   - Air-cooled chiller system for supplemental cooling
2. **Indirect Evaporative**
   - Multiple 280 kW capacity Indirect Evap AHUs
   - Merv 8 Filters
   - DX supplemental cooling system

# Energy / Water Use Comparison

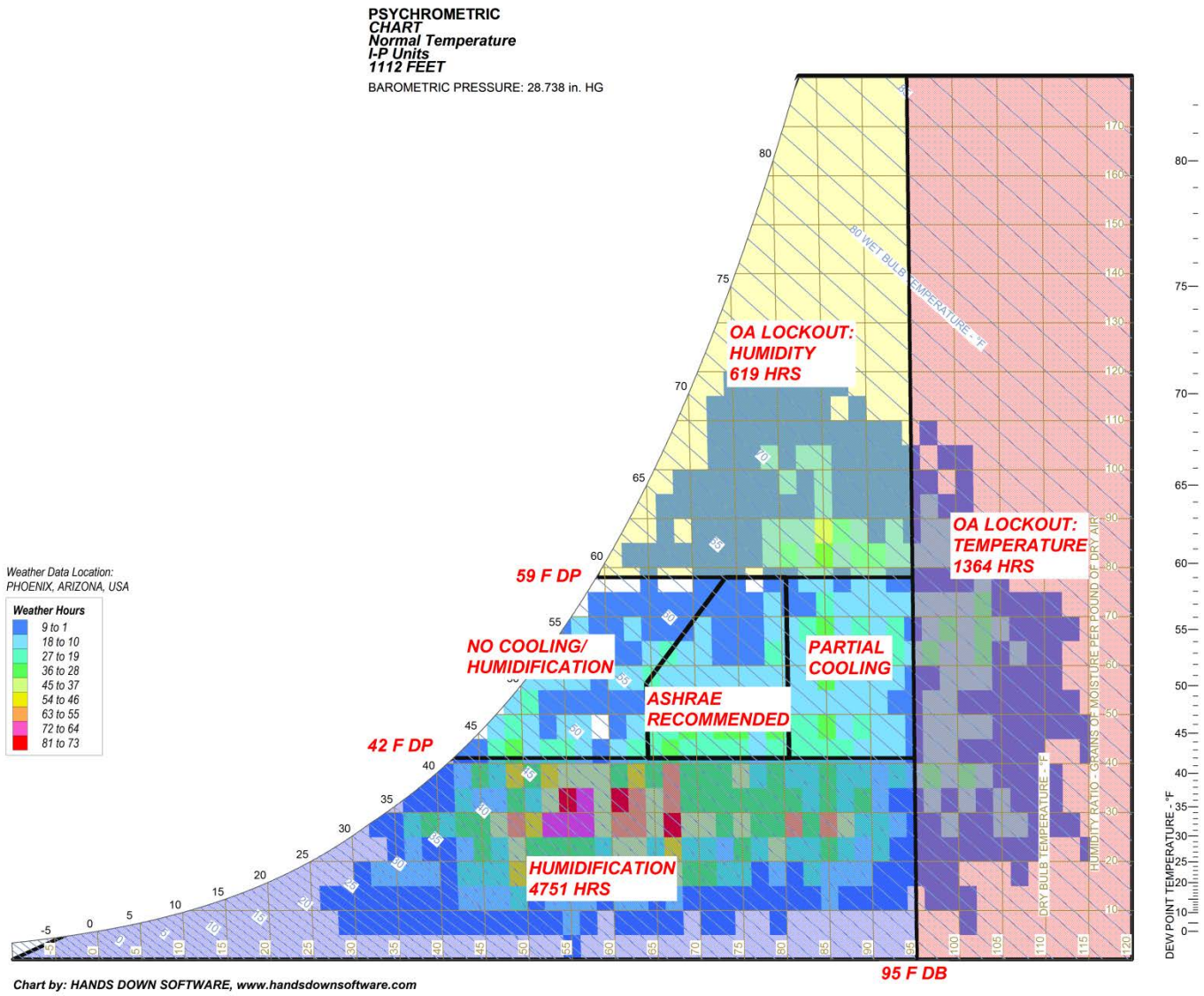
Water-side Economizer Options:

1. **Water-cooled Chillers with Cooling Towers**
   - High efficiency variable speed chillers (.4 kW/ton)
   - Induced draft cooling towers
   - Plate and frame heat exchangers in series w/chillers
   - CRAH units with high efficiency EC fans on raised floor
2. **Air-cooled Chillers with Dry Coolers**
   - Air-cooled chillers with integral dry-cooler coils
   - 3-way valves to allow partial economization
   - CRAH units with high efficiency EC fans on raised floor

# Air-side Economizer Free Cooling Zones – Charlotte, NC



# Air-side Economizer Free Cooling Zones – Phoenix, AZ



# Air-side Economizer Free Cooling Zones – Chicago, IL