RESOURCE INNOVATION INSTITUTE

Efficient Yields
Best practices on energy, water efficiency, and productivity

HVAC with a Plant Perspective

NYSERDA

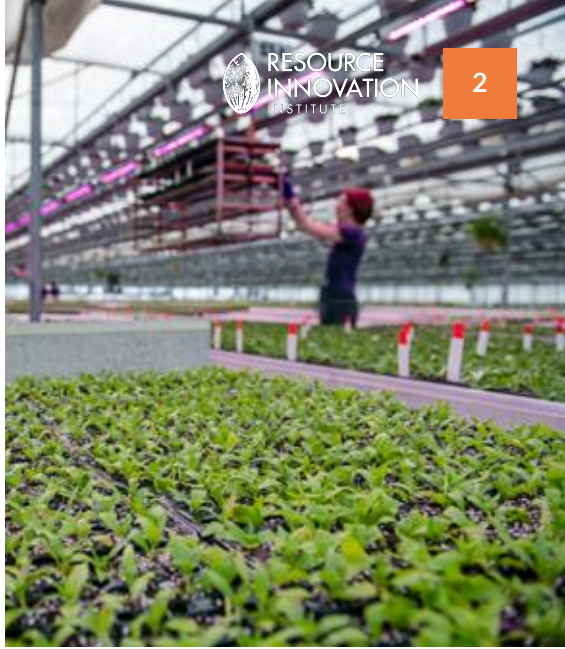
Office of Cannabis Management

December 12, 2023

Agenda

Introduction & Context	1:30
HVAC for Plants	1:45
NY HVACD Regulations	2:00
HVACD 101	2:15
Utility Incentives by National Grid	2:30
Q & A	2:40
Sign Off	3:00

- Feel free to ask questions in the chat! The panel will try to get to as many as they can either by writing a response or during the Q & A.
- A recording of today's presentation will be available after the webinar! It will be emailed to all registrants this week.
- We'll be conducting polls and knowledge checks throughout the webinar



SECTION 01

Introduction

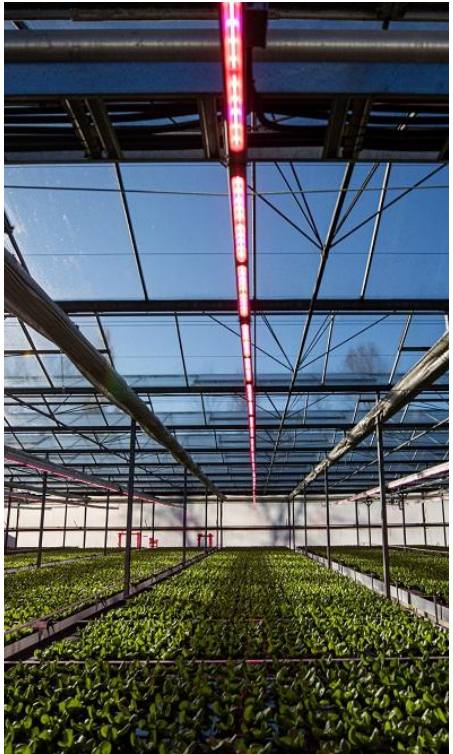
POLL ALERT!

What is the typical size room/zone do you work with or plan to?

- < 500 ft^2
- 500 - 750 ft^2
- 750 - 1,000 ft^2
- > 1,000 ft^2
- N/A

About RII

- Non-profit, objective, data-driven organization
- Founded 2016 in Portland, Oregon
- Since 2020, USDA-funded and partner with US Department of Energy
- Spent first three years focused on the cannabis industry
- Help crop producers like you through Education, Training, Policy, Benchmarking



Our Network

Governments
Resource Suppliers
Efficiency Programs
Producers
Supply Chain
Standards

INPUT from industry leaders and partners
RESOURCE INNOVATION INSTITUTE
EDUCATION and advocacy about best practices for growers

RII Industry Working Groups

- **Guides** development of climate-smart methods
- **Publishes** free Best Practices Guides
- **Advocates** for fair, informed policies, incentives and regulations

Equipment/Service providers: If this seems like a good fit for your company, become a Member!

Free Best Practices Guides

Collaboration by Industry Experts

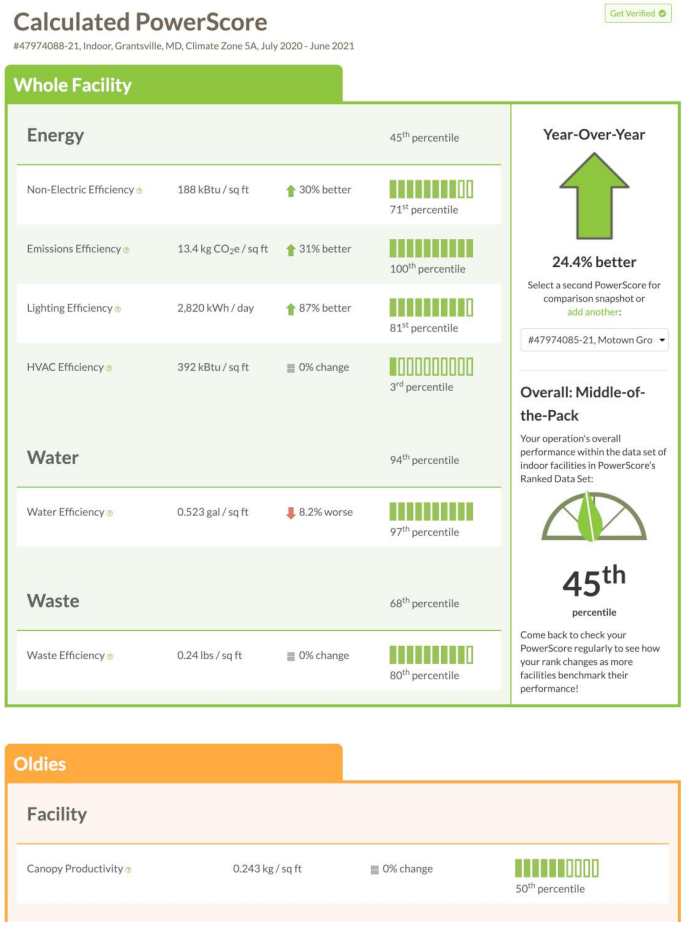
Free guidance on efficient cultivation

- Water Circularity for CEA Operations, 2023
- CEA Facility Design & Construction Best Practices, 2022
- CEA HVAC Best Practices, 2022
- Cannabis HVAC Best Practices, 2019
- CEA Lighting Best Practices, 2022
- Cannabis Lighting Best Practices, 2019

Resource Efficiency & Productivity Benchmarking

What data should you collect?

- Energy consumption for all fuel types
- Water consumption
- Water quality
- Productivity
- *Benchmarking with RII is free to growers in partnership with the NY OCM!*
- *Learn more at resourceinnovation.org/powerscore*



Access Your New York Virtual Classroom

Continue Learning Online

Free guidance on efficient cultivation

All live workshops are available for on-demand viewing!

- Recordings of live workshops
- Downloadable resources
- NY State program tools

Create an account at the NY Efficient Yields Classroom

Purpose of Today's Workshop

- Help NY cannabis growers improve energy and water efficiency in greenhouse and indoor facilities
- Convey scientific insights and industry expertise directly to producers and find the best ways to translate them in the context of their location
- Assist cannabis producers and their design and construction project partners with what they need to know to stay competitive and comply with regulations

Efficient Yields
Best practices on energy, water efficiency, and productivity

Today's Experts

Rob Eddy

Dan Dettmers

Randy Lenz

Craig Yendrek

John (Jay) Snyder

POLL ALERT!

What is the typical size room do you work with?

Discuss Results

SECTION 02

HVAC for Plants

POLL ALERT!

What role do you play in the cultivation space?

- Equipment provider / Vendor
- Owner
- Grower
- Operations Manager
- Consultant / Advisor

Abiotic Factors Impacting Plant Growth

Growing in controlled environments requires knowledge of each factor

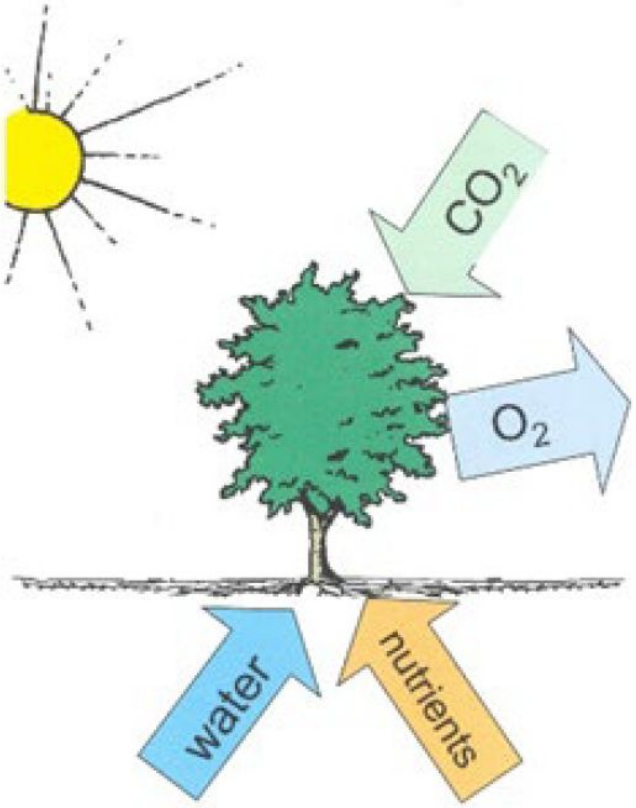
SUPPLY OF MINERAL NUTRIENT ELEMENTS	*Complete hydroponic feed program containing all essential plant elements*
ROOTZONE CHEMISTRY	*Specific substrate type (stonewool vs organic) will dictate irrigation strategy*
MOISTURE SUPPLY	
LIGHTING	*Intensity and spectrum*
TEMPERATURE	*Maximize photosynthesis; minimize fluctuations*
RELATIVE HUMIDITY	*Match equipment capacity with maximum plant transpiration*

Today's focus

Influence of Abiotic Factors on Photosynthesis

What is Photosynthesis?

- The primary function of photosynthesis is to convert solar energy into chemical energy and then store that chemical energy as food for future use.
- This process of *photosynthesis* literally means "to put together with light."
- To produce food, a plant requires energy from the sun, carbon dioxide from the air and water from the soil.
- **Fun Fact**: It is estimated that an adult person consumes about 740 kg of oxygen in a year. This amount of oxygen is produced by about eight trees in a year.



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Influence of Abiotic Factors on Photosynthesis

Finding the Optimum Temperature

- Growing plants in controlled environments makes it possible to maximize photosynthesis.

- Photosynthesis is one aspect of plant ***metabolism***. Similar to human metabolism, it is possible to measure the rate of photosynthesis.

Influence of Abiotic Factors on Photosynthesis

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Influence of Abiotic Factors on Photosynthesis

Finding the Optimum Temperature

- Growing plants in controlled environments makes it possible to maximize photosynthesis.
- Photosynthesis is one aspect of plant ***metabolism***. Similar to human metabolism, it is possible to measure the rate of photosynthesis.
- Using a device like this to monitor photosynthetic rates across different environmental conditions it is possible to make sure plant metabolism is maximized.

Impact on HVAC Considerations

- Higher metabolism usually leads to faster growth and higher yields.
  - With the proper temperature and RH, you can grow olympic caliber plants.

Influence of Abiotic Factors on Transpiration

What is Transpiration?

- Transpiration is the process of water movement through a plant and its evaporation from aerial parts, such as leaves, stems and flowers.

Control Points

- Substrate type
  - Physical properties like porosity
- Root uptake
  - Determined by container size
- Leaf stomata
  - 1% of a leaf's surface but 90% of the water transpired.

Result is a 'Tug-of-War' on a rope of water between soil and atmosphere

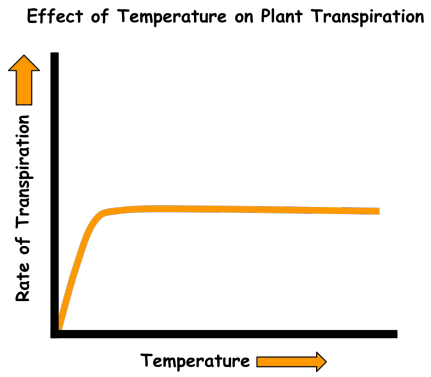
Influence of Abiotic Factors on Transpiration

Purpose of Transpiration

- Transpiration is a necessary process and uses about 90% of the water that enters a plant's roots. The other 10% is used in chemical reactions and in plant tissues. Transpiration is responsible for several things:
  - Transporting minerals from the soil throughout the plant.
  - Cooling the plant through evaporation.
  - Moving sugars and plant chemicals.
  - Maintaining turgor pressure.

Impact on HVAC Considerations

- Dehumidification capacity should be based on expected maximum daily transpiration rates.
  - How much water vapor will need to be removed from the grow room?



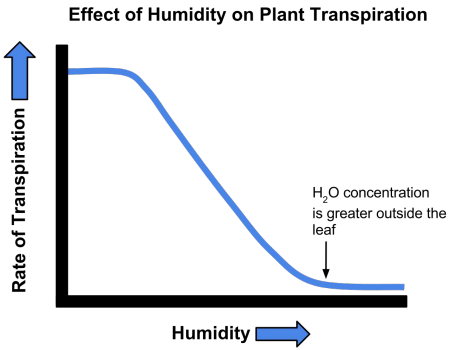


Image Source

VPD is Another Way to Think About Water Loss

What is VPD?

- **Vapour-pressure deficit**, or **VPD**, is the difference (deficit) between the amount of moisture in the air and how much moisture the air can hold when saturated.
- VPD is measured as a pressure, and for plant applications, we usually use the unit kilopascal (kPa).
  - Room air temp and RH are used to calculate VPD

Manipulating VPD in Controlled Environments

- Many growers use VPD to crop steer
  - Target 'LOW' during Veg
  - Target 'MOD' > 'HIGH' during Bloom

VERY LOW (<0.3 kPa)	*Little movement of water (and nutrients) through plants. Leaves stay wet, increasing chance of disease. Only desirable for slow-drying conditions such as propagation.*
LOW (0.3-0.7 kPa)	*Minimum for most plant growth due to low transpiration. Desirable for newly propagated clones during Early Veg.*
MODERATE (0.7-1.5 kPa)	*Appropriate target for most plant growth situations. Good movement of water via transpiration will supply adequate nutrients for fast growth while prevent soil from staying too wet.*
HIGH (>1.5 kPa)	*Provides 'dry air' needed to maximize transpiration for growth near genetic potential. Be careful - one missed irrigation event due to equipment failure can result in crop loss.*

Source

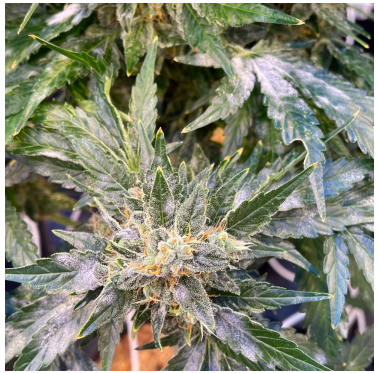
Warning Signs That VPD is Off

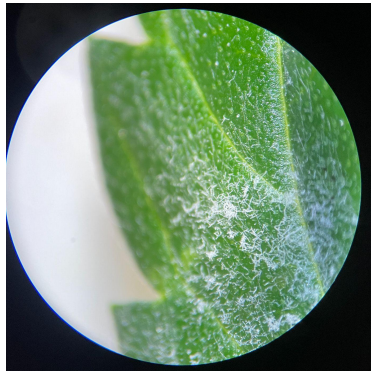
Leaf Curling

- Also called ‘tacoing’
- Leaves start turning a leathery texture that gets dry and brittle
- Caused in part by high VPD
  - RH too low
  - Temp too high
  - Poor irrigation management

Disease

- Widespread powdery mildew infestation can ruin a crop
- Low nighttime VPD can lead to perfect conditions for fungal growth.





POLL ALERT!

What role do you play in the cultivation space?

Discuss Results

SECTION 03

NY HVACD Regulations

POLL ALERT!

When I say "regulation", what is your first reaction?

1. Boring
2. Complicated
3. Boring and Complicated
4. Get outta my business, bruh
5. Yeah! I'm getting free help from my state government in the form of regulations designed to guide me to build an efficient and effective grow operation based on their research of the best practices from other states!

§ 120.3 License Specific Tiers and Options

- **Nursery**: produce clones, seedlings, immature cannabis plants, cloned propagation material, tissue culture and cannabis seeds
- **Cultivator**: Performs soil preparation, planting, micropropagation-tissue culture, growing, cloning, harvesting, drying, curing, grading, and trimming of cannabis plants for sale
  - Indoor, Mixed light, Combination outdoor/mixed light, outdoor
  - Tier 1: 5,000 ft^2
  - Tier 2: >5,000 ft^2 to 12,500 ft^2
  - Tier 3: >12,500 ft^2 to 25,000 ft^2
  - Tier 4: >25,000 ft^2 to 50,000 ft^2
  - Tier 5: >50,000 ft^2 to 100,000 ft^2
- **ROND**: Registered organization non-dispensing (cultivator, processor and distributor)
- **ROD**: Registered organization with dispensing (cultivator processor distributor retail dispensary)

§125.1 Energy and Environmental Standards

(a) Odor Control Standards

A licensee shall use acceptable odor mitigation technology in all consumption facilities, exception areas, nursery areas, propagation areas, or canopy areas that are indoors or in mixed light; processing facilities; or storage areas to mitigate odors to minimize impacts off-site. Acceptable odor mitigation technology includes, activated carbon filtration, vapor-phase systems, or other mitigation technology approved by the Office. The Office shall be authorized to identify additional odor mitigation technology.

Terpenes (Essential Oils)

Cannabis has 100+ different terpenes…and they all smell

Humulene	A or B_Pinene (pine)	Eucalyptol
Farnesene (grassy)	Limonene (citrus)	Transnerolido
Caryophyllene	Linalool (dank)	Citronellol (citrus)
Myrcene	A-bisabolol	Limonene (citrus)

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Technology options listed:

- Activated Carbon - good at trapping Volatile Organic Compounds
- Vapor-phase systems - (i.e. gas phase, molecular, chemical)

Other options:

- MERV 13 up to HEPA filtration (*Note: change at least every grow cycle*)
- Ozone & Photocatalytic Oxidation (PCO) (*Note: Be careful of by products and reported effectiveness.*)

Other standards (Primarily Indoor air quality):

- UL 4402: *Indoor Air Quality in Buildings and Facilities Utilized for the Cultivation and Post-Harvest Processing of Cannabis*
- NFPA 1, Chapter 38: *Marijuana Growing, Processing, or Extraction Facilities*

§125.1 Energy and Environmental Standards

(b) Horticultural Lighting Equipment Standards

(1) A nursery, tier 1 cultivator, tier 2 cultivator, cooperative, or microbusiness licensee shall use horticultural lighting equipment with a PPE of at least 1.7 µmol/J measured at the lamp.

(2) A tier 3 cultivator, tier 4 cultivator, tier 5 cultivator, ROD, or ROND licensee shall use horticultural lighting equipment with a PPE of at least 2.2 µmol/J measured at the lamp.

ASHRAE 90.1 - 2022

- PPE of at least 1.9 µmol/J & automatically turns off on schedule
- If < 40 kW load, PPE of at least 1.7 µmol/J

Lighting is the primary sensible (heat) load of a space

- 75%-95% of the sensible load (addition)
- Typical light density/cooling load
  - 25-50 watt/ft^2
  - 25-60 ft^2/ton
- Rule of thumb for sizing A/C
  - 0.5 - 0.7 ton per HPS light (~1,000W/fixture)
  - 0.3 - 0.6 ton per LED light (~650W/fixture)

§125.1 Energy and Environmental Standards

(c) Heating, Ventilation, and Air Conditioning (HVAC) and Dehumidification Standards

HVAC Standards. A nursery, cultivator, cooperative, microbusiness, ROD, or ROND licensee authorized to cultivate indoors, cultivate in mixed light, operate a nursery area indoors, or operate a nursery area in mixed light shall, unless the licensee has a written plan for managing refrigerant leaks and disposal that has been approved by the Office, use HVAC and refrigeration equipment which uses a refrigerant with a twenty-year global warming potential of 10 or less.

"...use HVAC and refrigeration equipment which uses a refrigerant with a twenty-year global warming potential of 10 or less."

Result:

- Eliminates 99.95% of commercially available HVAC equipment options
- Custom built systems
- Increased regulations/dangers using natural refrigerants

Refrigerant	Type	20 yr GWP
R-22	HCFC	5,310
R-410A	HFC	4,500
R-454B	HFC/HFO	1,700
R-744 (CO_2)	Natural	1
R-290/R-600a	HC (Natural)	<1
R-717 (NH3)	Natural	0

§125.1 Energy and Environmental Standards

(c)(1) Heating, Ventilation, and Air Conditioning (HVAC) and Dehumidification Standards

…unless the licensee has a written plan for managing refrigerant leaks and disposal that has been approved by the Office…

(c)(3) A nursery, tier 1 cultivator, tier 2 cultivator, cooperative, or microbusiness licensee shall meet applicable HVAC and dehumidification standards prior to the second license renewal.

(c)(4) A tier 3 cultivator, tier 4 cultivator, tier 5 cultivator, ROD, or ROND licensee shall meet applicable HVAC and dehumidification standards prior to the first license renewal.

From the NY Office of Cannabis Management:

"The Office will release additional information including guidance, a refrigerant leakage management plan template and instructions for attaining approval on refrigerant leakage management plans in the future. "

Examples of "Refrigerant Management Plans":

- U.S. EPA "Recordkeeping and Reporting Requirements for Stationary Refrigeration"
- California Air Resources Board "R4 Program"
- Washington State "Refrigerant Management Program"

Will likely include:

- ***Record keeping***
- ***Leak rate reporting***
- ***Leak repair***
- ***Disposal requirements***

§125.1 Energy and Environmental Standards

(c)(2) Dehumidification Standards. A nursery, cultivator, cooperative, microbusiness, ROD, or ROND licensee shall only use dehumidification equipment, including in drying areas, that is one of the following:

(i) stand-alone dehumidifiers that have a minimum integrated energy factor of 1.77 L/kWh for product case volumes of 8.0 cubic feet or less, and a minimum integrated energy factor of 2.41 L/kWh for product case volumes greater than 8.0 cubic feet;

Note: Does not list testing conditions!!

§ 430.32 (v)(2) uses incoming air at 73F / 60% / 0.2" esp

From 10CFR430.1 (Definitions):

Dehumidifier means a product, other than a portable air conditioner, room air conditioner, or packaged terminal air conditioner, that is a self-contained, electrically operated, and mechanically encased assembly consisting of—

(1) A refrigerated surface (evaporator) that condenses moisture from the atmosphere;

(2) A refrigerating system, including an electric motor;

(3) An air-circulating fan; and

(4) A means for collecting or disposing of the condensate.

§125.1 Energy and Environmental Standards

(c)(2) Dehumidification Standards.

(ii) an integrated HVAC system with on-site heat recovery designed to fulfill at least 75% of the annual energy for dehumidification reheat;

From California Title 24, Energy Code 2022:

INTEGRATED HVAC SYSTEM is an HVAC system designed to handle both sensible and latent heat removal. Integrated HVAC systems may include, but are not limited to: HVAC systems with a sensible heat ratio of 0.65 or less and the capability of providing cooling, dedicated outdoor air systems, single package air conditioners with at least one refrigerant circuit providing hot gas reheat, and dehumidifiers modified to allow external heat rejection.

§125.1 Energy and Environmental Standards

(c)(2) Dehumidification Standards.

(iii) a chilled water system with on-site heat recovery designed to fulfill at least 75% of the annual energy for dehumidification reheat; or

Two common variations of chillers:

- Air cooled chiller - Less efficient and large, but self contained like packaged unit. Heat rejection is straight to ambient air so no opportunity for on-site heat recovery.
- Water cooled chiller - More efficient. On-site heat recovery by using condenser water. Cooling tower required.

Air cooled chiller

Water cooled chiller

Photos courtesy of Multi-stack

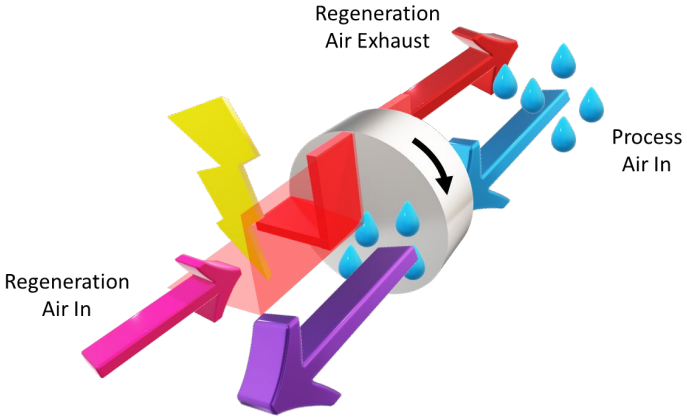
§125.1 Energy and Environmental Standards

(c)(2) Dehumidification Standards.

(iv) a solid or liquid desiccant dehumidification system for system designs that require dewpoint of 50°F or less.

Desiccants:

- Work on adsrobtion/desorbtion process
- Extremely low dew points possible - no defrost cycle, no refrigerant limitations
- Very inefficient at human comfort conditions



§125.1 Energy and Environmental Standards

(d) Energy Standards.

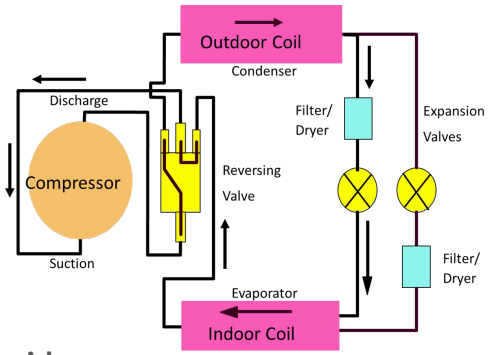
(2) A tier 3 cultivator, tier 4 cultivator, tier 5 cultivator, cooperative, ROD, or ROND licensees authorized to cultivate indoors shall use technologies for the primary source of energy that do not involve on-site combustion of fossil fuels. It is acceptable for such licensee's emergency back-up system to be technology that involves the on-site combustion of fossil fuels.

Acceptable alternatives to fossil fuel-based systems include, but are not limited to, ground-source (geothermal) systems or air-source heat pump systems. A tier 3 cultivator, tier 4 cultivator, tier 5 cultivator, cooperative, ROD, or ROND shall meet this requirement prior to the first license renewal.

Decarbonization: Building decarbonization describes methods that reduce human made GHG emissions related to buildings. Building decarbonization encompasses a building's life cycle, including building design, construction, operation, occupancy, and end of life.

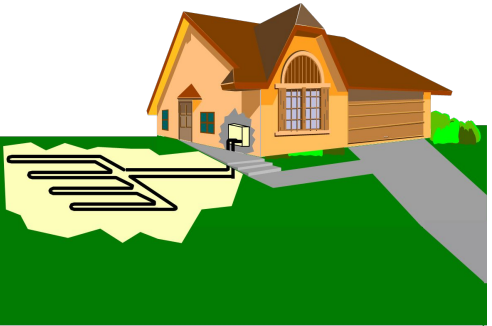
- **Embodied carbon reduction - reduce carbon used for construction and destruction of the building**
- **Operational carbon reduction - reduce carbon emitted during operation of the building (i.e. electrification)**

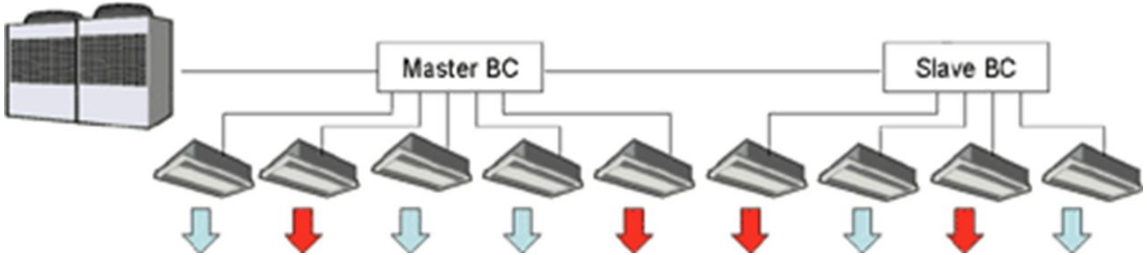
§125.1 Energy and Environmental Standards



Decarbonization options:

- Internal heat source:
  - Lights, pumps, fans create heat in the space…when they are on
  - Evaporative cooling from plant transpiration removes sensible heat
- Heat pumps:
  - Air conditioner that can run "backwards". Moves heat from outside to inside
  - Air source or ground source (i.e. geothermal)
- On-site heat recovery:
  - Recover heat from exhaust air. (e.g. Air-Air heat exchanger, Energy Recovery Ventilator)
  - Recover heat from air conditioning equipment. (e.g. Chiller condenser water)
  - Use heat pumps to move from warm rooms to cool rooms. (e.g. Water loop heat pumps, VRF systems)





POLL ALERT!

What is the best HVAC/D system for a cultivator in New York to use?

1. One that meets the minimum regulatory requirements of the NY OCM rules
2. The most efficient system money will buy, probably a chilled water system or geothermal heat pump
3. Desiccant!
4. The most efficient system I can properly operate and maintain.
   (And meets NY OCM regs.)

RESOURCE INNOVATION INSTITUTE

SECTION 04

HVACD 101

POLL ALERT!

What type of topics would you like to see for a series of focused 45-minute webinars in 2024? (Pick 2)

- "Ask Me Anything" Cannabis Cultivation Advice
- Cannabis Insect and Disease Prevention
- The Most Energy-Saving Design and SOPs for Cannabis
- Cannabis Nutrition Made Easy
- Science and Heart of Team Building
- Cannabis Plant Science 101

Vapor Pressure Deficit (VPD)

- Vapor Pressure Deficit (VPD) is the difference between the saturated vapor pressure of the plant and the air vapor pressure.
- VPD is Calculated using the measurements of air temperature, leaf temperature and relative humidity
- Controls the amount of transpiration & nutrient uptake

Ideal VPD is specific to phase of growth:

- Propagation/Early Veg: .4 - .8 kPa
- Late Veg/Early Flower: .8 - 1.2 kPa
- Mid/Late Flower: 1.2 - 1.6 kPa

RH (%)

Temp (°F)	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	0.5	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	1	1	1	1.1	1.1	1.1	1.1	1.1
52	-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	0.4	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	1	1	1	1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2
54	-0	-0	-0	-0	0	0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	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	1	1	1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3
55	-0	-0	-0	-0	0	0	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	0.6	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	1	1	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	1.4
57	-0	-0	-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	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1	1	1	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.5	1.5	1.5
59	-0	-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	1	1	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
61	-0	-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	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1	1	1	1.1	1.1	1.1	1.2	1.2	1.3	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
63	-0	-0	-0	-0	0	0.1	0.1	0.1	0.2	0.2	0.3	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	0.8	0.9	0.9	0.9	1	1	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	1.6	1.7	1.7	1.8	1.8	1.8	1.8
64	-0	-0	-0	-0	0	0.1	0.1	0.1	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	0.8	0.9	0.9	1	1	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	1.8	1.8	1.8	1.9	1.9	1.9	1.9
66	-0	-0	-0	-0	0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	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	1	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	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2	2	2
68	-0	-0	-0	-0	0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1	1	1.1	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	1.8	1.9	1.9	2	2	2.1	2.1	2.1	2.2	2.2	2.2
70	-0	-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	1	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	2	2.1	2.1	2.2	2.2	2.3	2.3	2.3	2.3	2.3
72	-0	-0	-0	-0	0	0.1	0.1	0.2	0.2	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	1	1.1	1.1	1.2	1.2	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	2	2.1	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.5	2.5
73	-0	-0	-0	-0	0	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	0.9	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	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.6	2.6	2.6
75	-0	-0	-0	-0	0	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.8	0.8	0.9	0.9	1	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9	1.9	2	2.1	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.5	2.6	2.7	2.7	2.7	2.8	2.8
77	-0	-0	-0	-0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.9	1.9	2	2.1	2.1	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.8	2.8	2.9	2.9	2.9	2.9
79	-0	-0	-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	0.9	0.9	1	1.1	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	2.1	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.7	2.8	2.9	2.9	3	3.1	3.1	3.1	3.1	3.1
81	-0	-0	-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	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.8	1.9	2	2	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.8	2.9	3	3	3.1	3.2	3.2	3.2	3.3	3.3
82	-0	-0	-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	1	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	2.1	2.2	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.8	2.9	3	3.1	3.1	3.2	3.3	3.4	3.4	3.5	3.5	3.5
84	-0	-0	-0	-0	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.9	0.9	1	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.9	2	2.1	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.9	2.9	3	3.1	3.2	3.3	3.3	3.4	3.5	3.6	3.7	3.7	3.7	3.7
86	-0	-0	-0	-0	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.8	1.9	2	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.9	2.9	3	3.1	3.2	3.3	3.4	3.4	3.5	3.6	3.7	3.8	3.9	3.9	4	4
88	-0	-0	-0	-0	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.2	4.2	4.2
90	-0	-0	-0	-0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.1	4.2	4.3	4.4	4.4	4.4
91	-0	-0	-0	-0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.7	4.7
93	-0	-0	-0	-0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.9	5	5	5
95	-0	-0	-0	0	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.4	4.5	4.6	4.7	4.8	4.9	5	5.1	5.2	5.2	5.2
97	-0	-0	-0	0	0.1	0.2	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2	2.1	2.2	2.4	2.5	2.6	2.7	2.8	3	3.1	3.2	3.3	3.4	3.5	3.7	3.8	3.9	4	4.1	4.2	4.4	4.5	4.6	4.7	4.8	5	5.1	5.2	5.3	5.4	5.5	5.5	5.5
99	-0	-0	-0	0	0.1	0.3	0.4	0.5	0.6	0.8	0.9	1	1.1	1.3	1.4	1.5	1.6	1.7	1.9	2	2.1	2.2	2.4	2.5	2.6	2.7	2.9	3	3.1	3.2	3.4	3.5	3.6	3.7	3.9	4	4.1	4.2	4.4	4.5	4.6	4.7	4.9	5	5.1	5.2	5.4	5.5	5.6	5.7	5.9	5.9	5.9
100	-0	-0	-0	0	0.1	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.5	1.6	1.7	1.8	2	2.1	2.2	2.4	2.5	2.6	2.8	2.9	3	3.2	3.3	3.4	3.6	3.7	3.8	4	4.1	4.2	4.3	4.5	4.6	4.7	4.9	5	5.1	5.3	5.4	5.5	5.7	5.8	5.9	6.1	6.2	6.2	6.2
102	-0	-0	-0	0	0.2	0.3	0.4	0.6	0.7	0.8	1	1.1	1.3	1.4	1.5	1.7	1.8	2	2.1	2.2	2.4	2.5	2.6	2.8	2.9	3.1	3.2	3.3	3.5	3.6	3.8	3.9	4	4.2	4.3	4.5	4.6	4.7	4.9	5	5.1	5.3	5.4	5.6	5.7	5.8	6	6.1	6.3	6.4	6.5	6.5	6.5
104	-0	-0	-0	0	0.2	0.3	0.5	0.6	0.7	0.9	1	1.2	1.3	1.5	1.6	1.8	1.9	2.1	2.2	2.4	2.5	2.6	2.8	2.9	3.1	3.2	3.4	3.5	3.7	3.8	4	4.1	4.3	4.4	4.5	4.7	4.8	5	5.1	5.3	5.4	5.6	5.7	5.9	6	6.2	6.3	6.4	6.6	6.7	6.9	6.9	6.9
106	-0	-0	-0	0	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.4	1.6	1.7	1.9	2	2.2	2.3	2.5	2.6	2.8	3	3.1	3.3	3.4	3.6	3.7	3.9	4	4.2	4.3	4.5	4.6	4.8	5	5.1	5.3	5.4	5.6	5.7	5.9	6	6.2	6.3	6.5	6.6	6.8	7	7.1	7.3	7.3	7.3
108	-0	-0	-0	0	0.2	0.4	0.5	0.7	0.8	1	1.2	1.3	1.5	1.7	1.8	2	2.1	2.3	2.5	2.6	2.8	3	3.1	3.3	3.4	3.6	3.8	3.9	4.1	4.2	4.4	4.6	4.7	4.9	5.1	5.2	5.4	5.5	5.7	5.9	6	6.2	6.4	6.5	6.7	6.8	7	7.2	7.3	7.5	7.7	7.7	7.7
109	-0	-0	-0	0	0.2	0.4	0.5	0.7	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.8	2.9	3.1	3.3	3.5	3.6	3.8	4	4.1	4.3	4.5	4.7	4.8	5	5.2	5.3	5.5	5.7	5.9	6	6.2	6.4	6.5	6.7	6.9	7	7.2	7.4	7.6	7.7	7.9	8.1	8.1	8.1
111	-1	-0	-0	0	0.2	0.4	0.6	0.8	0.9	1.1	1.3	1.5	1.7	1.8	2	2.2	2.4	2.6	2.7	2.9	3.1	3.3	3.5	3.6	3.8	4	4.2	4.4	4.5	4.7	4.9	5.1	5.3	5.4	5.6	5.8	6	6.2	6.3	6.5	6.7	6.9	7.1	7.2	7.4	7.6	7.8	8	8.1	8.3	8.5	8.5
113	-1	-0	-0	0	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.6	3.8	4	4.2	4.4	4.6	4.8	5	5.2	5.4	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.1	7.3	7.4	7.6	7.8	8	8.2	8.4	8.6	8.8	9	9	9

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Note: It takes 60 Seconds for the stomata to close and 6 hours to fully open.

Figure credit: Pulse Labs

Cooling Calculations – Sensible Load

Indoor agriculture

- Building envelope loads are much lower with insulated panels.
- Lighting - much higher than normal
- Daytime vs Nighttime cooling loads
- Ventilation kept to a minimum
  - Pressurization
  - CO_2 Augmentation

Calculating the Cooling Requirements

- The lighting is the largest source of heat. The number of lights per room and the wattage they operate on is added up to calculate the total Sensible BTU load.

- Heat rejection from standalone dehumidifiers must also be accounted for.

Figure credit: Design Mechanical

Moisture – Latent Load

Transpiration

- Release of Moisture to the space
- Exhalation of water vapor from the plant
- Delivered through the Stomata
- Evapotranspiration

Calculating the Latent Load

- Number of plants per room and water feed is critical to sizing dehumidification to remove the latent load.
- Runoff needs to be removed from the calculation
- Tables need to be pitched properly to prevent stagnant water from accumulating.
- All drips should be addressed to keep the floors dry.

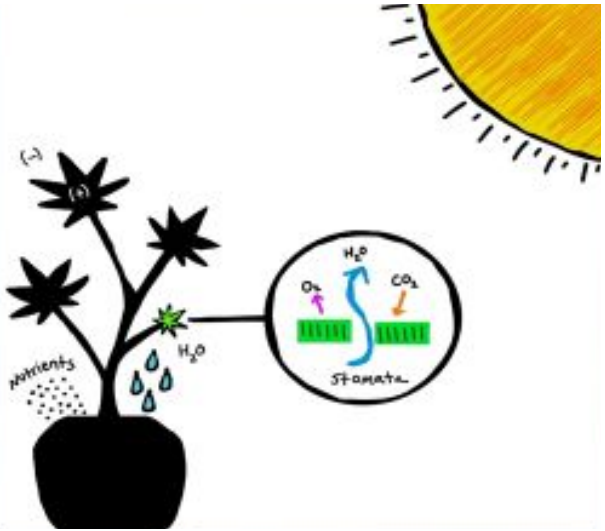


Figure credit: Design Mechanical

HVACD Choices: Indoor Cultivation

Air Conditioner with Standalone Dehumidifier

- Standard/Commercial HVAC systems
- Industrial Dehumidifiers designed for cultivation

Air Conditioner W/Reheat and Standalone Dehumidifier

- Commercial HVAC systems with reheat (Dehum)
- Industrial Dehumidifiers are still required (Nighttime)

Integrated HVACD (cooling & dehumidification)

- D/X system - Air-Cooled or Water-Cooled
- Hydronic/Chiller System (4-Pipe)
    - Could be gas chiller or heat recovery type

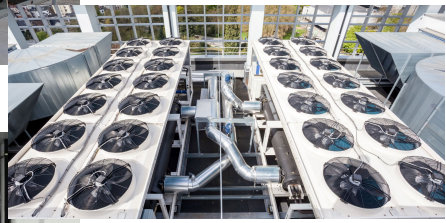
HVACD Choices: Indoor Cultivation

Air Conditioner with Standalone Dehumidifier

- Readily available, easy to install and maintain.
- Redundancy
- Lowest upfront cost
- More individual pieces of equipment to control and maintain

Air Conditioner with Reheat and Standalone Dehumidifier

- Requires fewer standalone dehumidifiers
- Dehumidifiers still required for nighttime moisture removal
- Reheat needs to be controlled to maximize dehumidification.



Integrated HVACD (cooling & dehumidification)

- Fewest pieces of equipment to control and maintain
- Highest upfront cost
- Requires mechanical contractors.

HVACD Greenhouse

Ventilation with Heat Exchanger (Daytime)

- Limited climatic control
- Using outside air to control indoor environment
- Use exchanger such as evaporative pad wall

Air Conditioner with Standalone Dehumidifier (Nighttime)

- During nighttime blackout dehumidification is required
- A small amount of A/C can be used during the warmer months and to offset the heat from the dehumidifiers.

Winter

- Dehumidification is required 24/7
- Standalone dehumidifiers can be used along with some burping.

Air Movement

- The plants uses the CO_2 around the leaf's surface in 4 minutes
- Air Movement helps avoid the formation of microclimates and replenishes the much-needed CO_2 where photosynthesis takes place
- The leaves should flutter but not be windblown
- Not enough airflow can lead to the proper conditions for mold and mildew to set in.
- Methods for achieving proper airflow are wall mount fans, inline fans, "V-Flow" Fans
- Using multiple points of dehumidification will help discourage micro-climates
- Multi-tier racking can create airflow challenges

Maintenance Planning

- Budget for maintenance (parts/people)
- Schedule system downtime or reduced capacity
- Schedule resources from vendors
- Common parts and consumables on hand
- Access to equipment
  - Aisle size
  - Overlapping equipment
  - Vertical access
  - Replacement of larger systems
  - Safety

HVACD Planning/Maintenance

- Filter maintenance
  - Filters need to be replace to keep the internal components of the dehum and A/C clean
  - At a minimum filters should be replaced after every harvest.
- Drain lines
  - Drain lines should also be cleaned or treated when filters are replaced.
- Schedule routine HVAC clean and checks as recommended by the Manufacture
- Common parts and consumables on hand
- When spraying in a room
  - Turn off dehumidifiers
  - Turn off the A/C
  - Bag all controls and sensors

Takeaways

- With proper understanding of plant metabolism, growers can manipulate temperature and RH to grow olympic caliber plants!
- 90% of water taken up by roots is transpired into the air
- Dehumidification is based on expected maximum daily transpiration rates
- Understanding Vapor Pressure Deficit allows growers to optimize growth in the various stages (low VPD for veg; high for flower)
- Lighting and dehumidifiers are major sources of *sensible* heat in a room
- Transpiration is the major source of *latent* heat in a room
- The plants uses the CO2 around the leaf's surface in 4 minutes
- The leaves should flutter but not be windblown
- Budget for HVAC maintenance parts and labor

SECTION 05

Utilities

National Grid Grants & Incentives

Economic Development grants available

- 3 Phase power extensions
- Brownfield Redevelopment
- Renewable Energy
- Electrical Capital Investment
- Others

www.shovelready.com

National Grid Grants & Incentives

Energy Efficiency Programs

- Lighting and controls
- HVAC
- Dehumidification
- Fans
- Refrigeration

NYS Clean Heat

- Air Source & Water Source Heat Pumps
- Building Envelope
- GeoThermal

National Grid Grants & Incentives

Electrical Vehicle Charging

	Make-Ready Program Components			
	Utility-Side Infrastructure	**Customer-Side Infrastructure**	**EVSE Hardware**	**Other Soft Costs**
Component Example	• Distribution Network • Transformers • Meters • Conductor	• Panel • Conductor • Boring • Trenching • Conduit	• Charging Station • Network Equipment	• Signs • Bollard • Network • Maintenance • Assoc. Fees
Paying Entity	National Grid Make-Ready Program *(Covers up to 50%, 90%, 100%)**		NYSERDA *(When available)*	Customer Responsibility
	Potential Customer Contribution		Customer Contribution	
Owning Entity	National Grid	Customer		

Note: Graphic is for illustrative purposes only, may not be exhaustive and contents are subject to change.

SECTION 5

Q & A

Today's Experts

Rob Eddy

RESOURCE INNOVATION INSTITUTE

Rob@resourceinnovation.org

Dan Dettmers

MADISONAIR

ddettmers@madisonair.com

Randy Lenz

anden

randy.lenz@anden.com

Craig Yendrek

HAWTHORNE™

craig.yendrek@scotts.com

John (Jay) Snyder

nationalgrid

John.snyderjr@nationalgrid.com

CONTACT US

RESOURCE INNOVATION INSTITUTE

Visit us at
www.ResourceInnovation.org

P.O. Box 5981
Portland, Oregon 97228
rob@resourceinnovation.org
carmen@resourceinnovation.org