GRAND RAPIDS 2030 DISTRICT

CANNABIS WEBINAR SERIES

MAKE IT OR BREAK IT WITH DEHUMIDIFICATION:

THE IMPORTANCE OF INDOOR AGRICULTURE HVAC, ITS FUNDAMENTALS, AND THINKING OUTSIDE OF THE BOX

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Mitch Kelley | Trane
Rachel Fredrickson | Consumers Energy

INTRODUCTIONS

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GRAND RAPIDS CANNABIS ENERGY MANAGEMENT

BEST PRACTICES GUIDE

Indoor Agriculture HVAC Design Fundamentals

Agenda

- What is Indoor Agriculture?
- Market Landscape
- Inside the grow room
- Understanding the Loads
- Pros and Cons of HVAC Systems
- Controls Considerations

Market Naming

Various names being used, including:

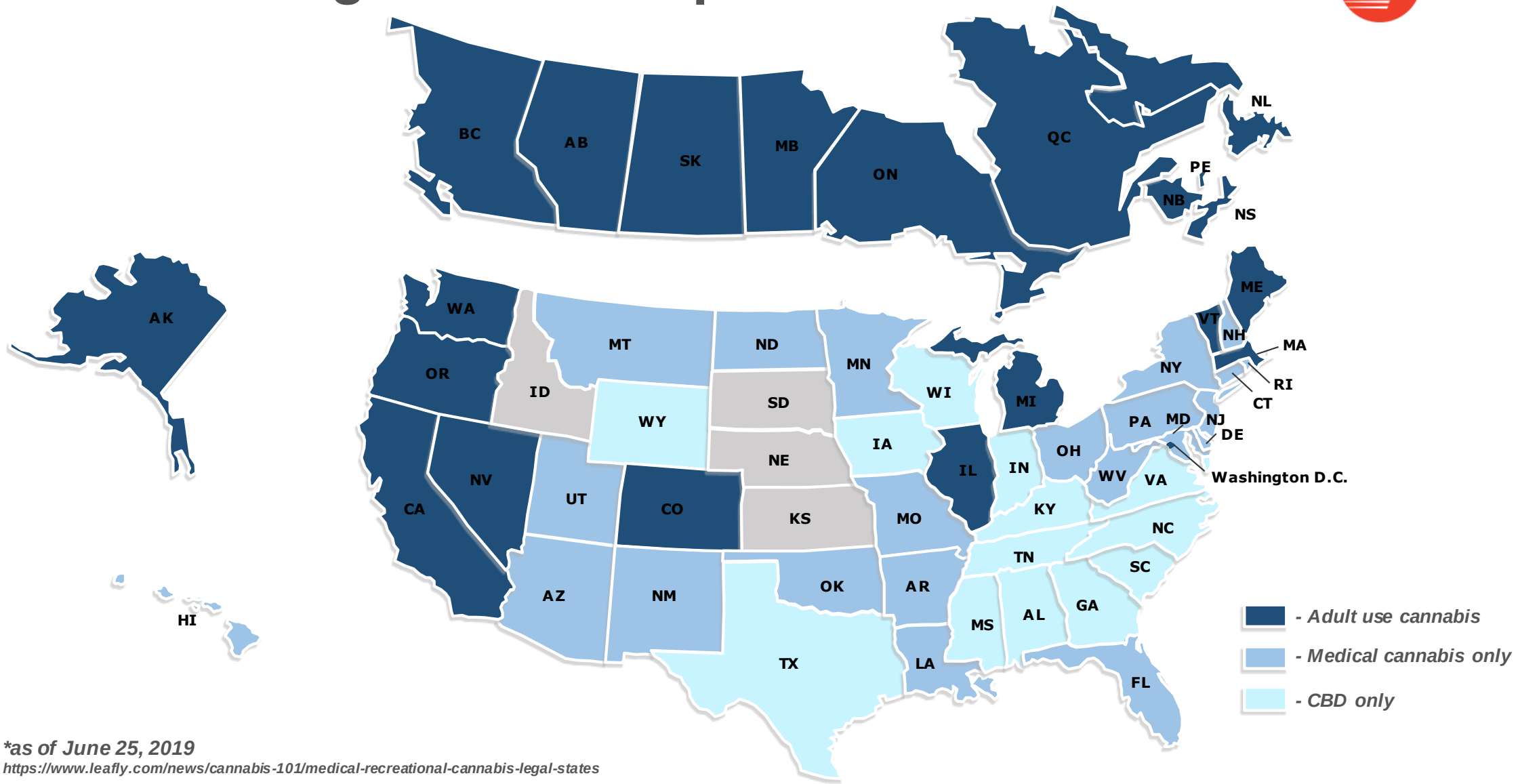
- Controlled environment agriculture (CEA)
- Indoor Agriculture
- Indoor Gardening (IG)
- Industrial Agriculture
- Plant Factories
- Vertical (Canopy) Farming – multiple shelves of plants, leafy greens. Maximize floor space.
- Urban Agriculture

What is Indoor Agriculture?

- **Indoor Agriculture…** a technology based approach to growing crops indoors allowing growers to set the ideal environment to achieve optimal harvest from each crop
  - Growers control temperature, humidity(or VPD), CO_2, lighting, irrigation, fertilization, etc.
- Indoor farming can use **~90 – 99% less water** than traditional farming
- Indoor farms can grow up to **100 - 350 times more crops** per ft^2 than traditional farms
- Crops include cucumbers, lettuce, leafy greens, herbs, tomatoes, or cannabis in legally licensed facilities

April 2018 - *https://www.vox.com/energy-and-environment/2017/11/8/16611710/vertical-farms*
January 2015 - *https://www.sciencealert.com/this-indoor-farm-is-100-times-more-productive-than-an-outdoor-one*

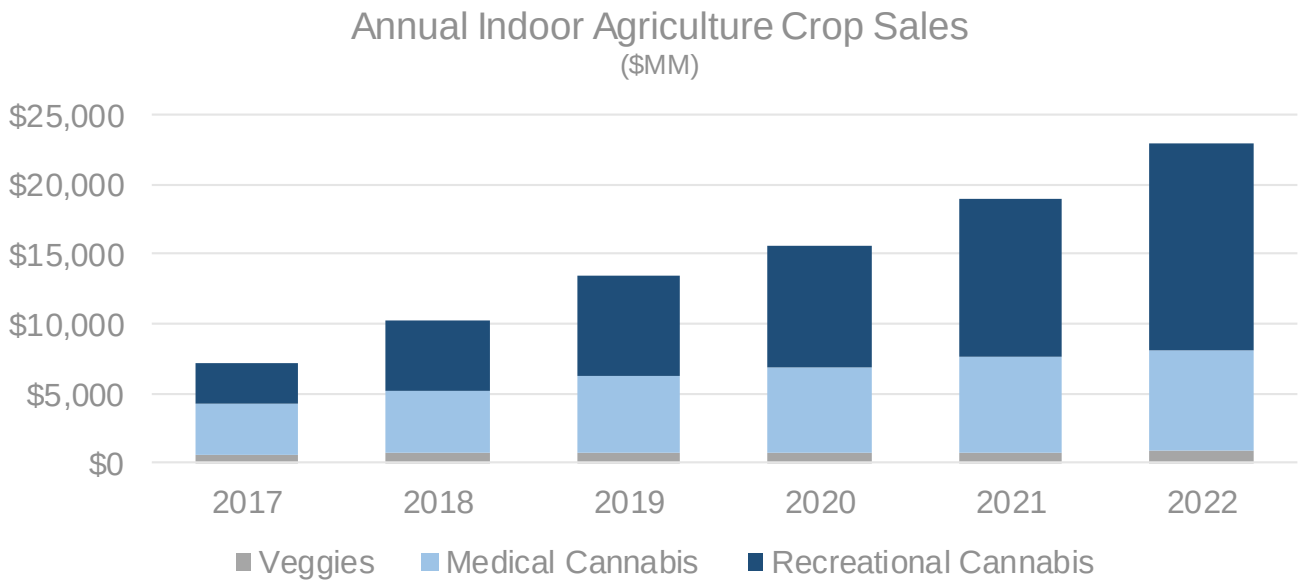
Cannabis Legalization Map



as of June 25, 2019

https://www.leafly.com/news/cannabis-101/medical-recreational-cannabis-legal-states

Market Trends and Size



- Indoor Agriculture Market growing at 26%+ per year
- Indoor Agriculture is HVAC intensive environment… ~1 ton per 50 ft^2
- Customer paying a premium for IA HVAC equipment… upwards of $3-$4K/ton
- $500M - $1B HVAC market opportunity per year

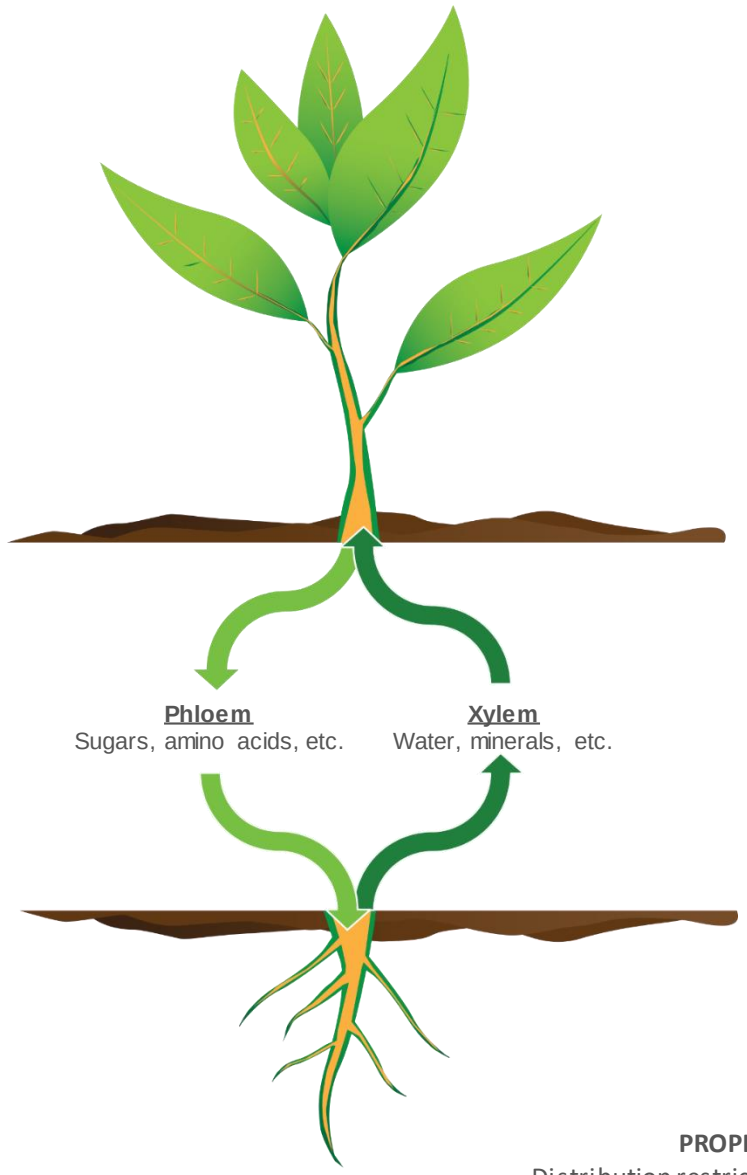
Sources: MJ Biz Daily 05/18, Grand View Research 04/17, MJ Biz Daily 11/17, CannaBusinessPlans 2019

IL Market Update

- 20 Existing Cultivation Centers
  - Capped at 210,000 sq. ft.
- Craft Growers
  - Capped at 5,000 sq. ft. for now
  - 40 Licenses issued by July 1st, 2020
  - Additional 60 Licenses by December 21st, 2021
- $3.2M on January 1st , $12.9M in the first week
  - CO sold $1M on 1st day
  - MI sold $3.1M in first 2 weeks

Inside The Grow Room

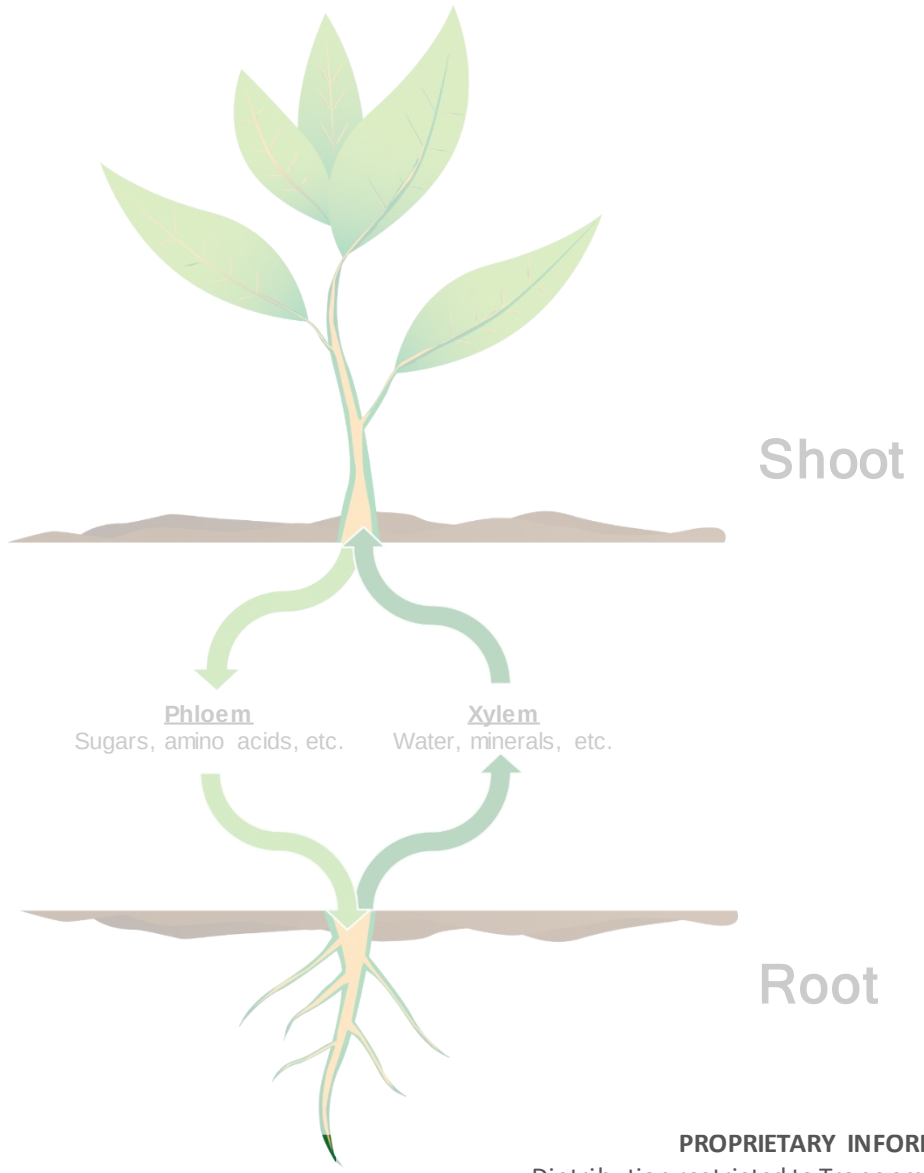
Plants need O_2, CO_2, minerals, vitamins, and H_2O

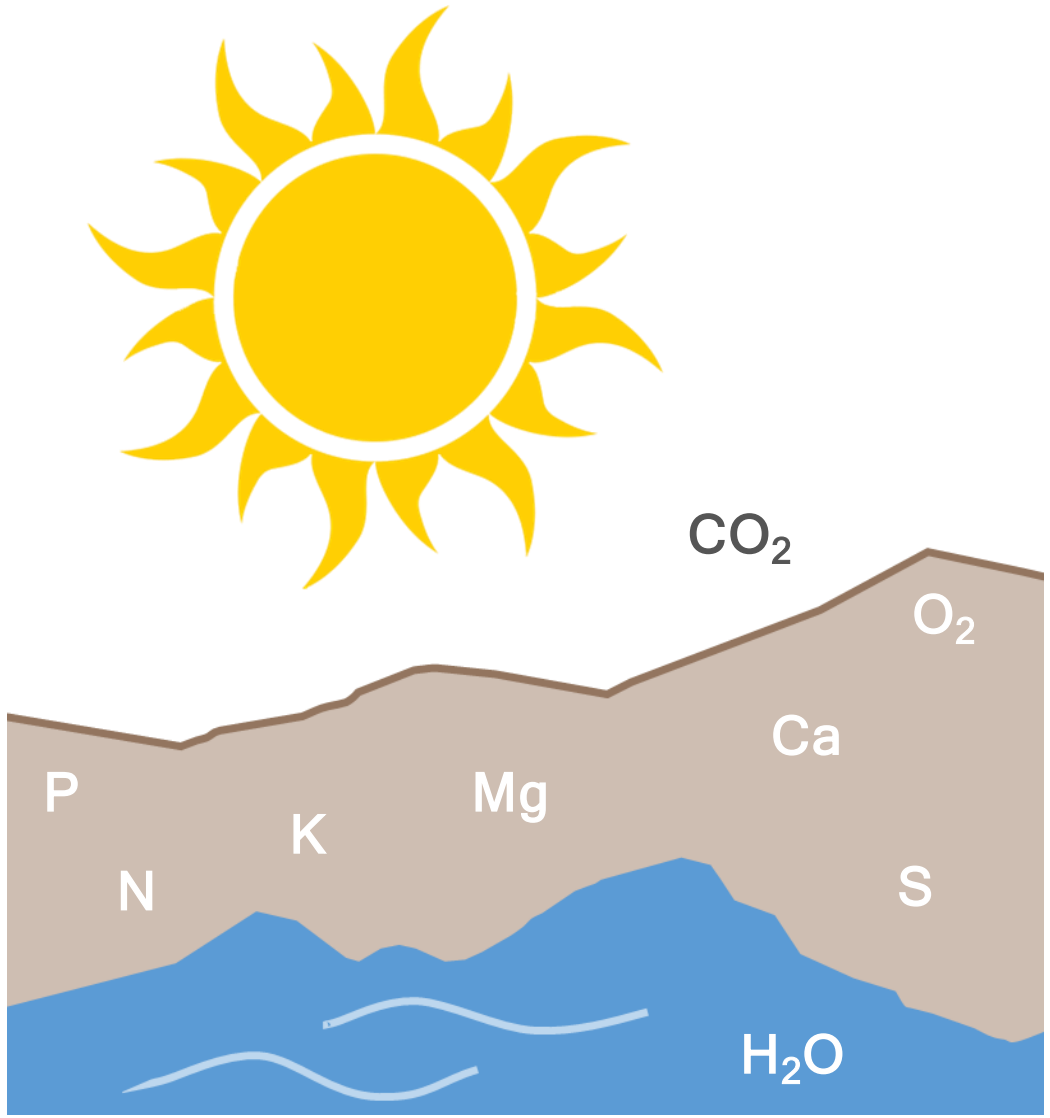


Shoot

Root

Plants need O_2, CO_2, minerals, vitamins, and H_2O

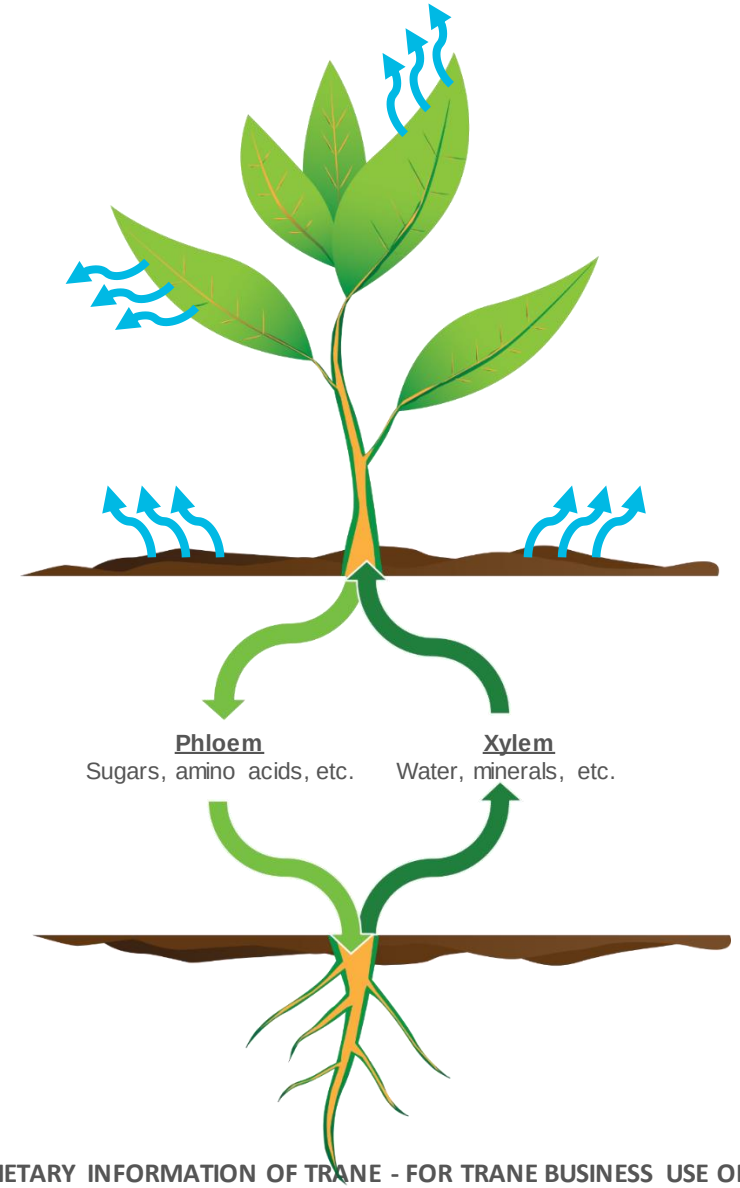




Evapotranspiration = evaporation + transpiration

Evaporation

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



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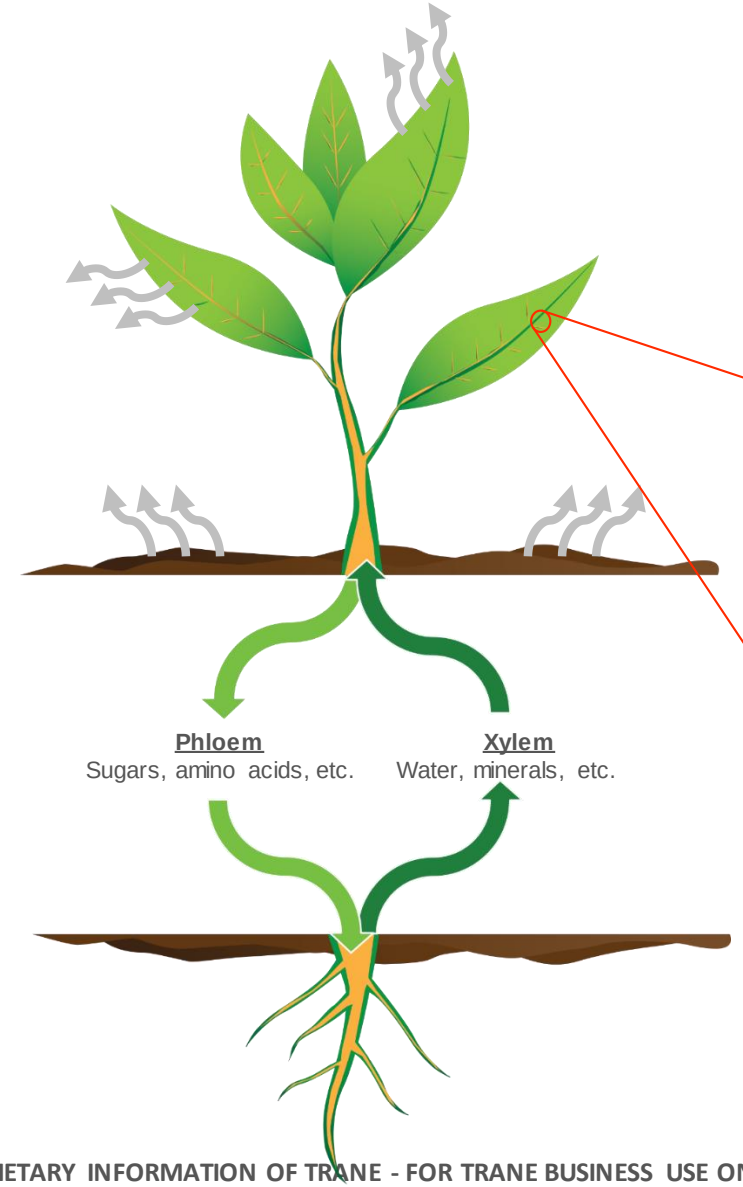
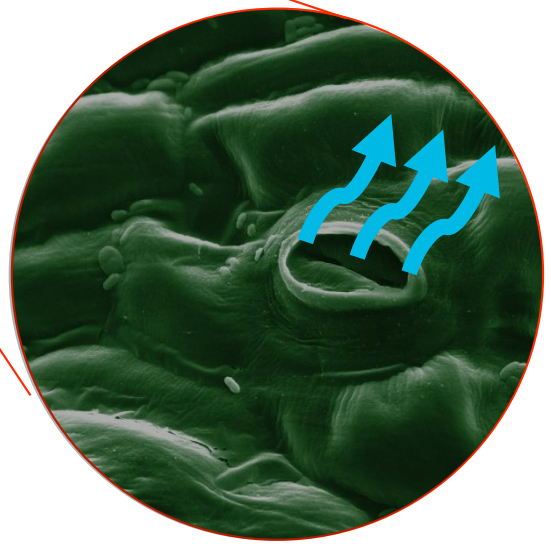


Transpiration

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



Transpiration rates at night

- Plant transpiration rates do not stop during nighttime modes
- Transpiration rates decrease by ~2/3 when lights are off
- Transpiration rates slowly decrease when lights are turned off… can take 30 – 60 minutes for rates to stabilize
- Experiment was done using barley… relationship should hold true for all C3 plants (tomatoes, lettuce, hemp, etc.)

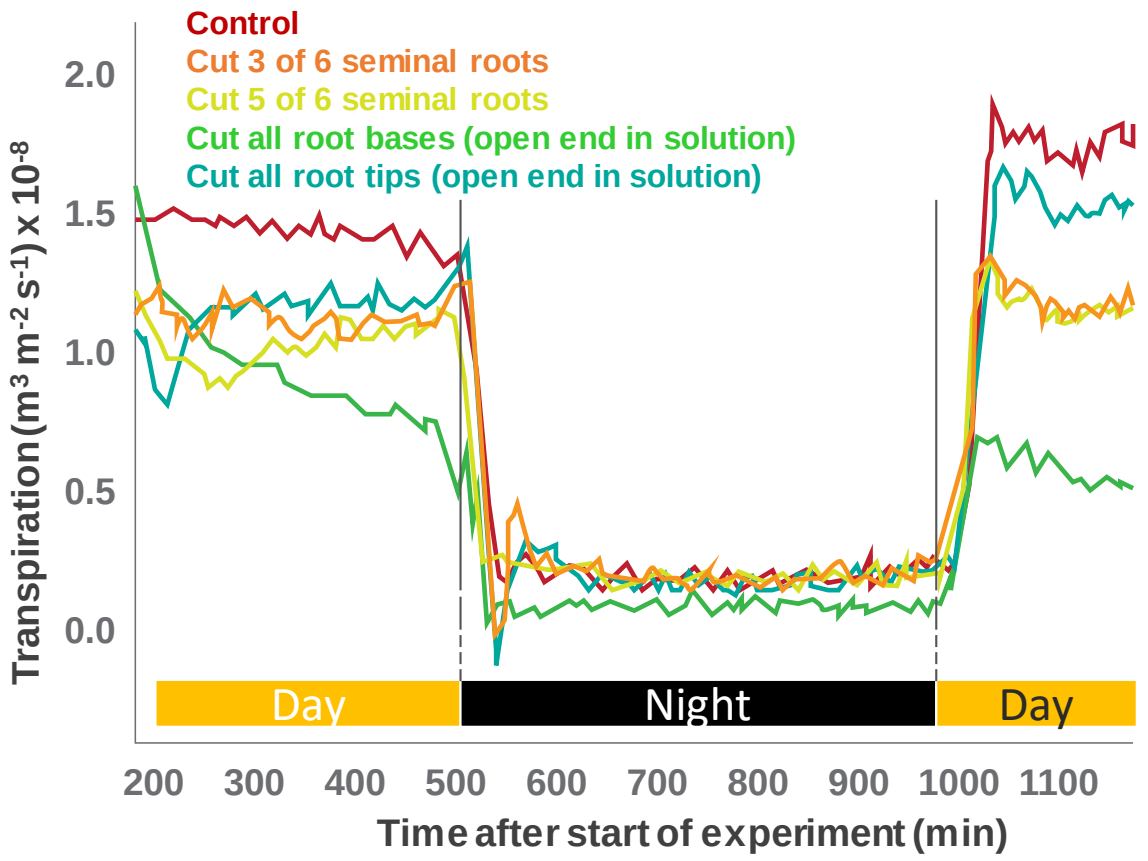


Chart source: https://academic.oup.com/jxb/article/62/2/717/593518

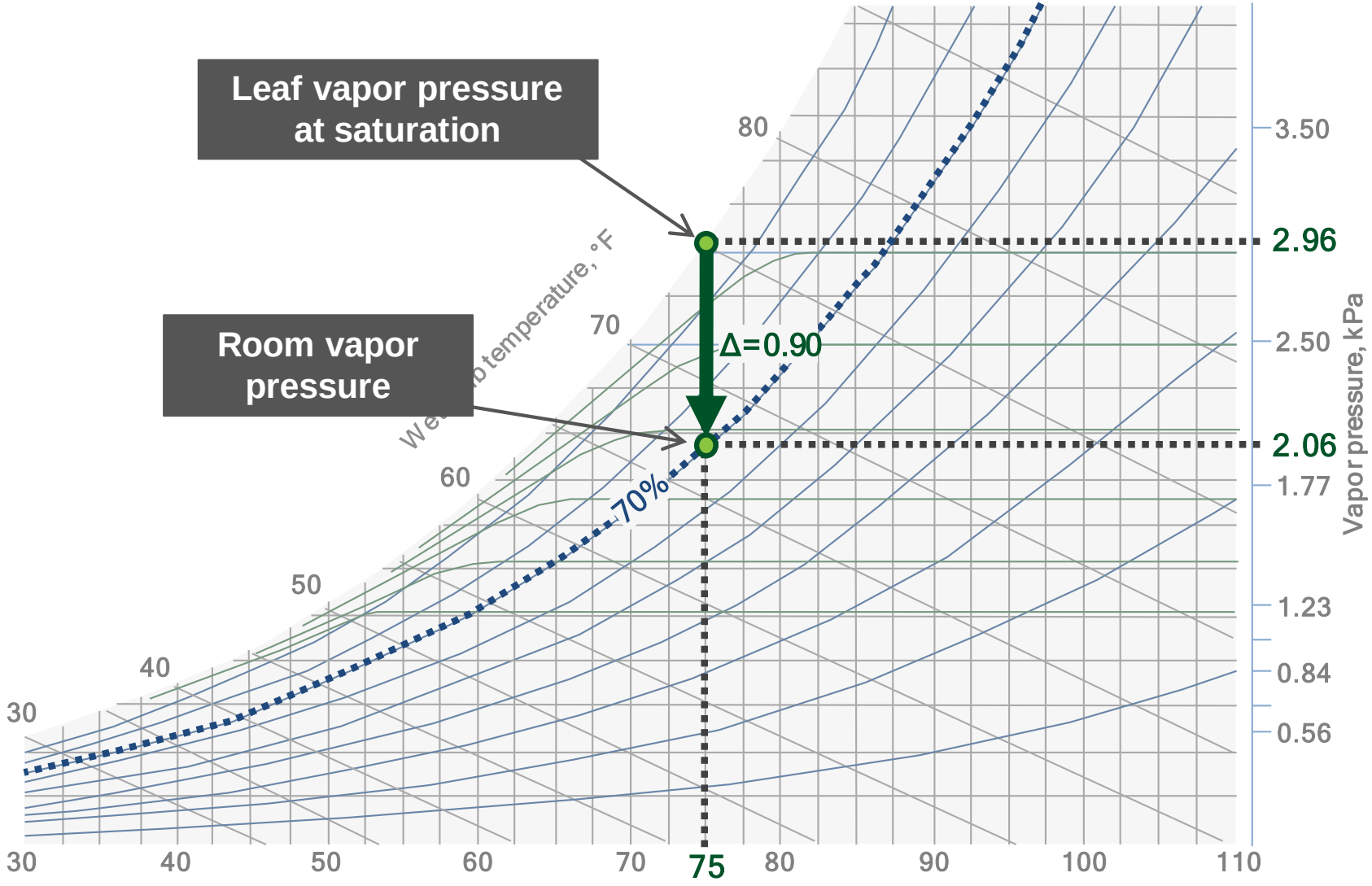
Vapor Pressure Deficit (VPD)

Vapor pressure deficit (VPD)

Vapor pressure difference, vapor pressure deficit (VPD): the difference between the saturation vapor pressure and the vapor pressure in the room at the dry bulb temperature of the leaf.

VPD is a measure on how easily water can transpire from the plant

Example: VPD = 0.90



VPD impact on plants

Low VPD (High RH)

- Low transpiration rates… limits the amount of nutrients and minerals that get transferred through the plant
- Excessive pressure within a plant, results in water being forced out through the leaf edges (guttation)
- Increased likelihood of rot, fungus or mold growth
- Limited carbon filtration capabilities (odor control)

VPD impact on plants

High VPD (Low RH)

- High transpiration rates: Plants will close their stomata to prevent excessive water loss… limits amount of CO_2 that can be absorbed for photosynthesis
- Leaves will curl inward to limit leaf surface exposure to the lights
- Very slow plant growth or stunting

VPD Chart

TRANE

TRANE

Air Temperature (°F) \ Relative Humidity (%)	100	98	96	94	92	90	88	86	84	82	80	78	76	74	72	70	68	66	64	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0
50	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2
52	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.3
54	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4
56	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5
58	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.6
60	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8
62	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	1.9
64	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	1.9	1.9	2.0	2.0
66	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.1	2.1	2.2
68	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3
70	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5
72	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.6	2.7
74	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.6	2.7	2.7	2.8	2.8
76	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.0
78	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.8	1.9	2.0	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.1	3.2	3.3
80	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.1	3.2	3.3	3.3	3.4	3.5
82	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.7	2.8	2.9	3.0	3.0	3.1	3.2	3.3	3.3	3.4	3.5	3.6	3.6	3.7
84	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.1	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.4	3.5	3.6	3.6	3.7	3.8	3.9	4.0
86	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.9	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.5	3.6	3.7	3.8	3.9	4.0	4.0	4.1	4.2
88	0.0	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.9	4.0	4.1	4.2	4.3	4.4	4.5
90	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8
92	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1
94	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4
96	0.0	0.1	0.2	0.3	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.5	1.6	1.7	1.8	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.6	3.7	3.8	3.9	4.0	4.1	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.1	5.2	5.3	5.4	5.5	5.6	5.7
98	0.0	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	2.0	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.5	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.1	5.3	5.4	5.5	5.6	5.7	5.9	6.0	6.1
100	0.0	0.1	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2	5.3	5.5	5.6	5.7	5.8	6.0	6.1	6.2	6.4	6.5
102	0.0	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.7	1.8	1.9	2.1	2.2	2.3	2.5	2.6	2.8	2.9	3.0	3.2	3.3	3.4	3.6	3.7	3.9	4.0	4.1	4.3	4.4	4.5	4.7	4.8	5.0	5.1	5.2	5.4	5.5	5.6	5.8	5.9	6.1	6.2	6.3	6.5	6.6	6.8	6.9
104	0.0	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.0	2.2	2.3	2.5	2.6	2.8	2.9	3.1	3.2	3.4	3.5	3.7	3.8	3.9	4.1	4.2	4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.8	6.0	6.1	6.3	6.4	6.6	6.7	6.9	7.0	7.2	7.3
106	0.0	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2.0	2.2	2.3	2.5	2.6	2.8	2.9	3.1	3.3	3.4	3.6	3.7	3.9	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.9	6.0	6.2	6.4	6.5	6.7	6.8	7.0	7.1	7.3	7.4	7.6	7.8

**assumes leaf temp and room temp are the same*

VPD Chart *(kPa)*

56% RH

76°F

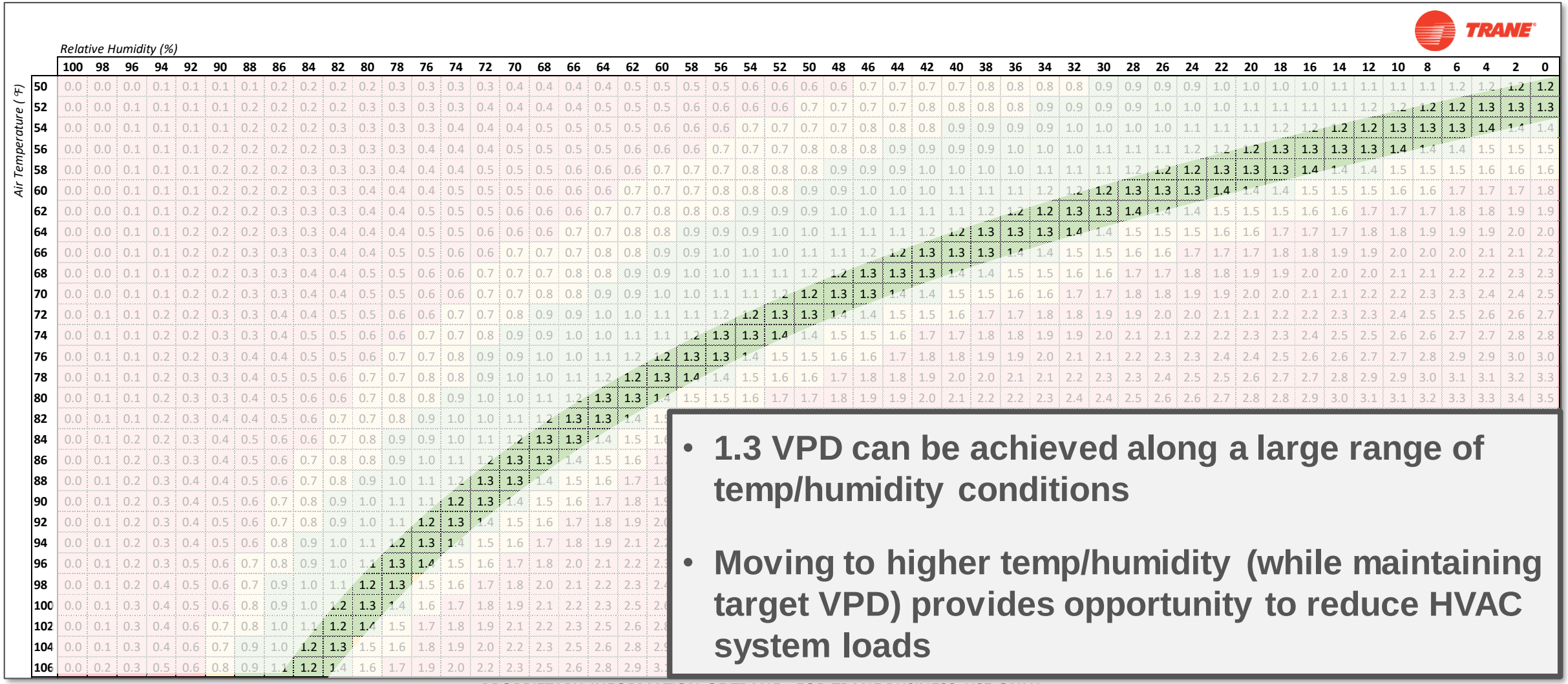
Relative Humidity (%)

Air Temperature (°F)

°F \ RH	100	98	96	94	92	90	88	86	84	82	80	78	76	74	72	70	68	66	64	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0
50	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2
52	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.3
54	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4
56	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5
58	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.6
60	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8
62	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	1.9
64	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	1.9	1.9	2.0	2.0
66	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.1	2.1	2.2
68	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3
70	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5			
72	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.6	2.7			
74	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.2	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.6	2.7	2.7	2.8	2.8				
76	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.2	1.3	1.5	1.6	1.6	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.0				
78	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.4	1.6	1.7	1.8	1.8	1.9	2.0	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.1	3.2	3.3				
80	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.3	1.5	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.1	3.2	3.3	3.3	3.4	3.5			
82	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.8	1.7	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.7	2.8	2.9	3.0	3.0	3.1	3.2	3.3	3.3	3.4	3.5	3.6	3.6	3.7
84	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.1	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.4	3.5	3.6	3.6	3.7	3.8	3.9	4.0
86	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.9	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.5	3.6	3.7	3.8	3.9	4.0	4.0	4.1	4.2
88	0.0	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.9	4.0	4.1	4.2	4.3	4.4	4.5
90	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8
92	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1
94	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4
96	0.0	0.1	0.2	0.3	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.5	1.6	1.7	1.8	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.6	3.7	3.8	3.9	4.0	4.1	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.1	5.2	5.3	5.4	5.5	5.6	5.7
98	0.0	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	2.0	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.5	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.1	5.3	5.4	5.5	5.6	5.7	5.9	6.0	6.1
100	0.0	0.1	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2	5.3	5.5	5.6	5.7	5.8	6.0	6.1	6.2	6.4	6.5
102	0.0	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.7	1.8	1.9	2.1	2.2	2.3	2.5	2.6	2.8	2.9	3.0	3.2	3.3	3.4	3.6	3.7	3.9	4.0	4.1	4.3	4.4	4.5	4.7	4.8	5.0	5.1	5.2	5.4	5.5	5.6	5.8	5.9	6.1	6.2	6.3	6.5	6.6	6.8	6.9
104	0.0	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.0	2.2	2.3	2.5	2.6	2.8	2.9	3.1	3.2	3.4	3.5	3.7	3.8	3.9	4.1	4.2	4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.8	6.0	6.1	6.3	6.4	6.6	6.7	6.9	7.0	7.2	7.3
106	0.0	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2.0	2.2	2.3	2.5	2.6	2.8	2.9	3.1	3.3	3.4	3.6	3.7	3.9	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.9	6.0	6.2	6.4	6.5	6.7	6.8	7.0	7.1	7.3	7.4	7.6	7.8

**assumes leaf temp and room temp are the same*

VPD Chart *(kPa)*



- **1.3 VPD can be achieved along a large range of temp/humidity conditions**
- **Moving to higher temp/humidity (while maintaining target VPD) provides opportunity to reduce HVAC system loads**

assumes leaf temp and room temp are the same

Types of Grow Rooms

Types of Grow Rooms

- Propagation/Clone Room
- Vegetative Rooms
- Mother Rooms
- Flowering/Bloom Rooms
- Drying/Curing Rooms

Propagation/Clone Rooms

- Seeds, or cuttings from the mother plants, are used to grow new plants
- Very low transpiration rates… may need to add humidity to the space
- ~70 - 80°F
- 65 – 80%+ RH
- Lights on: 18-24 hrs/day

Values are for illustrative purposes only. Growers will have specific target conditions for their grow rooms.

Vegetative Room

- Grow the plant…
- Increasing transpiration rates
- ~70 - 75°F
- 40 – 60% RH
- Lights on: 18 hrs/day

Values are for illustrative purposes only. Growers will have specific target conditions for their grow rooms.

Mother Room

- Large mature plants (sometimes kept in the veg room)… continue to grow the plant to take cuttings for clones
- High transpiration rates
- ~70 - 75°F
- 40 – 60% RH
- Lights on: 18 hrs/day

Values are for illustrative purposes only. Growers will have specific target conditions for their grow rooms.

Flowering/Bloom Rooms

- Plants will not grow flowers until the light exposure is decreased simulating end of summer
- High transpiration rates
- ~70 °F
- 35 – 50% RH (prevent mold on bud)
- Lights on: 12 hrs/day

Values are for illustrative purposes only. Growers will have specific target conditions for their grow rooms.

Drying/Curing Rooms

- Slow/controlled drying process
- ~70 °F
- 30-60% RH *(decreasing with time)*
- Lights on: occupancy sensor

***Values are for illustrative purposes only. Growers will have specific target conditions for their grow rooms.**

Other Grow Room Considerations

- Varying environmental set points… grower defined
- Elevated CO_2
- Room design… warehouse retrofit, new build, room within a room, etc.
- Methods of irrigation
- Type of lighting… HPS, LED, etc.

Understanding the Loads

Why this isn't normal air conditioning

	Comfort Cooling	Indoor Agriculture
Operating modes	Occupied Unoccupied	Lights-on / "Daytime" Lights-off / "Nighttime"
Lighting	0.7 – 1.2 W/ft^2	30 – 80 W/ft^2
Space temperature	70 – 75°F	65 – 83°F
Space humidity	50 – 60% relative humidity	40 – 75% relative humidity
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)

Process manufacturing

Lights-on (“daytime”)

High sensible load from lighting

High latent load from evapotranspiration

\+ Sensible cooling from evaporation

= **Sensible cooling** and **dehumidification**

Process manufacturing

Lights-on (“daytime”)

High sensible load from lighting

High latent load from evapotranspiration

\+ Sensible cooling from evaporation

= **Sensible cooling** and **dehumidification**

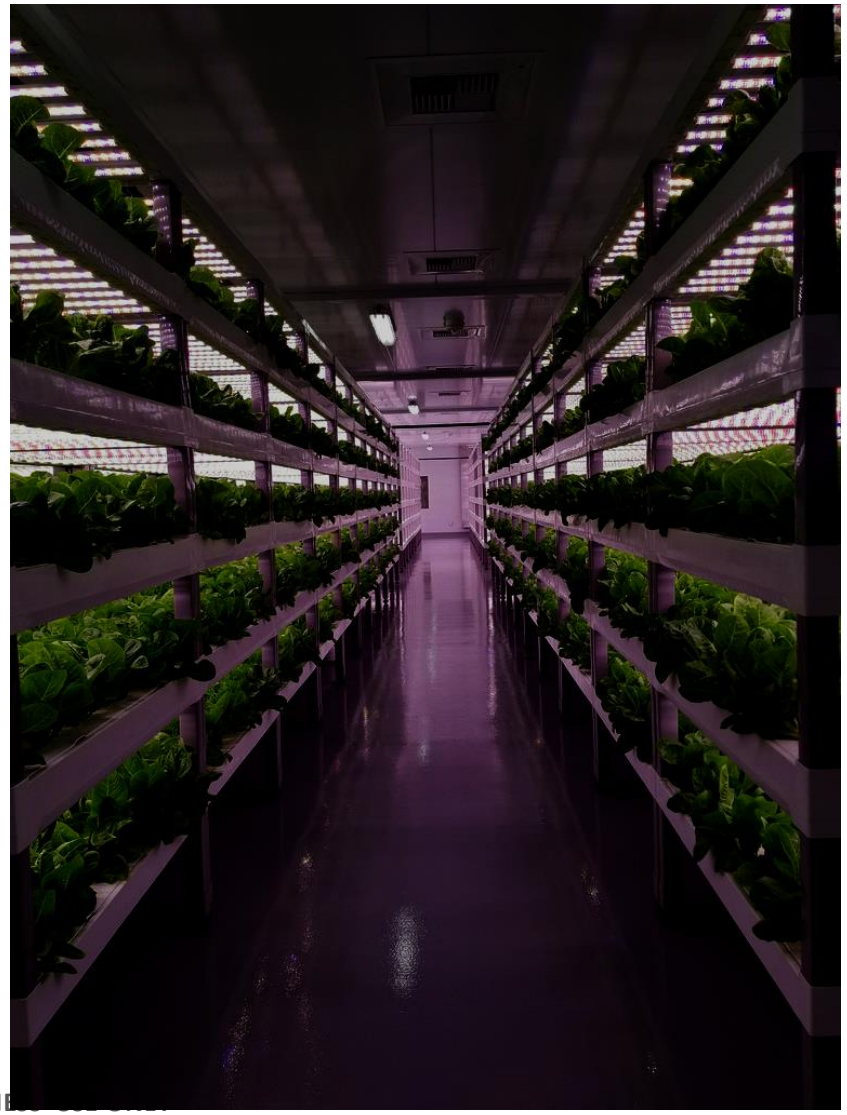
Lights-off (“nighttime”)

No sensible load from lighting

Medium latent load from evapotranspiration

\+ Medium sensible cooling from evaporation

= **Primarily dehumidification**



Load design

Sensible

- Lighting
- Envelope
  (e.g. walls, floors, roofs,
  glass conduction, glass solar)
- People
- Internal loads
  (e.g. dehumidifiers, fans, pumps,
  CO_2 generators)
- Infiltration
- Ventilation
- Sensible cooling effect from evapotranspiration

Latent

- Plants
- People
- Infiltration
- Ventilation

Critical points for sizing the HVAC system

- **Largest sensible load**: when lights are on at the lowest transpiration rates (clone room, early veg room)
- **Largest latent load**: when lights are on and plant evapotranspiration is at the highest (flower rooms, mother rooms)
- **Maximum reheat required**: when lights are turned off, plants continue to transpire for ~45 – 60 minutes. The HVAC system has to continue to dehumidify the air, however the sensible load has been significantly decreased or eliminated completely… increased risk of overcooling the space. Post dehumidification heating is required to get supply air back up to acceptable temperatures

Potential Grow Room Risks

- Thermally stressed plants
- White mold/mildew
- Insects/Pests
- Cross contamination
- Loss of a crop

A properly sized HVAC system can help mitigate these risks

HVAC Systems for Indoor Agriculture

Typical Indoor Ag HVAC Systems

1. DX Packaged or Splits with In-Space Dehumidification
2. Purpose-built DX Units
3. Applied Systems, Chilled water + AHUs

DX Packaged or Splits with In-Space Dehumidification

Sensible Load

-or-

+

Latent Load

Looks simple… but most grow rooms will require multiple units to handle loads

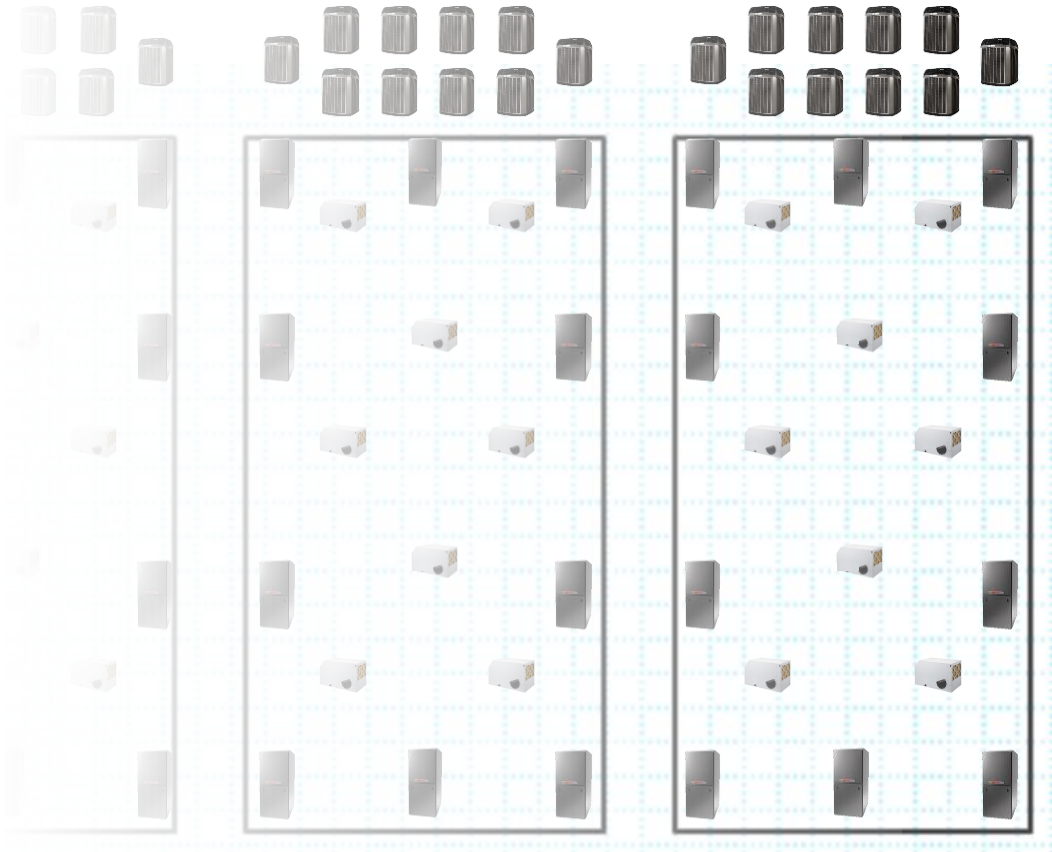
DX Packaged or Splits with In-Space Dehumidification

Advantages:

- Simple to install
- Simple to service
- Likely least expensive first cost
- Readily available

Drawbacks:

- Operating modes where units "fight each other"
- Frequent RTU/split cycling
- Increased unit quantity
- Likely most energy intensive



Purpose-Built DX Units

Split System

-or-

Packaged

Single system to handle both the sensible and latent loads

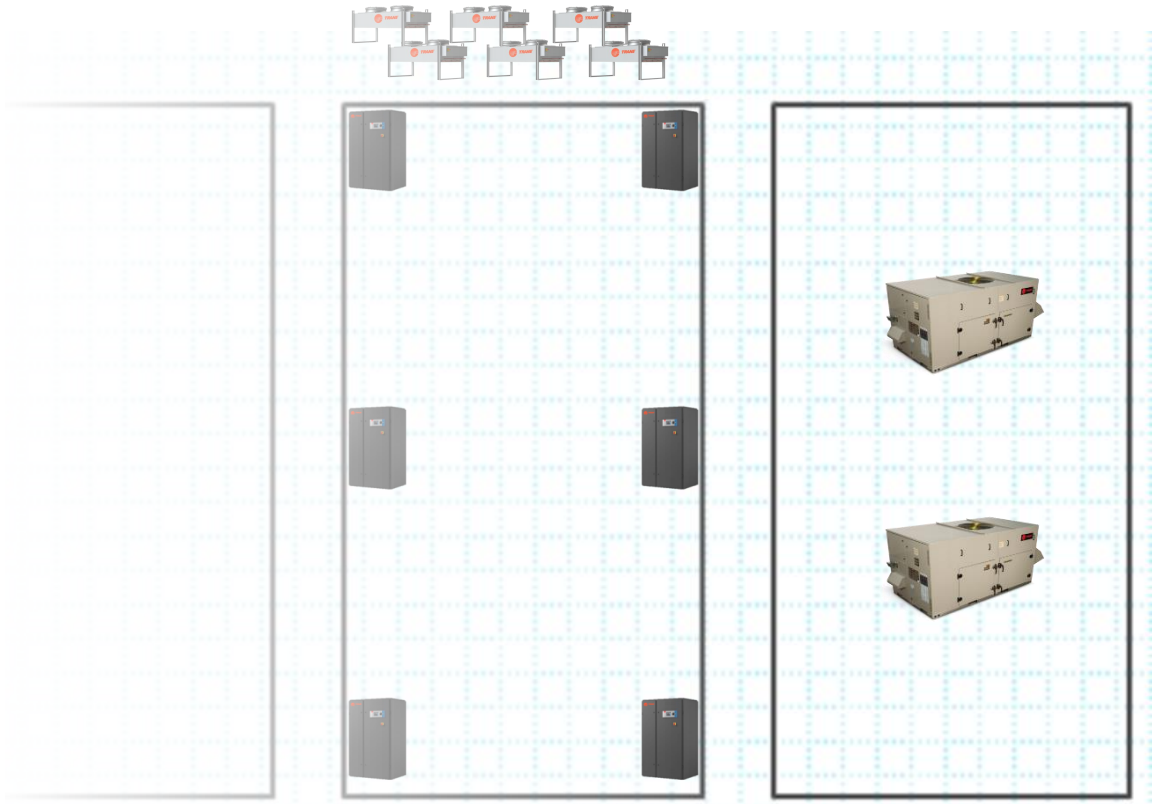
Purpose-Built DX Units

Advantages:

- Integrated operating modes
- Simple to install
- Fairly simple to control
- Improved energy efficiency

Drawbacks:

- Likely higher first cost
- Requires more skilled service personnel
- Likely longer lead time



(in room or outside room, ducted in)

(on roof)

Trane Indoor Ag Split System DX Units

Single Circuit DX Series

- Vertical Floor Mounted
- 5 – 10 Ton DX Systems
- Single Circuit DX
- Hot gas reheat
- Tandem Compressor Options*
- Utilizing EC Fan Technology

Dual Circuit DX Series

- Vertical Floor Mounted
- 15 – 30 Ton DX Systems
- Dual Circuit DX
- Hot gas reheat
- Tandem Compressor Options
- Utilizing EC Fan Technology

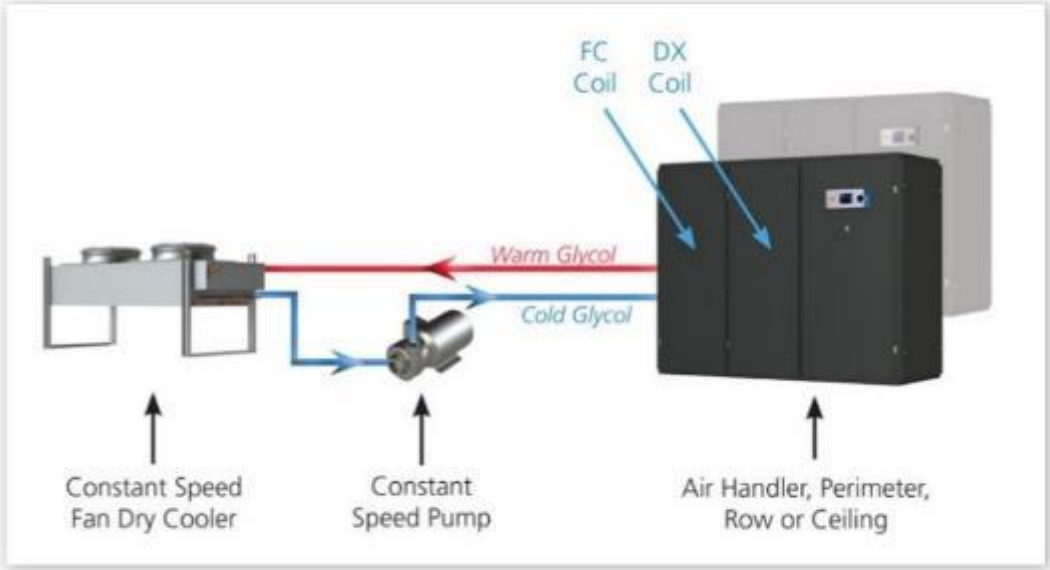
Heat Rejection Options

Remote Air Cooled Condensers

Microchannel Condensers

Glycol System Remote Dry coolers & Pump Packages

Energy Efficiency: Water-Side Economizer



Glycol Cooled DX

Free Cooling

Comprised of a dry cooler, pumps, and a glycol cooled free cooling AHU consisting of both a DX and a glycol cooling coil.

80%+ of the power is consumed by the compressors

Outside Air	Operation
Warm Weather Months	Unit acts as traditional DX; dry cooler supplies glycol to unit condenser
In-between Months	Combination of glycol free cooling coil and one DX compressor
Cold Weather Months	Cooled glycol transferred to free cooling coil; compressor off

Packaged Units

Packaged DX systems are designed to remove significant amounts of water while maintaining precise temperature and humidity conditions for indoor agriculture applications.

- Tonnage Range: 3 to 80
- CFM Range: 500 – 25,000
- Modulating hot gas reheat
- Can control to VPD directly
- Dehumidification: up to 600 lbs of water/hour (~1,700 gallons/day)
- Low Ambient Cooling down to -30 F
- UV Lights and multiple air filtration options

Applied Systems, Chilled Water + AHUs

Chillers

+

AHUs

Single system to handle both the sensible and latent loads

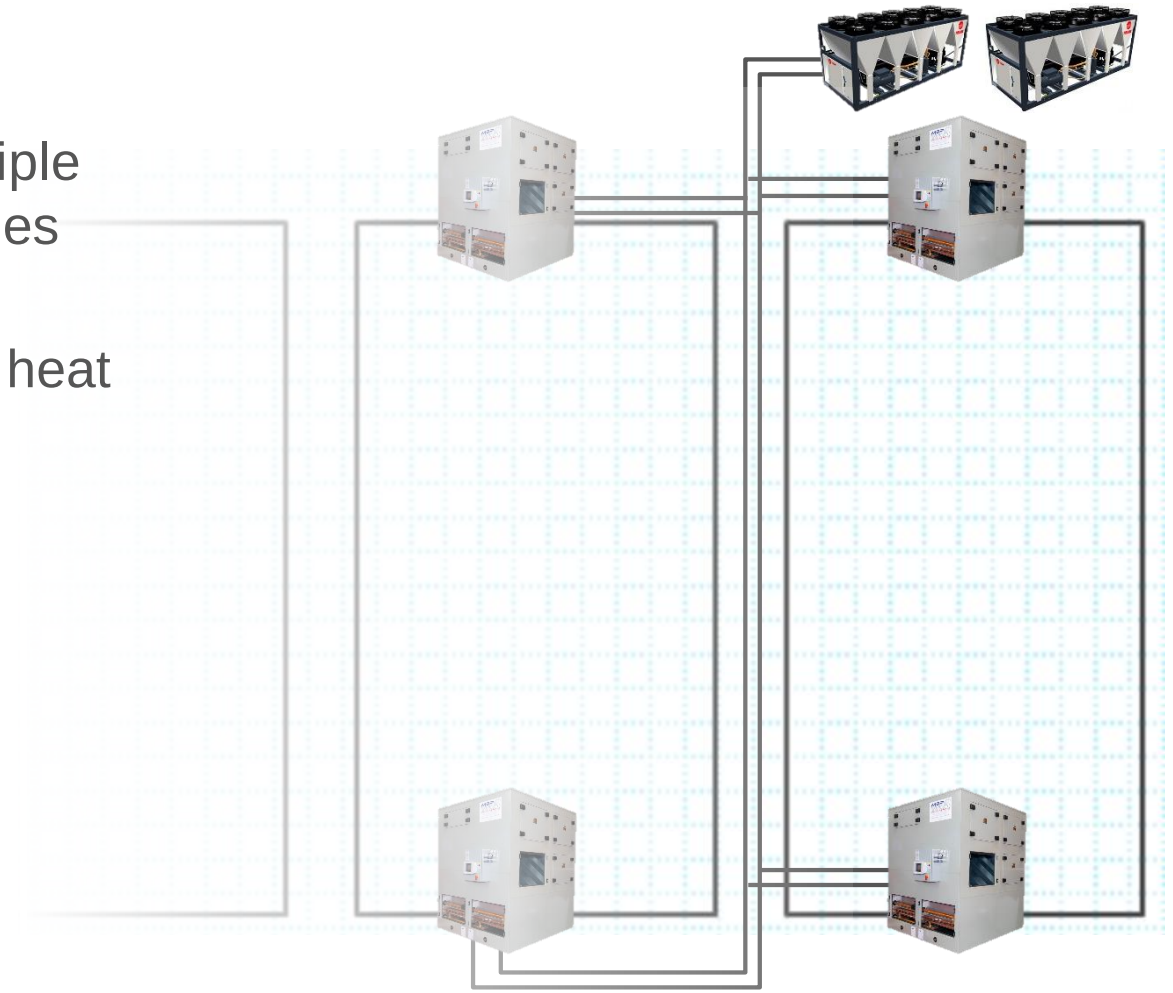
Applied Systems, Chilled Water + AHUs

Advantages:

- Sophisticated control options to handle multiple zones, varied set points, and varied schedules
- AHUs and Chillers are very flexible
- Opportunities for waterside free cooling and heat recovery
- Opportunities for air-to-air energy recovery
- Lowest operating costs
- Highest efficiency

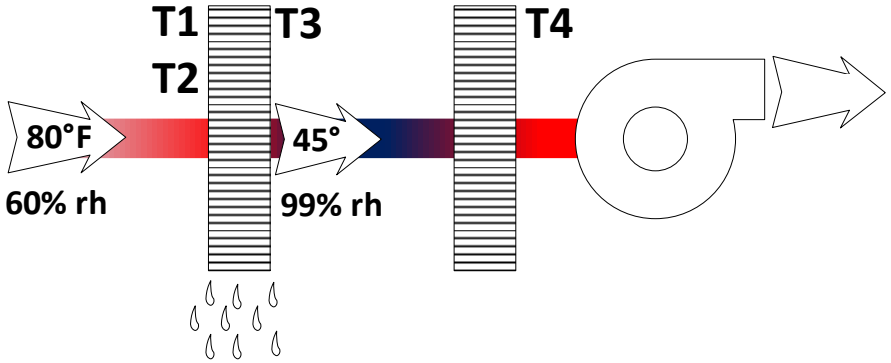
Drawbacks:

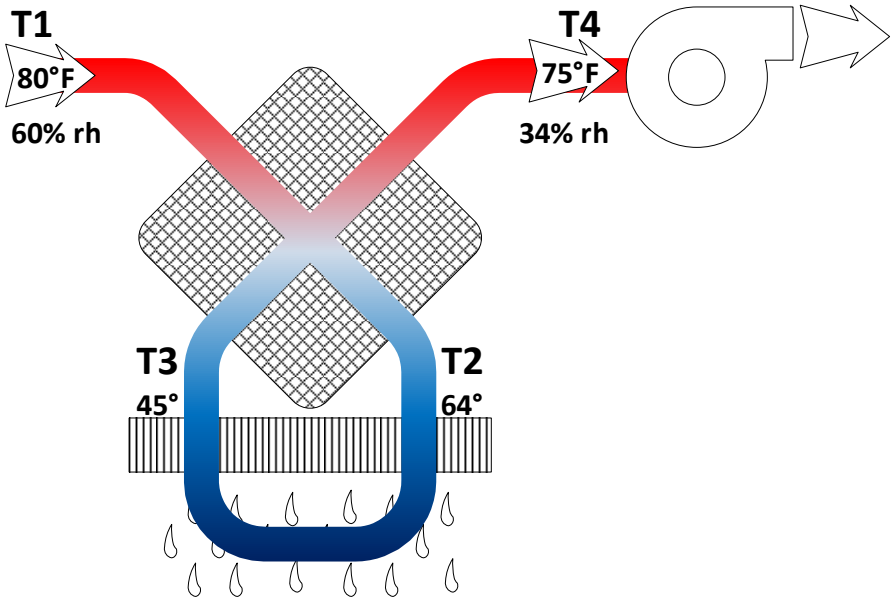
- Likely most expensive first cost
- Requires more skilled service personnel
- Likely longest lead time



(on roof, in room or next to room)

Wraparound Coil Technology - AHU





Traditional Cool – Heat Dehumidification

- No Precooling
- Condenser heat used for reheat

Wrap-around Dehumidifiers

- Supply air precools entering return air
- Supply air reheated by return air
- Energy balance!!!

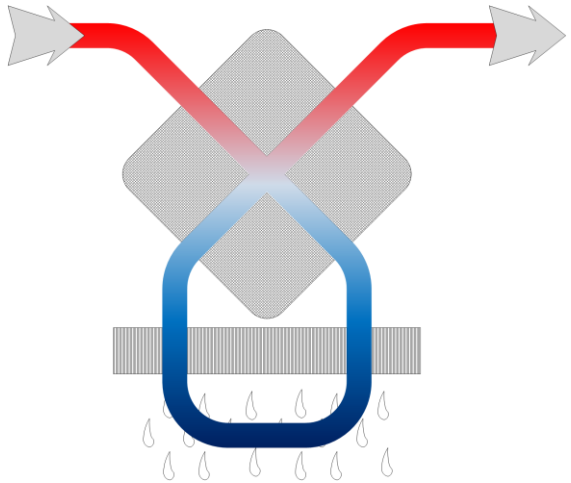
MSP® Technology

Decoupling Dehumidification and Temperature Control

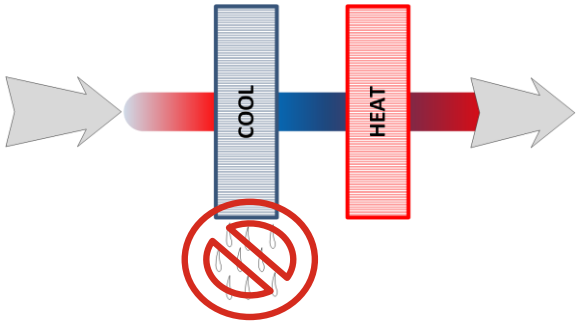
- Wrap-around Dehumidifiers provide 20% Cooling and 80% Dehumidification
- Traditional Air Conditioning provide 80% Cooling and 20% Dehumidification
- Post heating/cooling coils required if system is standalone

Dehumidifier responds to humidity, while cooling/heating coils responds to temperature.

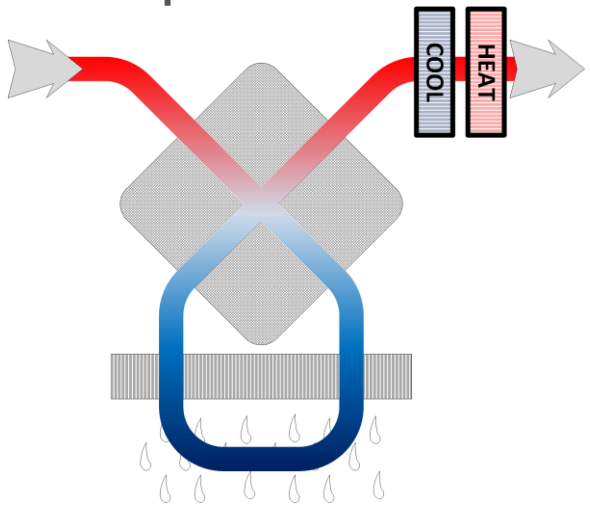
Wrap-around MSP dehumidifier



Temperature control



Combined dehumidification and temperature control



Trane solutions to meet Indoor Ag needs

Farm Size

Trane Split System DX

Trane Packaged DX

Trane Unitary

Trane chillers + MSP® Technology

Trane chillers + Trane AHU

Trane Controls and Lighting

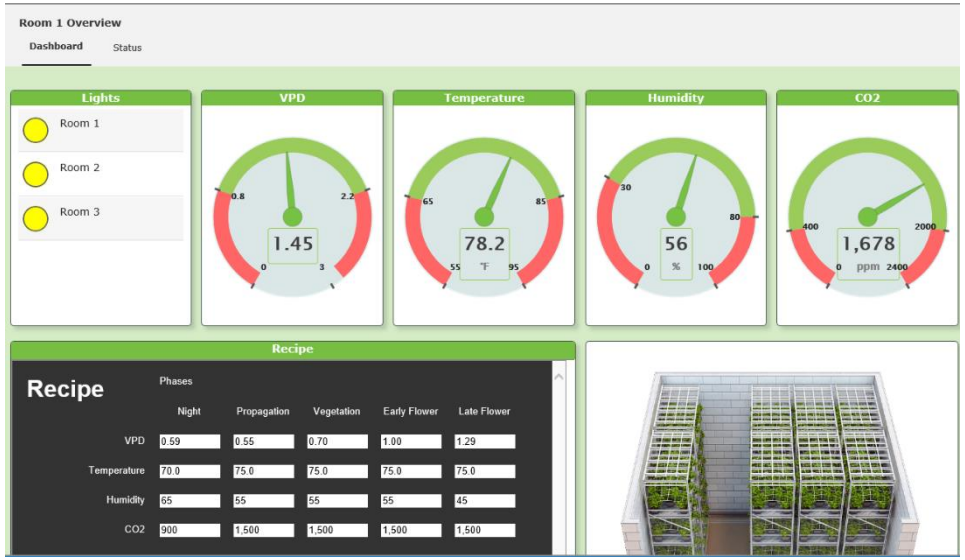
Trane Intelligent Services

Trane Energy/Energy Supply Services

Grow House Controls

Managing the Grow Room Environment

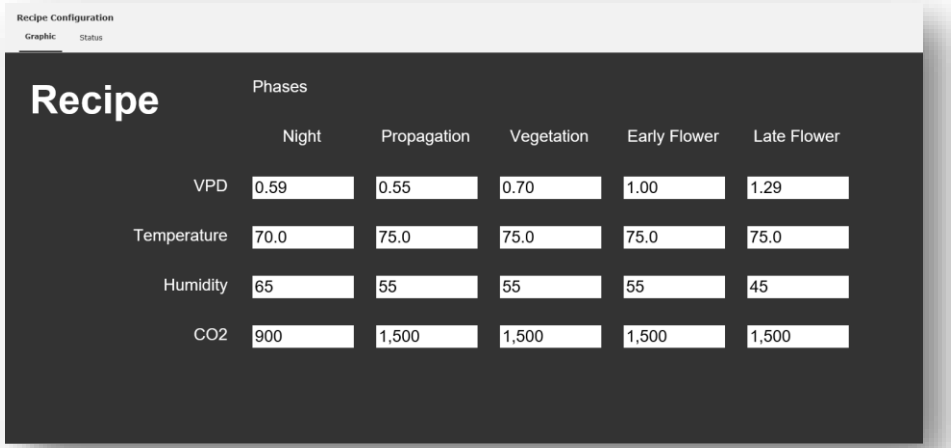
- Temperature, Humidity (RH) and VPD
  - Day cycle: High temp limit, VPD ➡ RH
  - Night cycle: Low temp limit, high RH limit
- Lighting
  - Day/Night
  - Variable intensity (PAR Sensors)
- CO2 Levels
  - CO2 injection during Day cycle
- Optional – Irrigation and Fertilization

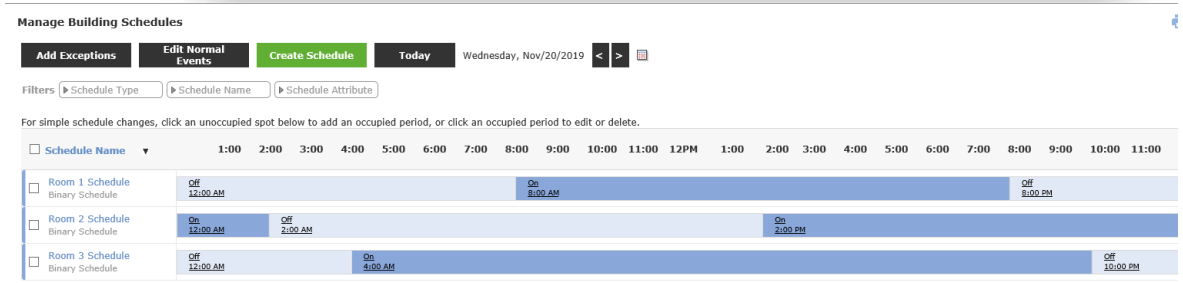


Integrating with the Workforce

Finding a balance between Plants, Energy, Cost and the workforce needs is an important consideration.

- Staggering Day/Night between grow rooms is important for capacity and energy cost reasons
- People may prefer to work in normal daytime hours for various reasons
  - Alternating Day/Night schedules at noon allows the workforce to be in each room equal amounts of time
- Automation versus Manual control





Air-Fi® Wireless Sensors

Air-Fi Wireless communication for room control

- Flexibility
  - Temperature, humidity and CO2 options
  - Multiple sensors – average or select
- Mobility – change location
  - Find the best sensing locations
  - Move for cleaning or room changes
- Helps reduce complexity in the grow room

Thank You!

Questions?

Consumers Energy
Business Energy Efficiency Program

Rachel Fredrickson

Consumers Energy
Count on Us®

We are Here to Help

Comprehensive Business Incentives

Prescriptive Incentives

- Over 300 measures in total
- 45 measures specific to agriculture

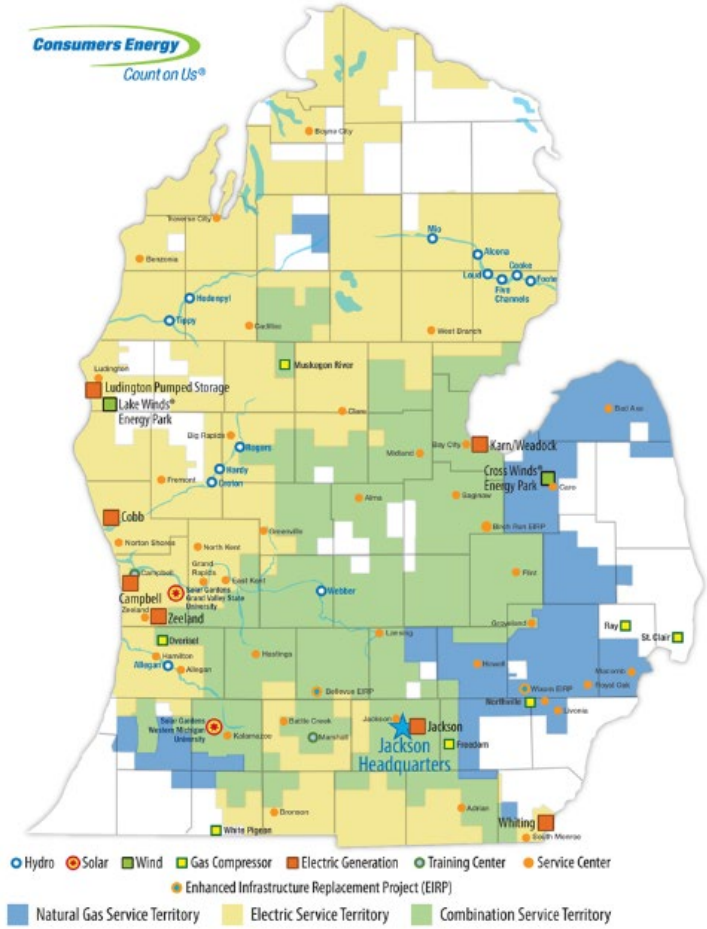
Custom Incentives

- Incentives are determined on a case-by-case basis
- Must be between a 1 and 8 year payback period

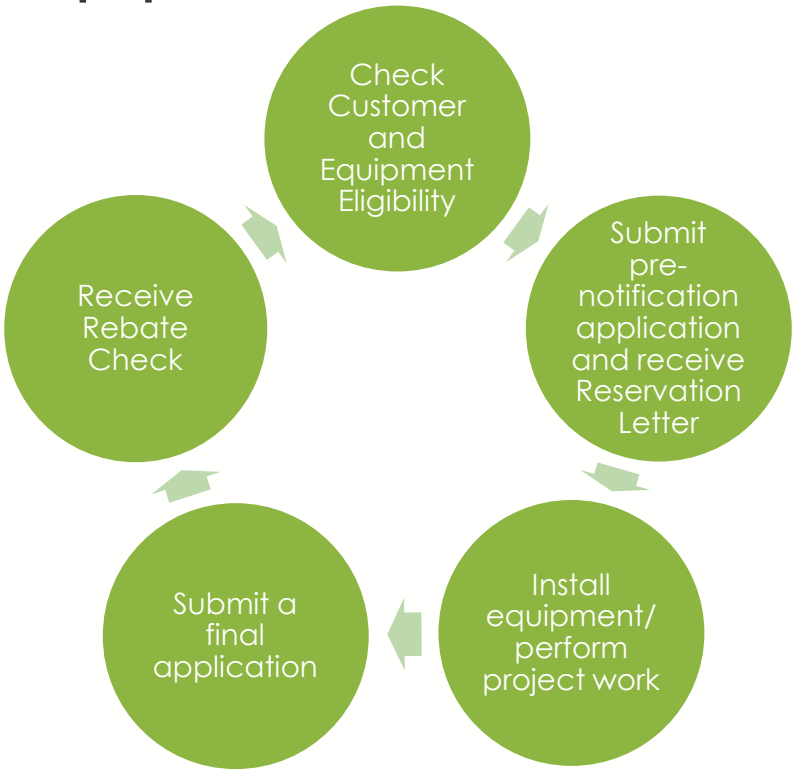
Note: Incentives are paid upon project completion and final engineering approval.

How Do I Qualify?

- Consumers Energy business account number (natural gas, electric or combination)
- Federal tax ID number
- New construction projects must be located within our territory and be using Consumers Energy as their energy provider



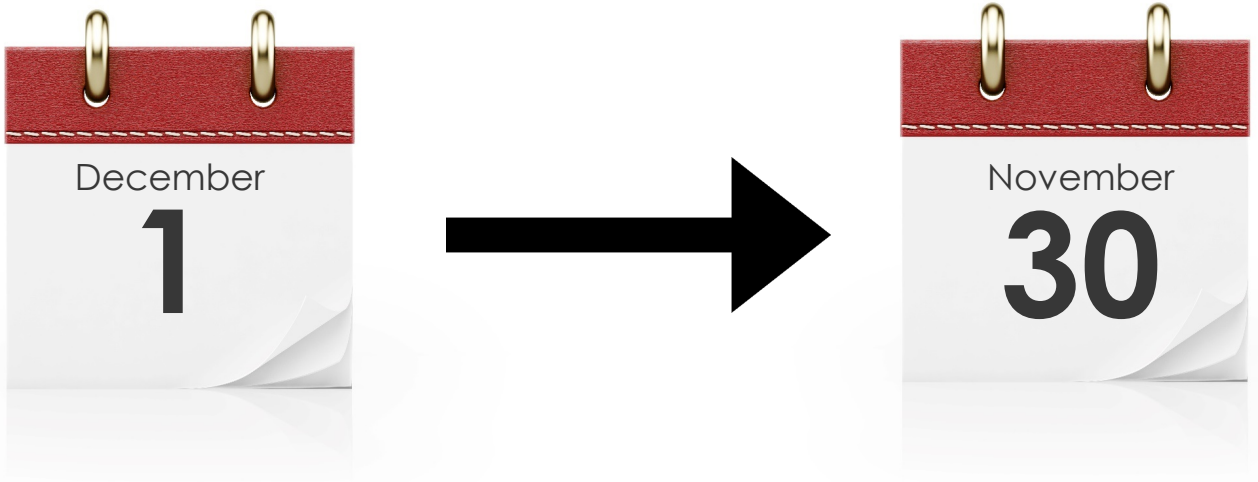
Incentive Application Process



Incentive Caps and Limits

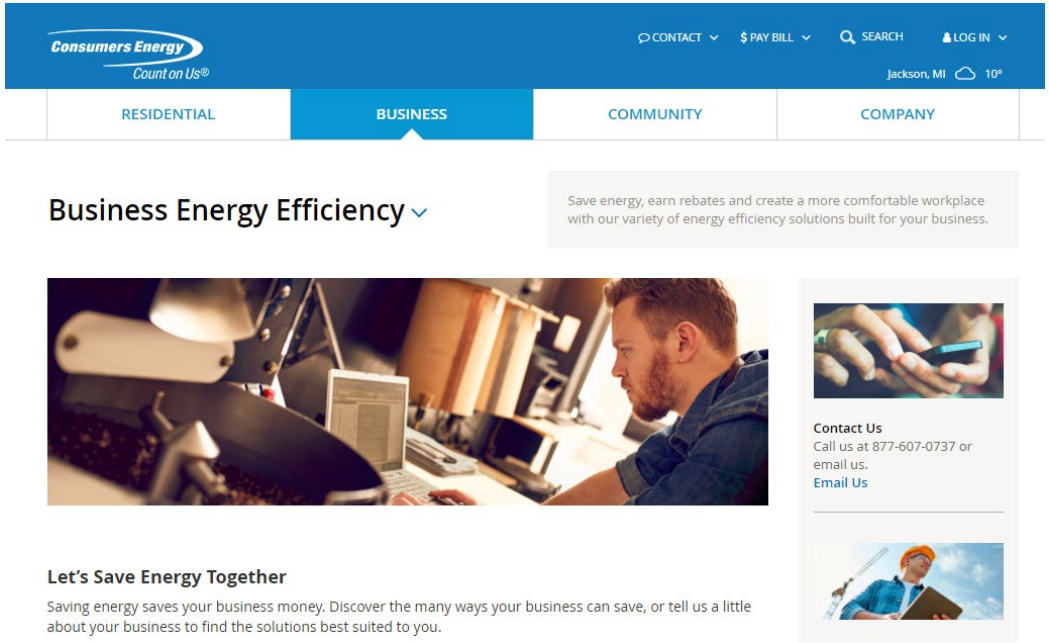
Facility Incentives	Cap per Program Year
Prescriptive	75% of the total project cost
Custom	50% of the total project cost
Customer Limits	**Cap per Program Year**
Large Natural Gas	$1M across all facilities per customer
Large Electric	$2M across all facilities per customer

Program Effective Dates



Incentive Resources

ConsumersEnergy.com/startsaving

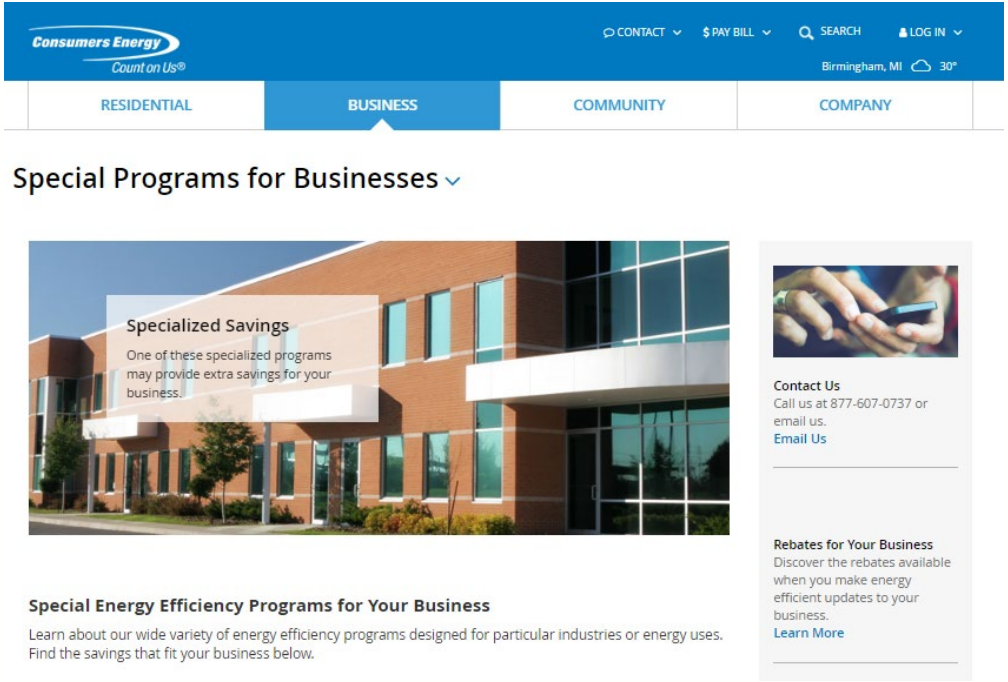


Trade Ally Program

- Contractors that have been trained by Consumers Energy on how to use the efficiency program
- Third party payment release
- Find a contractor
- Consumersenergy.com/business/energy-efficiency/select-a-contractor

Additional Specialty Programs

- New Construction
- Buy Michigan Bonus
- Steam Trap Express
- Network Lighting Controls
- Business Instant Discount
- Michigan Saves



Energy Efficiency Success

T REX Enterprises

Energy Efficiency Success

Fluresh

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