HVAC Best Practices for Controlled Environment Agriculture

Key Factors in HVAC Selection

DESERT AIRE
GROW ROOM
ENVIRONMENTAL CONTROL

Key Factors in HVAC System Sizing

- Lighting type
- Watering rate
- External Loads
  - Outside air
  - Heat gain or loss on structure
- Room design conditions
  - Temperature
  - Humidity

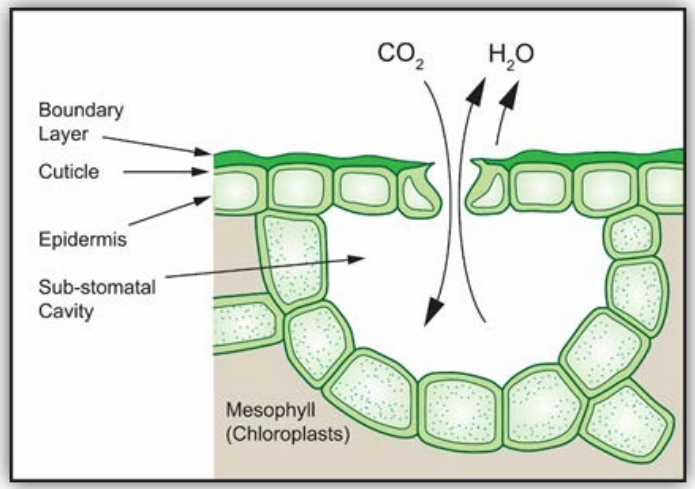
Impact of Lighting Types

- Lights are increasing their photon output with less power
- PPE
  - Photosynthetic Photon Efficacy
- Changes the starting point for sizing the HVAC system

Lighting Type	W/sq. ft.	PPE	Example Btuh
HID	65	1.7	222,000
LED	55	2.4	188,000
LED	45	2.7	155,000
LED	35	3.5	120,000

Watering Rates

- Components of the water feed rate
- Flush or overfeed
  - Drains immediately off the table to drain
- Evapotranspiration
  - Liquid that moves the nutrients to the leaf
  - Leaves plant by change from a liquid to gas
- Retained
  - The fluid that stays in the plant

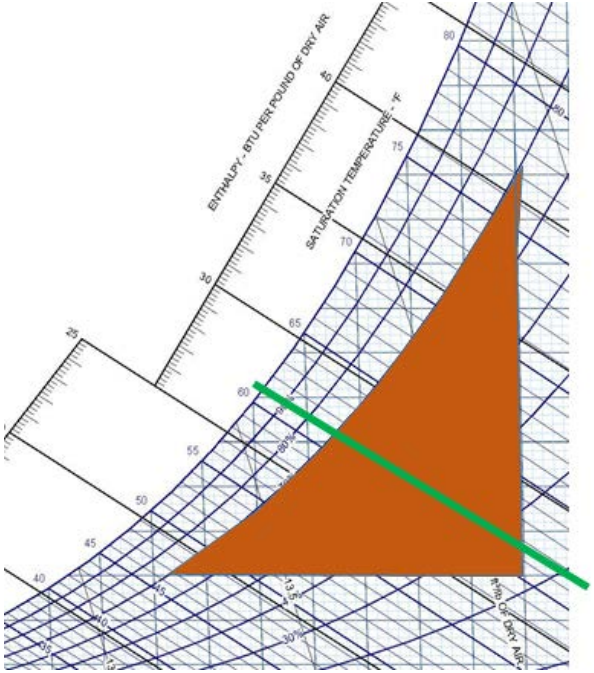


Design Conditions

- Wide range encountered in industry
  - 85F warmest
  - 70% RH highest
  - 42F dewpoint lowest moisture
- Vary by crop growth cycle
- Vary lights on vs. lights off

Conditions Impact

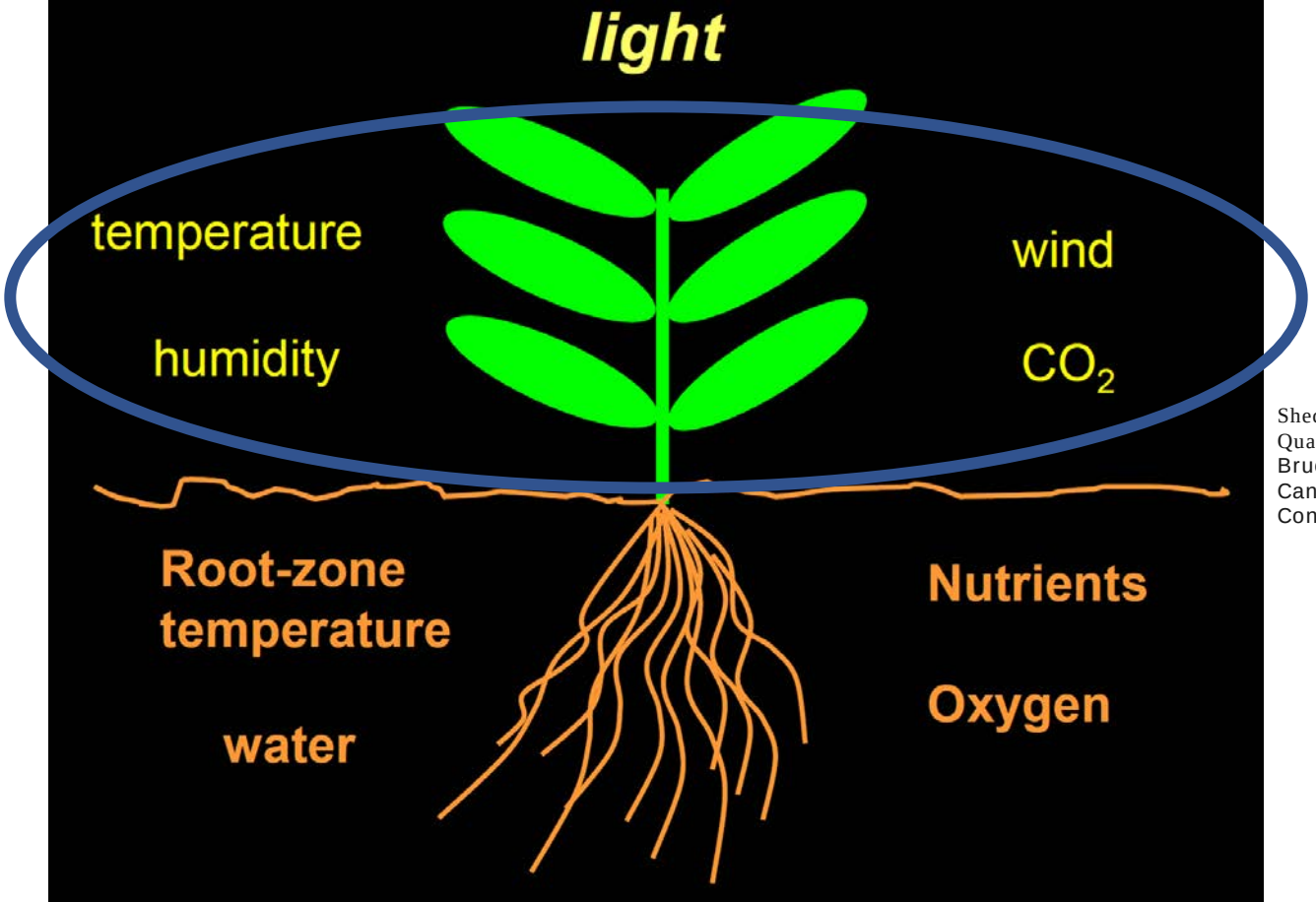
- HVAC performance impact
- Sensible cooling
  - Performance drops in lower quadrant
- Latent (moisture) removal
  - Performance is less the further away you are from the saturation curve
  - Performance drops in lower quadrant



Impact on Initial Cost & Operating Cost

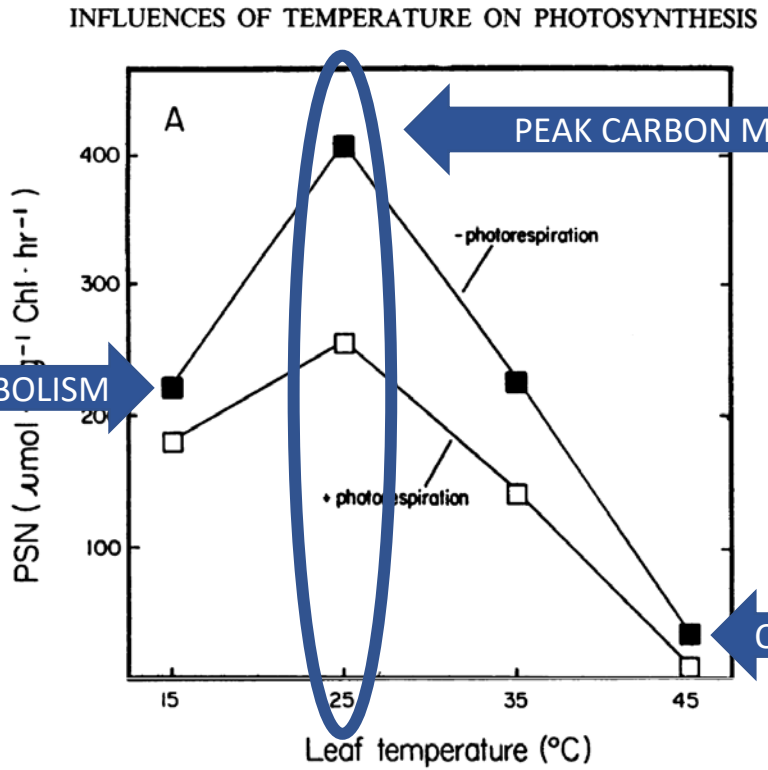
- Lower dew point conditions
  - Larger size HVAC
  - Higher purchase price
  - Higher monthly operating cost

Nine cardinal parameters



Shedding Light on Spectral Quality
Bruce Bugbee
Canadian Greenhouse Conference, Oct 2019

What is our goal?



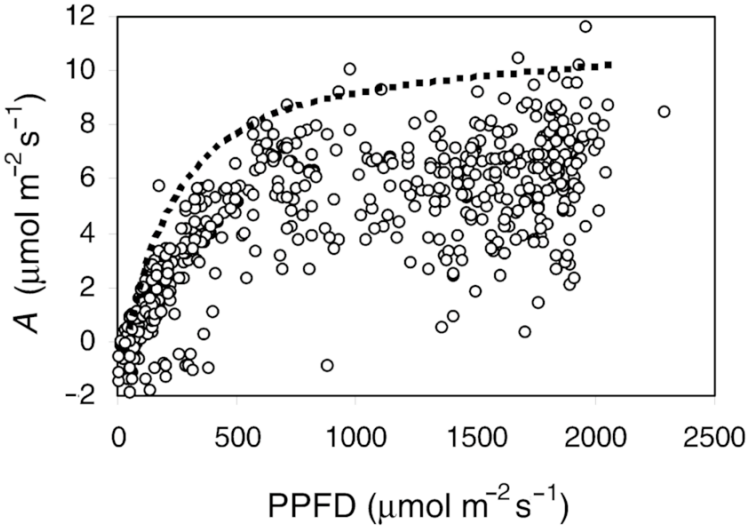
PEAK CARBON METABOLISM ~ 25˚C

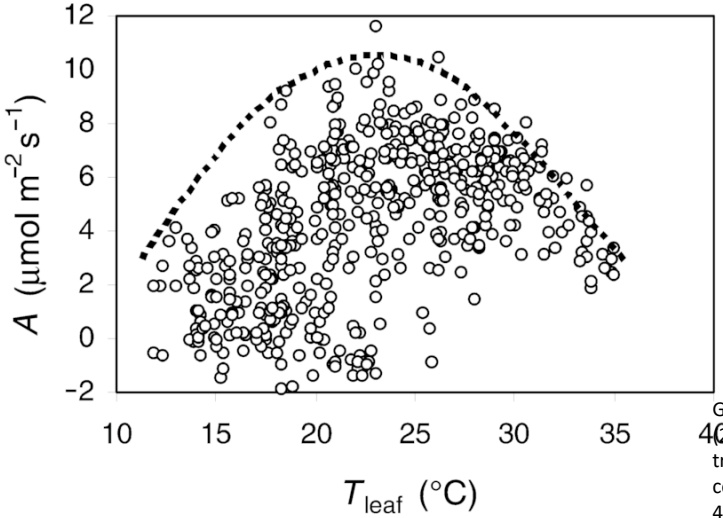
OFF PEAK CARBON METABOLISM

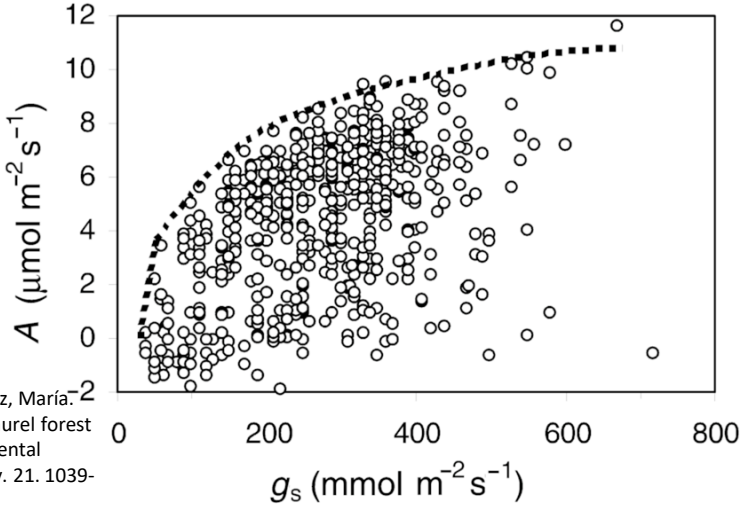
OFF PEAK CARBON METABOLISM

Influences of Leaf Temperature on Photosynthetic Carbon Metabolism in Wheat
John Kobza, Gerald E. Edwards
Plant Physiology Jan 1987, 83 (1) 69-74; **DOI:** 10.1104/pp.83.1.69

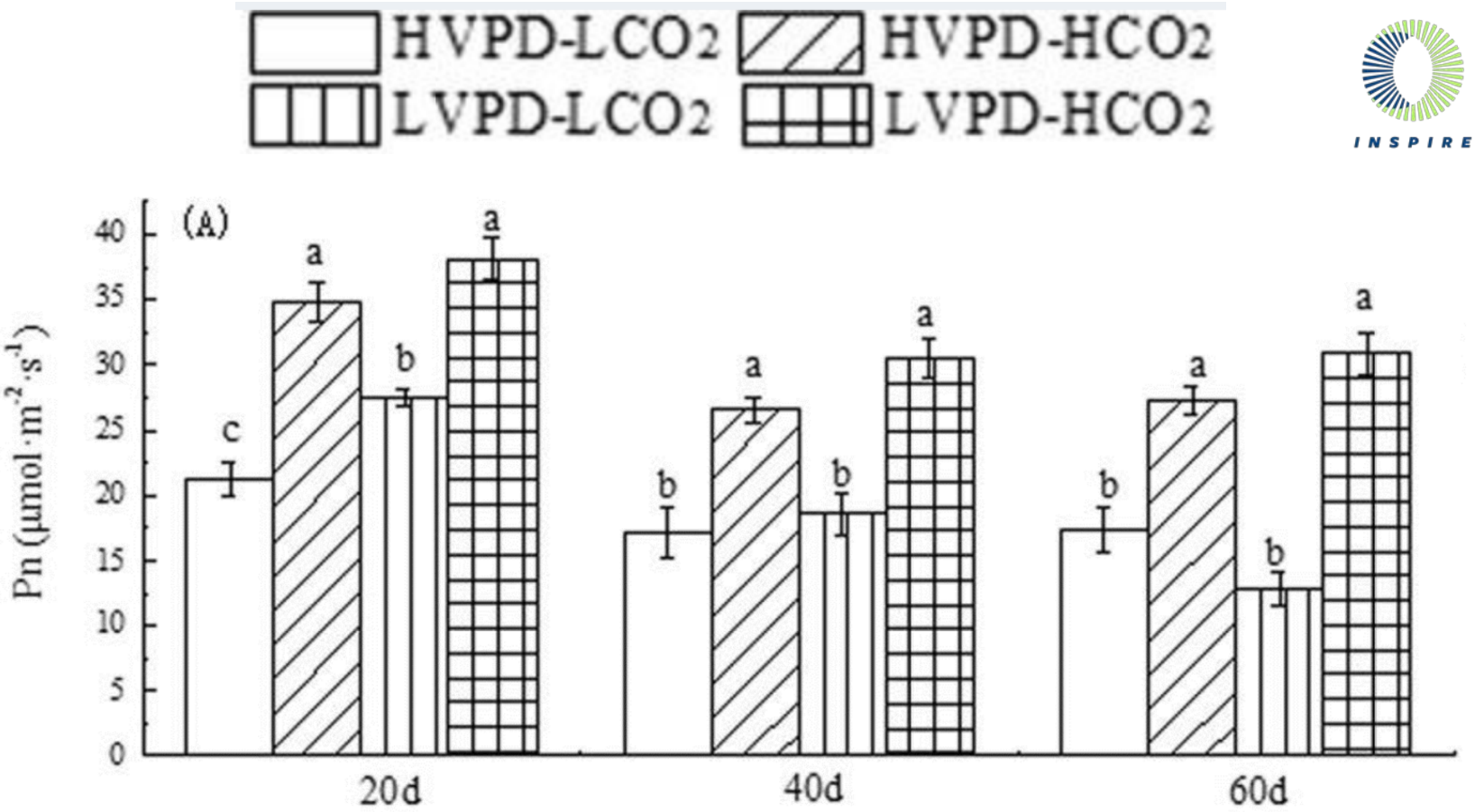
What are our ways of maximizing carbon assimilation?



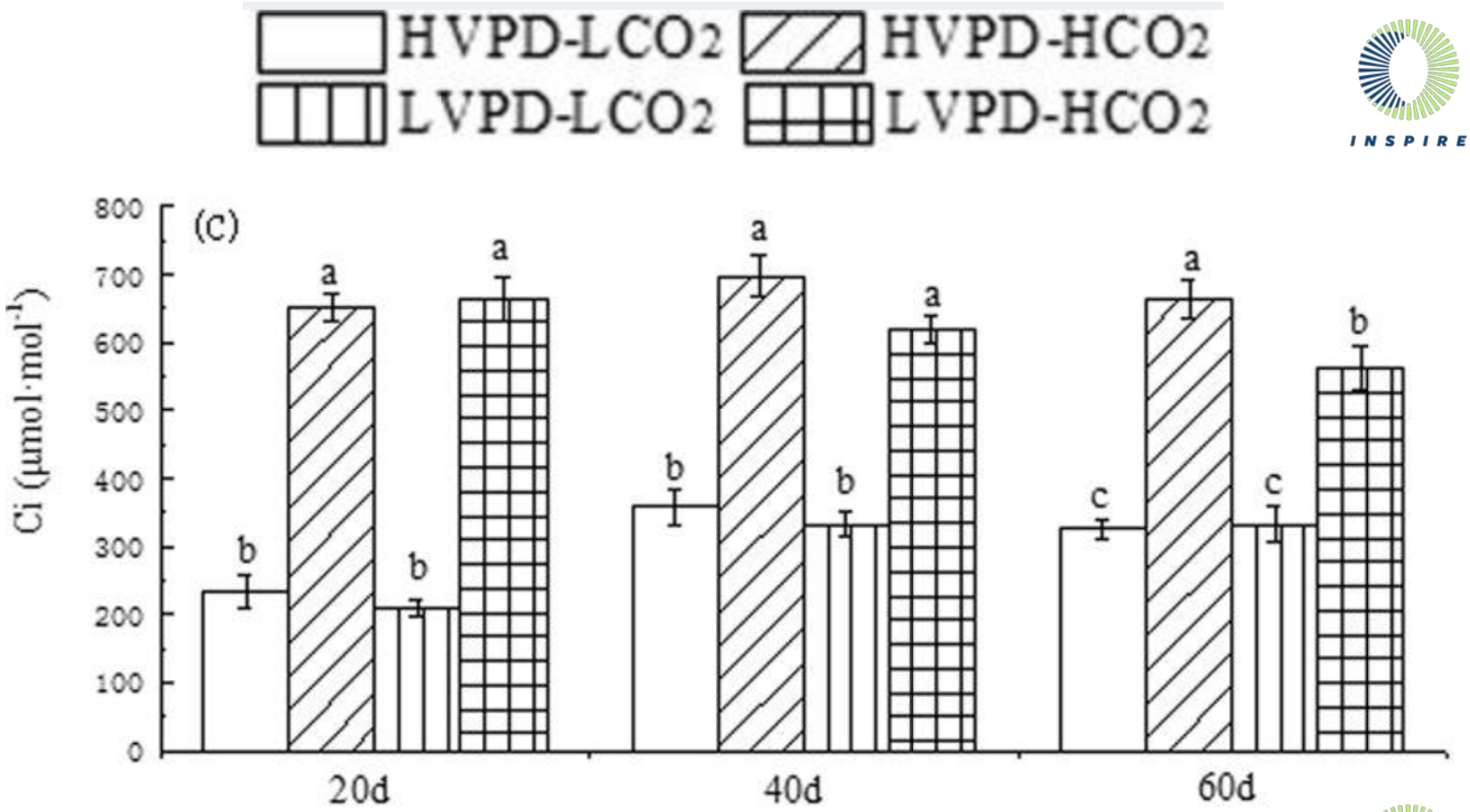




González-Rodríguez, Agueda & Morales, D & Jimenez, María. (2001). Gas exchange characteristics of a Canarian laurel forest tree species (Laurus azorica) in relation to environmental conditions and leaf canopy position. Tree physiology. 21. 1039-45. 10.1093/treephys/21.14.1039.



Jiao XC, Song XM, Zhang DL, Du QJ, Li JM. Coordination between vapor pressure deficit and CO_2 on the regulation of photosynthesis and productivity in greenhouse tomato production. *Sci Rep*. 2019;9(1):8700. Published 2019 Jun 18. doi:10.1038/s41598-019-45232-w



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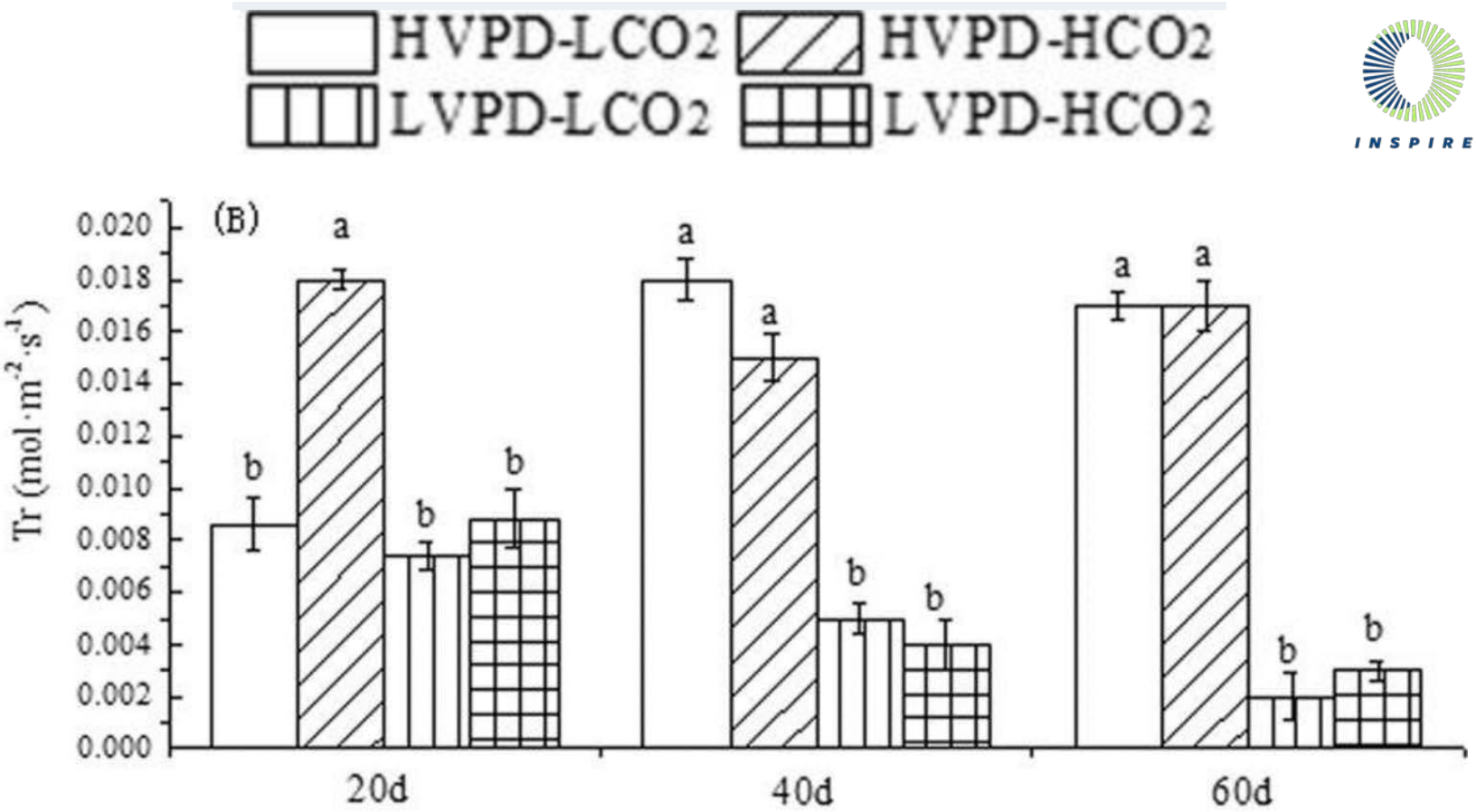

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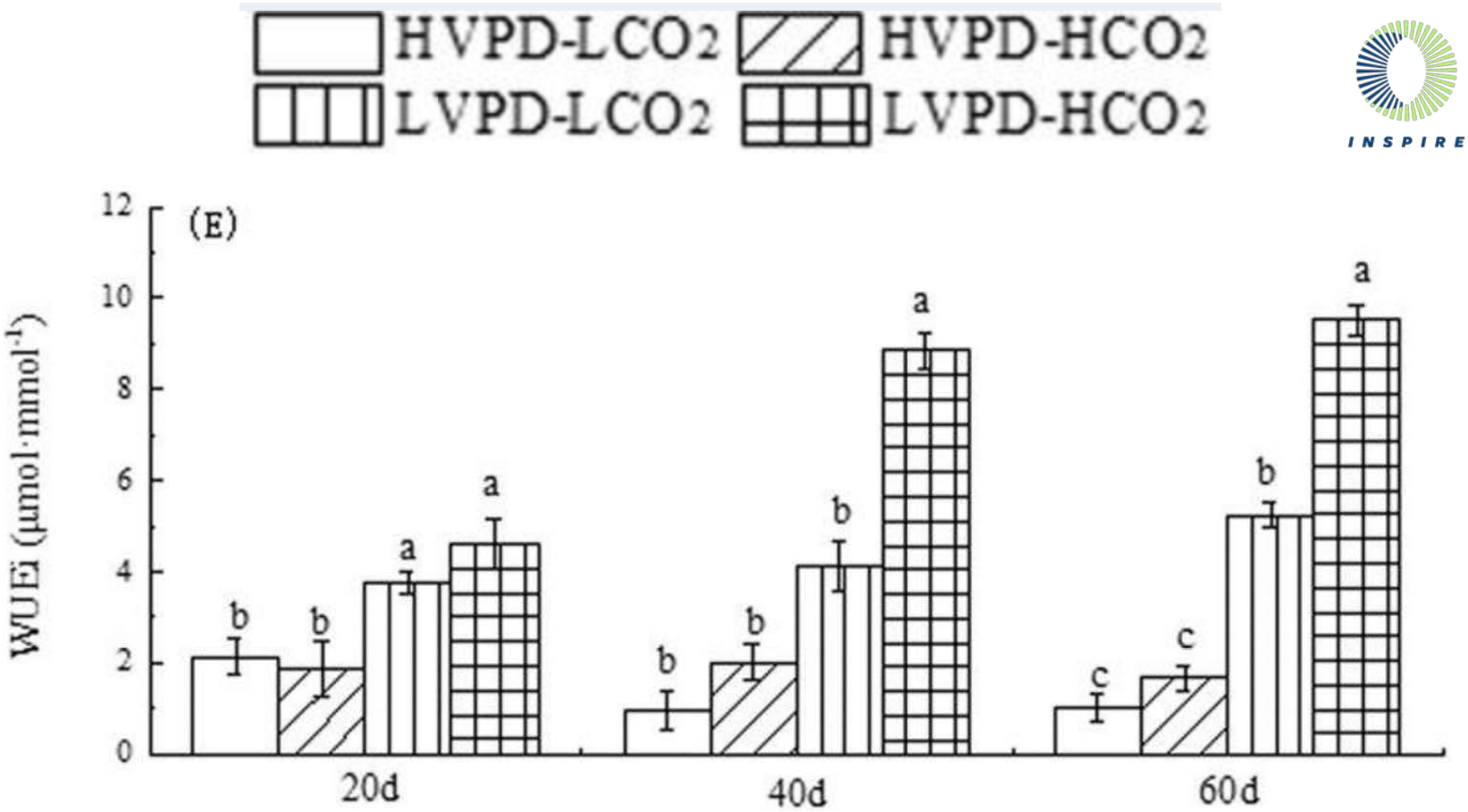

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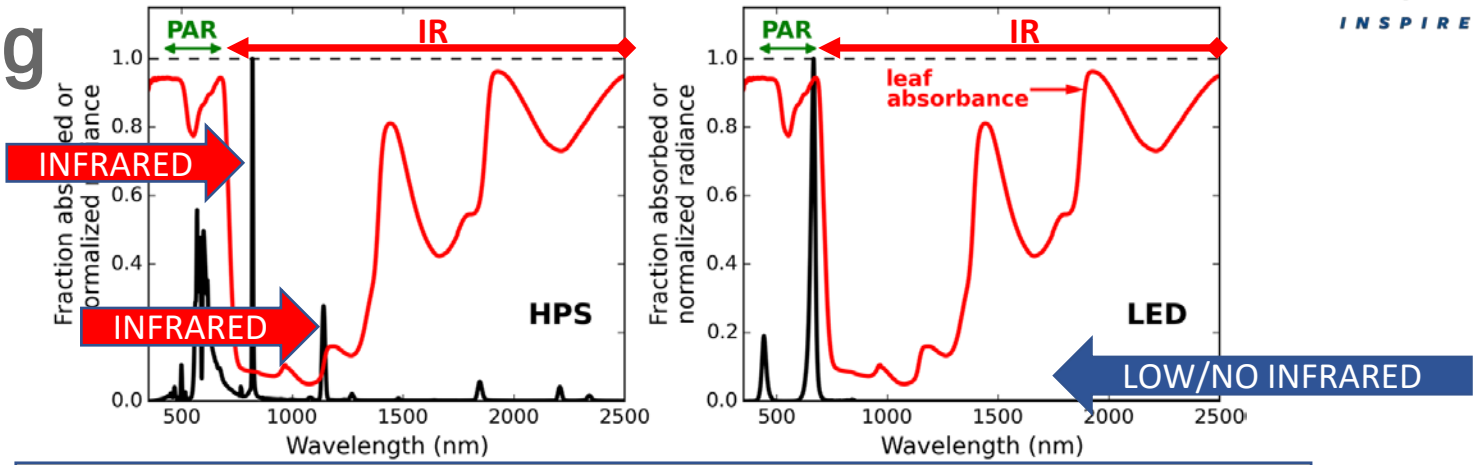
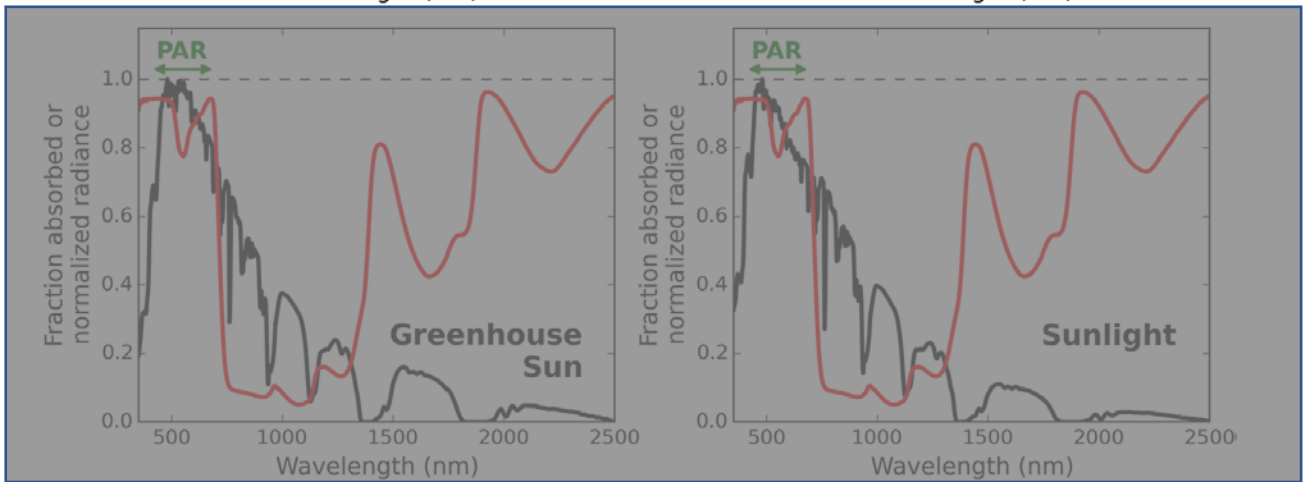
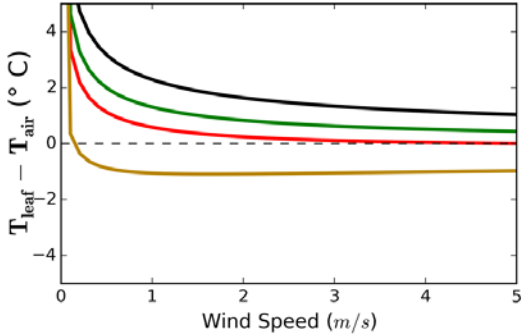
What happens to leaf temperature when using different lighting sources?

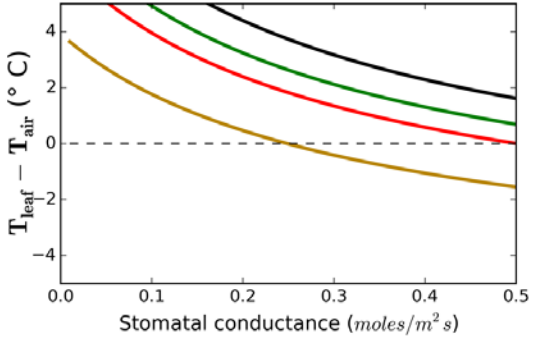


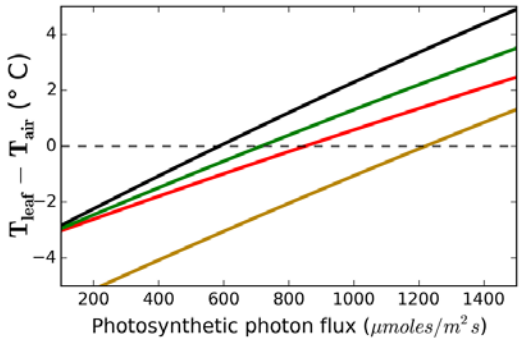


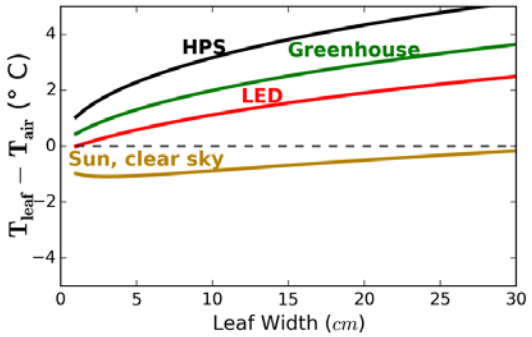
Analysis of Environmental Effects on Leaf Temperature under Sunlight, High Pressure Sodium and Light Emitting Diodes
Nelson JA, Bugbee B (2015) Analysis of Environmental Effects on Leaf Temperature under Sunlight, High Pressure Sodium and Light Emitting Diodes. PLOS ONE 10(10): e0138930. https://doi.org/10.1371/journal.pone.0138930

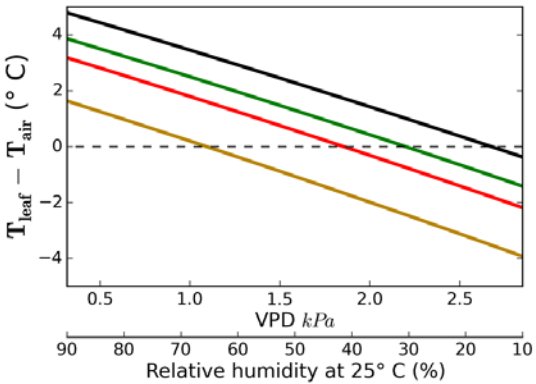
How do we maximize metabolism via leaf temperature control?











Default parameters:

Stomatal conductance	= 0.4 $moles/m^2 s$
Wind speed	= 1.0 m/s
Leaf width	= 5 cm
Relative humidity	= 50%
Air temp	= 25 ° C
Vapor pressure deficit	= 1.6 kPa
Photosynthetic photon flux (PPF)	=1000 $\mu moles/m^2 s$

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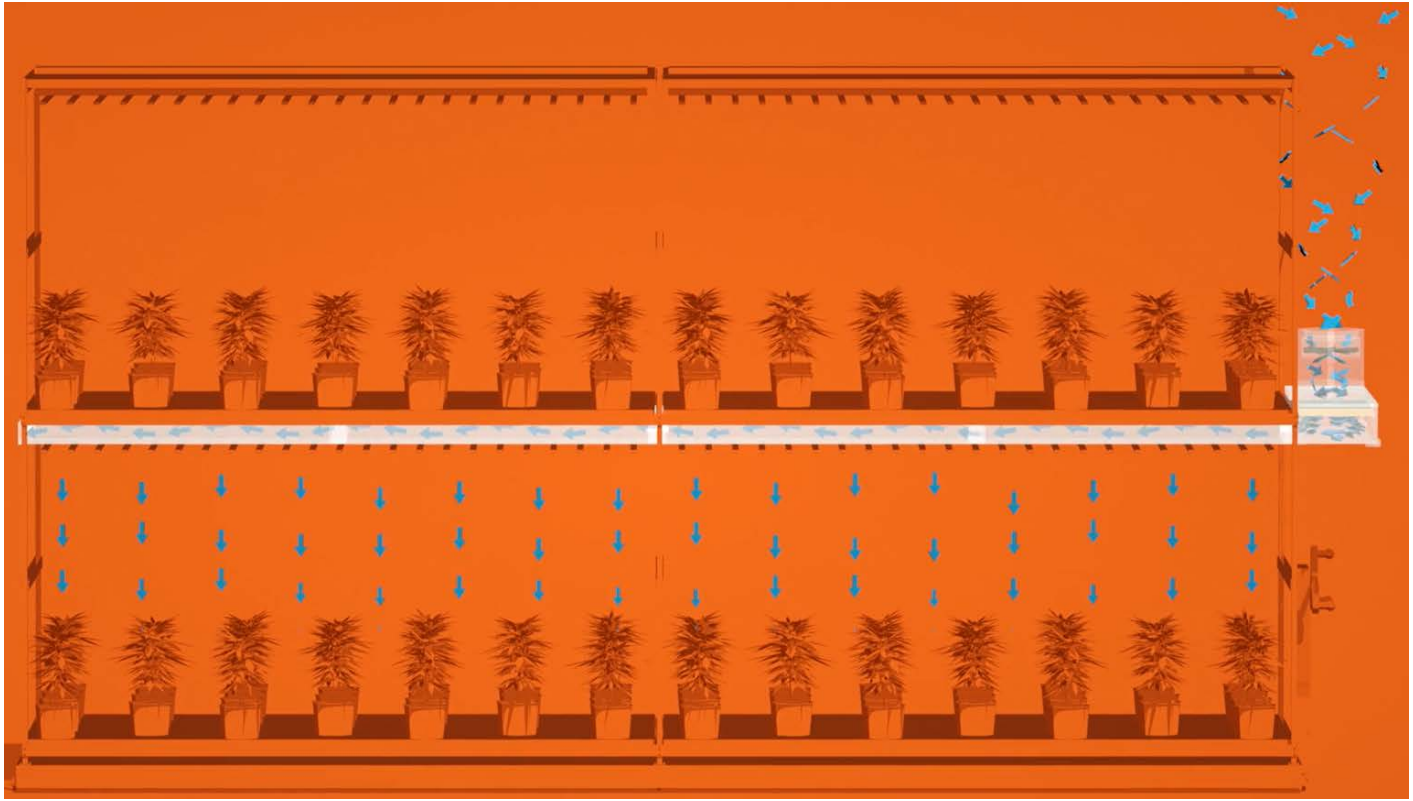
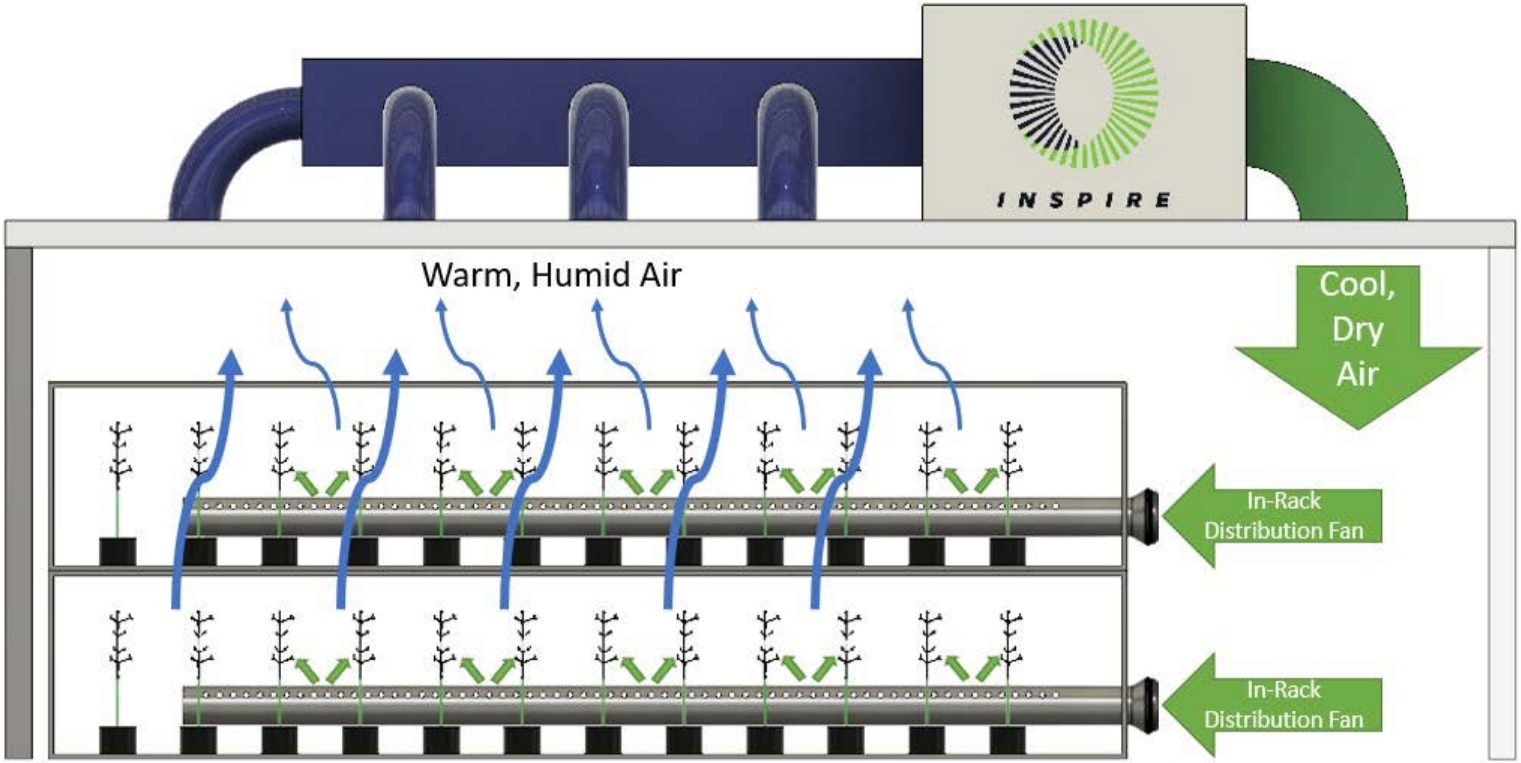
When we know the variables, how can we control the plants?

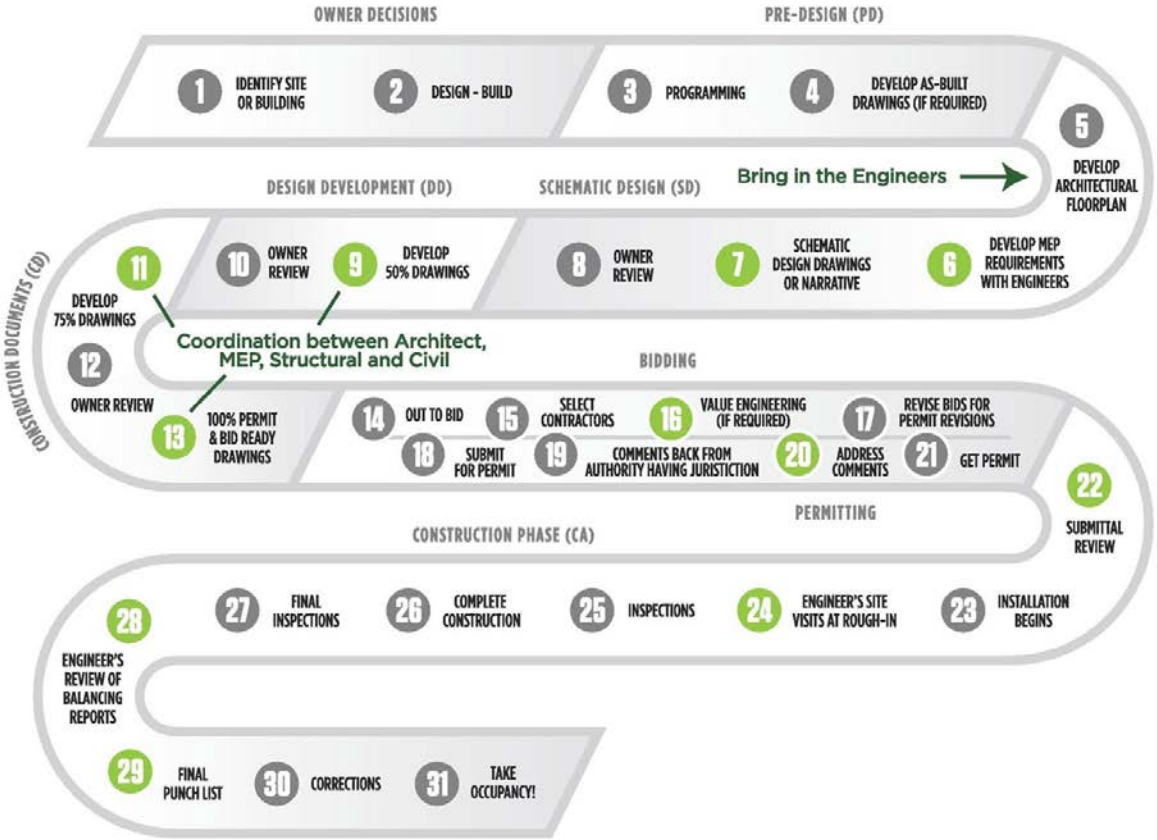



INSPIRE
Warm, Humid Air
Cool, Dry Air
In-Rack Distribution Fan
In-Rack Distribution Fan

Establishing a Team of Experts

- Owner, cultivation team, architects, engineers, designers, contractors, commissioning agents
- Engage early and often to avoid timely and costly mistakes
- Understand roles and responsibilities
- An integrated design team can:
  - Answer critical questions early on in the design process
  - Ensure code requirements are satisfied
  - Maximize operational efficiency
  - Lower costs

Typical Project Flow



Pre-Design Phase Considerations

- HVAC performance = process performance
  - Temperature
  - Humidity
- Up-front costs vs. long term costs
  - System popularity
  - Long term cost effectiveness

Pre-Design Phase Considerations

- Community and local impacts
  - Noise
  - Odors
- Energy efficiency
- Regulatory/utility considerations
  - Codes
  - Utility Incentives

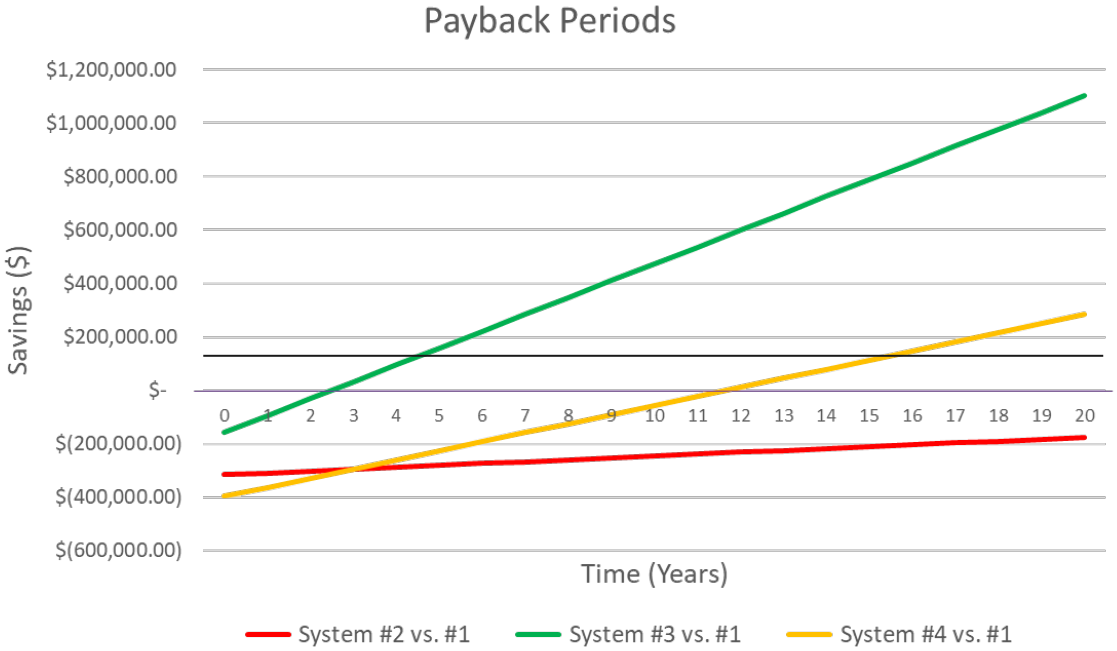
Key take-away: There is no one size fits all system

Balancing Efficiency & Cost

System #2: Doesn't pay back

System #3: Payback = 3 years

System #4: Payback = 12 years



root ENGINEERS

Construction, Permitting and Commissioning

- Engage the right team early & often
- Understanding permitting requirements, permitting setbacks can be very impactful to your project timeline and budget
- Commissioning allows your facility to better achieve energy performance and ensures that you are getting what you paid for
- Systems do more than just run, they run as they were specified to run

root ENGINEERS