Better Buildings®
U.S. DEPARTMENT OF ENERGY

Alternative Cooling Solutions in High Tech Buildings

Wednesday, May 17

9:30 AM – 10:45 AM

U.S. DEPARTMENT OF ENERGY

Panelists

- Dale Sartor, Lawrence Berkeley National Laboratory, Moderator
- Otto VanGeet, National Renewable Energy Laboratory
- John Sasser, Sabey Data Centers

Dale Sartor

Lawrence Berkeley National Laboratory

U.S. DEPARTMENT OF ENERGY

Advanced Data Center Cooling

Moderator Introduction and Context

Dale Sartor, PE
Lawrence Berkeley National Laboratory
Washington DC, May 17, 2017

V 04/25/17

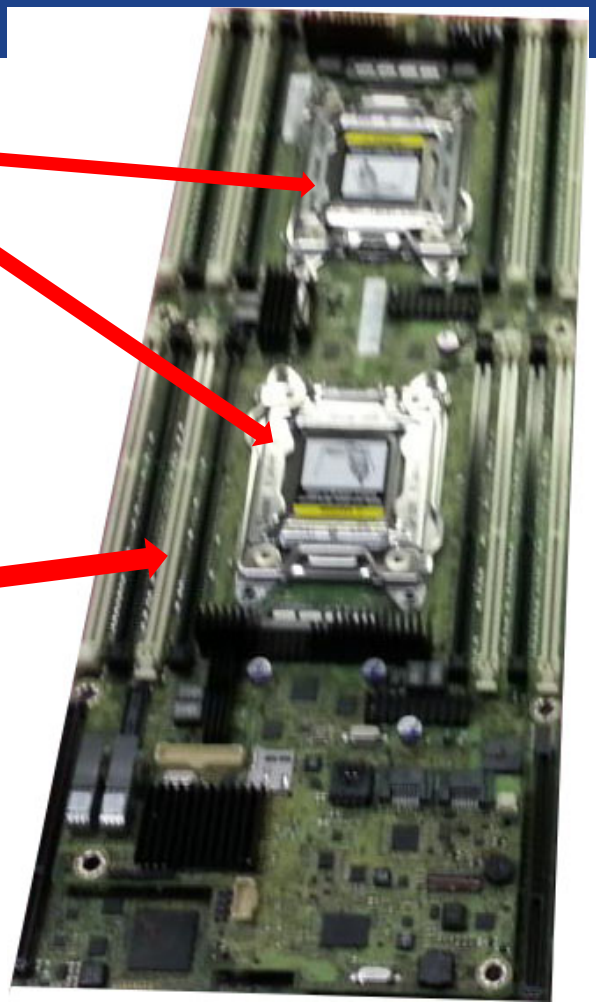
Data Center Cooling Context

- Thermal (environmental) guidelines
- Air management
- Free cooling
- Liquid based cooling
- Humidity control (or not)

Environmental conditions: Safe Temperature Limits

CPUs

~65C
(149F)



GPUs

~75C
(167F)

Memory

~85C
(185F)

So why do we need jackets in data centers?

CPU, GPU & Memory, represent ~75-90% of heat load …

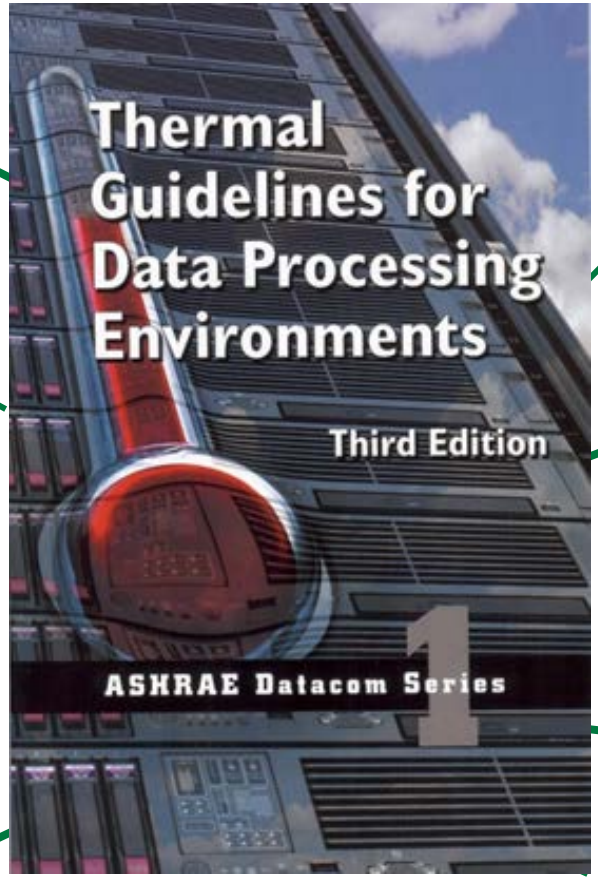
Slide courtesy of NREL

ASHRAE Thermal Guidelines
The defacto standard in the industry

Provides common understanding between IT and facility staff.

Developed with IT manufacturers

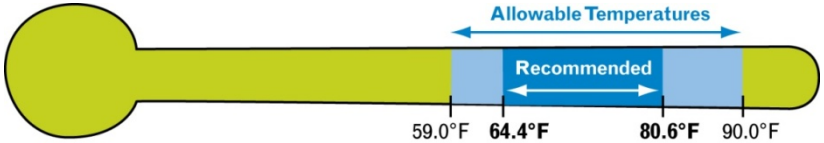
Provides wider humidity ranges



Recommends temperature range up to 80.6° F with "allowable" much higher.

Six classes of equipment identified with wider allowable ranges to 45° C (113° F).

Provides more justification for operating above the recommended limits



Air Management: The Early Days

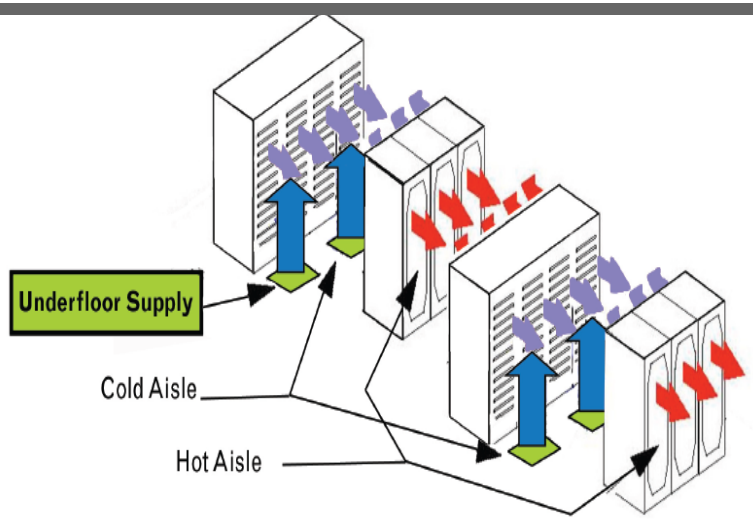
It was cold but hot spots were everywhere

Fans were used to redirect air

High flow tiles reduced air pressure

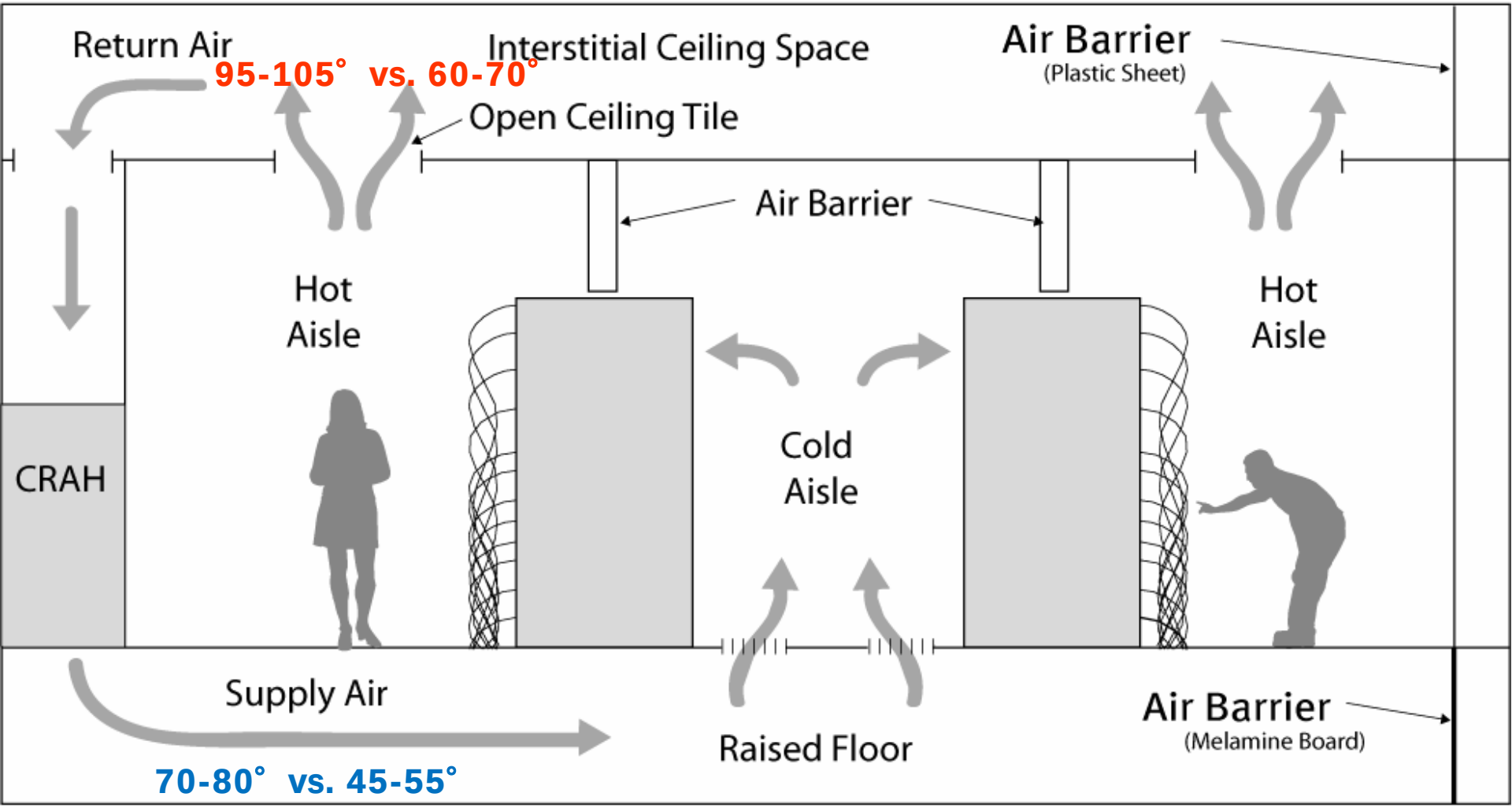
Air Management

- Typically, more air is circulated than required
- Air mixing and short circuiting leads to:
  - Low supply temperature
  - Low Delta T
- Use hot and cold aisles
- Improve isolation of hot and cold aisles
  - Reduce fan energy
  - Improve air-conditioning efficiency
  - Increase cooling capacity



Hot aisle / cold aisle configuration decreases mixing of intake & exhaust air, promoting efficiency.

Isolate Cold and Hot Aisles



Use Free Cooling

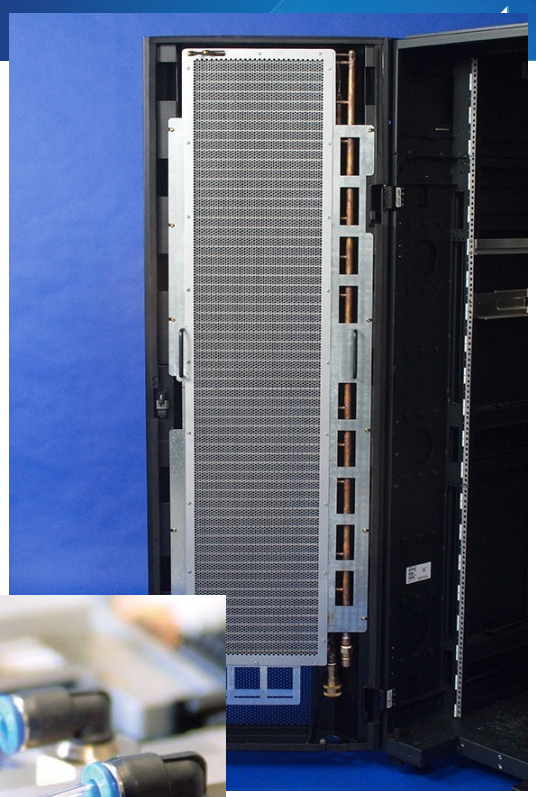
Cooling without Compressors

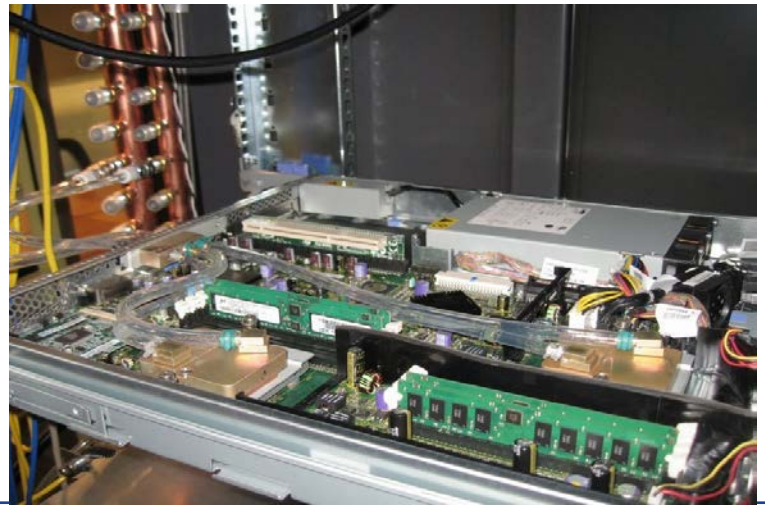
- Water-side Economizers
- Outside-Air Economizers

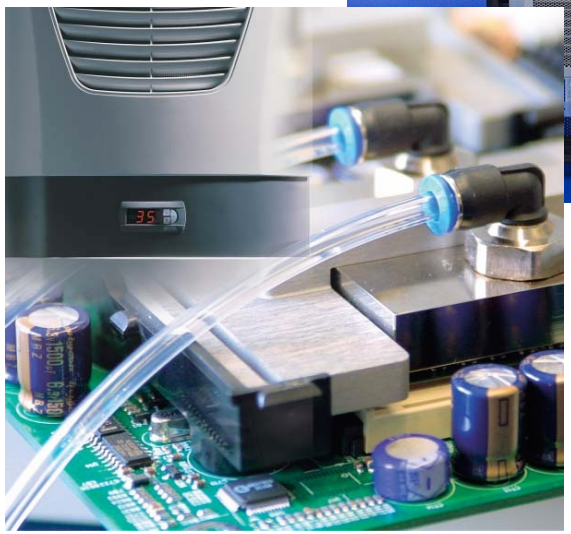
- Let’s get rid of chillers in data centers

Liquid Based Cooling

- Higher compute densities
- Higher efficiency
  - Heat removal
  - Transport energy
  - Cooling plant
  - Increased economizer hours
  - Potential use of waste heat

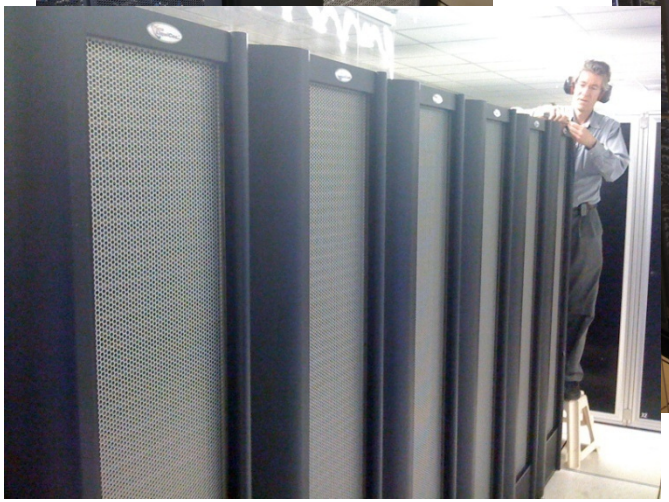




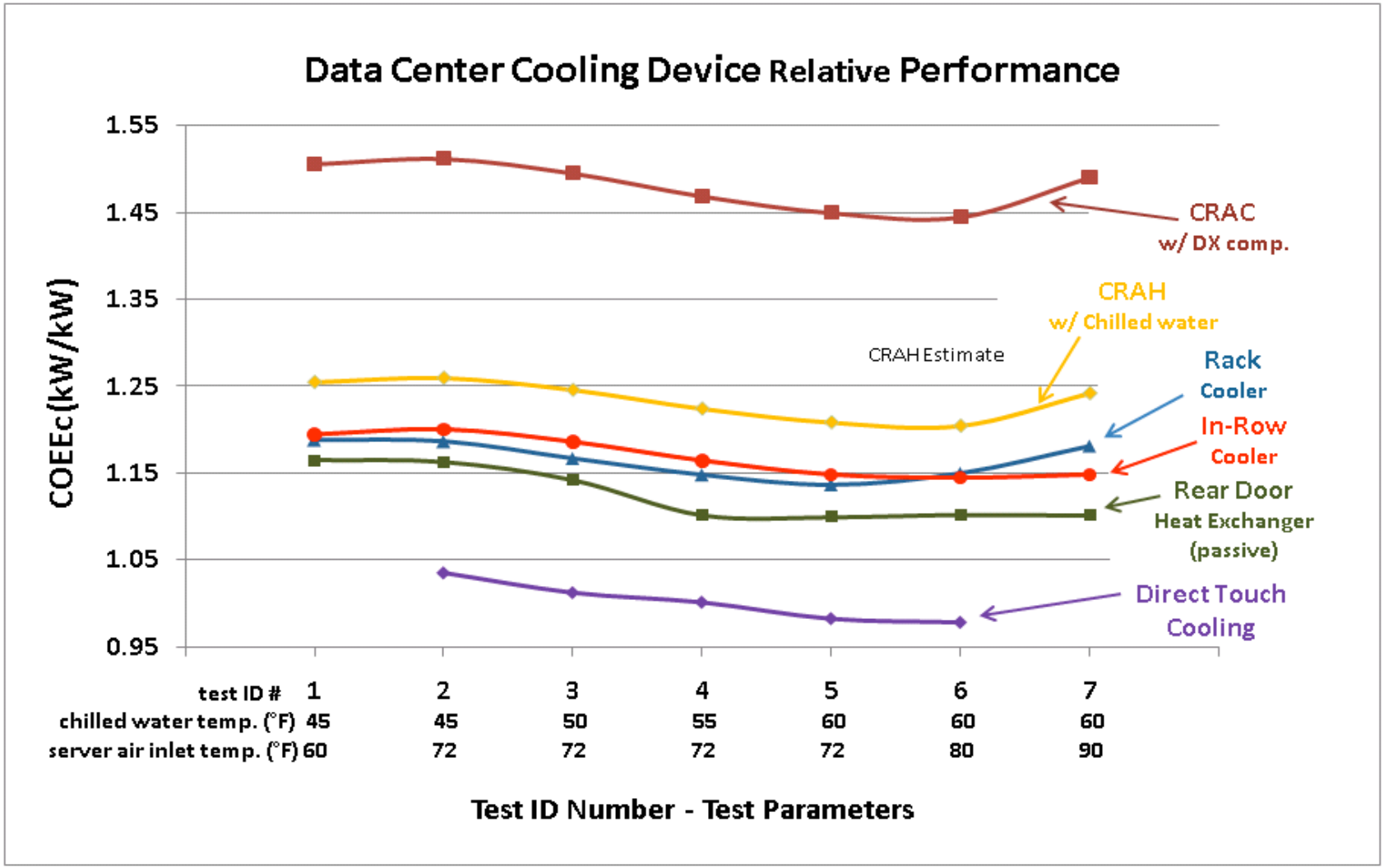


LBNL Example: Rear Door Cooling

- Used instead of adding CRAC units
- Cooling with tower-only or chiller assisted
  - Both options significantly more efficient than existing direct expansion (DX) CRAC units.



“Chill-Off 2” Evaluation of Liquid Cooling Solutions



Improve Humidity Control

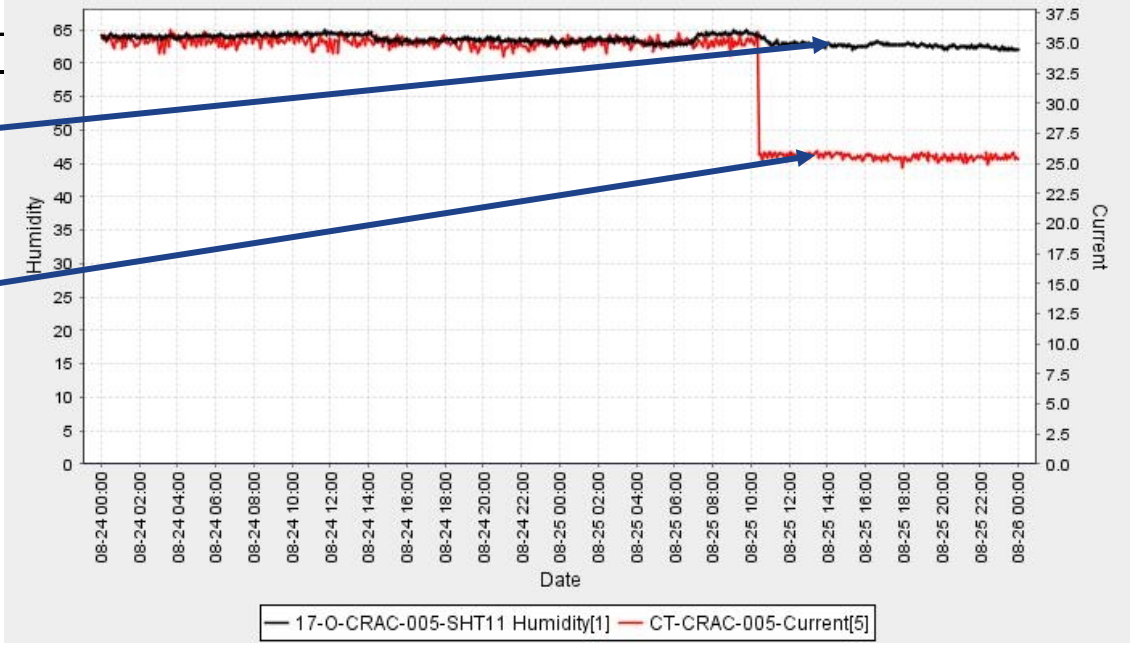
- Eliminate inadvertent dehumidification
  - Computer load is sensible only
- Use ASHRAE allowable RH and temperature
  - Many manufacturers allow even wider humidity range (e.g. 10 to 90%)
- Eliminate equipment fighting
  - Coordinate controls
  - Turn off

The Cost of Unnecessary Humidification

	Visalia Probe			CRAC Unit Panel			
	Temp	RH	Tdp	Temp	RH	Tdp	Mode
AC 005	84.0	27.5	47.0	76	32.0	44.1	Cooling
AC 006	81.8	28.5	46.1	55	51.0	37.2	Cooling & Dehumidification
AC 007	72.8	38.5	46.1	70	47.0	48.9	Cooling
AC 008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification
AC 010	77.5	32.8	46.1	68	45.0	45.9	Cooling
AC 011	78.9	31.4	46.1	70	43.0	46.6	Cooling & Humidification
Min	72.8	27.5	46.1	55.0	32.0	37.2	
Max	84.0	38.5	47.2	76.0			
Avg	79.2	31.7	46.4	68.8			

Humidity down 2%

CRAC power down 28%



Otto VanGeet

National Renewable Energy Laboratory

U.S. DEPARTMENT OF ENERGY

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Advanced Cooling in High Tech Buildings

Otto VanGeet, PE

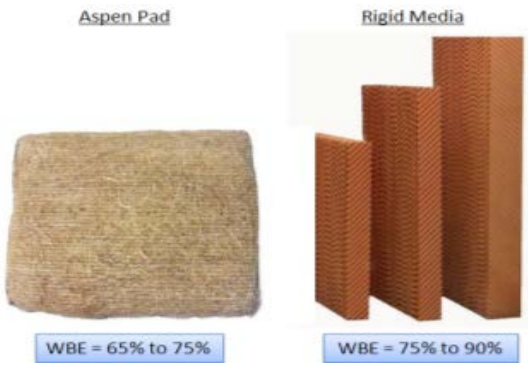
Washington DC, May 17, 2017

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

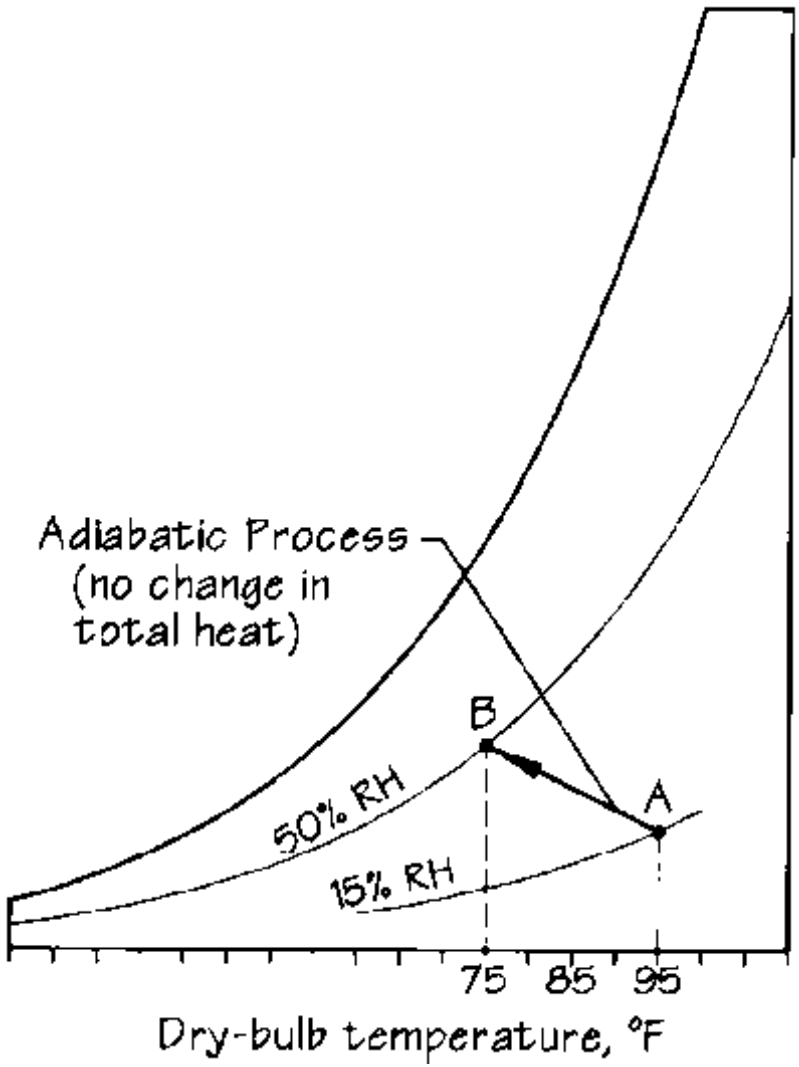
Evaporative Cooling

- Economizer stage cooling first, then…
  - Direct evaporation of water into working air
  - Temperature reduction function of latent cooling capacity (Twb)
    - Fog WBE 90%+

$$\varepsilon = \frac{T_{DB} - T_{supply}}{T_{DB} - T_{WB}}$$



Evaporative Cooling

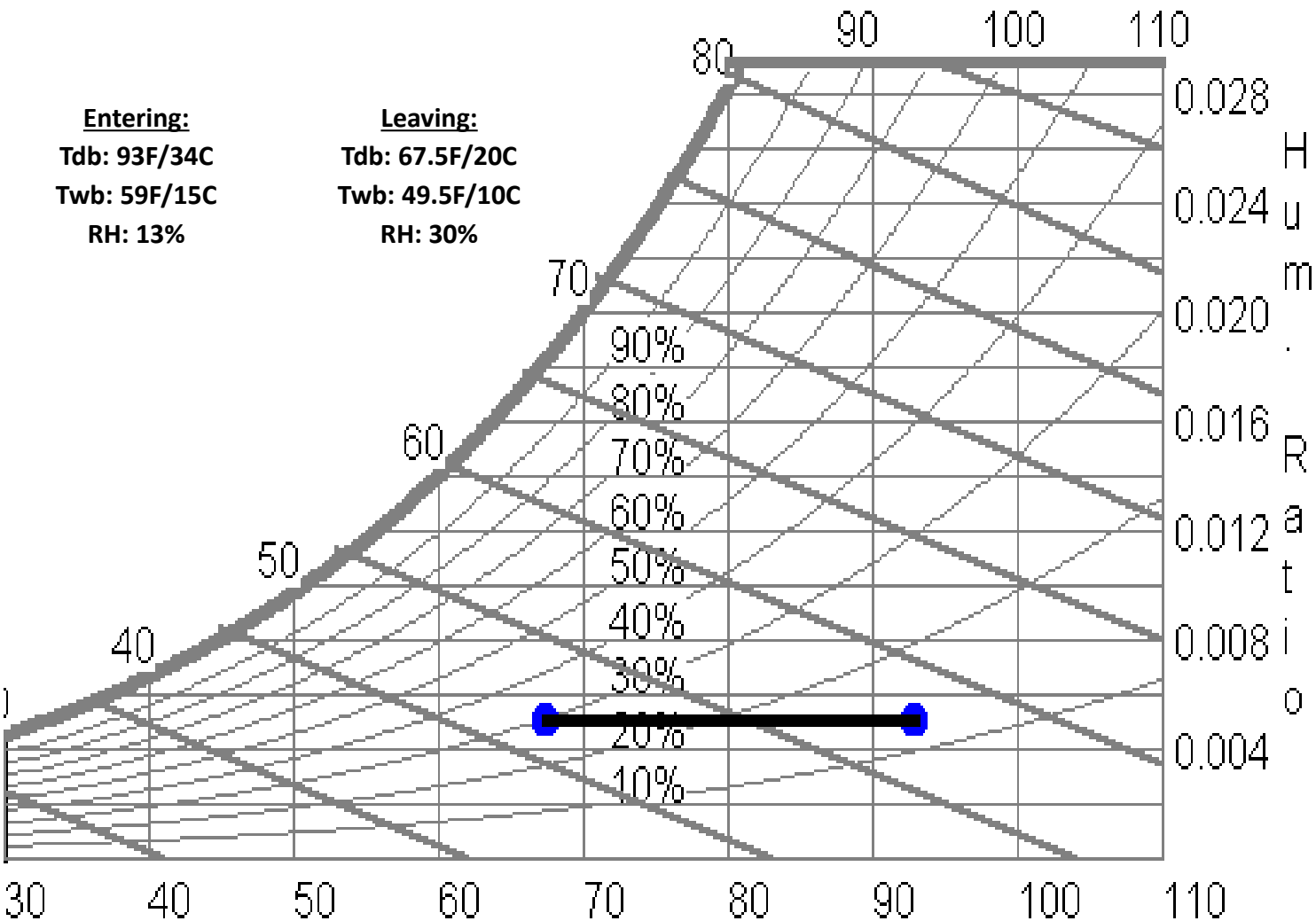


- Moisture evaporated in a low humidity air stream lowers the dry-bulb temperature, enthalpy (total energy content) remains constant.
- Consider direct evaporative cooling in dry climates, particularly when humidification is required.
- Indirect evap when humidification is not desirable.

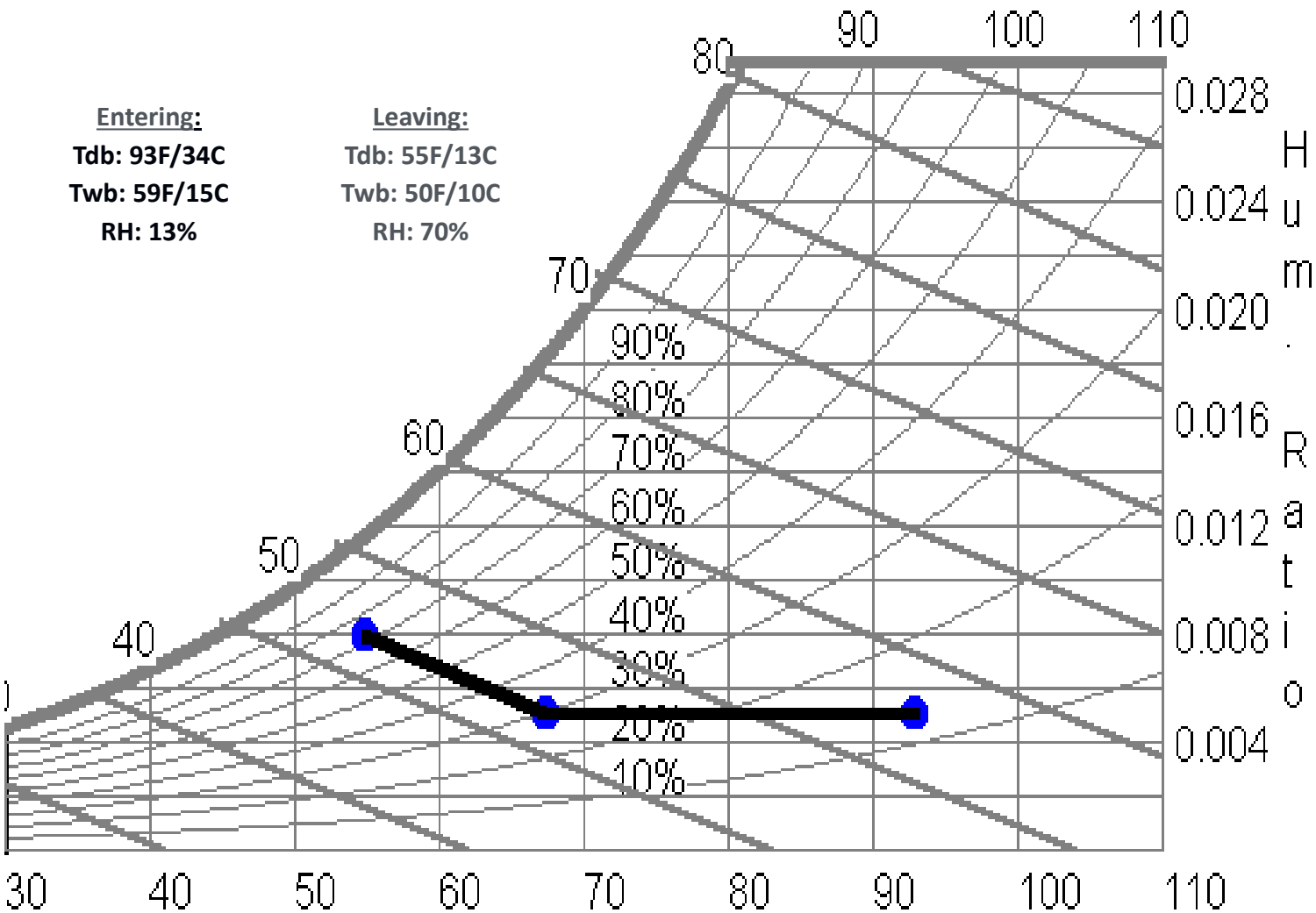
Indirect Evaporative Cooling

Entering:
Tdb: 93F/34C
Twb: 59F/15C
RH: 13%

Leaving:
Tdb: 67.5F/20C
Twb: 49.5F/10C
RH: 30%

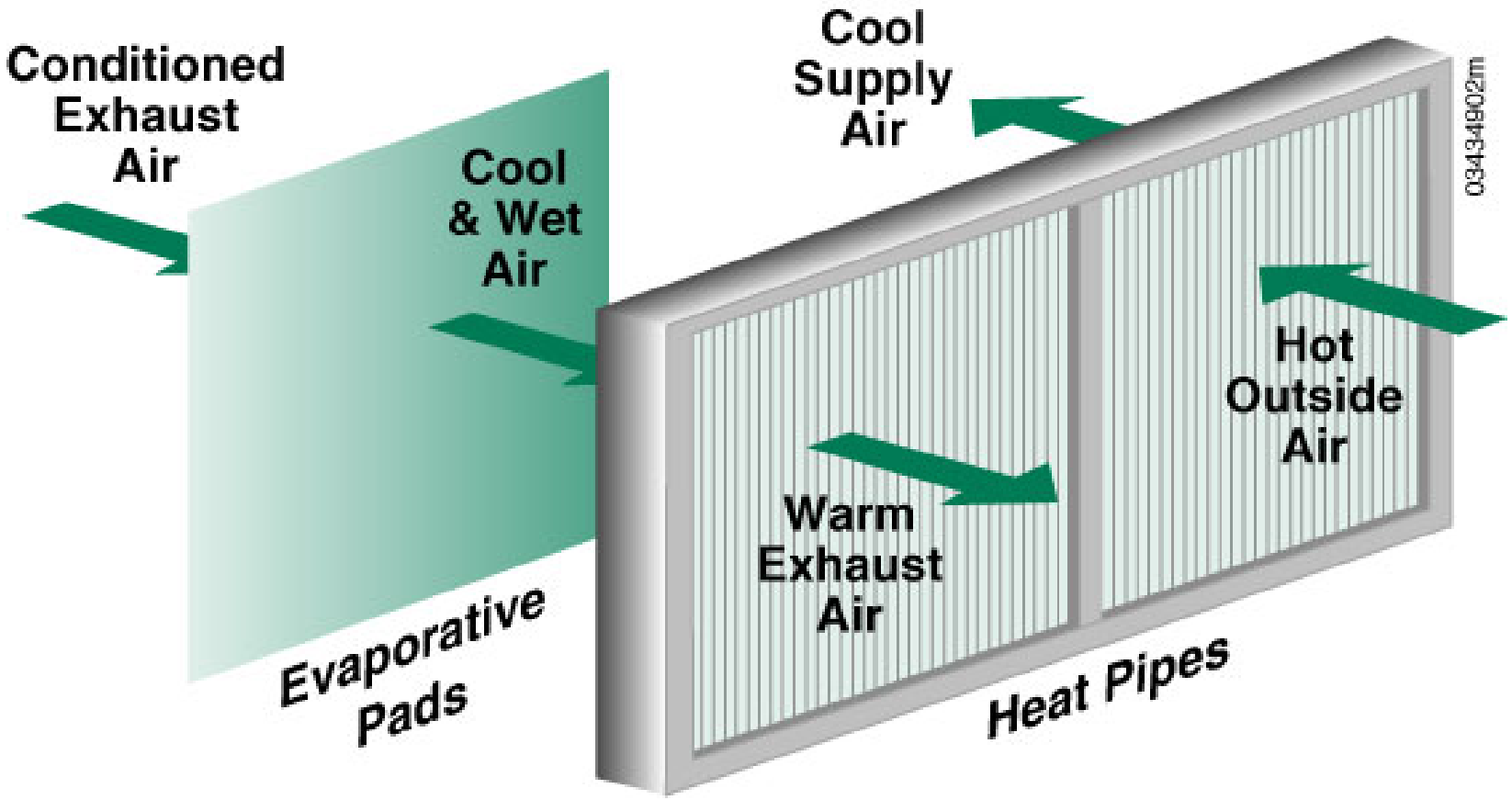


Indirect-Direct Evaporative Cooling



@ 5,000 feet (1,515 meters)

Energy Recovery with Indirect Evaporative Cooling



Evaporative Cooling Applications

- **Climate Dependent**
  - Offices, labs – primarily evap cooled
  - Evap only (no mechanical cooling)
    - Warehouses, industrial
    - Cafeterias
    - **Data Centers**

NREL STM CAMPUS - EVERY OCCUPIED BUILDING HAS EVAPORATIVE COOLING

600 K SQ FT Lab space ♦ 400 K SQ Ft Office Space ♦ 1 M Total SQ Ft

NREL PV Systems - South Table Mesa Campus

ASHRAE Thermal Guidelines - The defacto standard in the industry.

Provides common understanding between IT and facility staff.

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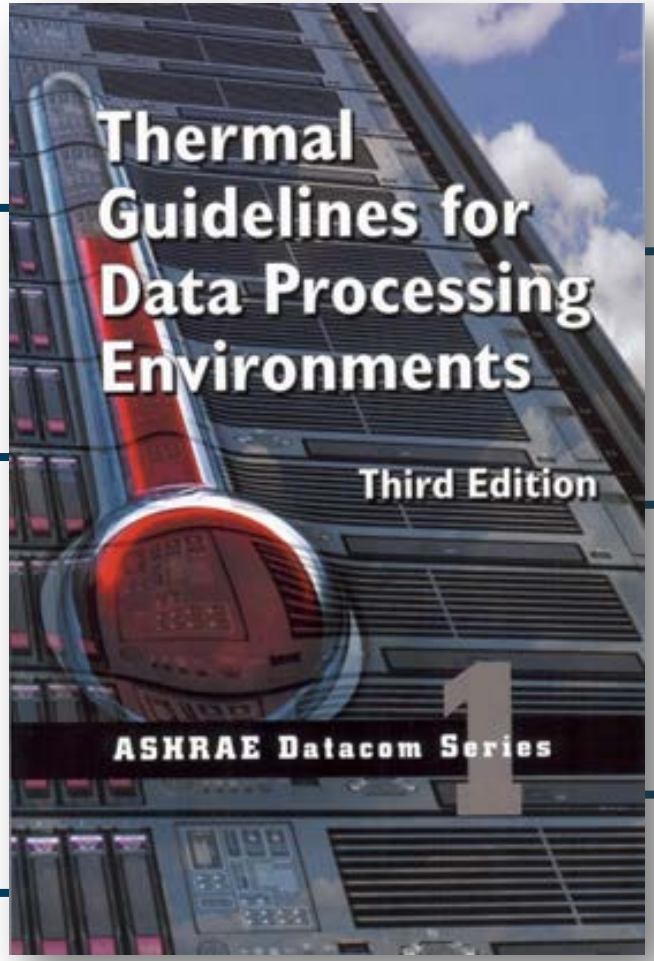

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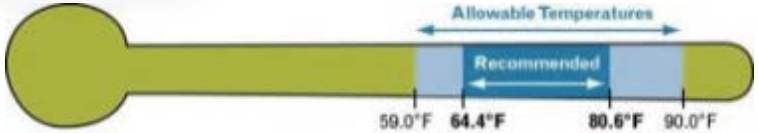
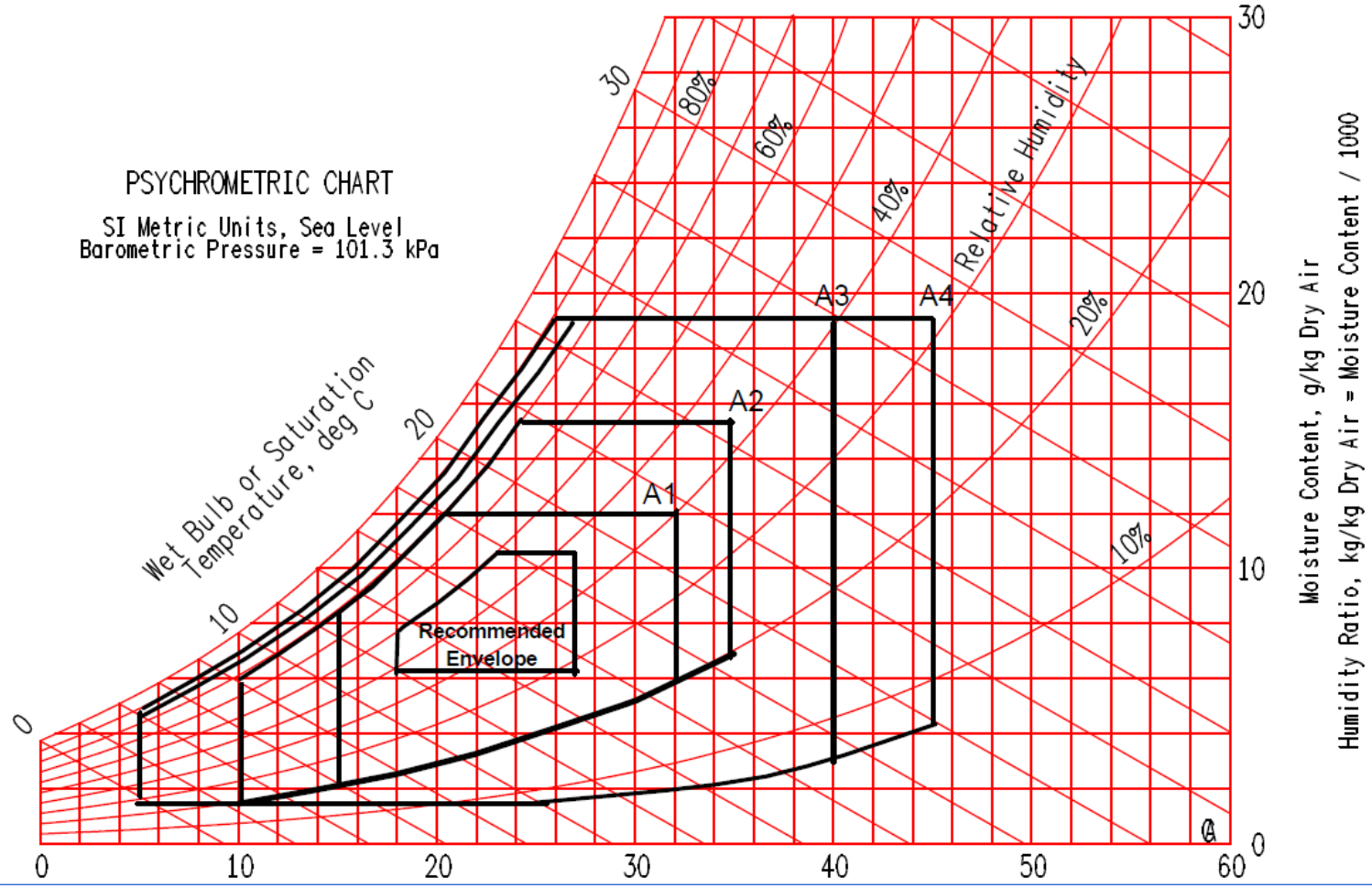
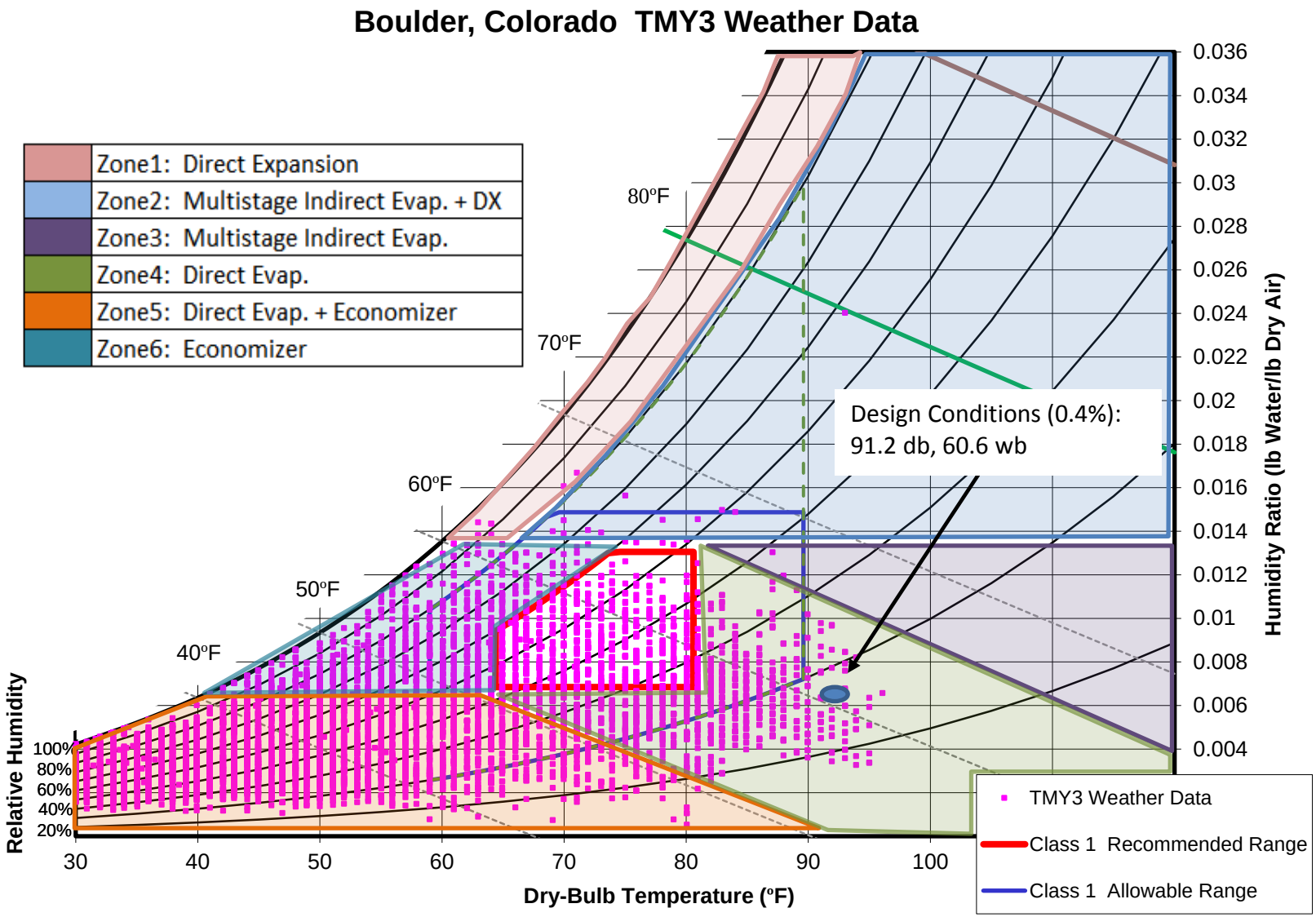


ASHRAE Recommended and Allowable ranges



Dry Bulb Temperature

Psychrometric Bin Analysis



http://www.nrel.gov/docs/fy17osti/68218.pdf

Estimated Savings

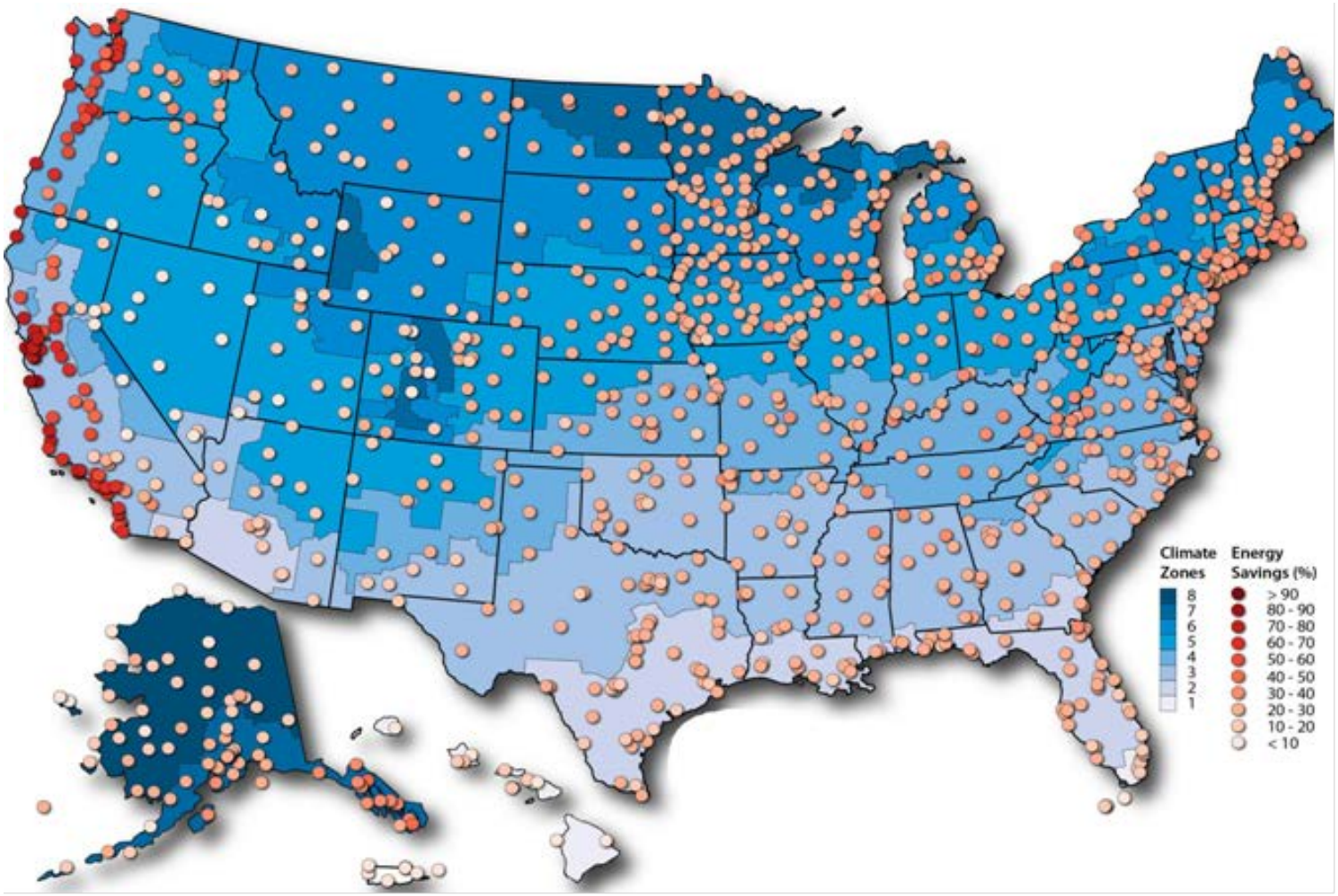
Baseline

System	DX Cooling with no economizer
Load	1 ton of cooling, constant year-round
Efficiency (COP)	3
Total Energy (kWh/yr)	**10,270**

Results

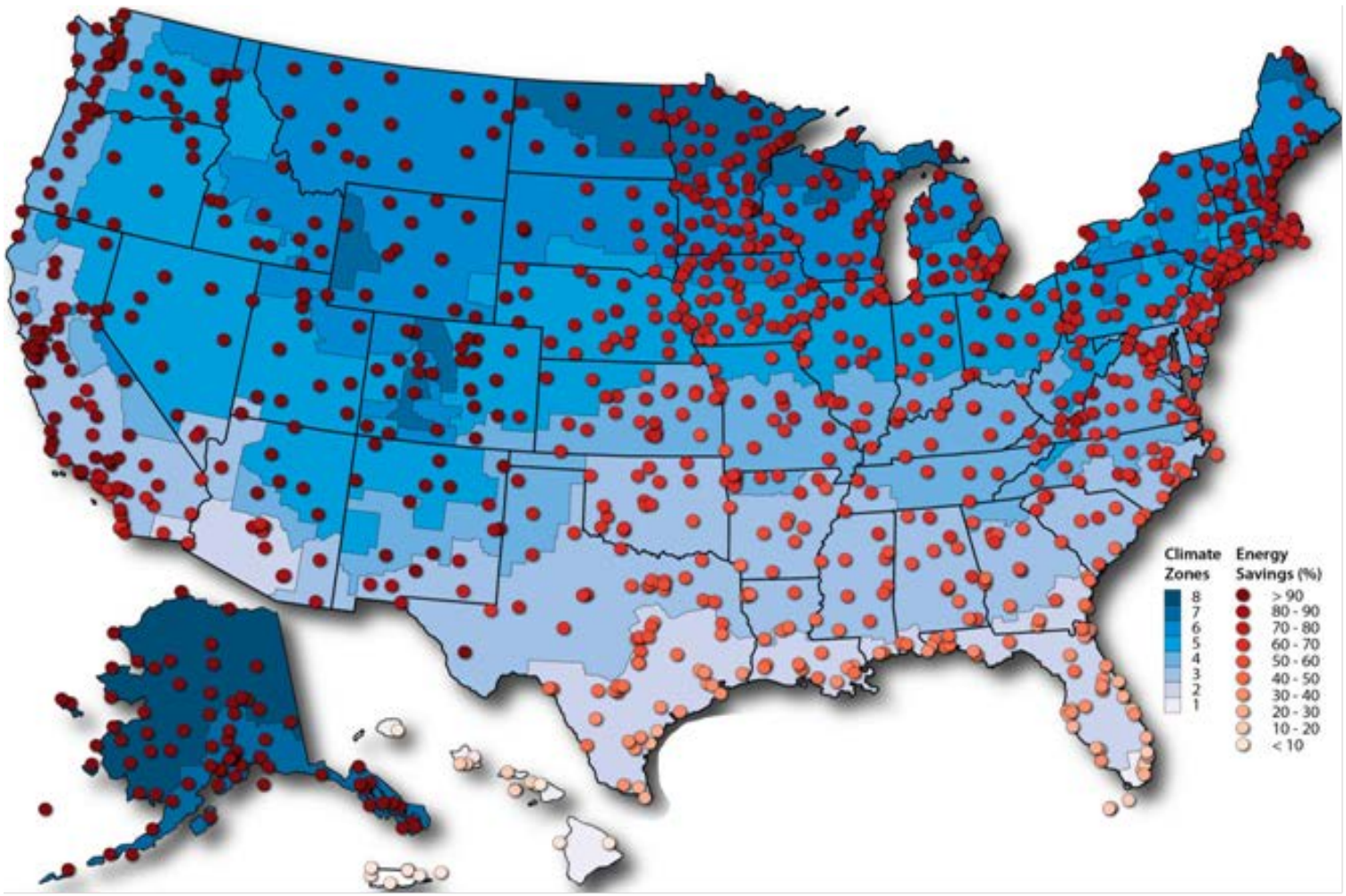
	Recommended Range		Allowable Range	
	Hours	**Energy (kWh)**	**Hours**	**Energy (kWh)**
Zone1: DX Cooling Only	25	8	2	1
Zone2: Multistage Indirect Evap. + DX (H80)	26	16	4	3
Zone3: Multistage Indirect Evap. Only	3	1	0	0
Zone4: Evap. Cooler Only	867	97	510	57
Zone5: Evap. Cooler + Economizer	6055	417	1656	99
Zone6: Economizer Only	994	0	4079	0
Zone7: 100% Outside Air	790	0	2509	0
Total	**8,760**	**538**	**8,760**	**160**
Estimated % Savings	**-**	**95%**	**-**	**98%**

Energy Savings Potential: Economizer Cooling



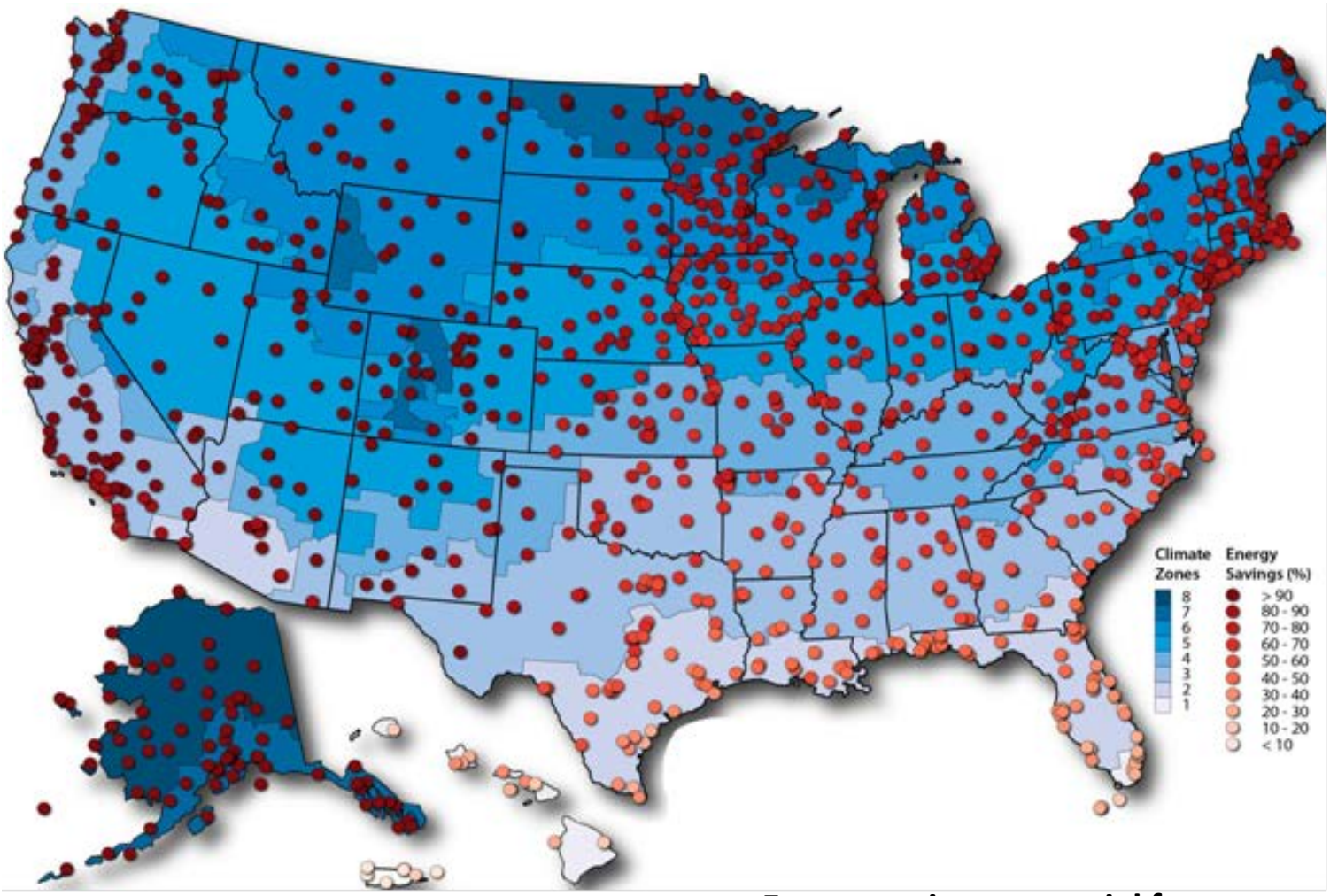
Energy savings potential for recommended envelope, Stage 1: Economizer Cooling. (Source: Billy Roberts, NREL)

Energy Savings Potential: Economizer + Direct Evaporative Cooling



Energy savings potential for recommended envelope, Stage 2: Economizer + Direct Evap. Cooling. (Source: Billy Roberts, NREL)

Energy Savings Potential: Economizer + Direct Evap. + Multistage Indirect Evap. Cooling



Energy savings potential for recommended envelope, Stage 3: Economizer + Direct Evap. + Multistage Indirect Evap. Cooling. (Source: Billy Roberts, NREL)

NREL Campus

Photo by Dennis Schroeder, NREL 37864

NREL ESIF Data Center

Showcase Facility

- ESIF 182,000 s.f. research facility
- Includes 10MW, 10,000 s.f. data center
- LEED Platinum Facility, **PUE 1.04**
- NO mechanical cooling (*eliminates expensive and inefficient chillers*).
- Use evaporative cooling only.

Data Center Features

- Direct, component-level liquid cooling (75F cooling water).
- 95-110F return water (waste heat), captured and used to heat offices and lab space.
- Pumps more efficient than fans.
- High voltage 480VAC power distribution directly to compute racks (*improves efficiency, eliminates conversions*).

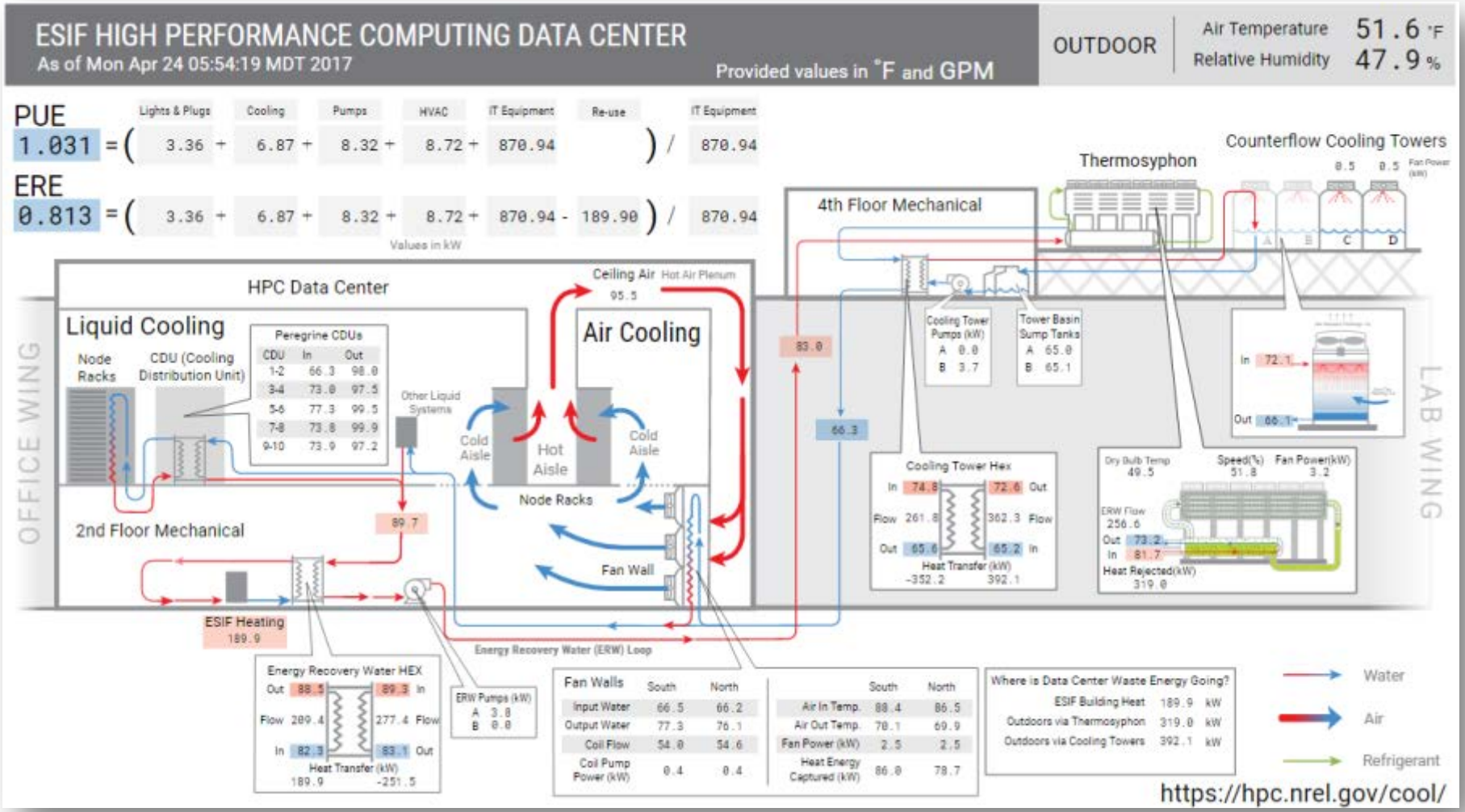
Compared to a typical data center….

- Lower CapEx – cost less to build
- Lower OpEx – efficiencies save ~$1M per year in operational expenses.

Integrated "chips to bricks" approach.

Utilize the bytes and the BTUs!

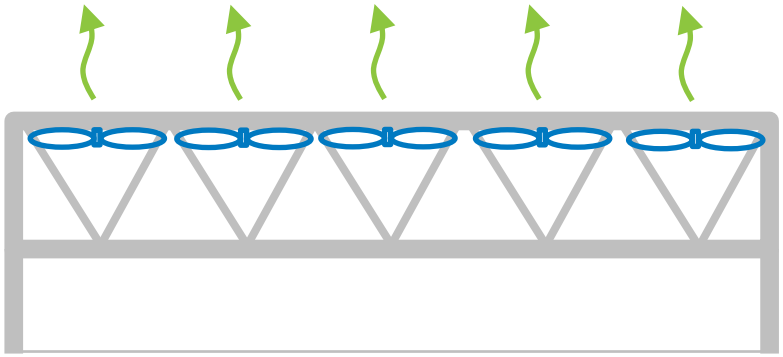
ESIF Data Center



Air- and Water-Cooled System Options

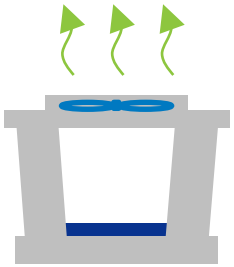
Air-Cooled System

- Design day is based on **DRY BULB** temperature
- Consumes no water (no evaporative cooling)
- Large footprint/requires very large airflow rates.



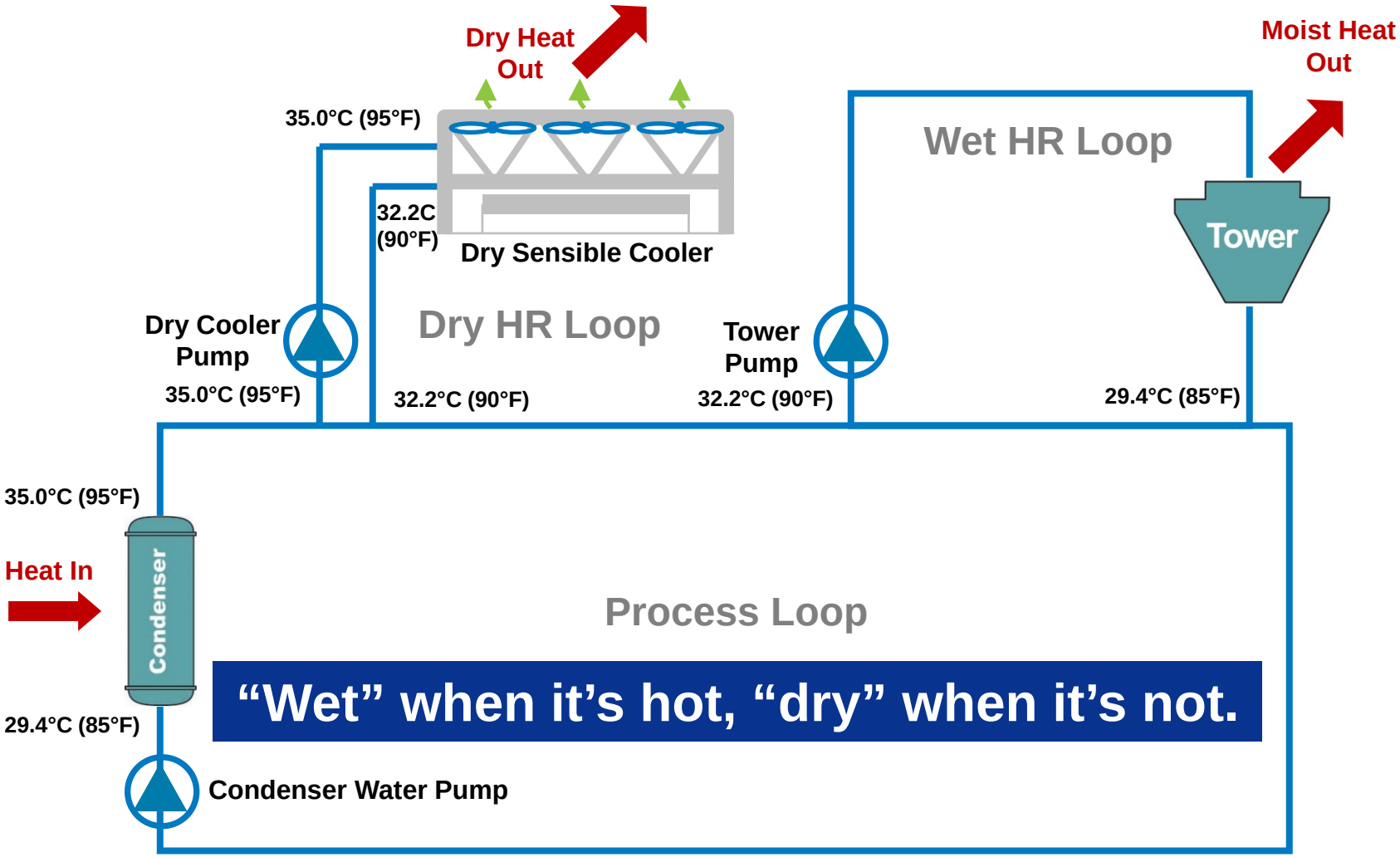
Water-Cooled System

- Design day is based on the lower **WET BULB** temperature
- Evaporative cooling process uses water to improve cooling efficiency
  - **80% LESS AIRFLOW → Lower fan energy**
  - Lower cost and smaller footprint.
- Colder heat rejection temperatures improve system efficiency.



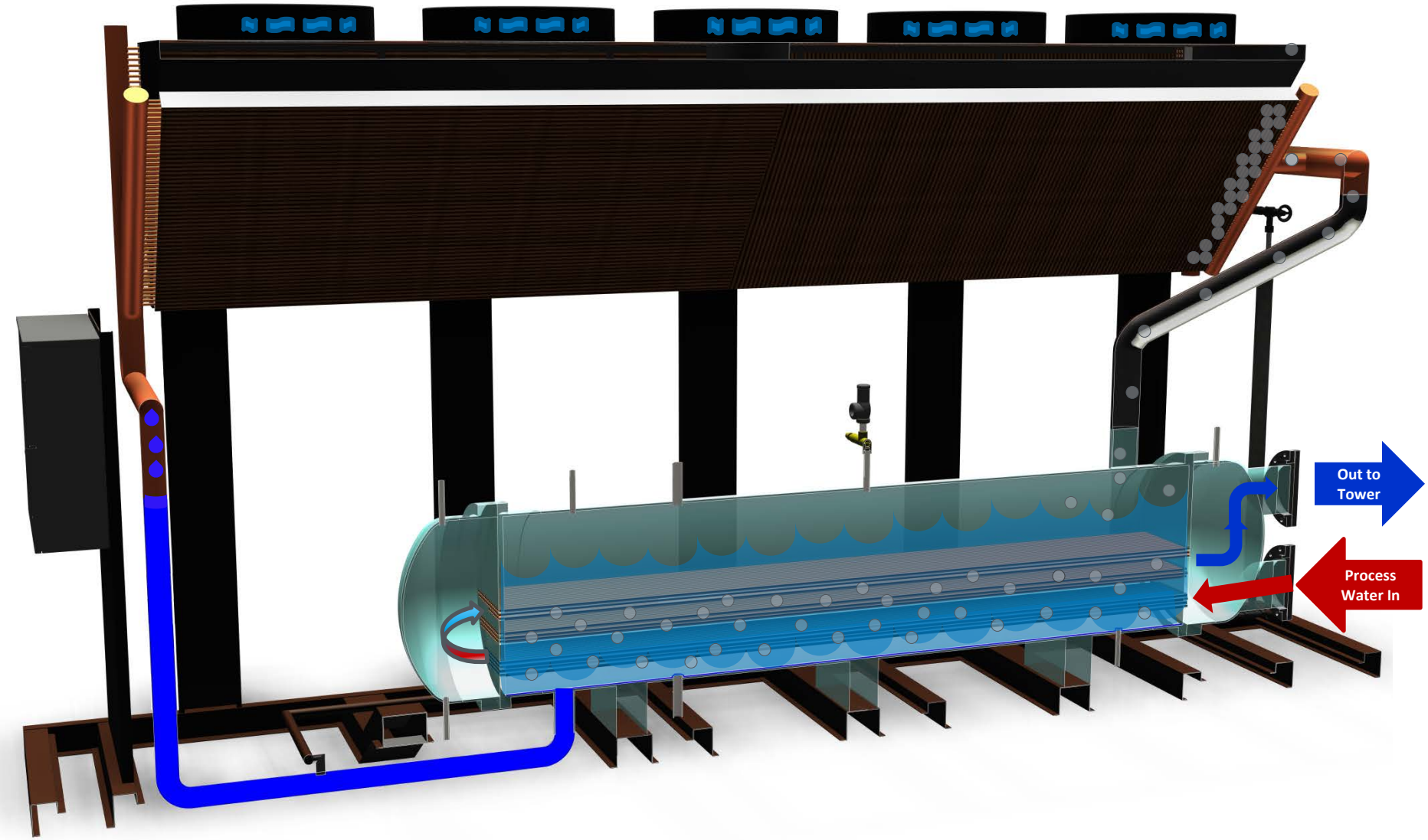
However, water-cooled systems depend on a reliable, continuous source of low-cost water.

Basic Hybrid System Concept



"Wet" when it's hot, "dry" when it's not.

Thermosyphon Cooler



TSC Installation

843,000 gallons saved 8-2-16 to 4-7-17

http://www.nrel.gov/docs/fy17osti/66690.pdf

QUESTIONS?

Otto VanGeet ♦ 303.384.7369 ♦ Otto.VanGeet@nrel.gov

NREL PV Systems - South Table Mesa Campus

John Sasser

Sabey Data Centers

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Alternative Cooling Solutions In High Tech Buildings

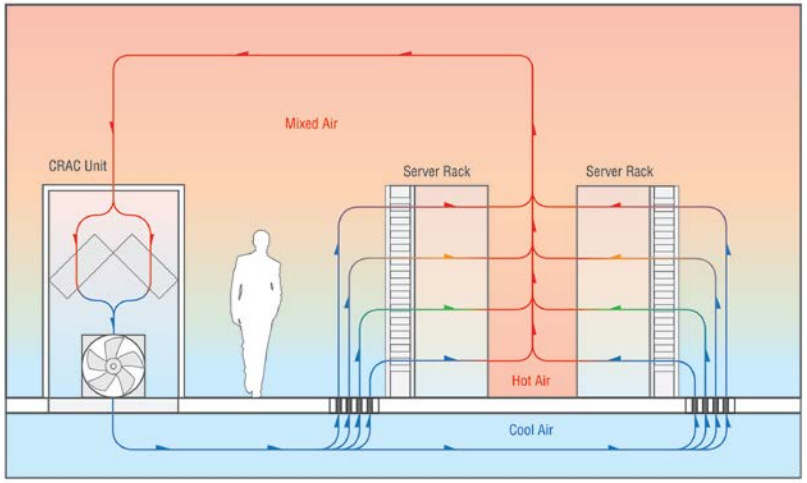
Better Buildings Summit 2017

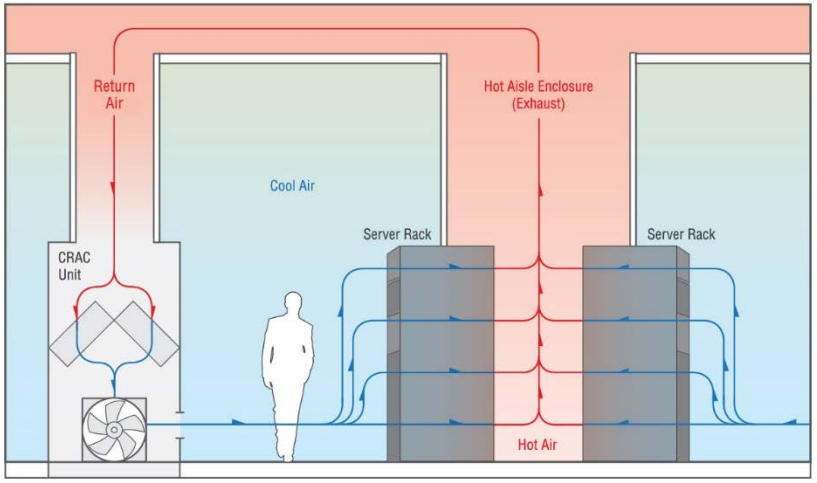
Presentation by:
John Sasser
Senior Vice President, Operations
Sabey Data Centers

Sabey Data Centers

- Privately held data center provider
- Powered shell & wholesale colocation
- Data Centers in Seattle, Central Washington State, New York City, and, most recently, Ashburn Virginia

Traditional Cooling vs Hot Aisle Containment

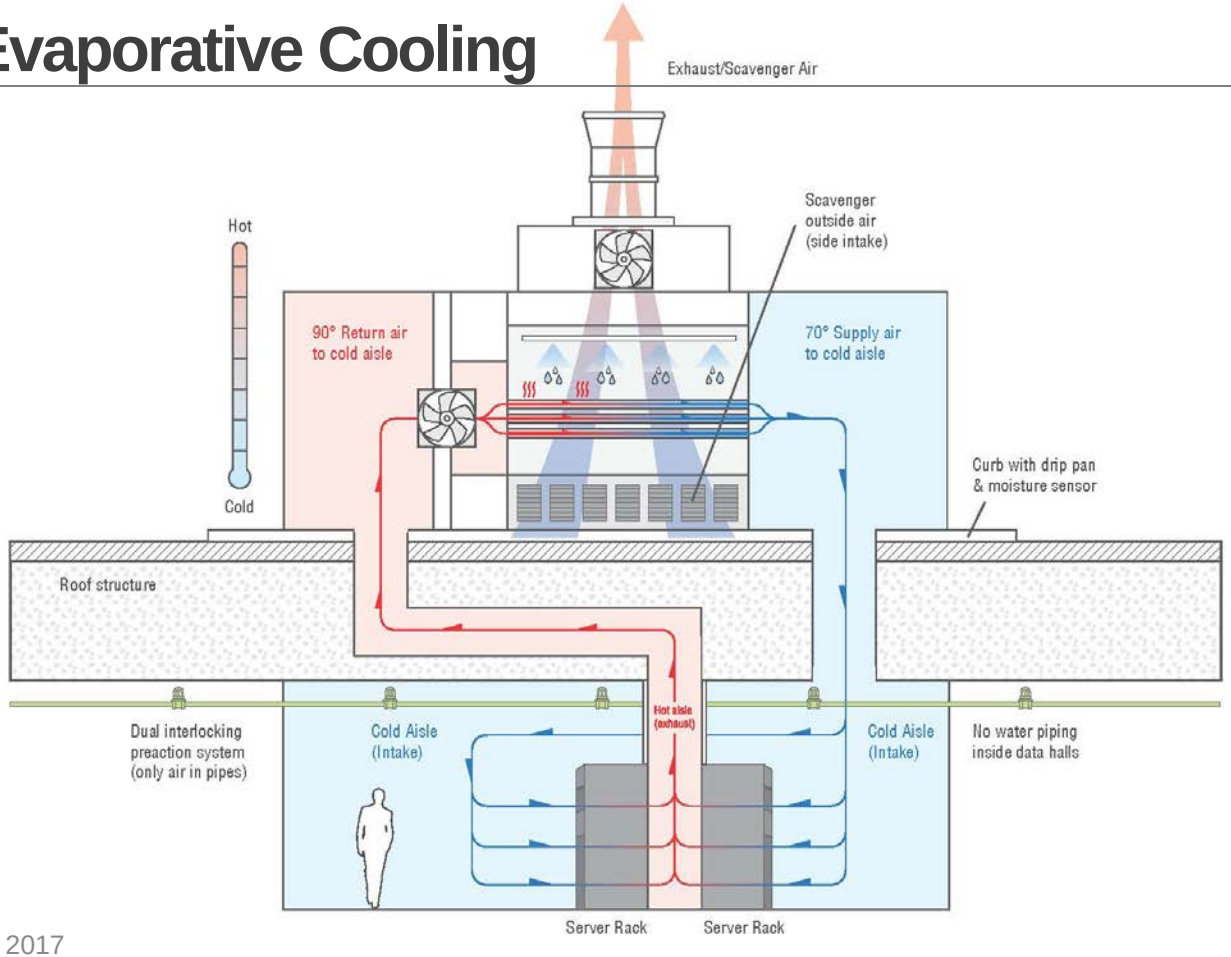




Enclosures

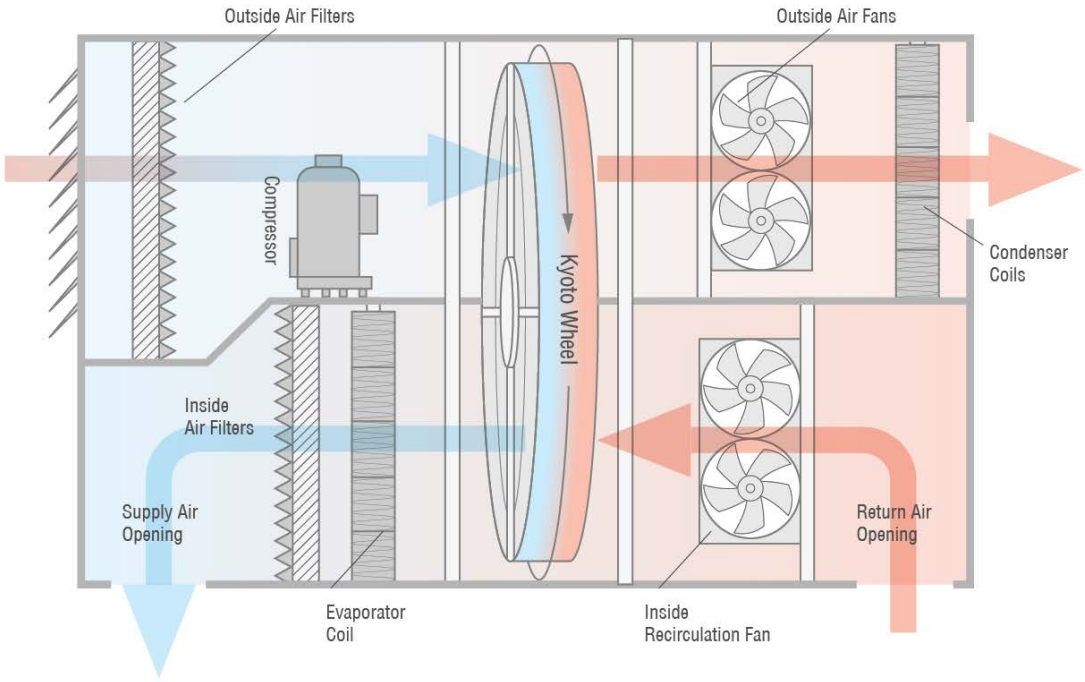
- Standard & customized solutions
- Flexibility & density

Indirect Evaporative Cooling



Heat Wheel

Kyoto Cooling



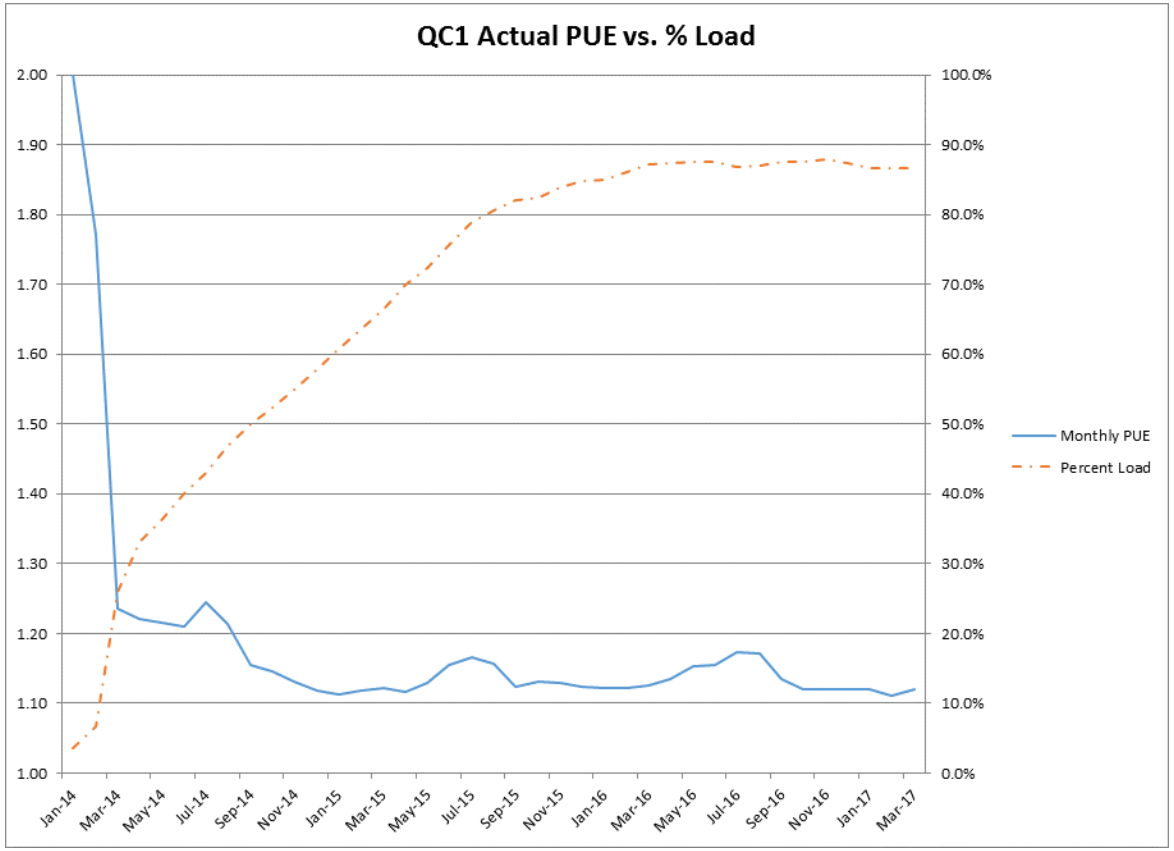
Mobile Commissioning Assistants

- A practical means of proving airflow capacity within the data center
- Patented

Intergate.Quincy

Energy Star Certified:

- 2015 - 2017
- 2 Buildings
- Scores of 99-100



Questions?

Thank You!

Better Buildings Summit 2017

Presentation by:
John Sasser
Senior Vice President, Operations
Sabey Data Centers

Thank You

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