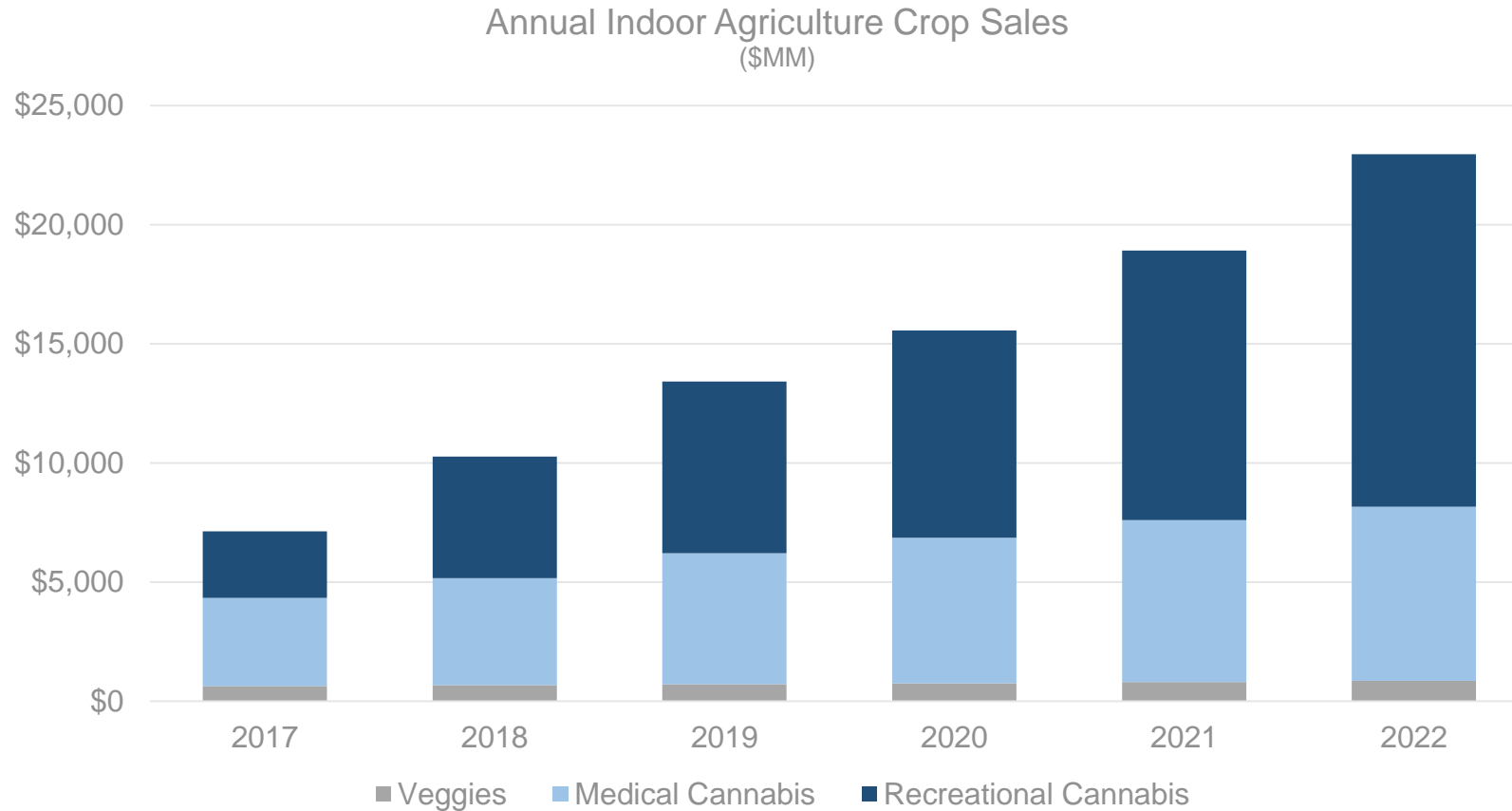


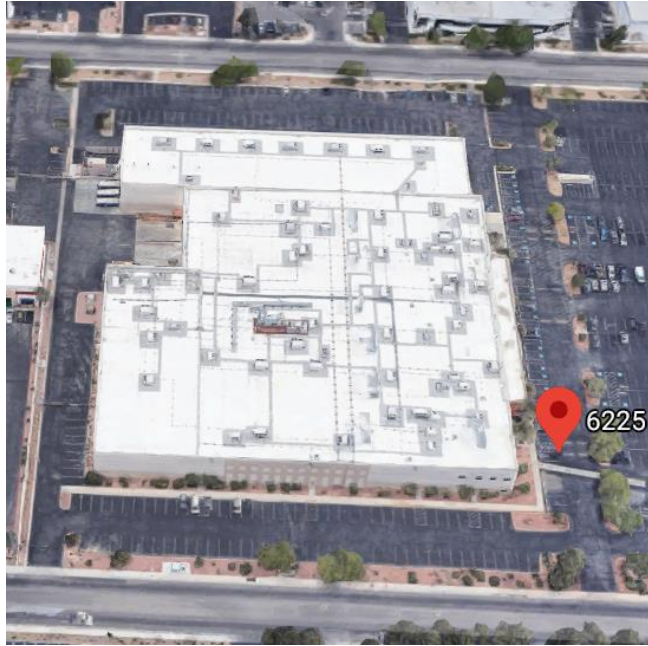
# Agenda

- Market Trends
- What is indoor agriculture?
- Thermal Basics for Indoor Agriculture
- Differences vs. Comfort Cooling
- Vapor Pressure Deficit
- Dehumidification Technologies
- Facility Design Considerations

# Market trends and size



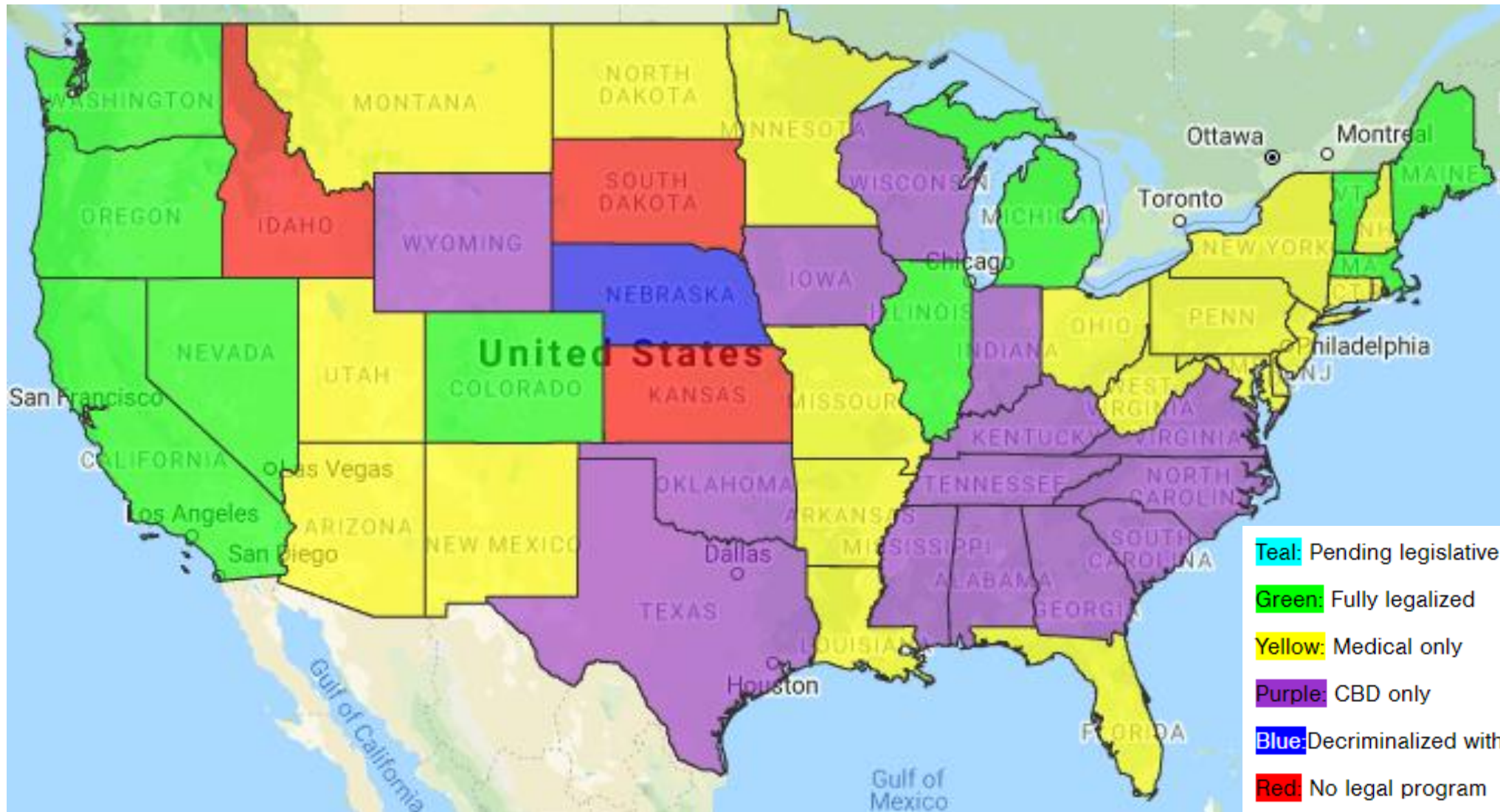
- Indoor Agriculture Market growing at 26%+ per year
- Indoor Agriculture is HVAC intensive environment... ~1 ton per 50 ft<sup>2</sup>
- Customer paying a premium for IA HVAC equipment... upwards of \$3-\$4K/ton
- Farm development to meet annual growth to generate \$500M - \$1B HVAC market opportunity per year



Our 215,000-square-foot indoor vertical farm facility is the only of its kind in Las Vegas, NV. There, we grow an ever-widening array of edible produce and non-traditional crops for our customers. In a city famous for amazing restaurants and world-class chefs who demand the best in fresh, healthy food, we grow a wide selection of delicious lettuces, microgreens, herbs and more.

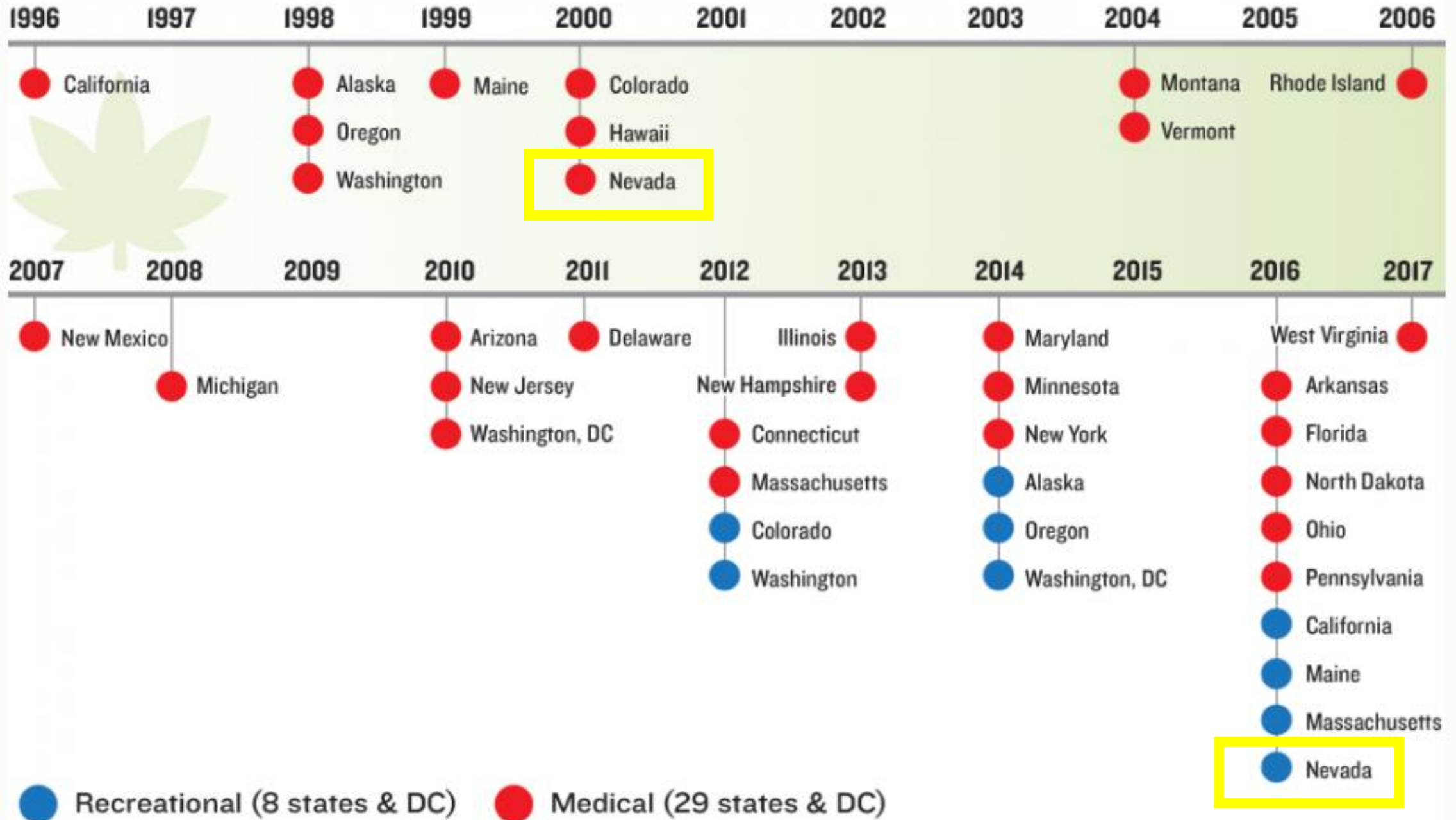


# NA Cannabis Legalization Map



Source: Cannabis Business Times as of March 31, 2020

# Timeline of State Marijuana Legalization Laws



Recreational Marijuana Establishments with Final  
Certificates as of February 2019

County	Dispensary	Cultivation	Production	Laboratory
Carson City	2	5	4	0
Churchill	1	0	0	0
Lyon	1	0	0	0
Nye	1	12	6	0
Clark	49	96	72	9
Washoe	13	23	16	2
<b>TOTAL</b>	<b>66</b>	<b>134</b>	<b>96</b>	<b>11</b>



**MMG**  
BOUTIQUE PREMIUM

Home

Products

Locations

Apply

Strains

A map of Nevada with county boundaries. Green cannabis plant icons are placed in the following counties: Carson City, Ely, Fernley, Henderson, Las Vegas, Lovelock, and Reno.

**CITIES**

- [CARSON CITY](#)
- [ELY](#)
- [FERNLEY](#)
- [HENDERSON](#)
- [LAS VEGAS](#)
- [LOVELOCK](#)
- [RENO](#)

Facility: The MMG Agriculture cultivation facility is 8,000 square feet and features 3 flowering rooms, 2,300 flowering plants, and 15 strains,

# What is Indoor Agriculture?

*a.k.a. Controlled Environment Agriculture (CEA), Vertical Farming, Indoor Farming*

- **A technology based** approach of growing crops indoors allowing growers to set the ideal environment to achieve optimal harvest from each crop
  - Growers control **temperature, humidity (or VDP)**, CO<sub>2</sub>, lighting, irrigation, fertilization, etc.
- Indoor farming uses **~90% less water** than traditional farming
- Indoor farms can grow **10 – 100 times more crops** per ft<sup>2</sup> than traditional farms
- Crops include cucumbers, lettuce, leafy greens, herbs, tomato, legally licensed cannabis facilities

# Why use Indoor Agriculture vs. Traditional Outdoor?

- **Controllability** = Consistency, Quality, Predictable Yields
- **Reduces risk of Disease, Mold, Mildew, Cross-pollination**
- **Multiple Annual Growth Cycles** = Add CO<sub>2</sub> for faster growth production cycles
- **Security** = High security required by laws



# Indoor Environment Types

- Enclosed Indoor Considerations:
  - Pros – Controllability, Maximize Yields, Tight Envelope
  - Cons – Initial Costs
- Greenhouse Considerations:
  - Pros – Sunlight is free, ability to grow year round
  - Cons – Lifetime costs, increased HVAC loads, poor security, indoor climate effected by seasons, outdoor air contaminants, poor odor control

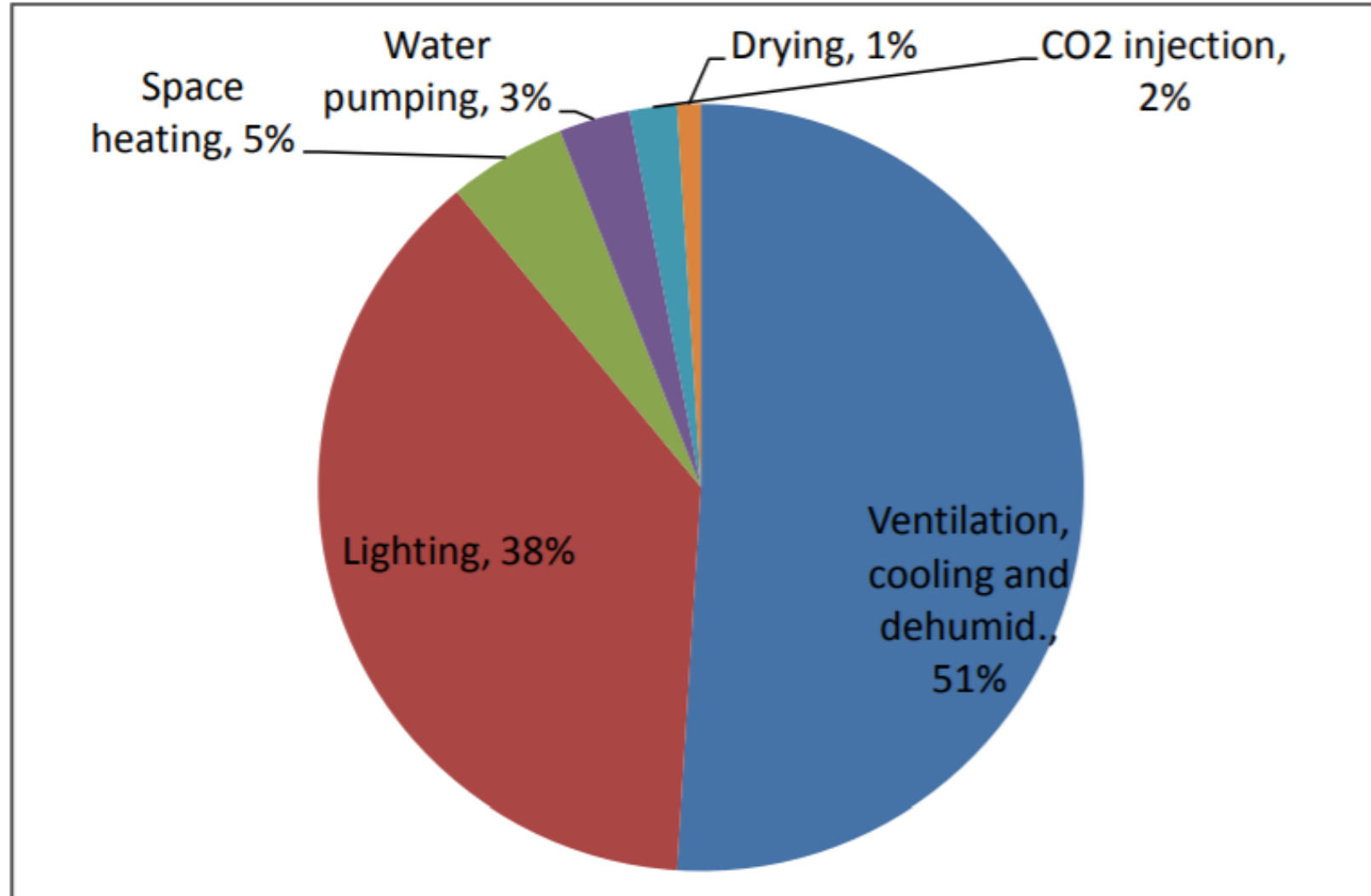
# Types of Indoor Agriculture Rooms

Stage	Weeks	Temp	Relative Humidity
Clone/Seedling	#1 to #2	74 to 80 F	75% to 85%
Veg	#2 to #8	70 to 80 F	45% to 55%
Flower	#8 to #16	68 to 76 F	40% to 50%
Drying	#16+	68 to 76 F	45% to 55%

- Ranges Vary by Grower, Strain
- Temperature, Humidity, Irrigation Rates
  - Critical Inputs for HVAC Design
  - Generally Start Warmer, Higher Humidity
  - Move to Colder, Lower Humidity
- VPD (Vapor Pressure Deficit) is a better data point to manage grow rooms by.

# Energy

**Figure 1 – Energy Use Breakdown for a Typical Indoor Cannabis Grow<sup>9</sup>**



<sup>9</sup> "Trends and Observations of Energy Use in the Cannabis Industry," Jesse Remillard and Nick Collins, ERS, ACEEE Summer Study of Energy Efficiency in Industry, 2017.

# Indoor Ag Thermal Basics - What are the loads?

- Sensible = Lighting (watts to Btu)
- Latent = Evapotranspiration / Irrigation rate (lbs/hr)
- Sensible Heat Ratio (SHR)



# Indoor Agriculture is Process Manufacturing

## Lights-on (“daytime”)

- + High sensible load from lighting
- + High latent load from evapotranspiration
- = **Sensible cooling and dehumidification**



# Indoor Agriculture is Process Manufacturing

## Lights-on (“daytime”)

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## Lights-off (“nighttime”)

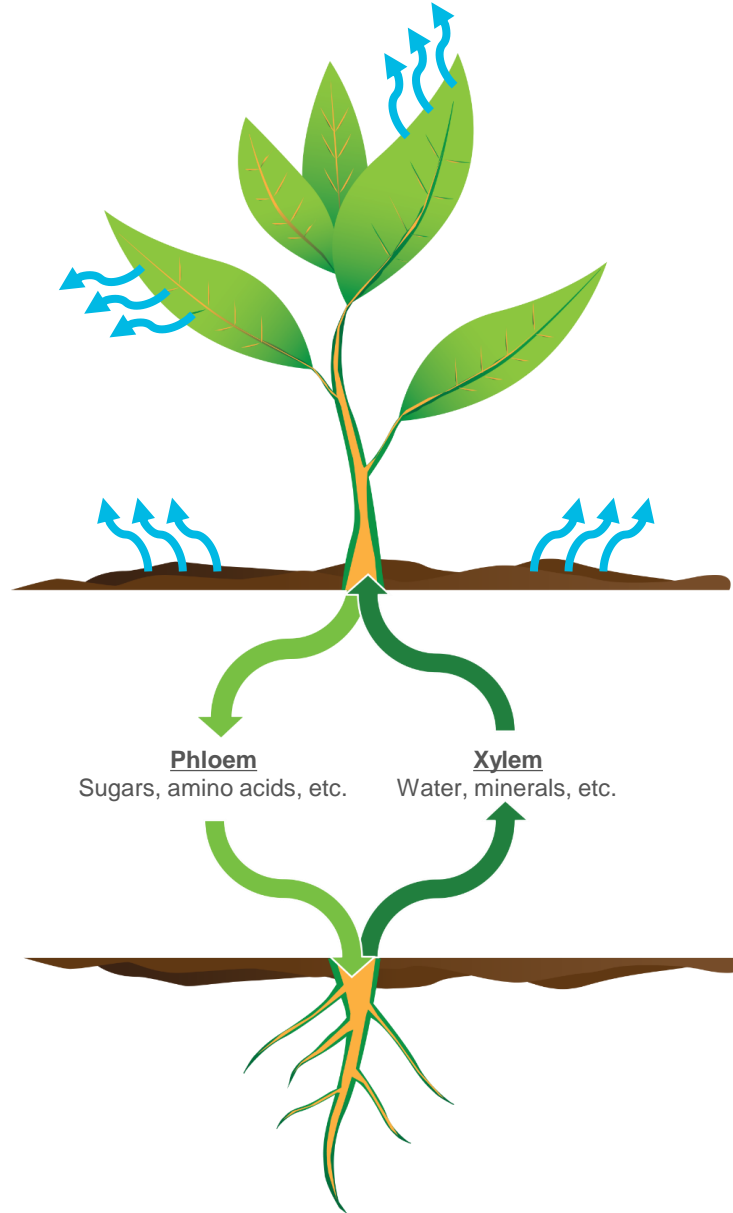
- + No sensible load from lighting
- + Medium latent load from evapotranspiration
- = **Primarily dehumidification**



# Evapotranspiration = evaporation + transpiration

## Evaporation

**Water** movement from the **soil** and **plant surfaces** to surrounding air.



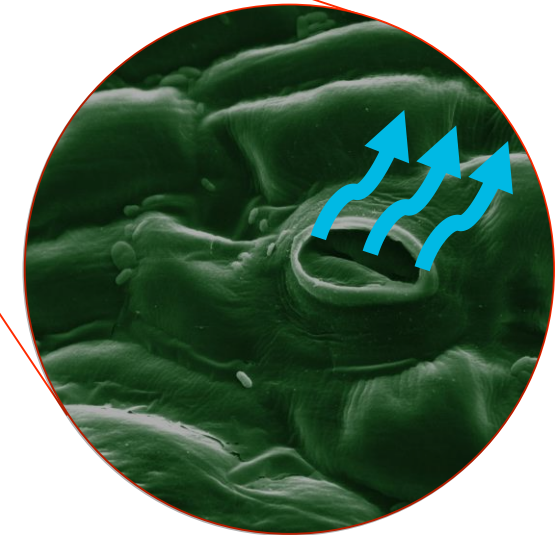
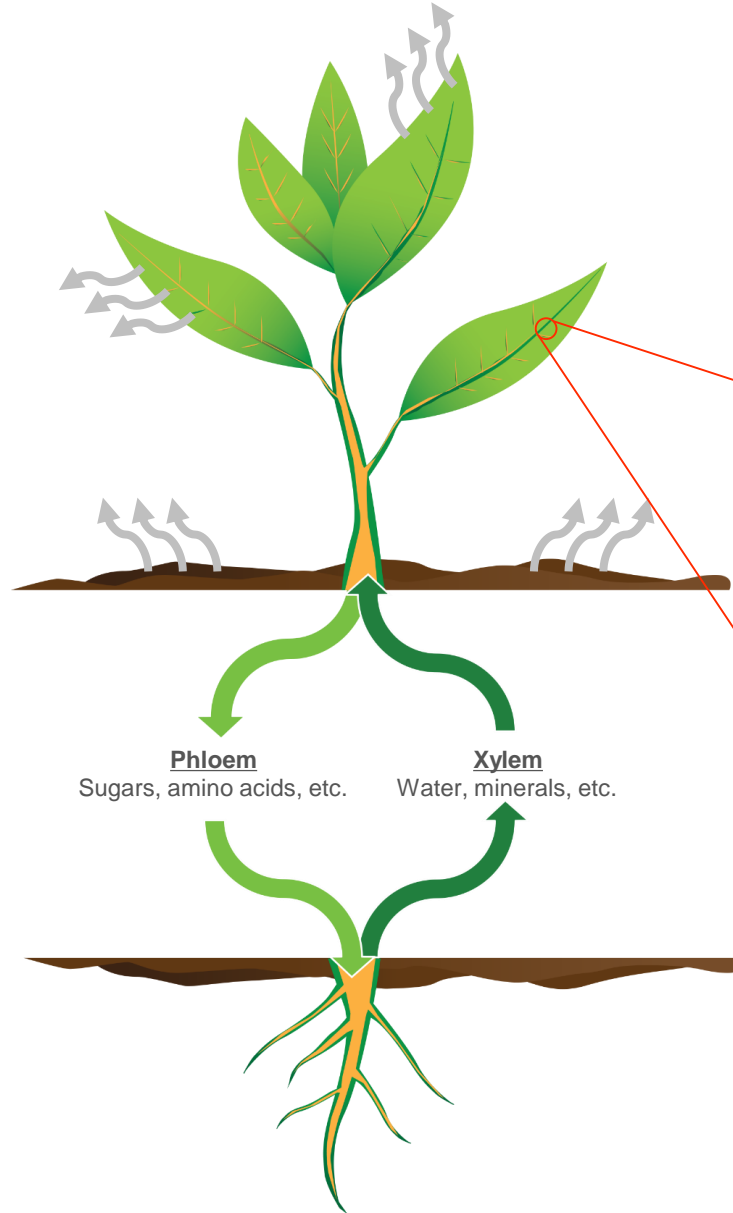
# Evapotranspiration = evaporation + transpiration

## Evaporation

**Water** movement from the **soil** and **plant surfaces** to surrounding air.

## Transpiration

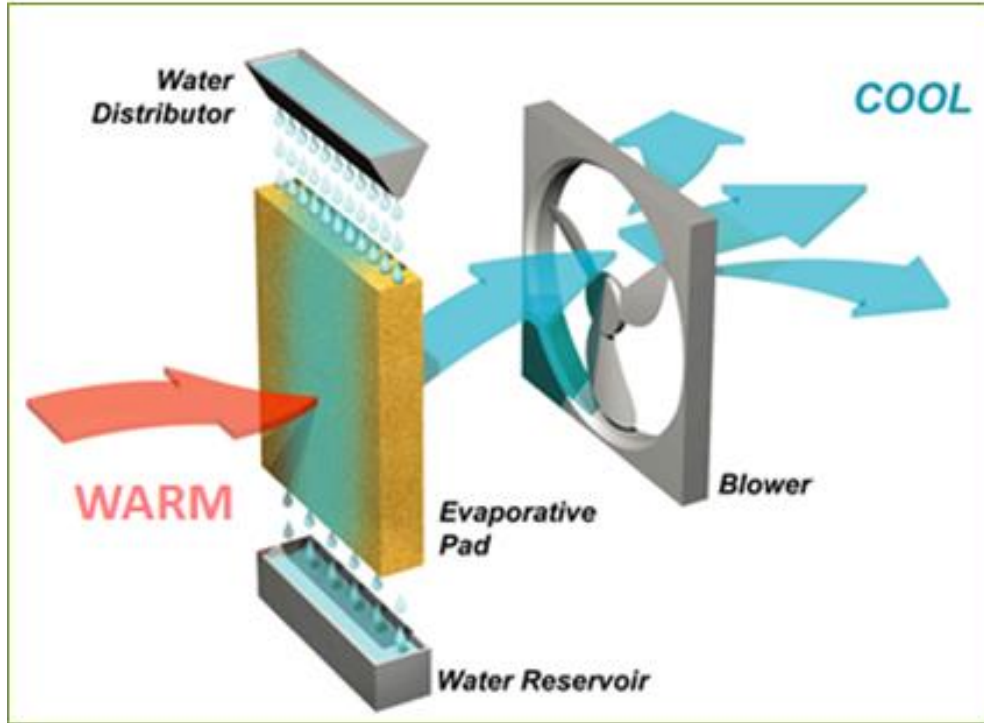
**Water** movement within the **plant** and eventual release from **leaf stomata**.



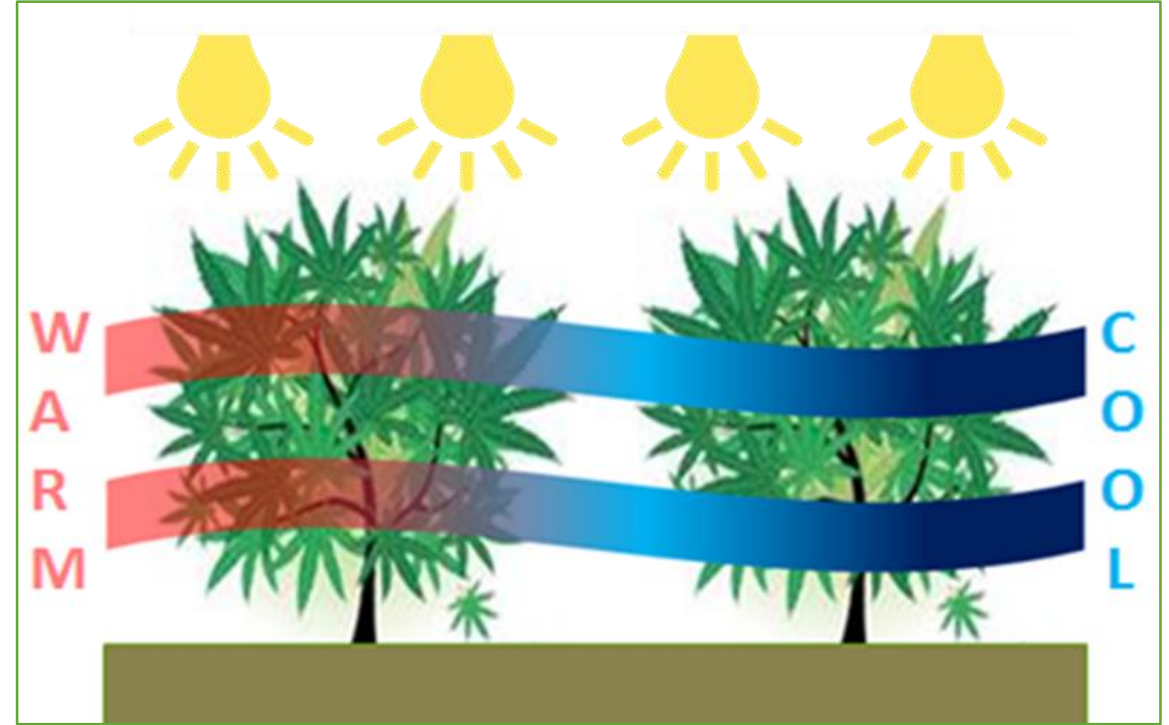


# PLANTS ARE NATURAL EVAPORATIVE (SWAMP) COOLERS

## MECHANICAL EVAPORATIVE COOLER



## NATURAL EVAPORATIVE COOLING



***One-gallon*** of ***evapotranspiration*** produces more than ***8,700-BTU*** of evaporative cooling, and offsets more than ***2,500 watts*** of lighting

EVAPORATIVE COOLING = DEHUMIDIFICATION

# CULTIVATING ROOM SENSIBLE-HEAT %

SENSIBLE HEAT (TEMPERATURE) = Evaporative Cooling and Grow Lighting

LATENT HEAT (HUMIDITY) = Dehumidification from Evapotranspiration

TOTAL HEAT (TEMPERATURE + HUMIDITY) = Sensible Heat + Latent Heat

$\frac{\text{Sensible Heat}}{\text{Total Heat}} = \text{SH\%}$

TYPICAL GROW ROOM STATISTICS			
LIGHTING	Sensible	btuh	100,000
DEHUMIDIFICATION	Latent	btuh	60,000
	Total	btuh	160,000
EVAPORATIVE COOLING	Sensible	btuh	-60,000



(Latent = 37.5%)

$$\frac{100,000}{(100,000 + 60,000)} = 62.5\%$$



***CORRECT***

$$\frac{(100,000 - 60,000)}{(100,000 + 60,000)} = 25\%$$

(Latent = 75%)



# Why this isn't normal A/C

	Comfort Cooling	Indoor Agriculture
Operating modes	Occupied Unoccupied	Lights-on / “Daytime” Lights-off / “Nighttime”

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Space SHR	0.70 – 0.90	Daytime: 0.25 – 0.50 Nighttime: 0.00 – 0.40
Ventilation	Based upon Standard 62.1 Requirements	Often no ventilation
Carbon dioxide	Diluted with ventilation air (sometimes controlled with DCV)	Increased beyond ambient (e.g. 1500 ppm)

# SENSIBLE-HEAT-RATIO (SHR) IN TYPICAL APPLICATIONS

TYPICAL SENSIBLE HEAT RATIOS FOR VARIOUS APPLICATIONS		
APPLICATION	MIN	MAX
Auditoriums, Theaters	0.65	0.75
Apartments	0.80	0.95
Banks, Court Houses, Municipal Buildings	0.75	0.90
Churches	0.65	0.75
Dining Halls	0.65	0.80
Computer Rooms	0.80	0.95
Cocktail Lounges, Bars, Taverns, Clubhouses, Nightclubs	0.65	0.80
<b>Cultivating Rooms</b>	<b>0.00</b>	<b>0.25</b>
Jails	0.80	0.95
Hospital Patient Rooms, Nursing Home, Patient Rooms	0.75	0.85
Kitchens	0.60	0.70
Libraries, Museums	0.80	0.90
Malls, Shopping Centers	0.65	0.85
Medical/Dental Centers, Clinics and Offices	0.75	0.85
Motel and Hotel Public Areas	0.75	0.90
Motel and Hotel Guest Rooms	0.80	0.95
Police Stations, Fire Stations, Post Offices	0.75	0.90
Precision Manufacturing	0.80	0.95
Restaurants	0.65	0.80
Residences	0.80	0.95
Retail, Department Stores	0.65	0.90
Other Shops	0.65	0.90
School Classrooms	0.65	0.80
Supermarkets	0.65	0.85

# What is Vapor Pressure Deficit?

**VPD is derived from a combination of room temperature and humidity**

- VPD alone is not a measured value. There are numerous combinations of room temperatures and humidity that makeup a single VPD value.
- Both temperature and humidity are needed to calculate VPD.  
(As an analogy: The area of a rectangle requires both length and width to calculate)

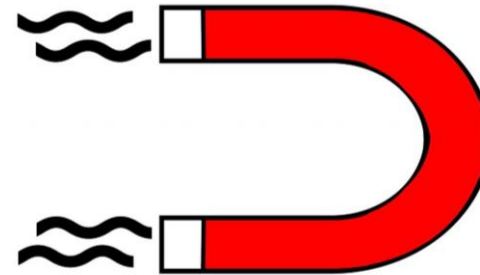
# VAPOR PRESSURE (VPD) EXPLAINED

Leaf surface = 80° f/100% =  
3.50 kPa



Room = 80° f/60% = 2.10  
kPa

$$3.50 \text{ kPa} - 2.10 \text{ kPa} = 1.40 \text{ kPa}$$



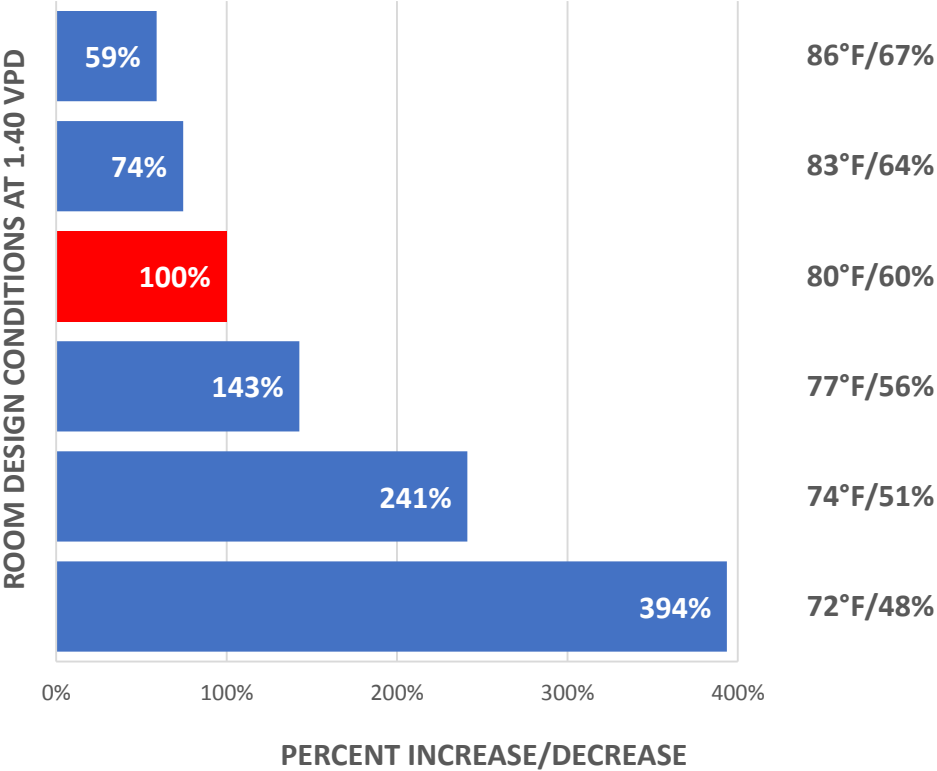
VPD value indicates the speed at which moisture evaporates from the plant to the surrounding air. Thus it is excellent way to evaluate the risk of Mold and Mildew.

# VAPOR PRESSURE DIFFERENCE (VPD) CHART

RELATIVE HUMIDITY VS. TEMPERATURE AND VAPOR PRESSURE DIFFERENCE (VPD) CHART																			
°F	VAPOR PRESSURE DIFFERENCE IN KILOPASCAL (kPa ) UNITS (For Millibar Units (mbar), Multiply Values Below by 10)																		°F
	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	
	Early Weeks							Mid Weeks					Final weeks						
	RELATIVE HUMIDITY																		
86								74%	73%	72%	72%	69%	68%	67%	66%	65%	63%	62%	86
85								73%	72%	71%	70%	68%	67%	66%	65%	64%	62%	61%	85
84								72%	71%	70%	69%	67%	66%	65%	64%	62%	61%	60%	84
83								71%	70%	69%	68%	66%	65%	64%	62%	61%	60%	59%	83
82								71%	69%	68%	67%	65%	64%	63%	61%	60%	58%	57%	82
81	79%	78%	76%	75%	74%	72%	71%	70%	68%	67%	65%	64%	63%	61%	60%	58%	57%	56%	81
80	79%	77%	76%	74%	73%	71%	70%	69%	67%	66%	64%	63%	61%	60%	59%	57%	56%	54%	80
79	78%	76%	75%	73%	72%	70%	69%	68%	66%	65%	63%	62%	60%	59%	57%	56%	54%	53%	79
78	77%	76%	74%	73%	71%	69%	68%	66%	65%	63%	62%	60%	59%	57%	56%	54%	53%	51%	78
77	76%	75%	73%	72%	70%	68%	67%	65%	64%	62%	61%	59%	57%	56%	54%	53%	51%	50%	77
76	76%	74%	72%	71%	69%	67%	66%	64%	62%	61%	59%	58%	56%	54%	53%	51%	49%	48%	76
75	75%	73%	71%	70%	68%	66%	65%	63%	61%	60%	58%	56%	54%	53%	51%	49%	48%	46%	75
74	74%	72%	70%	69%	67%	65%	63%	62%	60%	58%	56%	55%	53%	51%	49%	48%	46%	44%	74
73	73%	71%	69%	68%	66%	64%	62%	60%	59%	57%	55%	53%	51%	50%	48%	46%	44%	42%	73
72	72%	70%	68%	66%	65%	63%	61%	59%	57%	55%	53%	52%	50%	48%	46%	44%	42%	40%	72
71	71%	69%	67%	65%	63%	61%	59%	58%	56%	54%	52%	50%	48%	46%	44%	42%	40%	38%	71
70	70%	68%	66%	64%	62%	60%	58%	56%	54%	52%	50%	48%	46%	44%	42%	40%	38%	36%	70
69	69%	67%	65%	63%	61%	59%	57%	55%	52%	50%	48%	46%	44%	42%	40%	38%	36%	34%	69
68	68%	66%	64%	62%	59%	57%	55%	53%	51%	49%	47%	44%	42%	40%	38%	36%	34%	32%	68
67	67%	65%	62%	60%	58%	56%	54%	51%	49%	47%	45%	42%	40%	38%	36%	34%	31%	29%	67
66	66%	63%	61%	59%	56%	54%	52%	50%	47%	45%	43%	40%	38%	36%	34%	31%	29%	27%	66
65	64%	62%	60%	57%	55%	53%	50%	48%	45%	43%	41%	38%	36%	34%	31%	29%	26%	24%	65

## UNDERSTANDING THE IMPACT OF VPD ON CAPITAL COST OF HVAC EQUIPMENT

RELATIVE DEHUMIDIFICATION AIR VOLUME & COST

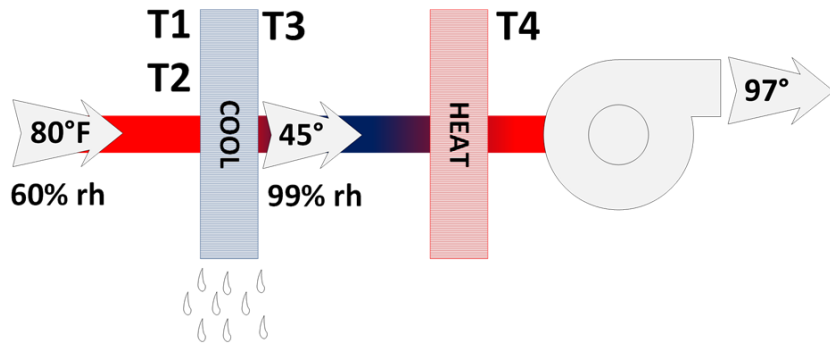


# What options make Indoor Ag HVAC equipment so special?

- Refrigeration designs to handle low leaving air dewpoint in ALL OUTDOOR CONDITIONS. Typically see a 42-45 deg leaving coil dewpoint. Enough HGRH capacity in ALL OUTDOOR CONDITIONS.
- Non-corrosive interior construction
- High efficiency if possible (Wrap around FP, Free Cooling)
- System controls integration to space VPD setpoints
- UV, Odor Control, and High Filtration requirements



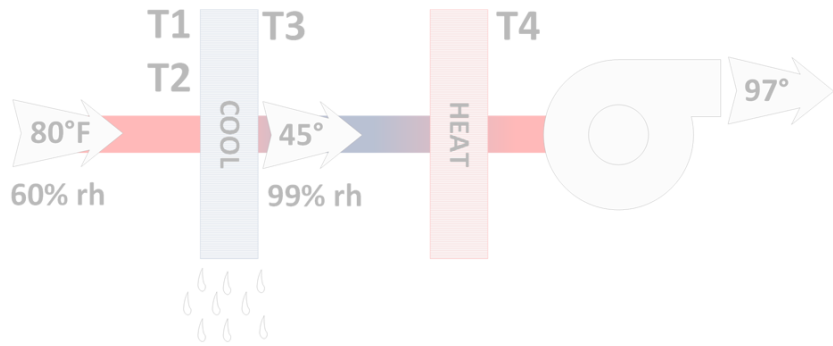
# Comparison of Technology



## TRADITIONAL DEHUMIDIFICATION

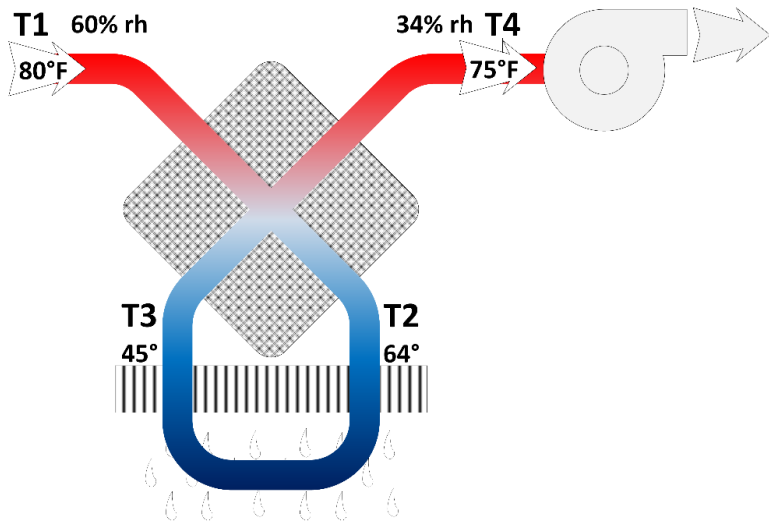
- Cooling + Heating
- No Precooling
- Portable dehumidifiers overheat rooms and increases A/C load

# Comparison of Technology



## TRADITIONAL DEHUMIDIFICATION

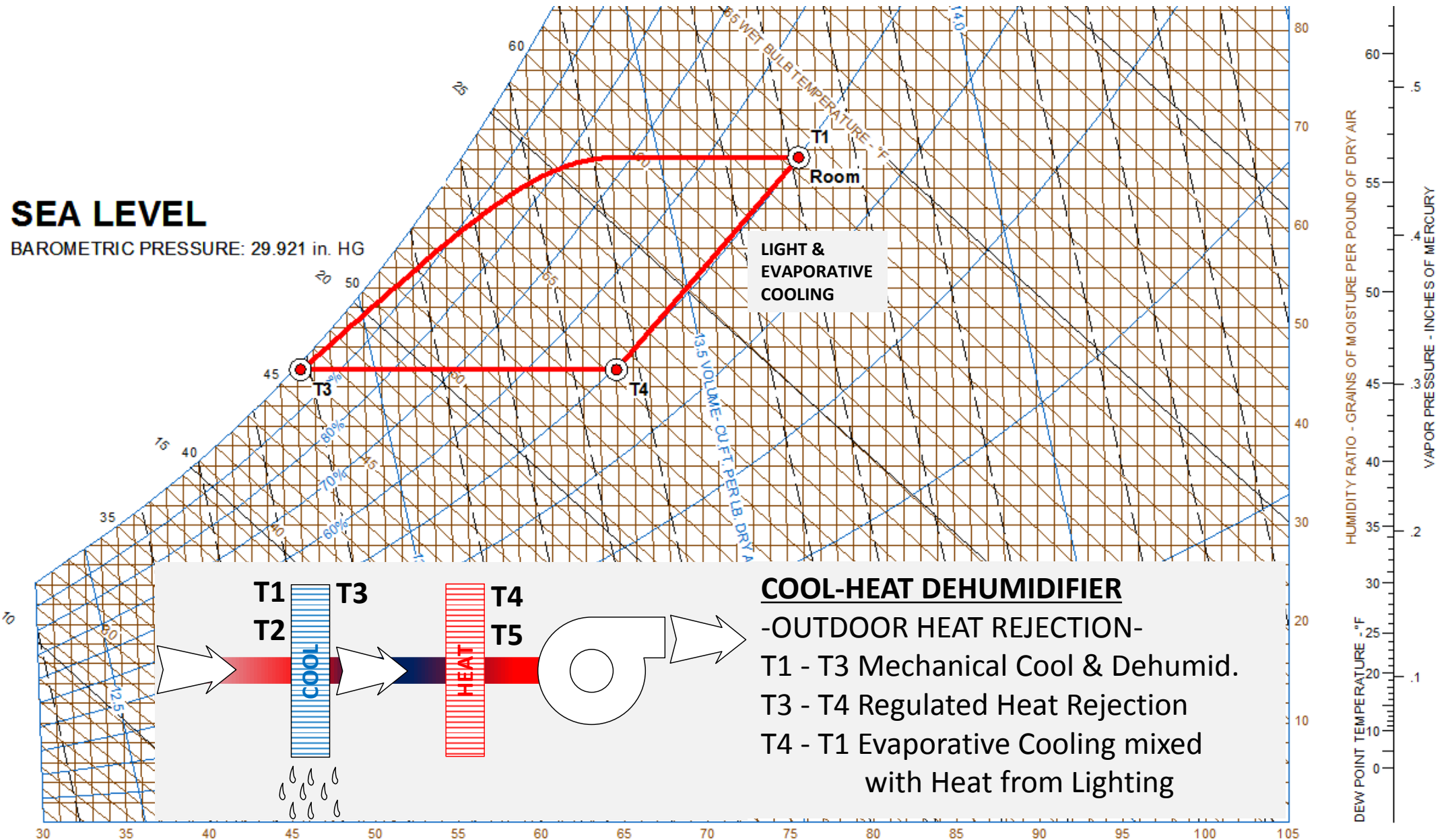
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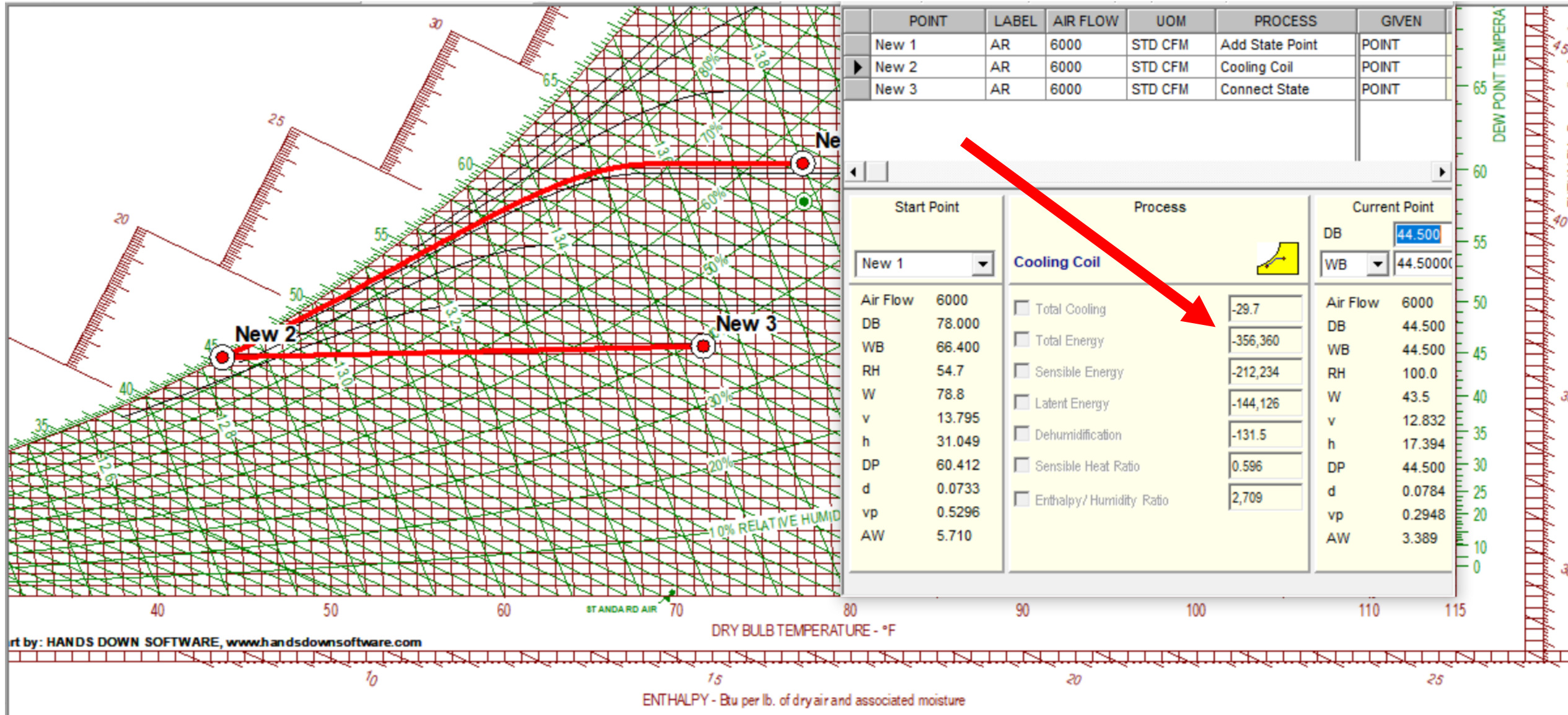
## Wrap-around DEHUMIDIFIERS

- Precooling reduces up to 65% energy
- Reduces all ancillary MEP equipment and installation
- Fast Return on Investment (ROI)... typically less than 1 year

# Traditional Dehumidification with Hot Gas Reheat



# Traditional Dehumidification with HGRH





# Wrap Around Free Pre-cooling with Wrap Around Design

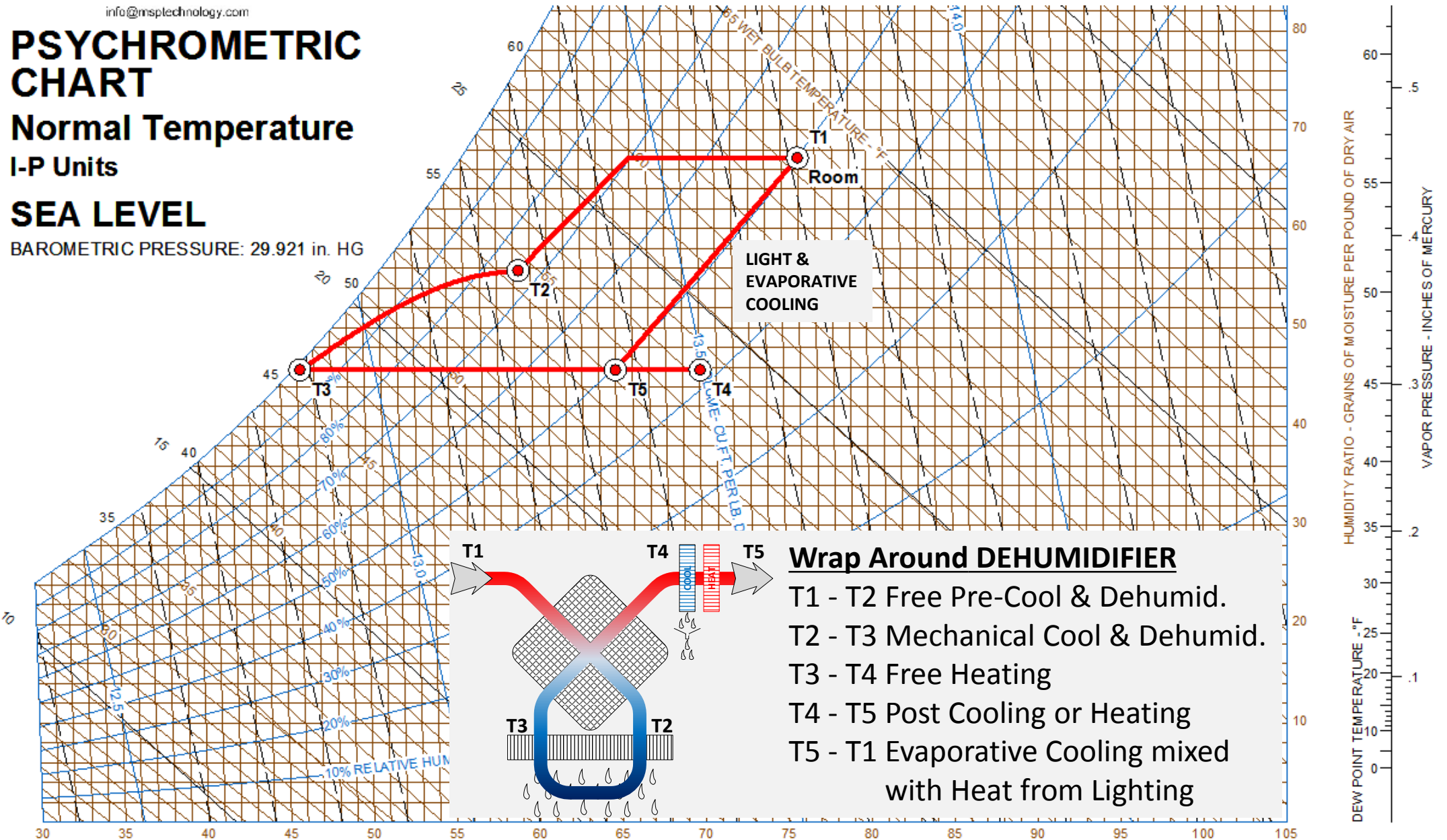
## PSYCHROMETRIC CHART

Normal Temperature

I-P Units

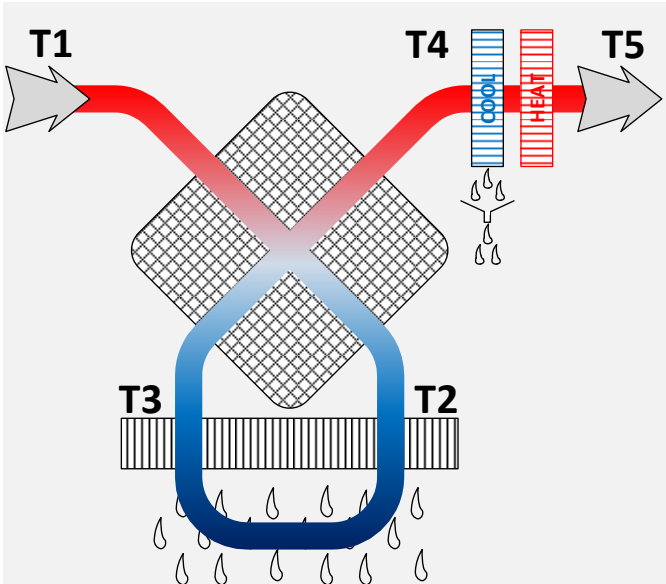
SEA LEVEL

BAROMETRIC PRESSURE: 29.921 in. HG



**Wrap Around DEHUMIDIFIER**

- T1 - T2 Free Pre-Cool
- T2 - T3 Mechanical Cooling
- T3 - T4 Free Heating
- T4 - T5 Post Cooling or Heating



**WRAP-AROUND PLATE**

**MSP® DEHUMIDIFYING COIL SELECTION PROGRAM v18B**

Inlet condition	T1	T3	Altitude	0 ft
Standard air volume	6,000	5,932 scfm	Efficiency	HIGH
Air volume	6,128	5,664 cfm	MSP® Coil size	48 Units
Temperature DB	78	44.50 °F	Recommended airflow	6,000 cfm
Relative humidity	55	99.00 %	Cooling required	-189,271 btu/h
Absolute humidity	79.3	42.9 gr/lb	Savings	-179,931 btu/h / 49%
Wet bulb	66.5	44.4 °F	Capacity	139.9 lb/h
Dew point	60.7	44.2 °F	Sensible heat ratio	0.19 Sensible
Enthalpy	31.21	17.3 btu/lb		
Coil face velocity	421.51	fpm		
Total pressure drop	2.24	in. wg		

Outlet condition	T2	T4
Standard air volume	5,985	5,932 scfm
Air volume	5,918	5,978 cfm
Temperature	61.6	72.4 °F
Relative humidity	75.9	36.3 %
Absolute humidity	61.8	42.9 gr/lb
Wet bulb	57.0	56.5 °F
Dew point	53.9	44.2 °F
Enthalpy	24.45	24.1 btu/lb

The diagram shows a schematic of the wrap-around plate. Air enters at T1, passes through a pre-cooler (labeled PRE-COOL), then through a cooling coil (labeled COOL), and finally through a re-heater (labeled RE-HEAT) before exiting at T4. The temperature points are labeled T1, T2, T3, and T4. A red arrow points from the top right towards the re-heater section.



# RESULTS!!!

## Design:

EAT - 78db/66.4wb at 6,000 CFM

Coil – 45.5 deg F

LAT – 72db/57wb at 6,000 CFM

Traditional Dehumidification with HGRH = ~356,000 btu or 30 tons

Wrap Around Technology = ~190,000 btu or 16 tons

**Wrap Around Savings = ~166,000 btu or 14 tons**

# Wrap around Dehumidification

Capital Costs

Wrap around FP Technology



Wrap around heat pipe






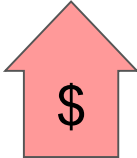


Traditional Dehumidification






Wrap Around FP Technology has significantly lower lifetime cost than any other dehumidification equipment

# Wrap around Dehumidification

	Capital Costs	MEP Costs
Wrap around FP Technology		
Wrap around heat pipe		
Traditional Dehumidification		













Wrap Around FP Technology has significantly lower lifetime cost than any other dehumidification equipment

# Wrap around Dehumidification

	Capital Costs	MEP Costs	Operating Costs
Wrap around FP Technology			
Wrap around heat pipe			
Traditional Dehumidification			

Wrap Around FP Technology has significantly lower lifetime cost than any other dehumidification equipment

# Wrap around Dehumidification

	Capital Costs	MEP Costs	Operating Costs	Total Lifetime Costs
Wrap around FP Technology				
Wrap around heat pipe				
Traditional Dehumidification				

Wrap Around FP Technology has significantly lower lifetime cost than any other dehumidification equipment

**Question? Comments?**

**THANK YOU!**