Outline & Speakers

- Introduction to Drying
  - Chris Callahan (UVM Extension) and
  - Gretchen Schimelpfenig (RII)
- Energy Efficiency
  - Lauren Morlino (Efficiency VT)
- Safety
  - Landon Wheeler (VT Division of Fire Safety)
- Q&A

Drying Basics: Hemp

August 6, 2020

Chris Callahan
go.uvm.edu/ageng

Gretchen Schimelpfenig
www.resourceinnovation.org

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Agricultural ENGINEERING

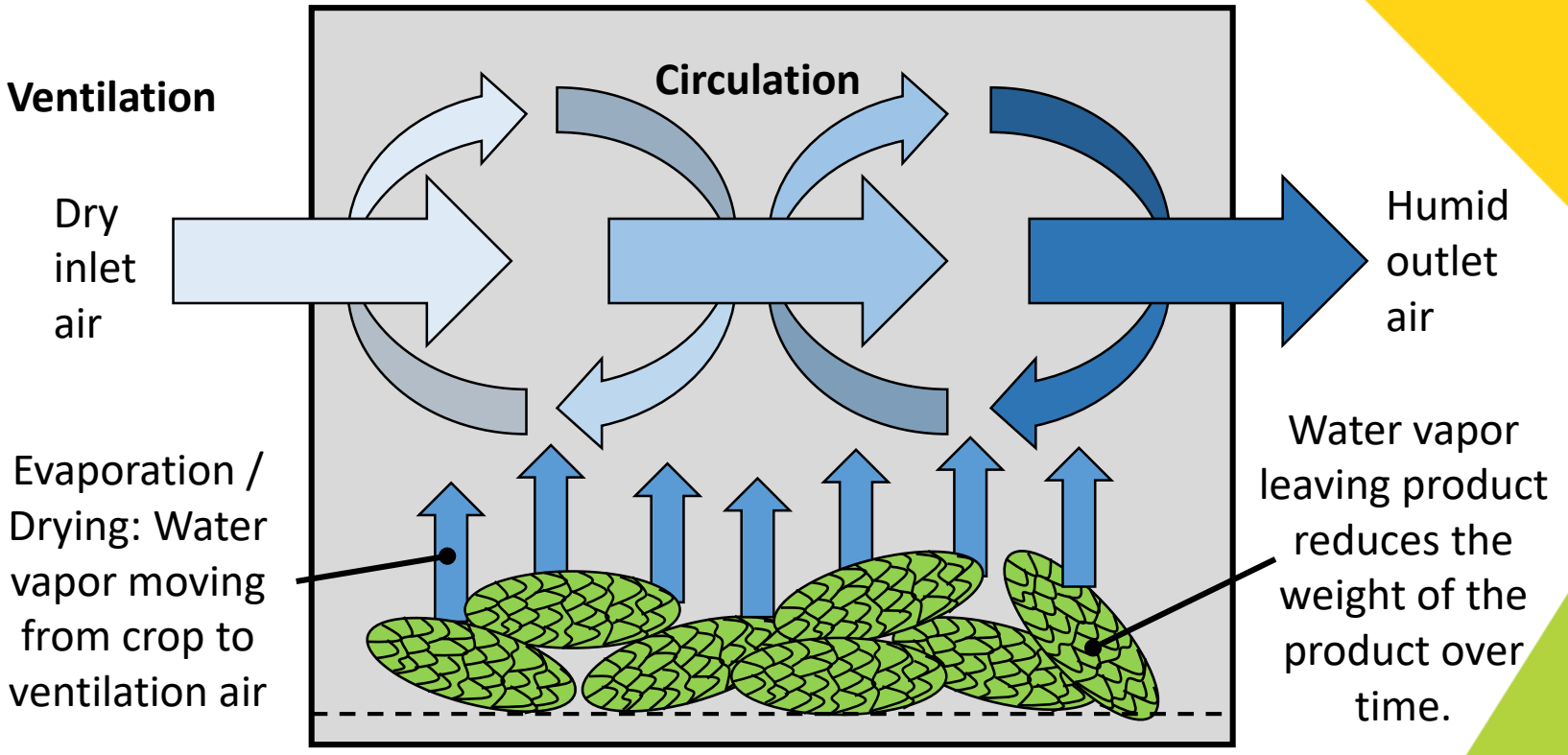
RESOURCE INNOVATION INSTITUTE

Outline

- Drying and Curing - What are We Doing?
- Air, Water, Humidity
- Drying Approaches
  - Ambient Drying
  - Heated, Forced Air
  - Dehumidification Systems
- Drying Systems & Pros and Cons
- Q&A

Drying

- Passing relatively dry air over freshly harvested crops **drives moisture** from the crop **into the air**.
- The dry inlet **air becomes more humid** as it passes through the crop and exits with more moisture than it started with.
- Over time, this **reduces the weight** of the crop (by removing water) and leads to **lower moisture content** (MC).



NOTE: The amount of water removed from crops can be significant, e.g. 70% of the initial crop weight (80% MC at harvest dried to 10% MC for storage). For **one ton** (2,000 lbs of harvested crop, you will need to remove 1,400 lbs of water or **168 gallons**.

Drying and Curing Conditions – What's Your Market?

Drying

- Higher Temp (>90 ˚F)
- Lower Humidity (<50%)
- Products/Markets:
  - Extracts
  - Biomass
- To minimize drying time, higher temperature (up to 180 ˚F) is preferred.
- 8-10% moisture content target, but varies

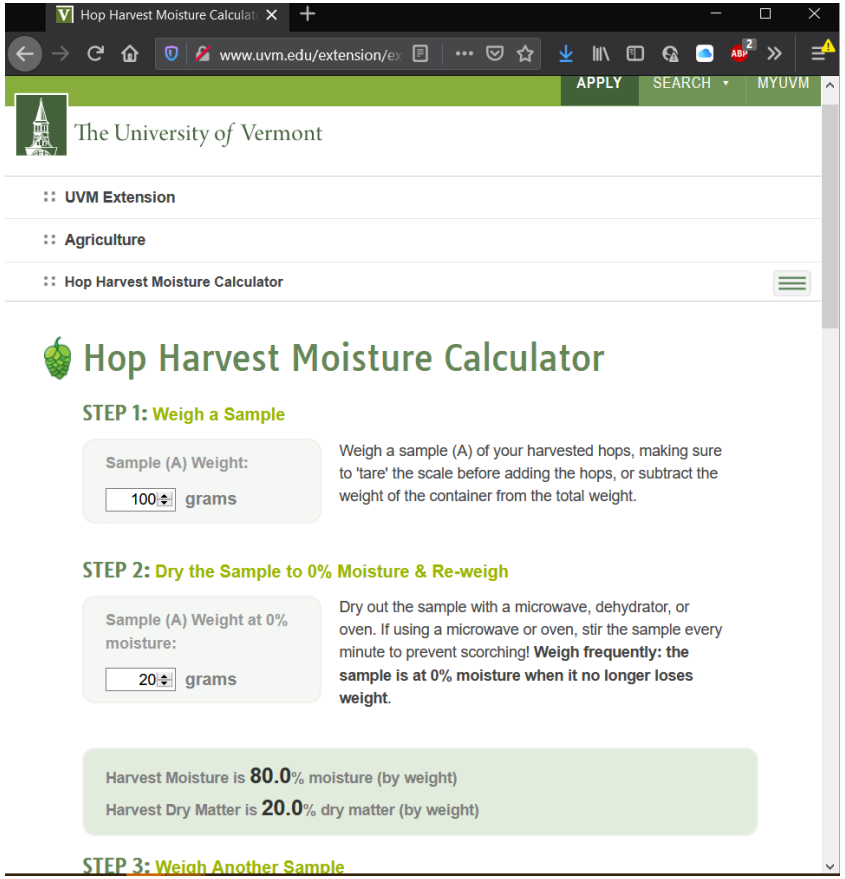
Curing

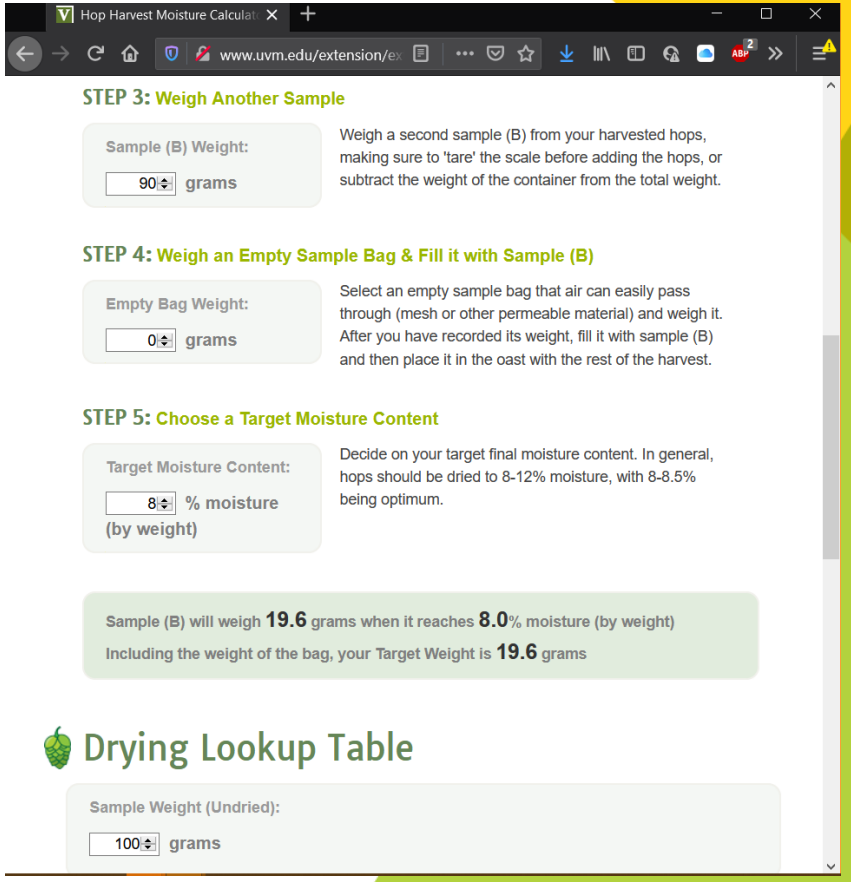
- Lower Temp (<=90 ˚F)
- Higher Humidity (>50%)
- Products/Markets:
  - Smokable
  - Visual / Aroma Quality
- To maximize terpenes and other desirable oils, lower temperature is generally preferred.
- 10-11% moisture content target, but varies

Also important to remember that air temperature is not product temperature due to evaporation of water.

How to Measure Moisture Content?

- There are **moisture meters**. Difficult to get a good representative measurement.
- A more accurate method is a **weighed, dried, and weighed** sample.
- **Video guide and calculator online**.





http://go.uvm.edu/**moisture**

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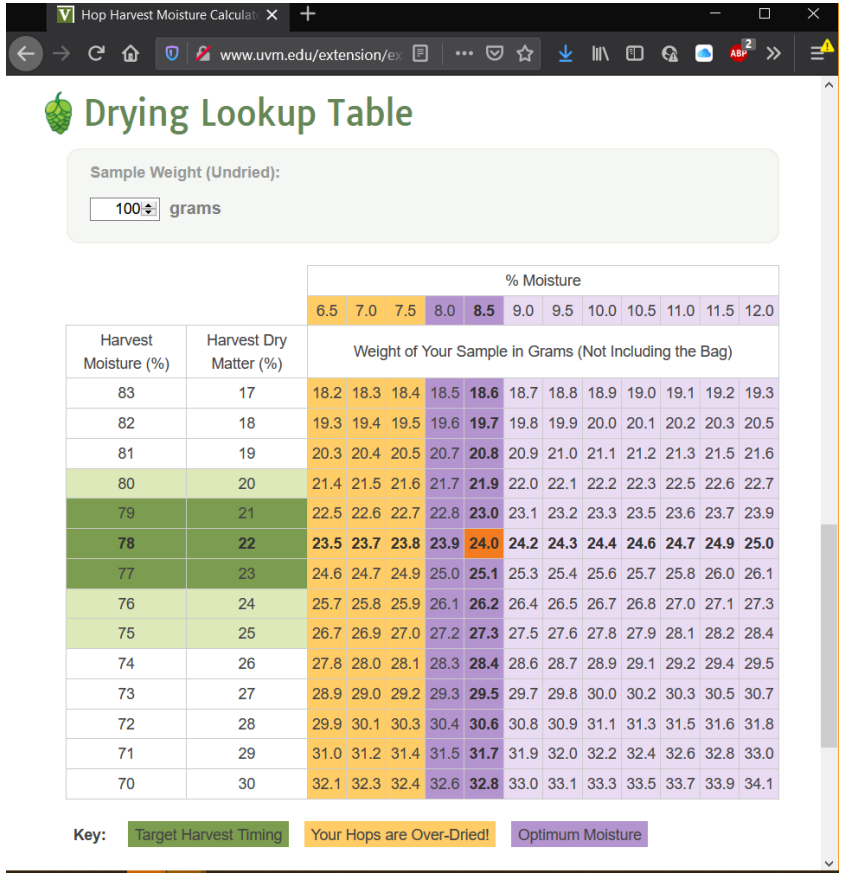
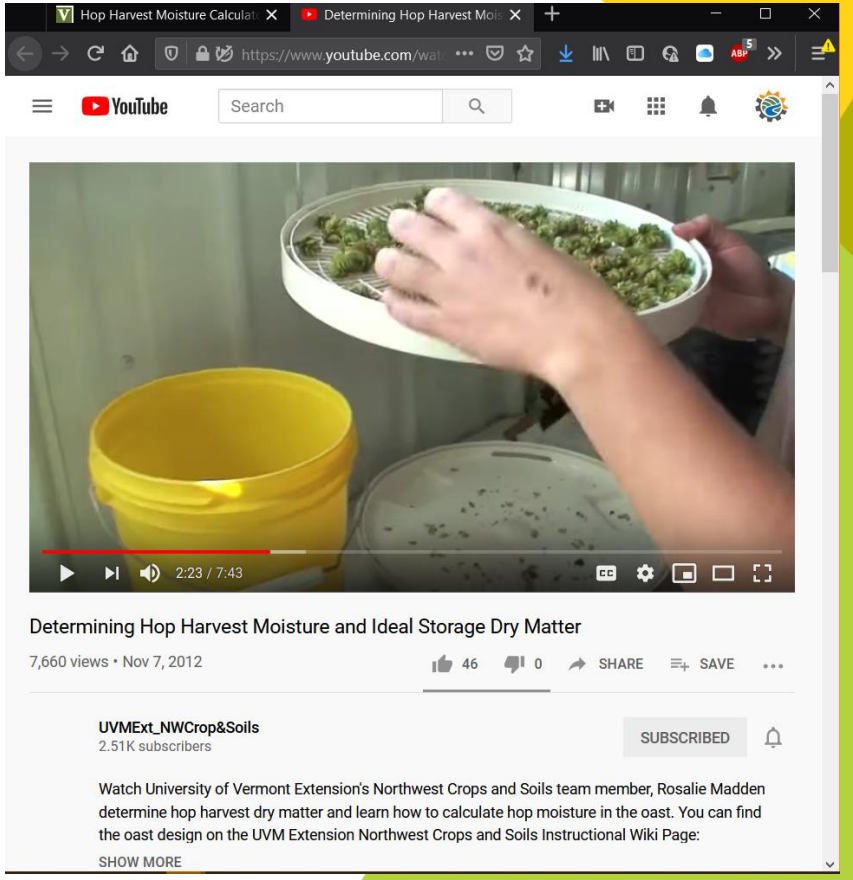


		% Moisture											
		6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0
Harvest Moisture (%)	Harvest Dry Matter (%)	Weight of Your Sample in Grams (Not Including the Bag)											
83	17	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3
82	18	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.5
81	19	20.3	20.4	20.5	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.5	21.6
80	20	21.4	21.5	21.6	21.7	21.9	22.0	22.1	22.2	22.3	22.5	22.6	22.7
79	21	22.5	22.6	22.7	22.8	23.0	23.1	23.2	23.3	23.5	23.6	23.7	23.9
78	22	23.5	23.7	23.8	23.9	24.0	24.2	24.3	24.4	24.6	24.7	24.9	25.0
77	23	24.6	24.7	24.9	25.0	25.1	25.3	25.4	25.6	25.7	25.8	26.0	26.1
76	24	25.7	25.8	25.9	26.1	26.2	26.4	26.5	26.7	26.8	27.0	27.1	27.3
75	25	26.7	26.9	27.0	27.2	27.3	27.5	27.6	27.8	27.9	28.1	28.2	28.4
74	26	27.8	28.0	28.1	28.3	28.4	28.6	28.7	28.9	29.1	29.2	29.4	29.5
73	27	28.9	29.0	29.2	29.3	29.5	29.7	29.8	30.0	30.2	30.3	30.5	30.7
72	28	29.9	30.1	30.3	30.4	30.6	30.8	30.9	31.1	31.3	31.5	31.6	31.8
71	29	31.0	31.2	31.4	31.5	31.7	31.9	32.0	32.2	32.4	32.6	32.8	33.0
70	30	32.1	32.3	32.4	32.6	32.8	33.0	33.1	33.3	33.5	33.7	33.9	34.1

Key: Target Harvest Timing | Your Hops are Over-Dried! | Optimum Moisture



http://go.uvm.edu/**moisture**

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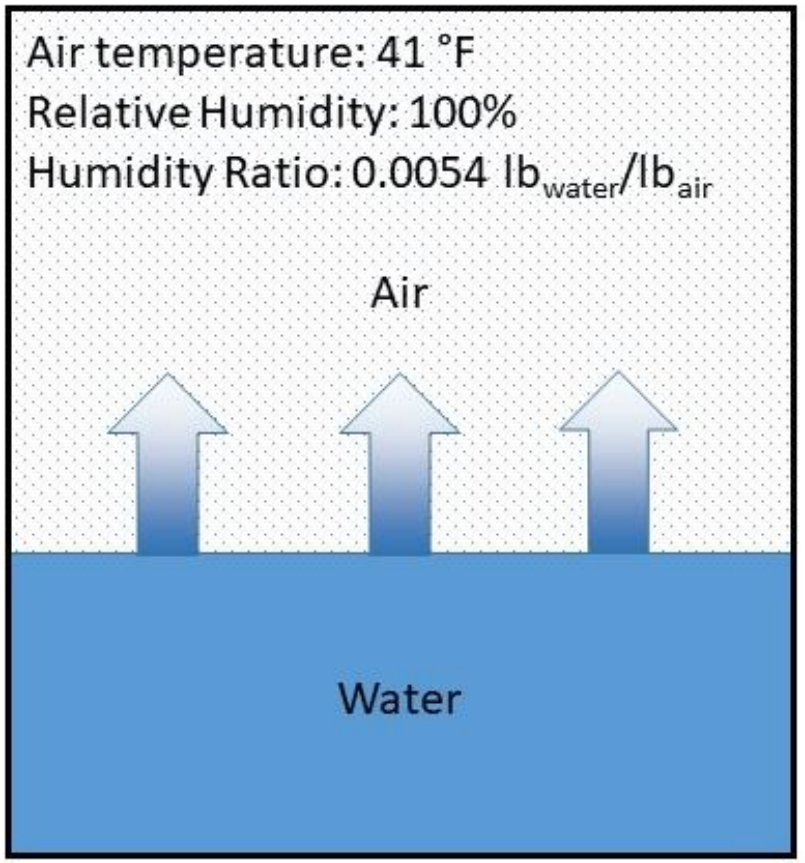
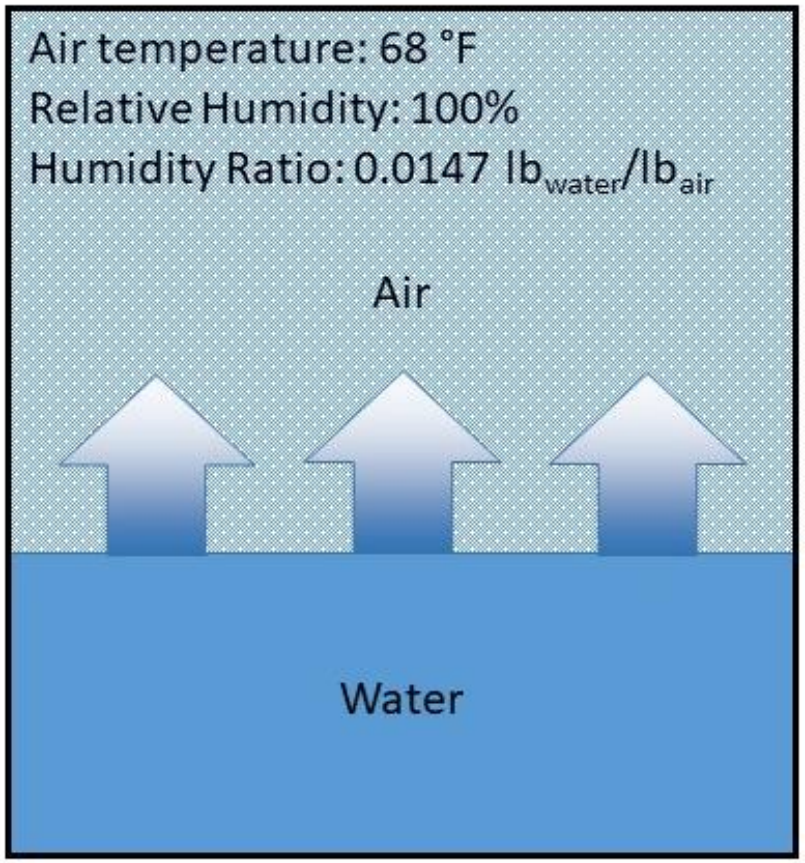
What is Humidity? Water Vapor in Air

- The maximum amount of water vapor that can be carried by air (i.e. at 100 % RH) depends on the temperature of the air.
- Air at 68 ˚F can carry almost 3 times the amount of water vapor as air at 41 ˚F.
- Warmer, drier air will absorb more water vapor more quickly than cooler, more humid air.
- Drying vs. Curing





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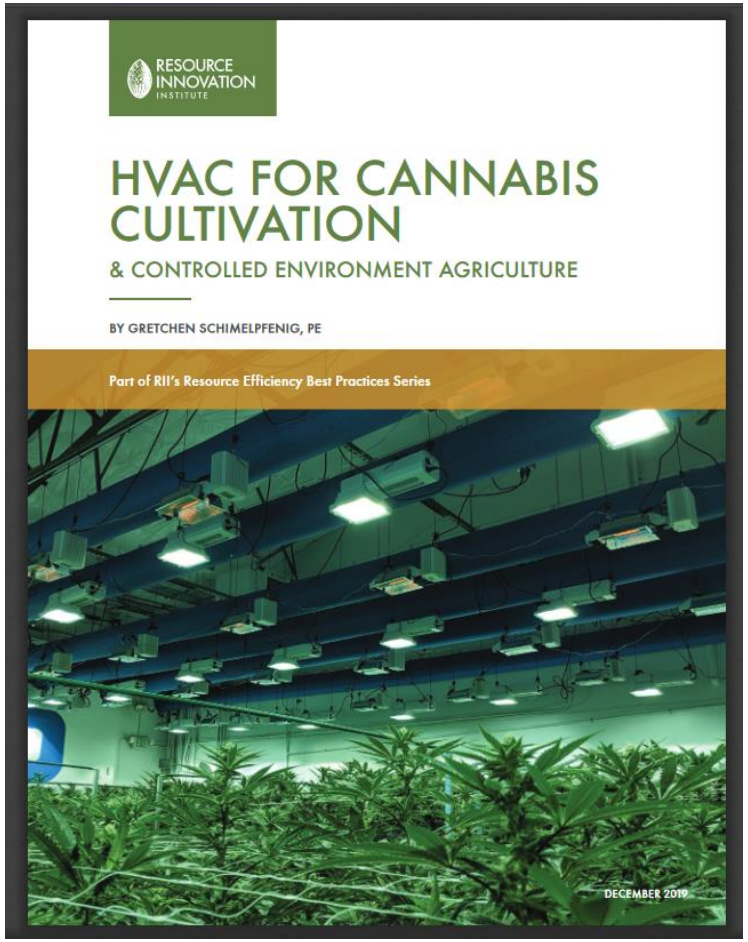
HVAC Guide



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HVAC FOR CANNABIS CULTIVATION & CONTROLLED ENVIRONMENT AGRICULTURE

PLANNING YOUR PROJECT

Designing the HVAC equipment in your facility to both successfully serve the needs of your plants and run efficiently requires thoughtful planning before you start construction or a major renovation.

PRE-DESIGN PHASE

Determine Your Setpoints - Temperature and relative humidity setpoints can greatly influence the efficiency of your systems. Establish temperature, RH, and/or VPD targets for your grow rooms when your lights are on and when your lights are off, as well as for the variety of strains that you grow, to accurately estimate your HVAC system's capacity.

Set Goals for Energy Performance - Discuss with your engineers and other team members how you might use energy efficiency to reduce your energy bills. You will need to determine what sort of equipment would be best suited for your facility to meet both the operational goals (i.e., space temperature and humidity targets) and also energy efficiency goals to minimize operational costs.

Decide What You Want - You or the building owner may have some idea of the scope of work your project will entail, but consider developing more detailed *owner's project requirements* (OPR) to quantify what success looks like for your facility. Define your parameters for success: describe the environmental conditions you would like to achieve, include your preferred temperature, RH, and VPD ranges, and elaborate on energy efficiency goals and how you would like the project to accomplish them.

The Owner's Project Requirements (OPR) is the single most important document in developing a design for an existing or new cultivation facility.

An OPR defines the Owner's goals, objectives and performance metrics, and is developed by the owner (not your design team). Creating an OPR should be one of the first items on your to-do list when planning a project, big or small.

Choose Wisely - Select the members of your project team based on their expertise relative to cultivation applications. Consider using qualified and experienced designers, consultants, and contractors in your region to receive local customer support. Request case studies and references to qualify the experience of your designers, consultants, and contractors.

HVAC equipment for cultivation environments needs to be designed and selected with care. Interactive effects between your plants and the systems you use to manage the macro and micro-level environmental conditions for them, like lighting, and HVAC systems as well as CO2, fertigation, pest management, and condensate collection are something an expert in engineering grow facilities will understand and thoughtfully consider.

Your project team may be big or small, depending on the size and scope of project you are planning for your facility. For new construction or a major renovation project, you should consider having the following members on your team, or at least consider having someone to play these parts:

- You, or your Owner's Representative
- Your Architect
- Your Engineer(s)
  - Civil
  - Structural
  - Mechanical (Includes Plumbing)
  - Electrical
  - Horticultural Process
- Your Energy Modeler
- Your Construction Manager and/or General Contractor
- Your Subcontractor(s)
  - Mechanical
  - Electrical
  - Plumbing
  - Air & Water Balancing
  - HVAC Controls
- Your Commissioning Agent(s)
  - Building Envelope
  - Mechanical, Electrical, Plumbing & HVAC Controls

Assemble Your Team Early - To improve team coordination and communication, get critical design questions answered as early as possible, ensure code requirements are satisfied, maximize operational efficiency, and lower costs of your project, employ a collaborative *integrated design* approach to effect the greatest changes to your facility's operational efficiency and associated environmental impacts.

An integrated design team works together early and often throughout a project's planning, design, construction, and occupancy phases to execute a project to its maximum potential. Working collectively from the start allows your team to have a better understanding of the project and interactive elements of their scopes of work. By engaging frequently, issues can be identified and resolved in the design phase rather than later in construction or occupancy phases, when resolution is much more expensive.

Understand Roles - Engage with team members to understand their responsibilities early in the planning process. Document roles and dependencies between roles for effective communication down the road. For the smoothest process, consider assigning a lead designer (generally an Architect, but sometimes an Engineer or a General Contractor) as the main point of contact for all design team members.

OPTIMIZING YOUR FACILITY DESIGN

Before you build or renovate, consider the basis of your facility design so that you can optimize the efficiency and impact of your HVAC decisions.

A basis of design (BOD) is the foundational design document and is developed by your designers to inform you how they intend to achieve the criteria laid out in your OPR, by specifying and describing the heating, ventilation, cooling, and dehumidification systems that can meet your expectations. Ideally this document is a living document that is updated as the design progresses.

In your facility, some criteria you may care about include key performance indicators (KPIs) relevant to profitability, sustainability, and operational efficiency. In the BOD process, help your design team translate the cultivation KPIs to design criteria related to their scope of work. As you may not be able to do that alone, working with a Horticultural Process Engineer could help you connect the dots.

DESIGN PHASE

Count Your Plants - Understand the number of plants in each cultivation space, as the latent load to be managed by your HVAC equipment is dependent on the moisture given off by your plants, their grow media, and irrigation systems. Consider how the number of plants may fluctuate based on time of year, growth cycle, market forces, and issues with regulations or crop damage.

The number of plants in your grow environment will impact the amount of moisture generated - and HVAC energy used.

http://resourceinnovation.org/Resources/

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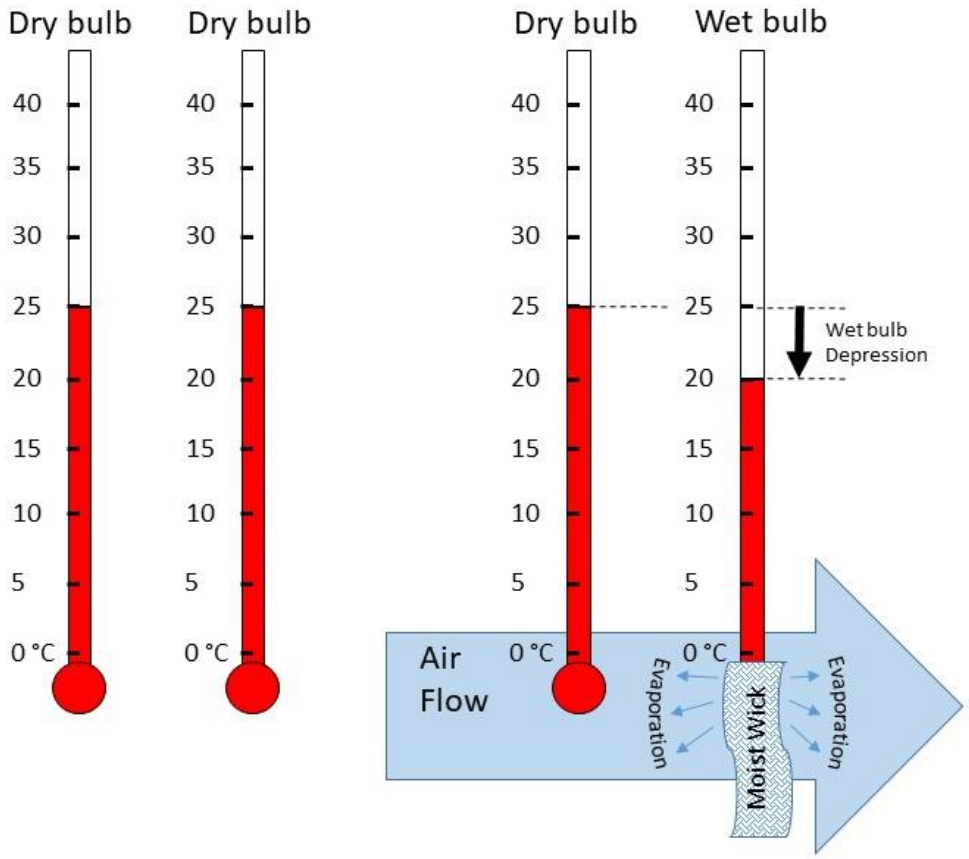
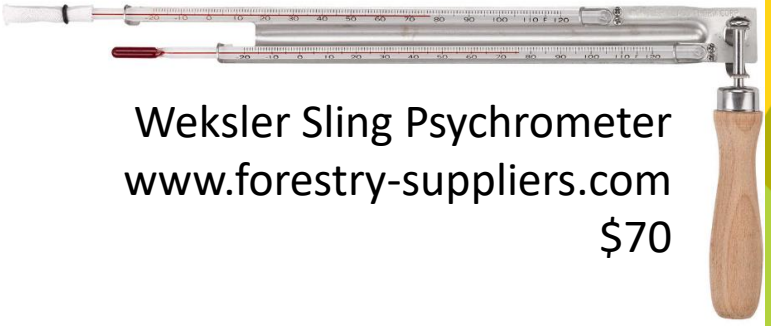
How to Measure Humidity?

- Most **electronic RH sensors** are inaccurate at high RH (>80% RH) and low temps.
- **Sling Psychrometer** is the gold standard
- Advanced **electronic psychrometer** (DewRight)





Weksler Sling Psychrometer
www.forestry-suppliers.com
$70

VECS DewRight, $250

http://www.vecs.org/

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Why Does Condensation Happen?

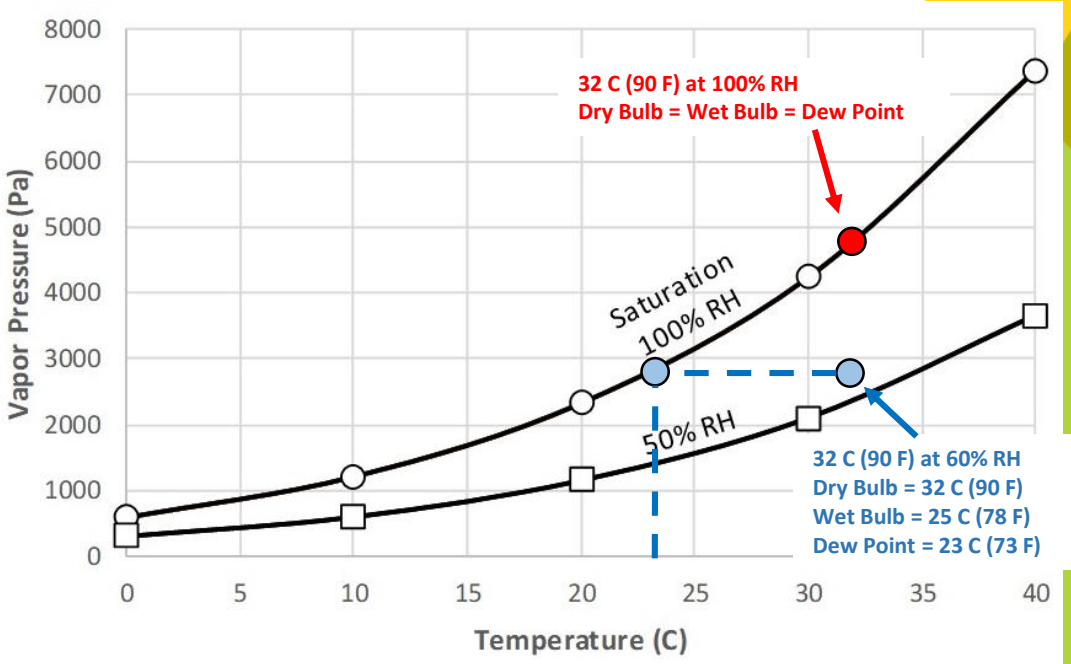
Relatively **warm**, relatively **humid** air…

Relatively **cold**, relatively **dry** surface… at or below **Dew Point**

Time…

Condensation…

Dripping…



https://www.flickr.com/photos/crazyangelblue/4270749617

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Common Approaches to Drying

- **Ambient Drying**
  - Hung in a barn or laid on greenhouse benches
- **Forced, Heated Air**
  - Plenum or rotary drier
  - Heated, ventilated room
  - Oast
- **Dehumidification**
  - Refrigeration cycle (heat pump) to cool air (condense water vapor) with reheat

Ambient Drying

Photos: 2 left by H. Prussack, 2 right by A. Chamberlin.

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Ambient Drying

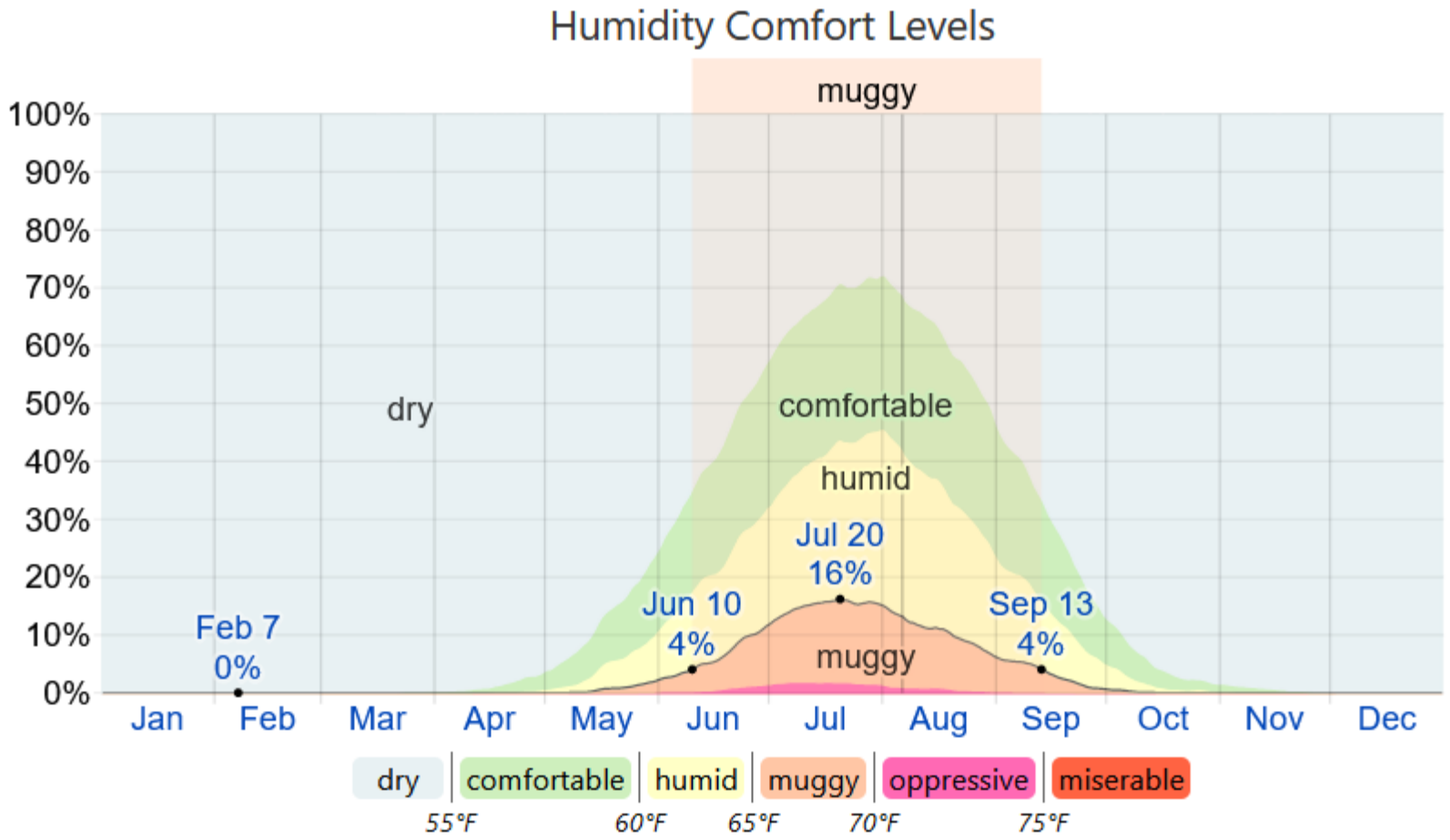
Pros (+)

- Simple, low tech
- Generally available already
- Inexpensive or free
- High capacity, but low density
- No additional heat energy input (minimal GHG)

Cons (-)

- Subject to ambient conditions, capacity and quality impact
- Drying will take longer, could result in disease or pest issues
- Drying time also depends on ambient conditions
- Circulation and ventilation important.

Average / Historical Ambient Conditions



The percentage of time spent at various humidity comfort levels, categorized by dew point.

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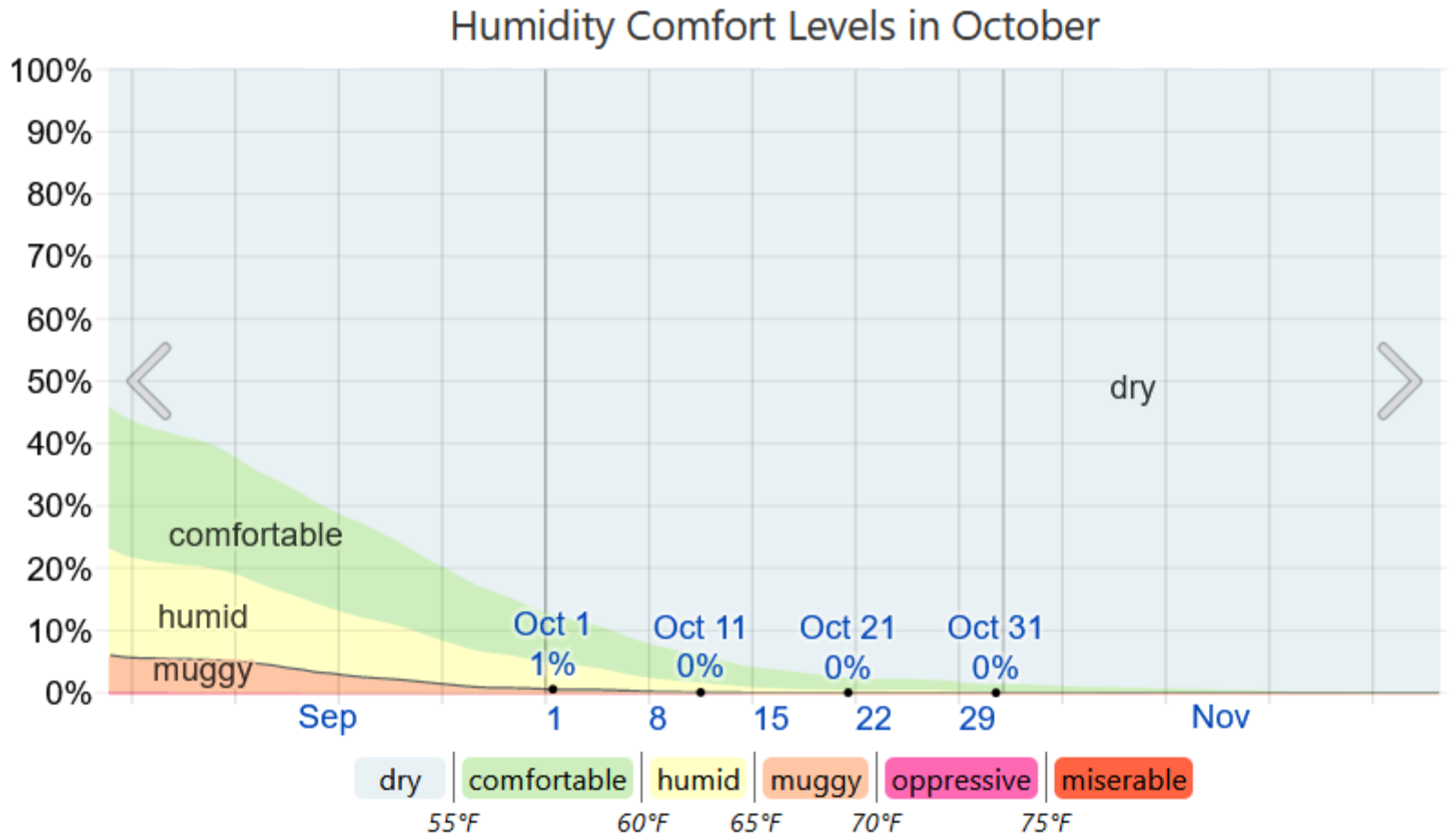

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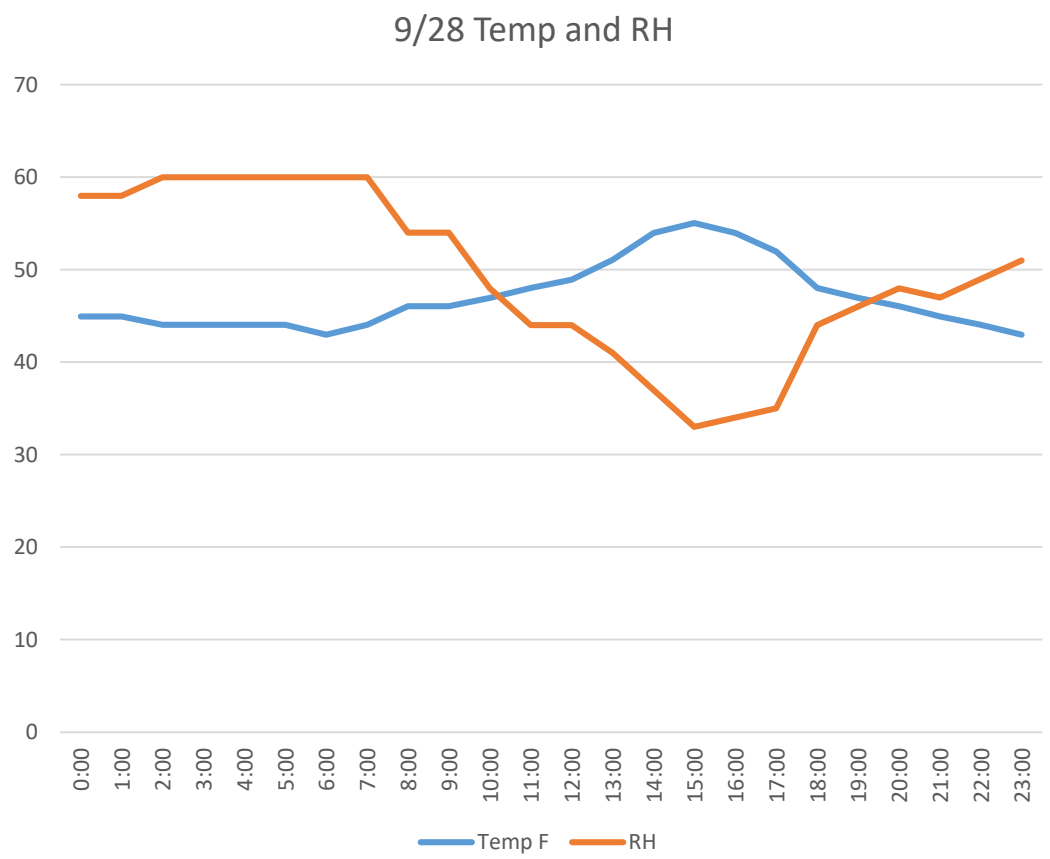

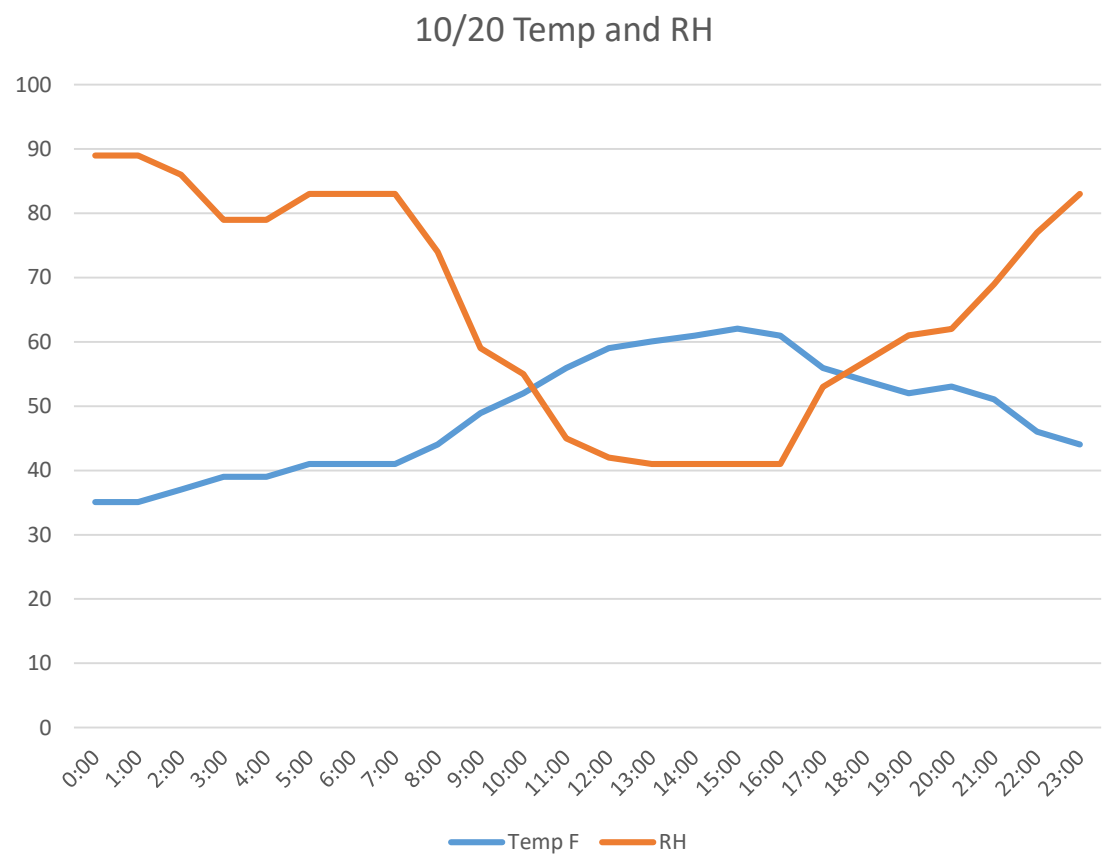

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Forced, Heated Air, Plenum

Photos: 3 Left by C. Callahan, 1 right D. Robinson

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Forced, Heated Air / Plenum

Pros (+)

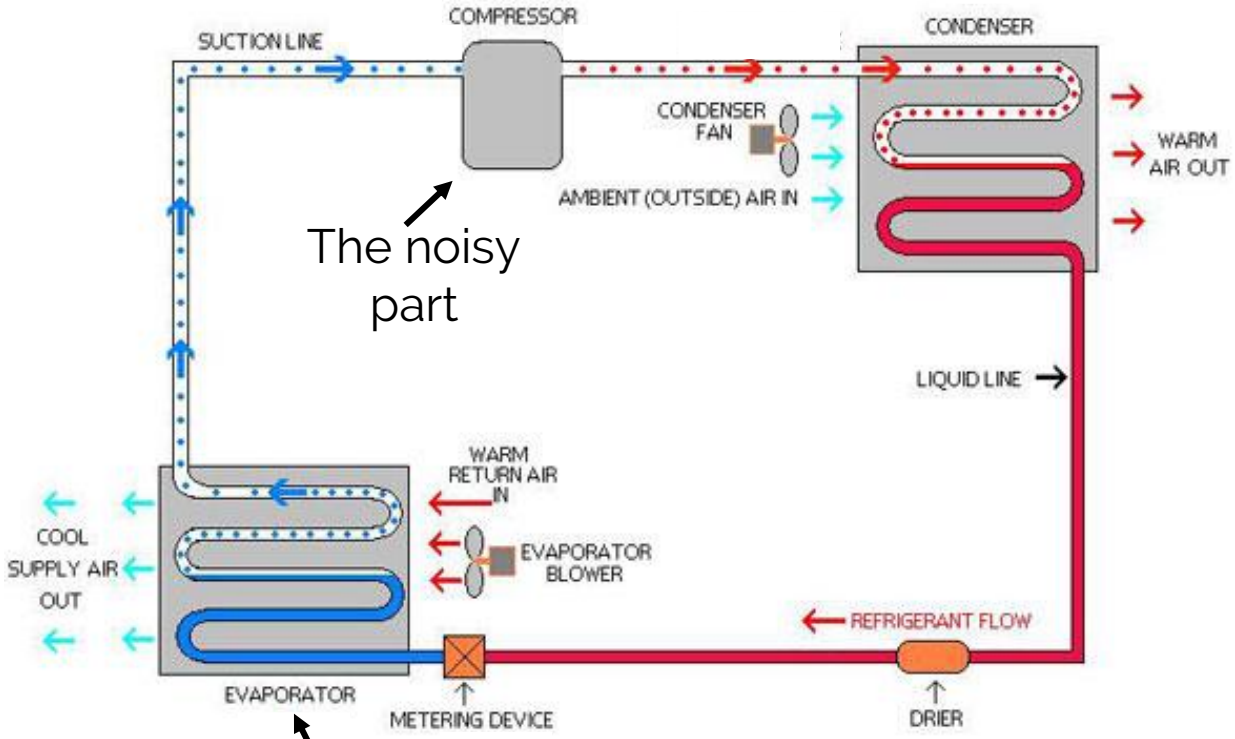
- Enables rapid drying, though at higher temp
- Can be modulated for low temp drying
- Fuel is flexible
- Can be sized to need
- Moderate operating costs

Cons (-)

- Initial cost is moderate
- Some system complexity / controls but can be self-built.
- Generally needs ventilation and circulation of air
- Possibly increased GHG impact (fossil fuels)
- Possible quality loss due to high temperatures

Dehumidification / Heat Pump

Some systems can be reversed to both heat and cool (and dehumidify)



The noisy part

In dehumidifiers water is dropped out here.

Quest 195 pint/day (24 gal/day, 200 lbs/day) 5.9 pints/kWh. $3,500

Photos/Figures: Left by C. Callahan, 1 right D. Robinson, inset right from Quest via Growinglabs.com

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Dehumidification / Heat Pumps

Pros (+)

- Allows low temp drying
- Can be used in a closed space (no ventilation)
- Fuel is electricity
- Can be sized to need
- Possibly decreased GHG impact (depends on grid mix and use)
- Possible efficiency incentives
- Possible quality improvement for aroma and appearance sensitive markets.

Cons (-)

- Initial cost is relatively high
- Capacity may be limiting
- Generally needs circulation of air
- Higher operating costs

Wrap-up

- Drying vs. Curing – impact on conditions
- Seasonal/short term use
- Reach out (EARLY!)
- Resources
  - Technical assistance
  - Continuous improvement
  - Web resources such as RII guide
  - RII and Efficiency VT Event coming up
    - resourceinnovation.org/events/

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August 6, 2020

Agricultural Drying

Lauren Morlino
Emerging Technologies & Services Manager

Efficiency Vermont

How We Can Help

Technical assistance

- Design review
- Energy modeling assistance
- Cost benefit analysis

Trade Ally Network

- Contractors
- Designers/Engineers
- Efficiency Excellence Network

Thermal shell assistance

- Building envelope recommendations
- Potential incentives

Possible electrical incentives

- Efficient Fans
- Energy Star dehumidifiers
- Heat Pump technologies

Technologies

Fans

- VFDs or variable speed ECM motors fans

Portable dehumidifiers

- $25-40 cash back on qualifying ENERGY STAR® models, plus a $50 bonus for income-eligible Vermonters

Heat pumps for drying

- Must be designed carefully and applied appropriately

Controls

Building Envelope

Air sealing is key

- Durable sheet goods, spray foam, caulk or liquid flashing
- Blower door testing
  - Incentives available for mechanical heating/drying spaces

Call Efficiency Vermont to talk more about your project!

Efficiency Vermont

Keep conditioned air in!

Seal top and bottom to mitigate chimney effect!

Electric Utilities

Incentives available

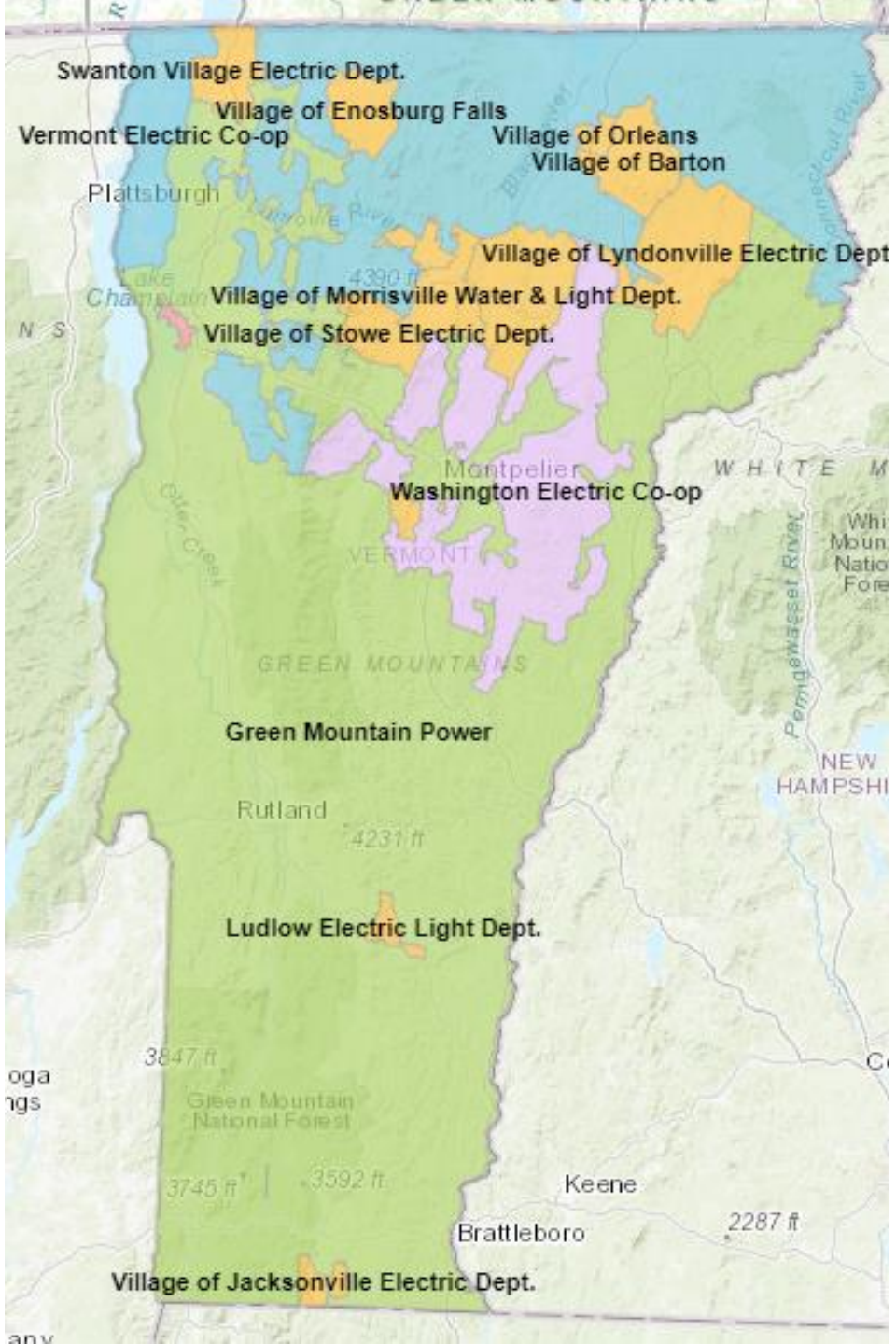
- Carbon reduction program incentives - Tier III

Tier III opportunities

- Opting for electric resistance heat
- Heat pump technologies

Electric services

- Access to three phase power
  - Limited to 5 tons of cooling with single phase
- New service locations



Questions?

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Division of Fire Safety

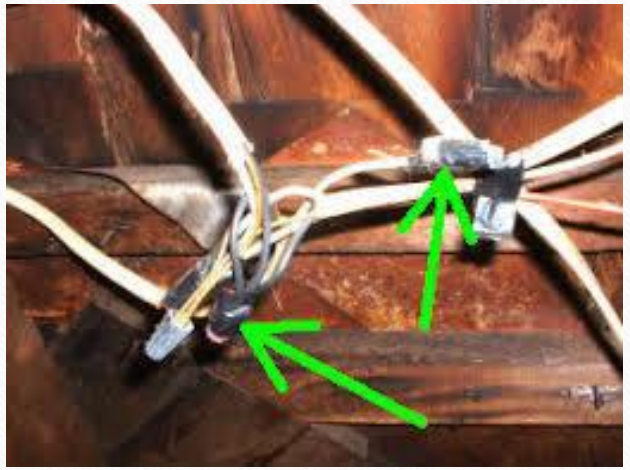
Landon Wheeler

- What is a public building: Defined in 20 VSA 173
- What makes a building a public building?
- Are some buildings exempt from Division of fire safety?
- What role does the DFS safety play?
- How do I find out if my building or process is required to comply with 20 VSA or the 2015 Vermont Fire and Building Safety Code?

Major Hazards associated with Drying operation

- Electrical
- Use of materials/ Vapor barriers
- Stored combustible materials
- High Pile storage
- Blocked exits/ Lack of exits
- Homemade equipment/ listed (UL) tested/ designed equipment
- Heat/moisture removal

- Extension cords
- Drawing more power than available
- Homemade appliances, cords, equipment
- Undersized electrical service
- Heat generation from electrical resistance



Use of materials

Remember to remove the moisture/heat from the building that you remove from the harvest!

Stored combustible materials

High pile storage

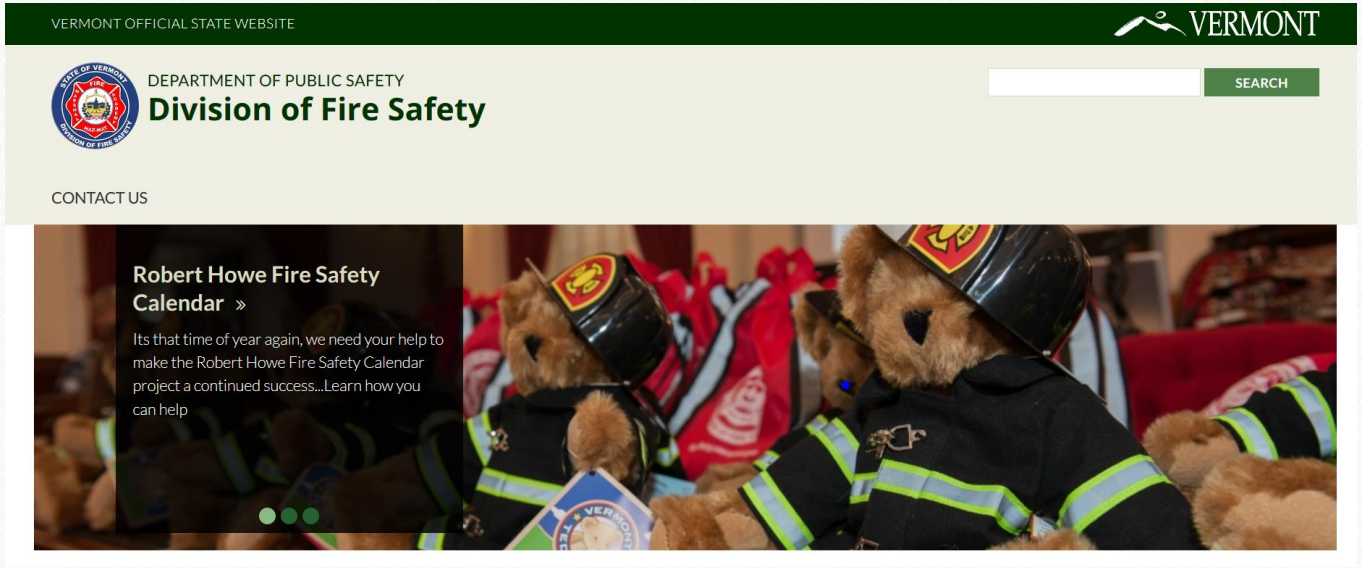
Means of egress

Time and Planning

- Each project is different
- Scale of project
- Scale of equipment
- Hazards of equipment
- Design of equipment

- Making contact as early in your process and planning as possible will help expedite the DFS process.

How to get in touch with us



https://firesafety.vermont.gov/

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Contact Us (EARLY and often…)

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  - Resource Innovation Institute, gretchen@resourceinnovation.org, 307-399-5837
    www.resourceinnovation.org
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    www.efficiencyvermont.com
- Landon Wheeler
  - VT Division of Fire Safety, landon.wheeler@vermont.gov, 802-369-0949
    firesafety.vermont.gov