MAKE IT OR BREAK IT WITH DEHUMIDIFICATION:
THE IMPORTANCE OF INDOOR AGRICULTURE
HVAC, ITS FUNDAMENTALS, AND THINKING
OUTSIDE OF THE BOX

Michael Ward | Harbor Farmz
Mitch Kelley | Trane
Rachel Fredrickson | Consumers Energy
INTRODUCTIONS

Moderator:
Gillian Giem, Program Manager, Grand Rapids 2030 District

Speakers:
Michael Ward, CEO & Founder, Harbor Farmz
Mitch Kelley, New System Sales, Trane Commercial HVAC North America
Rachel Fredrickson, Indoor Agriculture Specialist, Consumers Energy
IT'S HERE!

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), CO₂, 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 ft² than traditional farms

- Crops include cucumbers, lettuce, leafy greens, herbs, tomatoes, or cannabis in legally licensed facilities

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

Market Trends and Size

- Indoor Agriculture Market growing at 26%+ per year
- Indoor Agriculture is HVAC intensive environment… ~1 ton per 50 ft²
- 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, CannaBusiness Plans 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 \( H_2O \).
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.

**Phloem**

Sugars, amino acids, etc.

**Xylem**

Water, minerals, etc.
Evapotranspiration = evaporation + transpiration

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

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

Phloem
Sugars, amino acids, etc.

Xylem
Water, minerals, etc.
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

Leaf vapor pressure at saturation

Room vapor pressure

Δ = 0.90

Room vapor pressure
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
<table>
<thead>
<tr>
<th>Air Temperature (°F)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td>98</td>
<td>96</td>
</tr>
<tr>
<td>96</td>
<td>94</td>
</tr>
<tr>
<td>94</td>
<td>92</td>
</tr>
<tr>
<td>92</td>
<td>90</td>
</tr>
<tr>
<td>90</td>
<td>88</td>
</tr>
<tr>
<td>88</td>
<td>86</td>
</tr>
<tr>
<td>86</td>
<td>84</td>
</tr>
<tr>
<td>84</td>
<td>82</td>
</tr>
<tr>
<td>82</td>
<td>80</td>
</tr>
<tr>
<td>80</td>
<td>78</td>
</tr>
<tr>
<td>78</td>
<td>76</td>
</tr>
<tr>
<td>76</td>
<td>74</td>
</tr>
<tr>
<td>74</td>
<td>72</td>
</tr>
<tr>
<td>72</td>
<td>70</td>
</tr>
<tr>
<td>70</td>
<td>68</td>
</tr>
<tr>
<td>68</td>
<td>66</td>
</tr>
<tr>
<td>66</td>
<td>64</td>
</tr>
<tr>
<td>64</td>
<td>62</td>
</tr>
<tr>
<td>62</td>
<td>60</td>
</tr>
<tr>
<td>60</td>
<td>58</td>
</tr>
<tr>
<td>58</td>
<td>56</td>
</tr>
<tr>
<td>56</td>
<td>54</td>
</tr>
<tr>
<td>54</td>
<td>52</td>
</tr>
<tr>
<td>52</td>
<td>50</td>
</tr>
<tr>
<td>50</td>
<td>48</td>
</tr>
<tr>
<td>48</td>
<td>46</td>
</tr>
<tr>
<td>46</td>
<td>44</td>
</tr>
<tr>
<td>44</td>
<td>42</td>
</tr>
<tr>
<td>42</td>
<td>40</td>
</tr>
<tr>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td>38</td>
<td>36</td>
</tr>
<tr>
<td>36</td>
<td>34</td>
</tr>
<tr>
<td>34</td>
<td>32</td>
</tr>
<tr>
<td>32</td>
<td>30</td>
</tr>
<tr>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

*assumes leaf temp and room temp are the same*
<table>
<thead>
<tr>
<th>Relative Humidity (%)</th>
<th>Air Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>106</td>
</tr>
<tr>
<td>98</td>
<td>105</td>
</tr>
<tr>
<td>96</td>
<td>104</td>
</tr>
<tr>
<td>94</td>
<td>103</td>
</tr>
<tr>
<td>92</td>
<td>102</td>
</tr>
<tr>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>88</td>
<td>98</td>
</tr>
<tr>
<td>86</td>
<td>96</td>
</tr>
<tr>
<td>84</td>
<td>94</td>
</tr>
<tr>
<td>82</td>
<td>92</td>
</tr>
<tr>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>78</td>
<td>88</td>
</tr>
<tr>
<td>76</td>
<td>86</td>
</tr>
<tr>
<td>74</td>
<td>84</td>
</tr>
<tr>
<td>72</td>
<td>82</td>
</tr>
<tr>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>68</td>
<td>78</td>
</tr>
<tr>
<td>66</td>
<td>76</td>
</tr>
<tr>
<td>64</td>
<td>74</td>
</tr>
<tr>
<td>62</td>
<td>72</td>
</tr>
<tr>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>58</td>
<td>68</td>
</tr>
<tr>
<td>56</td>
<td>66</td>
</tr>
</tbody>
</table>

*assumes leaf temp and room temp are the same

VPD Chart (kPa)

<table>
<thead>
<tr>
<th>56% RH</th>
</tr>
</thead>
</table>

Distribution restricted to Trane employees and authorized recipients only and not to be redistributed.

PROPRIETARY INFORMATION OF TRANE - FOR TRANE BUSINESS USE ONLY
**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

<table>
<thead>
<tr>
<th></th>
<th><strong>Comfort Cooling</strong></th>
<th><strong>Indoor Agriculture</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operating modes</strong></td>
<td>Occupied&lt;br&gt;Unoccupied</td>
<td>Lights-on / “Daytime”&lt;br&gt;Lights-off / “Nighttime”</td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
<td>0.7 – 1.2 W/ft²</td>
<td>30 – 80 W/ft²</td>
</tr>
<tr>
<td><strong>Space temperature</strong></td>
<td>70 – 75°F</td>
<td>65 – 83°F</td>
</tr>
<tr>
<td><strong>Space humidity</strong></td>
<td>50 – 60% relative humidity</td>
<td>40 – 75% relative humidity</td>
</tr>
<tr>
<td><strong>Space SHR</strong></td>
<td>0.70 – 0.90</td>
<td>Daytime: 0.25 – 0.50&lt;br&gt;Nighttime: 0.00 – 0.40</td>
</tr>
<tr>
<td><strong>Ventilation</strong></td>
<td>Based upon Standard 62.1 Requirements</td>
<td>Often no ventilation</td>
</tr>
<tr>
<td><strong>Carbon dioxide</strong></td>
<td>Diluted with ventilation air (sometimes controlled with DCV)</td>
<td>Increased beyond ambient (e.g. 1500 ppm)</td>
</tr>
</tbody>
</table>
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, CO₂ 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

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
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

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
Warm Weather Months
In-between Months
Cold Weather Months

Operation
Unit acts as traditional DX; dry cooler supplies glycol to unit condenser
Combination of glycol free cooling coil and one DX compressor
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
Wraparound Coil Technology - AHU

Traditional Cool – Heat Dehumidification

- No Precooling
- Condenser heat used for reheat

Wrap-around Dehumidifiers

- Supply air precooling 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.
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
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

1. **Check Customer and Equipment Eligibility**
2. **Submit pre-notification application and receive Reservation Letter**
3. **Install equipment/perform project work**
4. **Submit a final application**
5. **Receive Rebate Check**
# Incentive Caps and Limits

<table>
<thead>
<tr>
<th>Facility Incentives</th>
<th>Cap per Program Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prescriptive</td>
<td>75% of the total project cost</td>
</tr>
<tr>
<td>Custom</td>
<td>50% of the total project cost</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Customer Limits</th>
<th>Cap per Program Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Natural Gas</td>
<td>$1M across all facilities per customer</td>
</tr>
<tr>
<td>Large Electric</td>
<td>$2M across all facilities per customer</td>
</tr>
</tbody>
</table>
Program Effective Dates

December 1 → November 30
Incentive Resources
ConsumersEnergy.com/startsaving

Business Energy Efficiency

Let’s Save Energy Together
Saving energy saves your business money. Discover the many ways your business can save, or tell us a little about your business to find the solutions best suited to you.
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
QUESTIONS?

Mitch Kelley
mitch.kelley@trane.com
312-533-8231

Michael Ward
michael@harborfarmz.com
269-459-0312

Rachel Fredrickson
Rachel.Fredrickson@cmsenergy.com
877-607-0737 Ex: 1932

TRANE®

HARBOR FARMZ

Consumers Energy
Count on Us®
TWEAKING THE MARGINS: HOW CONTROLS SET YOU UP FOR A BETTER YIELD AND A LEANER OPERATING BUDGET

Please fill out our 2 minute survey at the end of this webinar. Thank you!