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WEBINAR SERIES

THE ENERGY EFFICIENCY OPPORTUNITY FOR INDOOR AGRICULTURE

June 17, 2020

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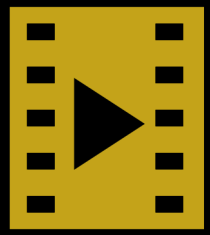
THE ENERGY EFFICIENCY OPPORTUNITY FOR INDOOR AGRICULTURE

Housekeeping

We will respond to questions after the presentation in Q&A

You'll get the slides via email after the webinar



You'll get a recording of the webinar within 24h

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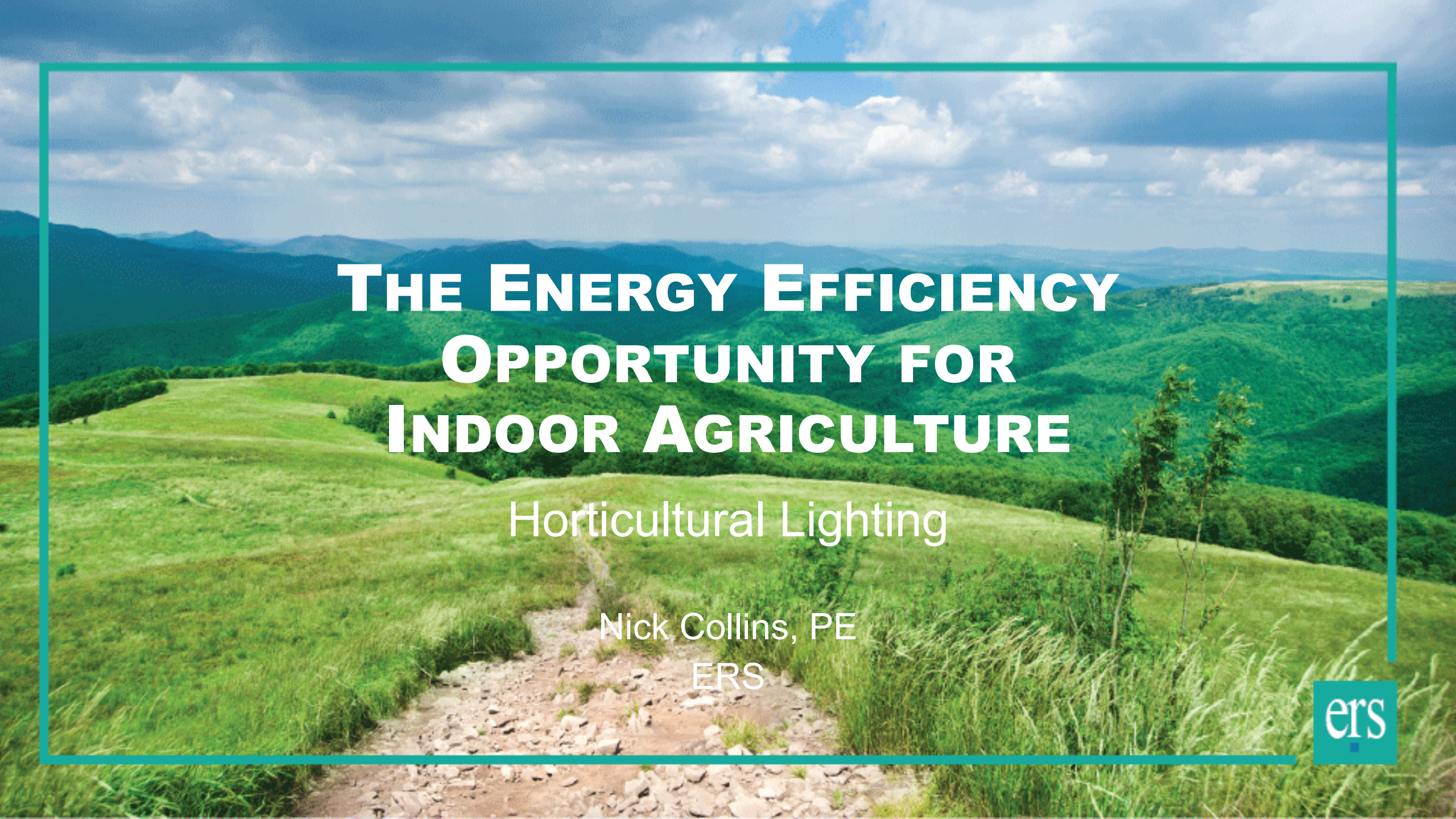

The Energy Efficiency Opportunity for Indoor Agriculture

Horticultural Lighting

Nick Collins, PE
ERS

Agenda

1. Introduction
2. Horticultural Process Overview
3. Horticultural Lighting
4. LED Impacts on Growing

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Horticultural Process Overview

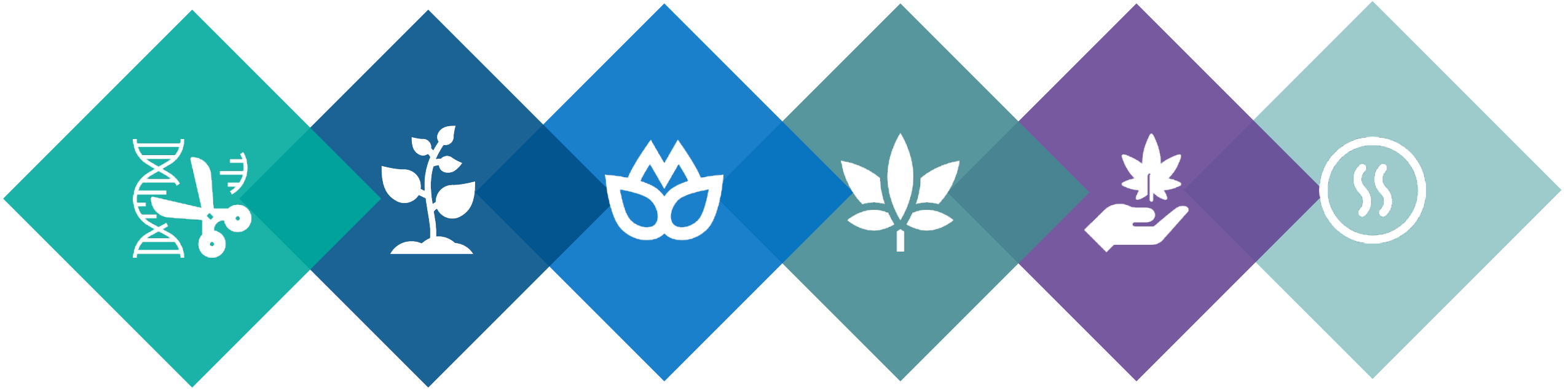
- Plant Requirements
- Energy Consumption

It's a Plant

What drives production?

- Light
- Environmental conditions
- Water
- Nutrients and CO_2

GROW CYCLE



Germination or cloning

Seedlings

Vegetative

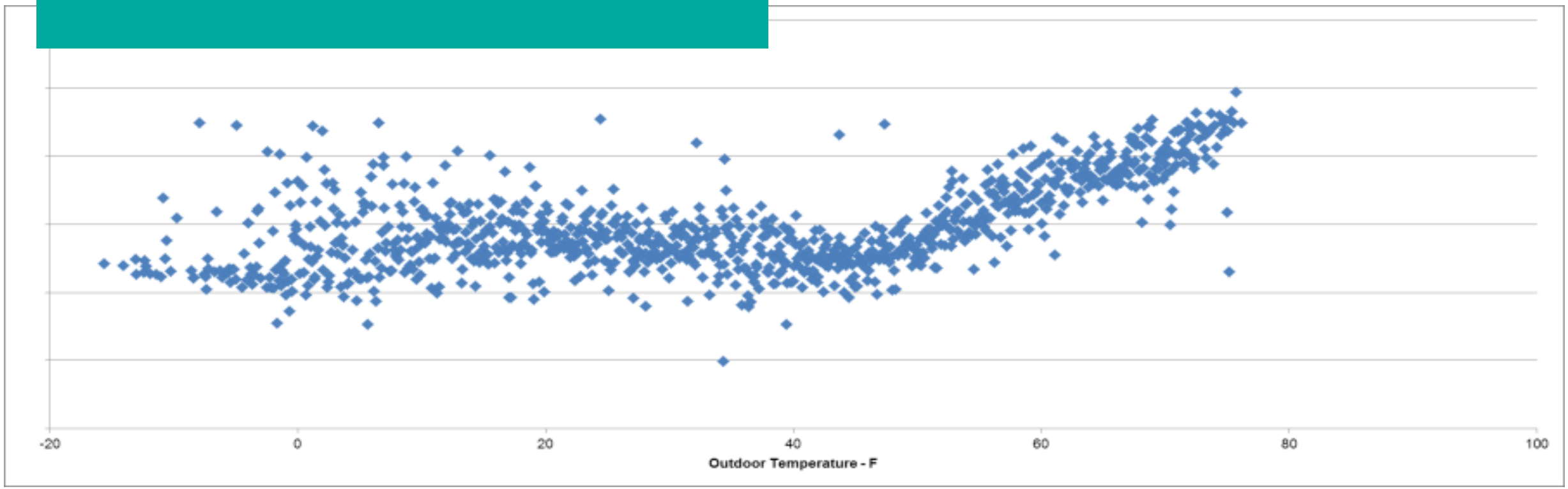
Flowering/ Fruiting

Harvest

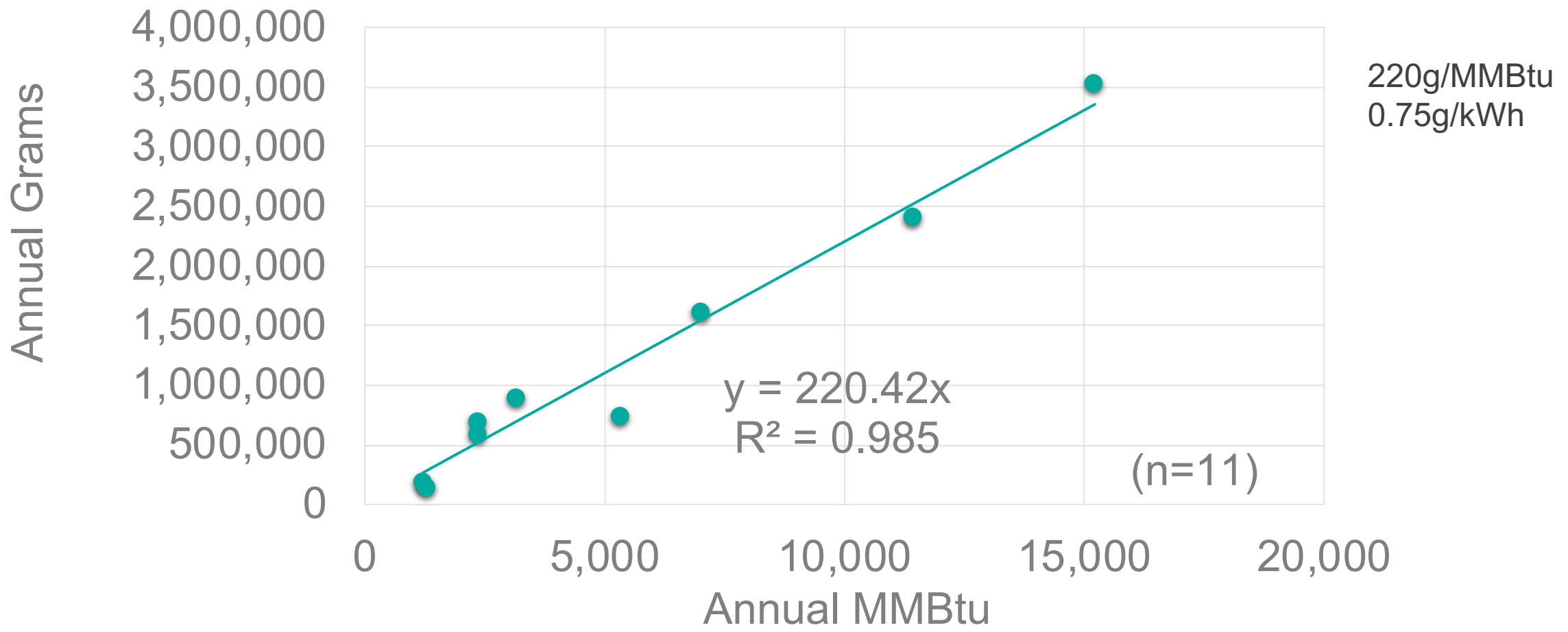
Processing

ENERGY CONSUMPTION

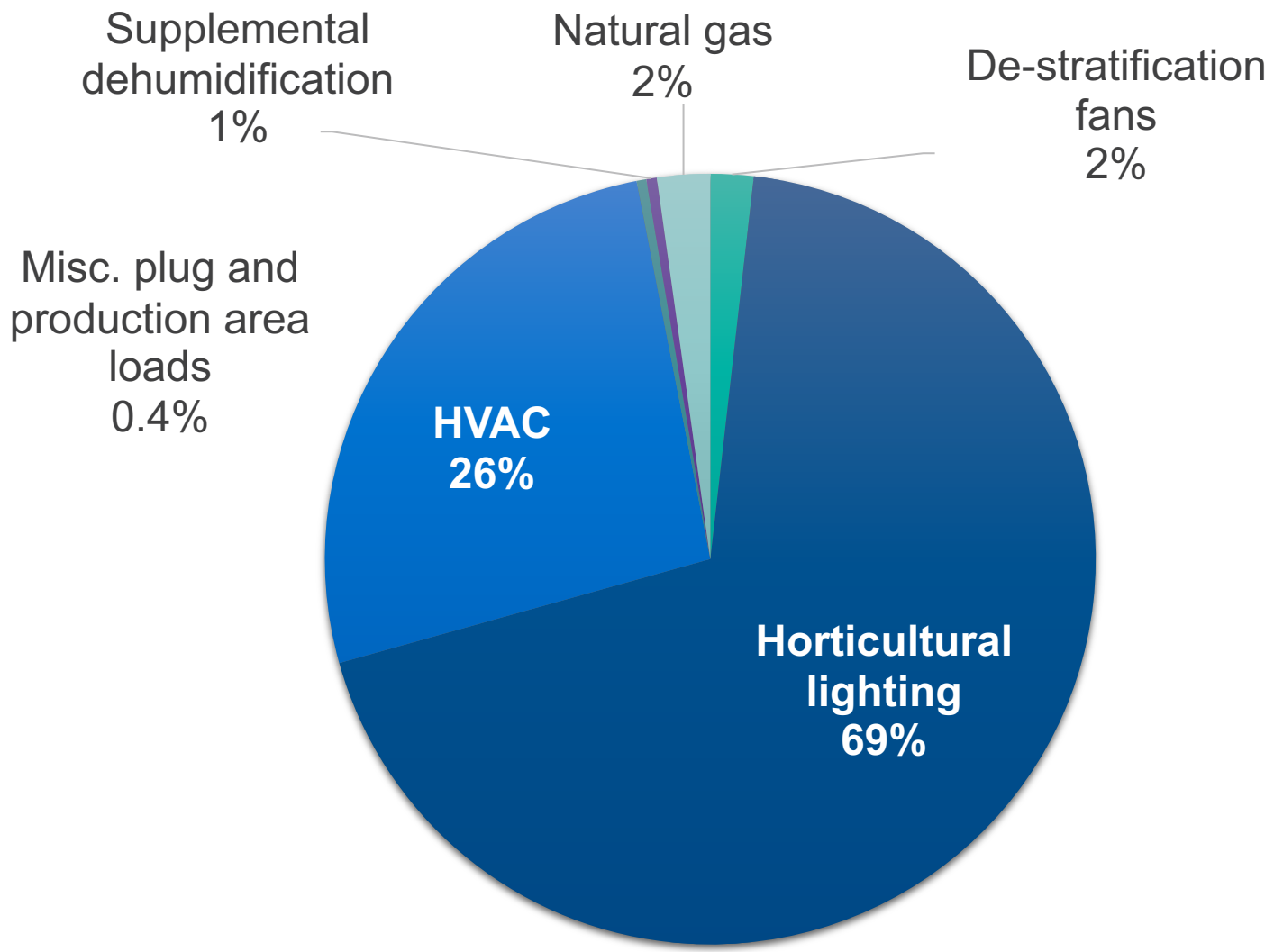
- End Uses
- Load Shapes



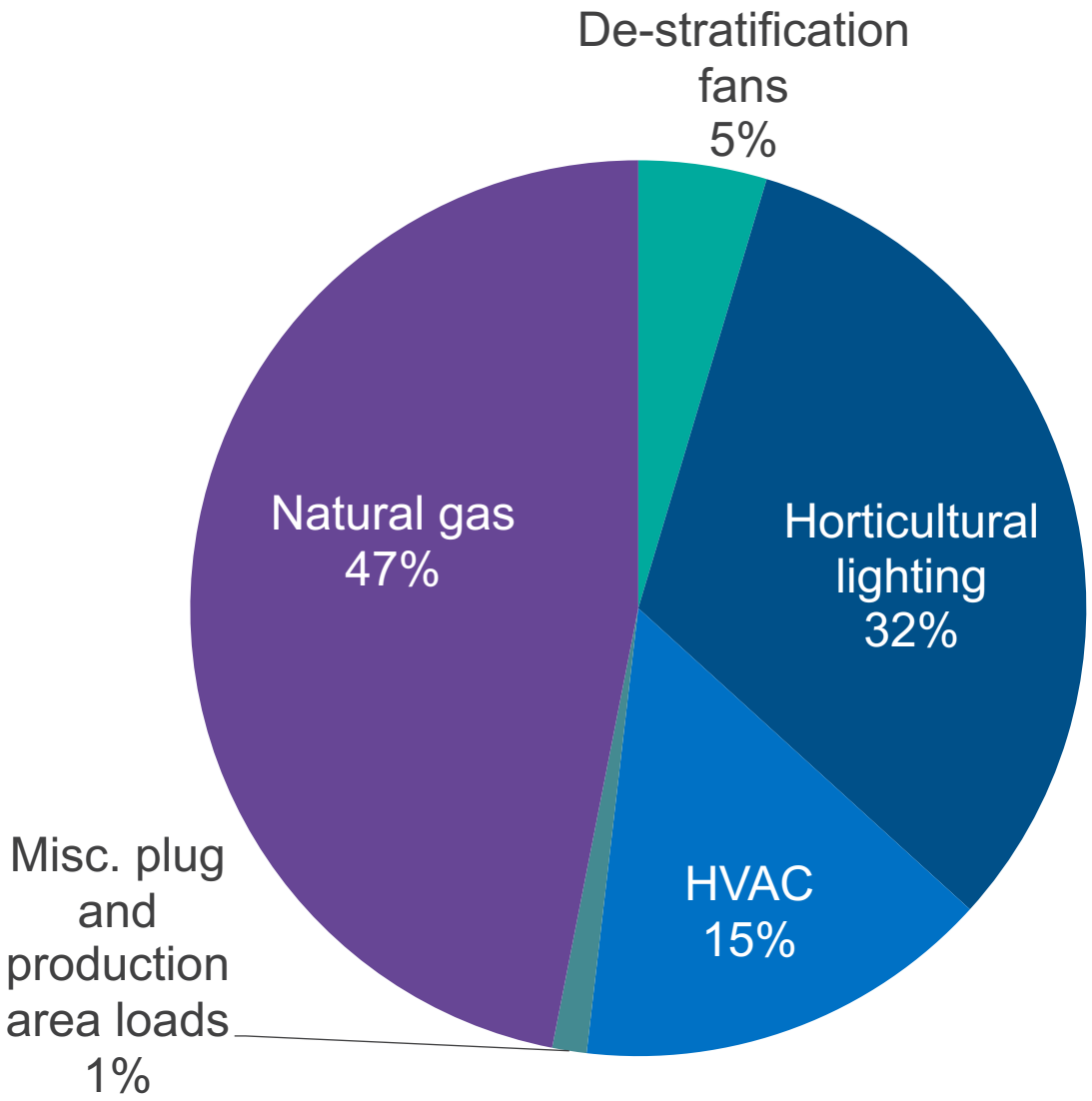
CANNABIS ENERGY INTENSITY



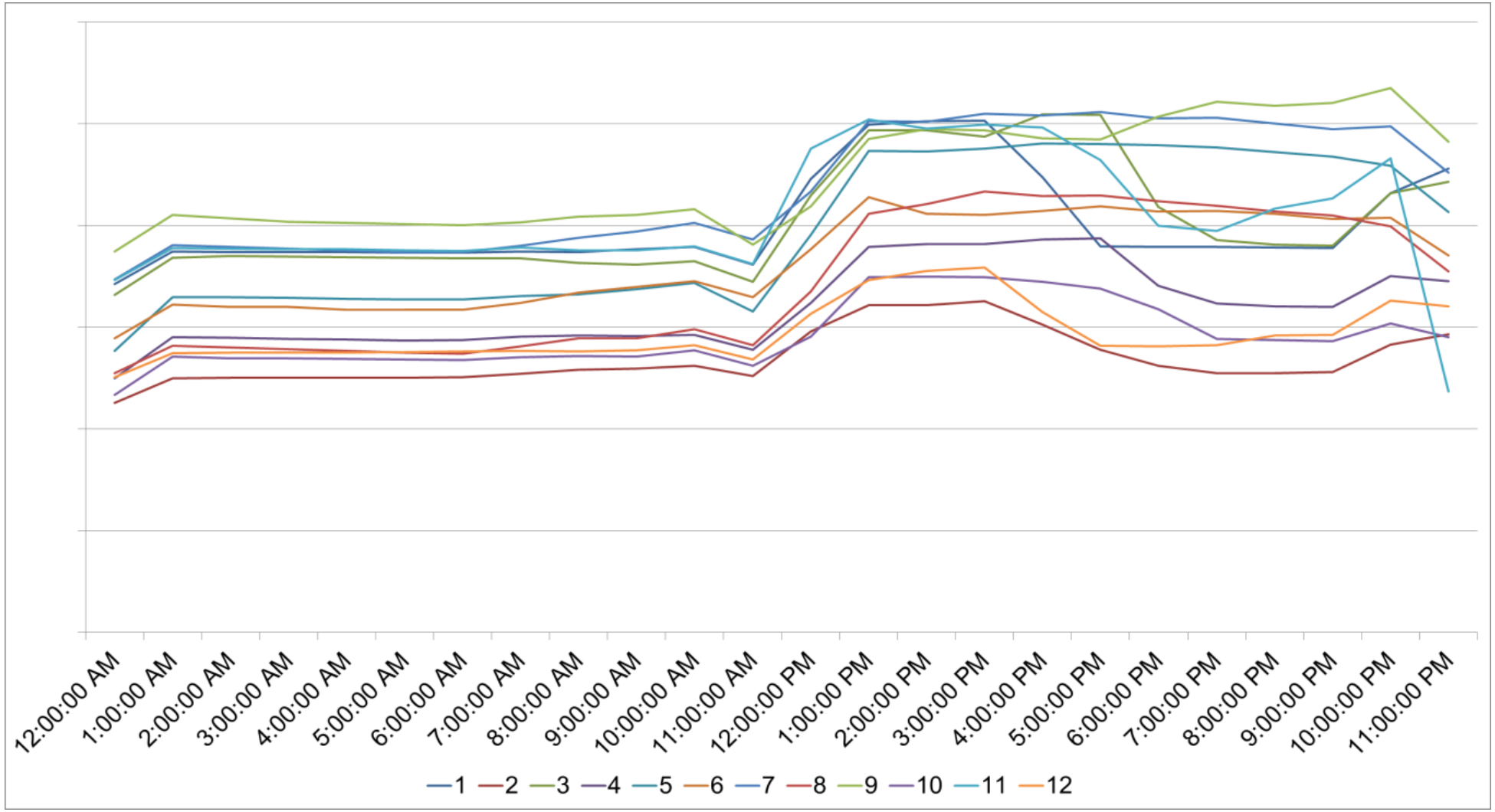
END USES – INDOOR



END USES – GREENHOUSE



LOAD SHAPES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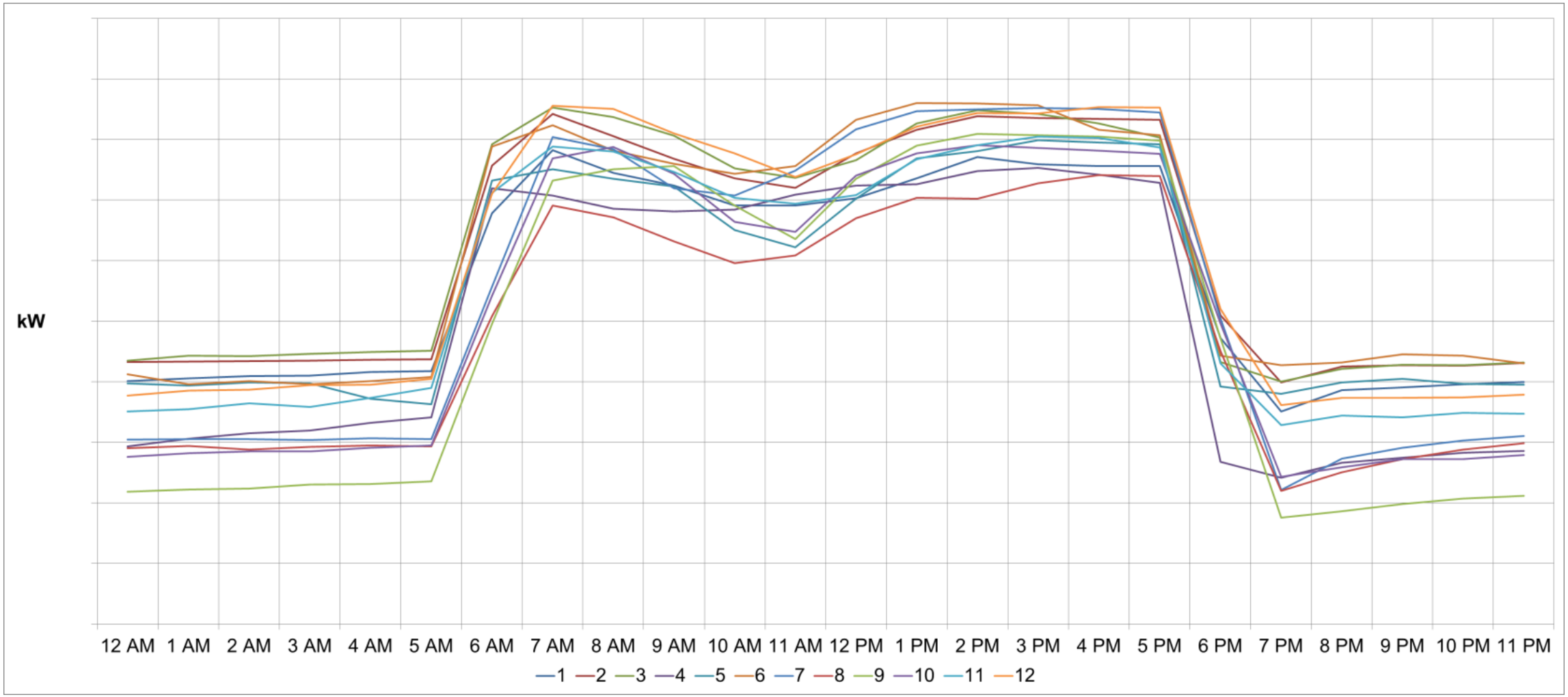
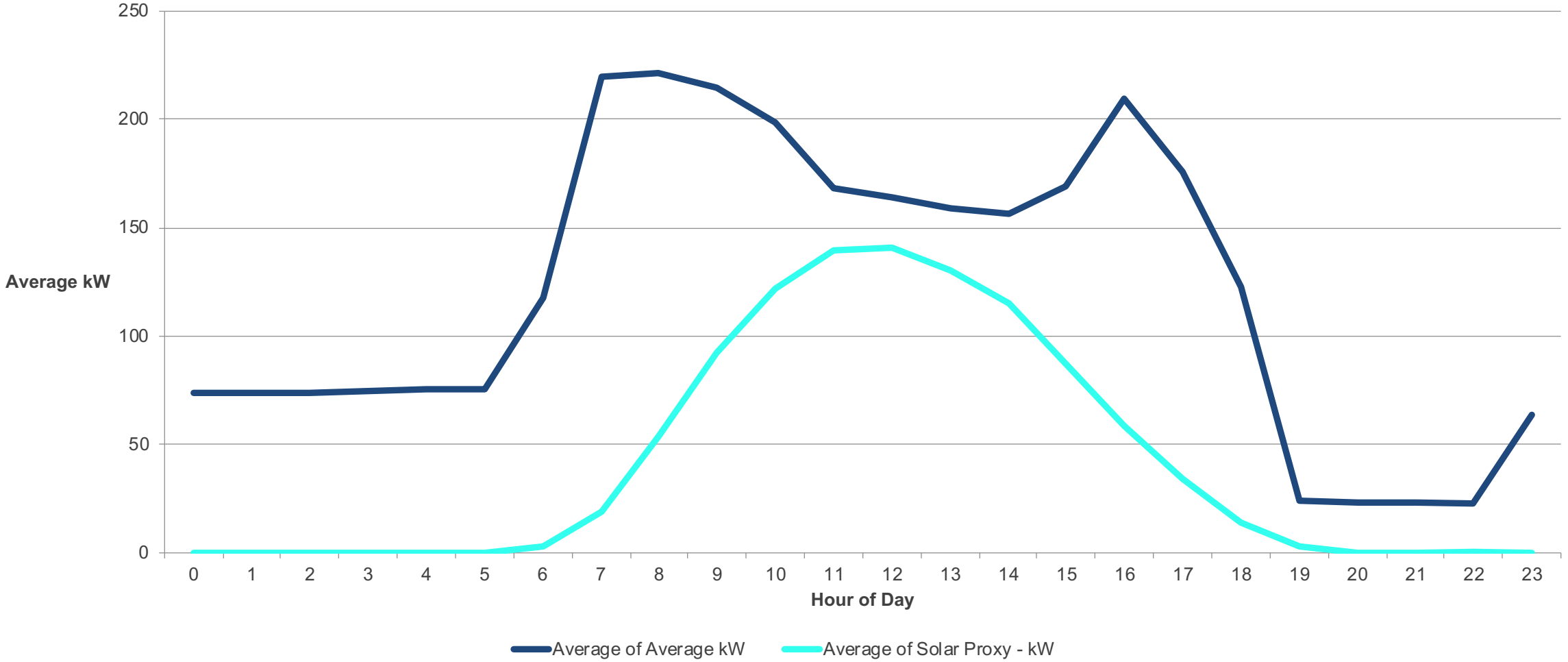
LOAD SHAPES

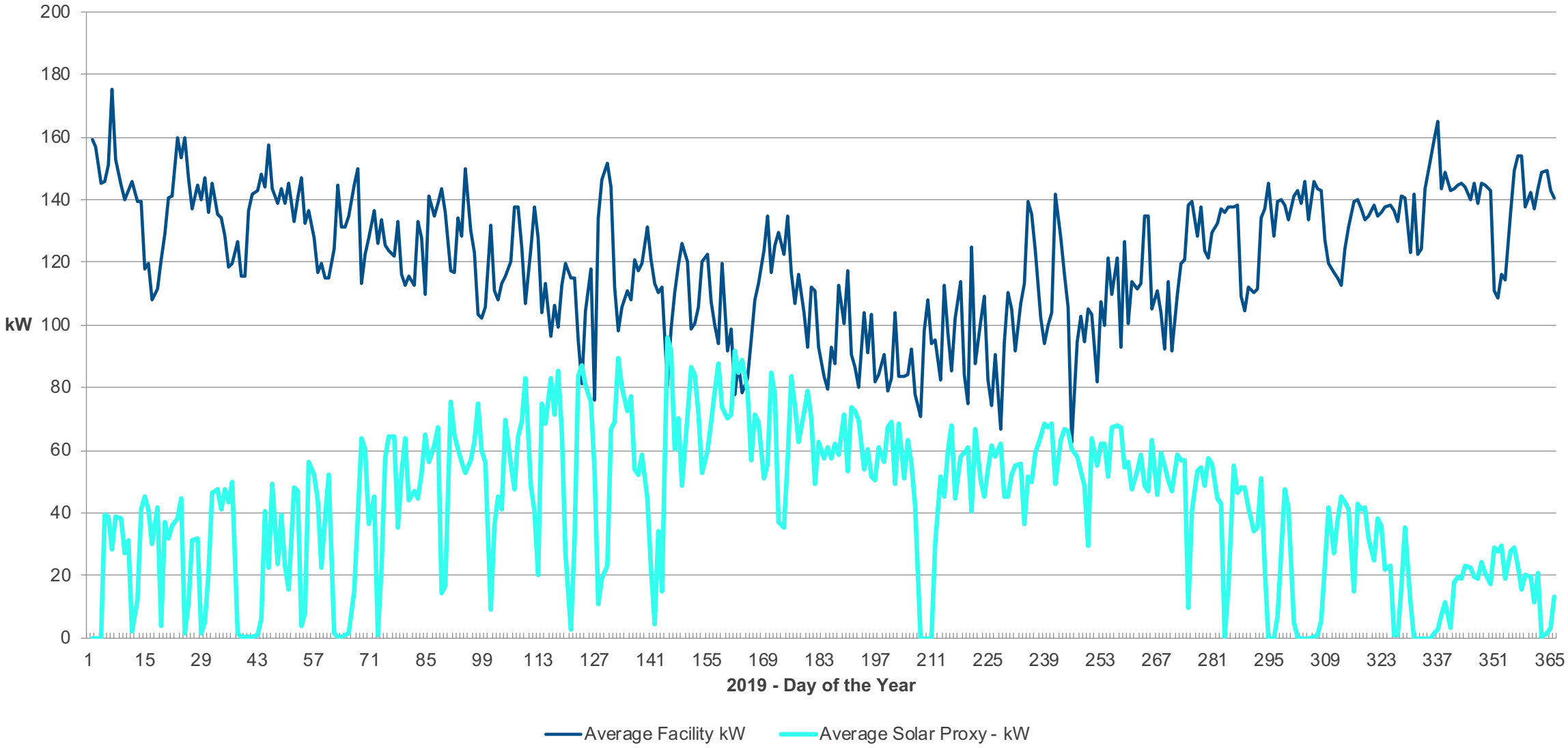


Concurrent Flower Rooms

LOAD SHAPES


250
200
150
100
50
0
Average kW
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of Day
Average of Average kW
Average of Solar Proxy - kW

LOAD SHAPES


200
180
160
140
120
kW 100
80
60
40
20
0
1
15
29
43
57
71
85
99
113
127
141
155
169
183
197
211
225
239
253
267
281
295
309
323
337
351
365
2019 - Day of the Year
Average Facility kW
Average Solar Proxy - kW

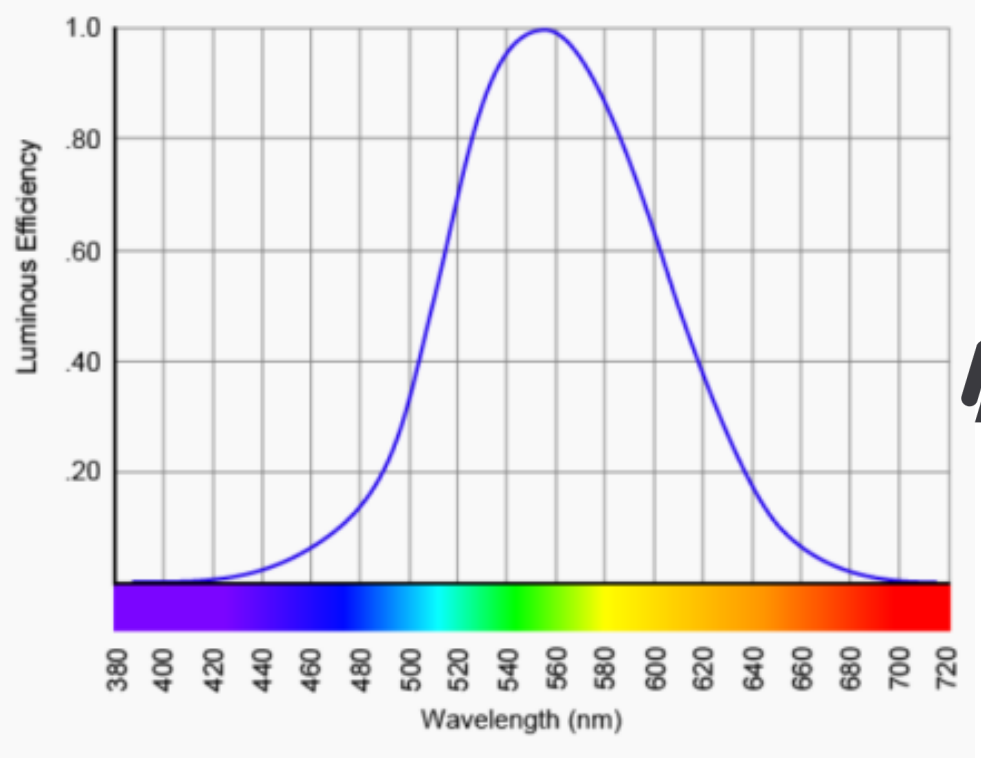
Horticultural Lighting

- Technologies
- Metrics
  - PAR
  - PPF
  - PPFD
  - PPE

LIGHTING TECHNOLOGIES

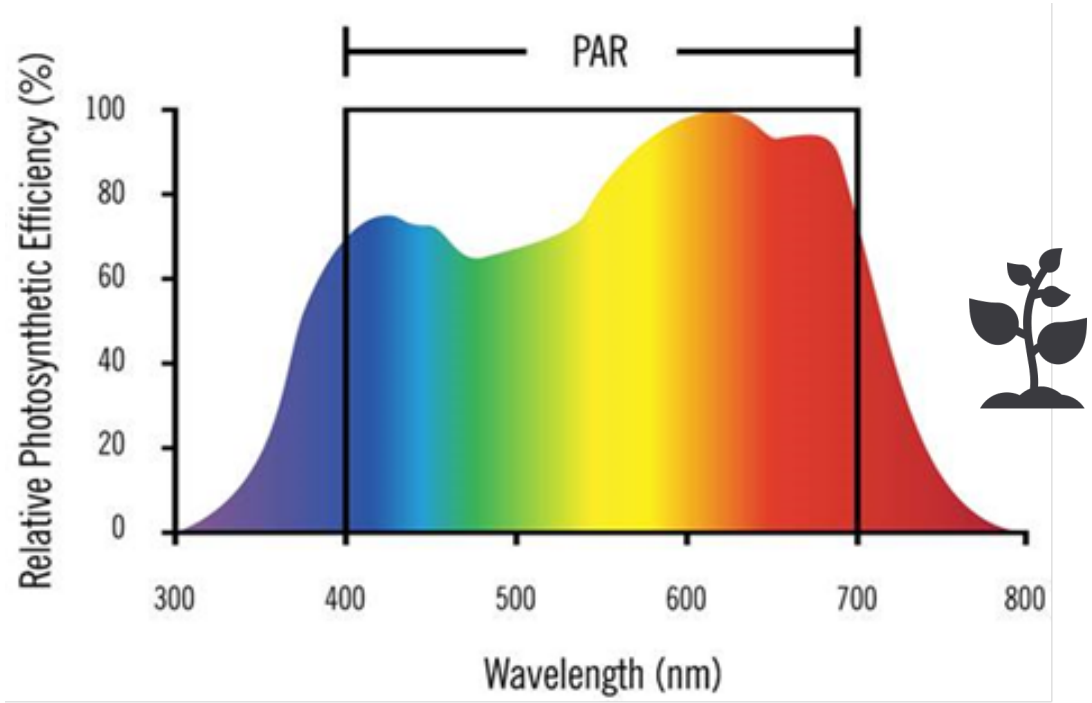
HORTICULTURAL LIGHTING METRICS

Visible light (400 nm to 700)



Visible light is weighted

PAR – Photosynthetic active radiation (400 nm to 700 nm)



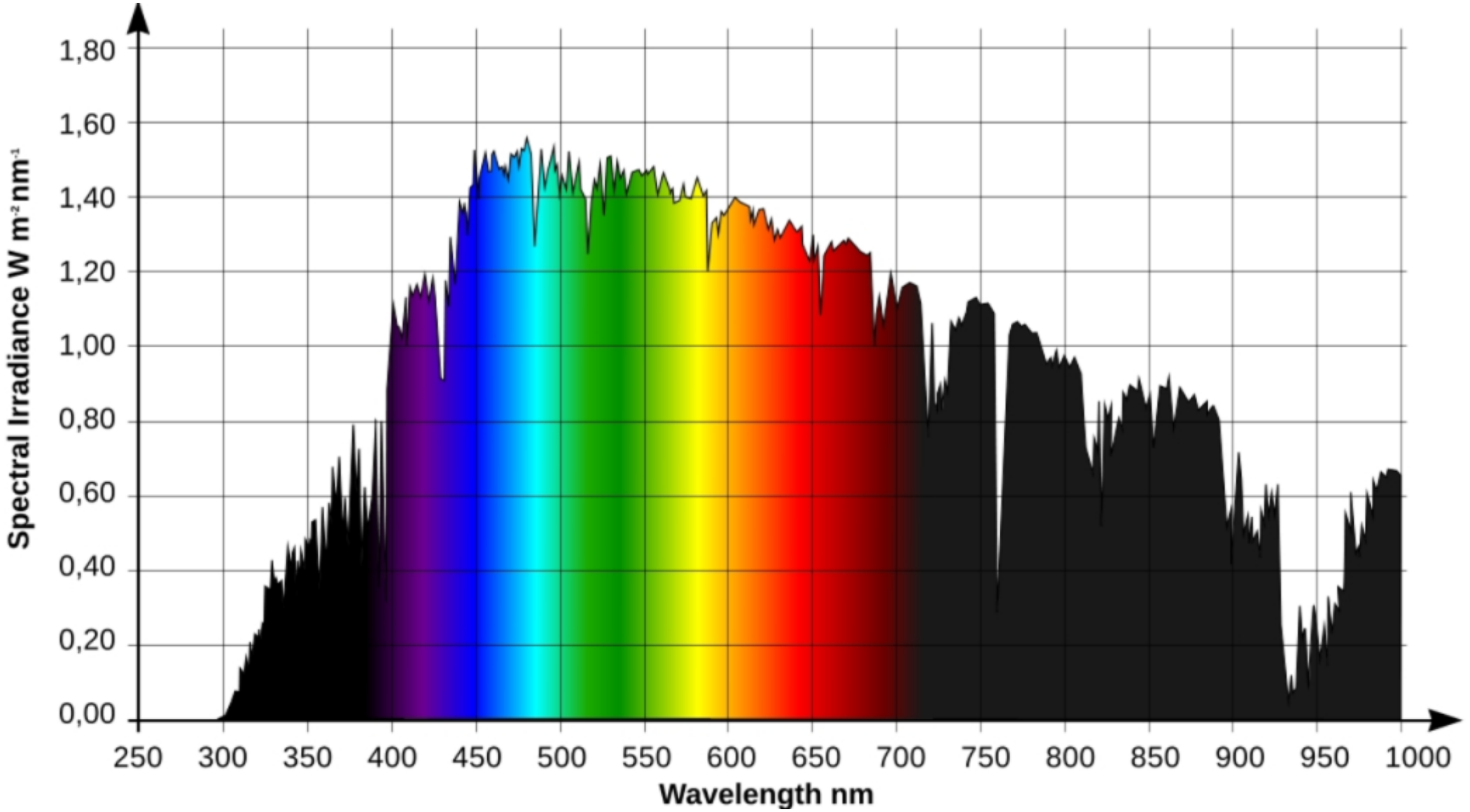
PAR is not typically weighted

HORTICULTURAL LIGHTING METRICS

Property	Visible Light Spectrum	PAR Spectrum
Fixture Output (photons)	Lumens	PPF – Photosynthetic photon flux (µMol/s) 400-700nm
Light Intensity (photons per area)	Footcandles or Lux	PPFD – Photosynthetic photon flux density (µMol/s/m^2)
Efficacy (photons per input power)	Lumens/Watt	PPE – Photosynthetic photon flux efficacy (µMol/J)

Bad slang: micromoles

COMPARISON OF SPECTRUM OUTPUT: DAYLIGHT

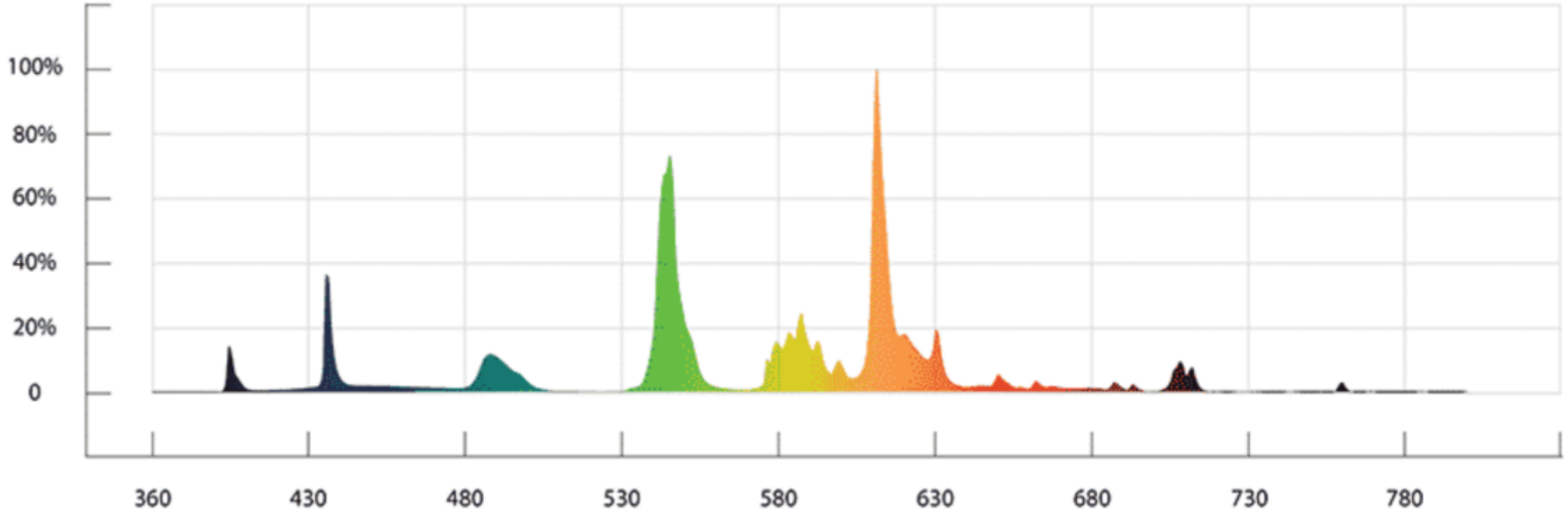


COMPARISON OF PHOTOMETRIC OUTPUT: FLUORESCENT

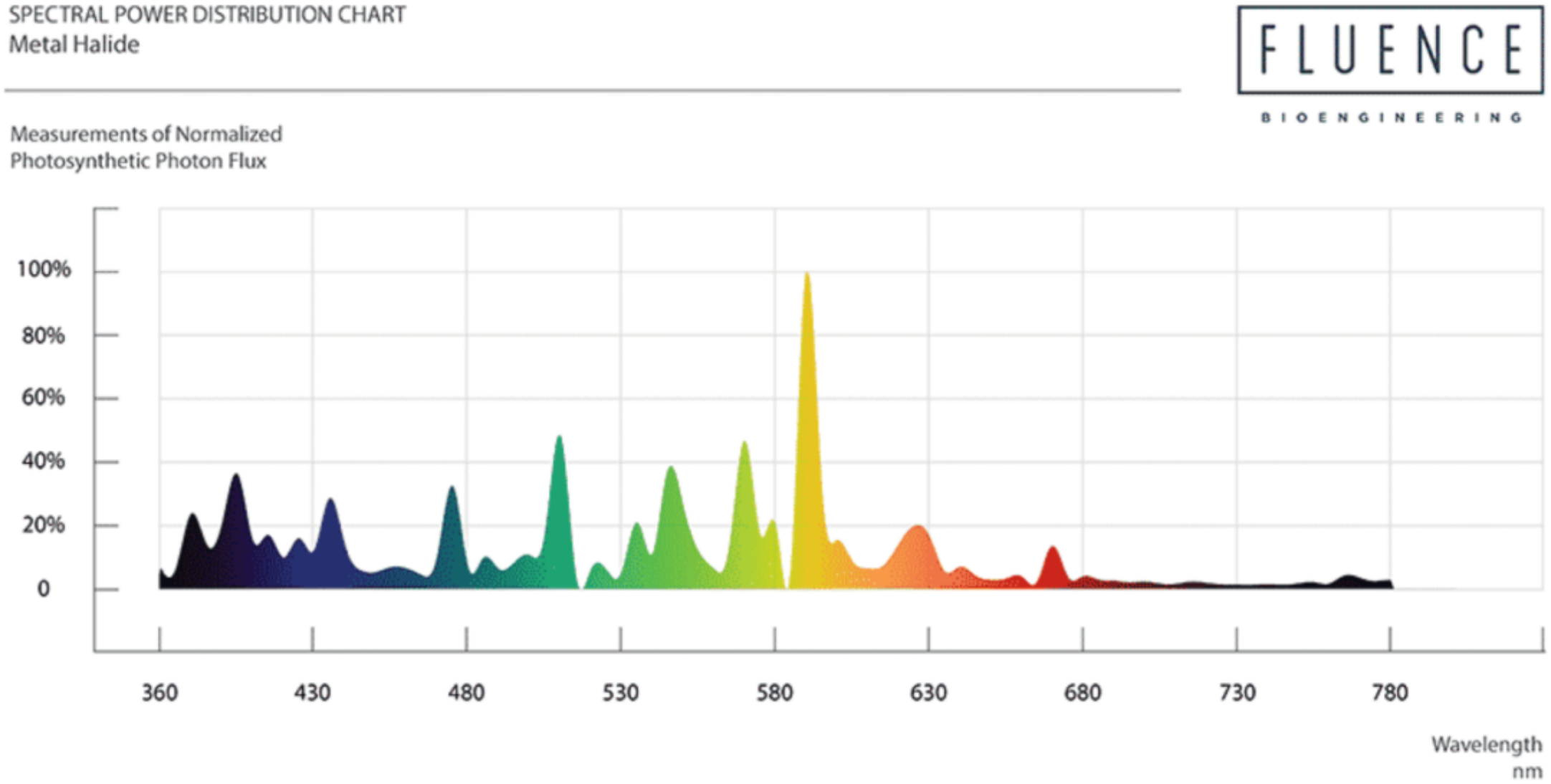
SPECTRAL POWER DISTRIBUTION CHART
T5 Fluorescent

FLUENCE
BIOENGINEERING

Measurements of Normalized
Photosynthetic Photon Flux



COMPARISON OF PHOTOMETRIC OUTPUT: MH

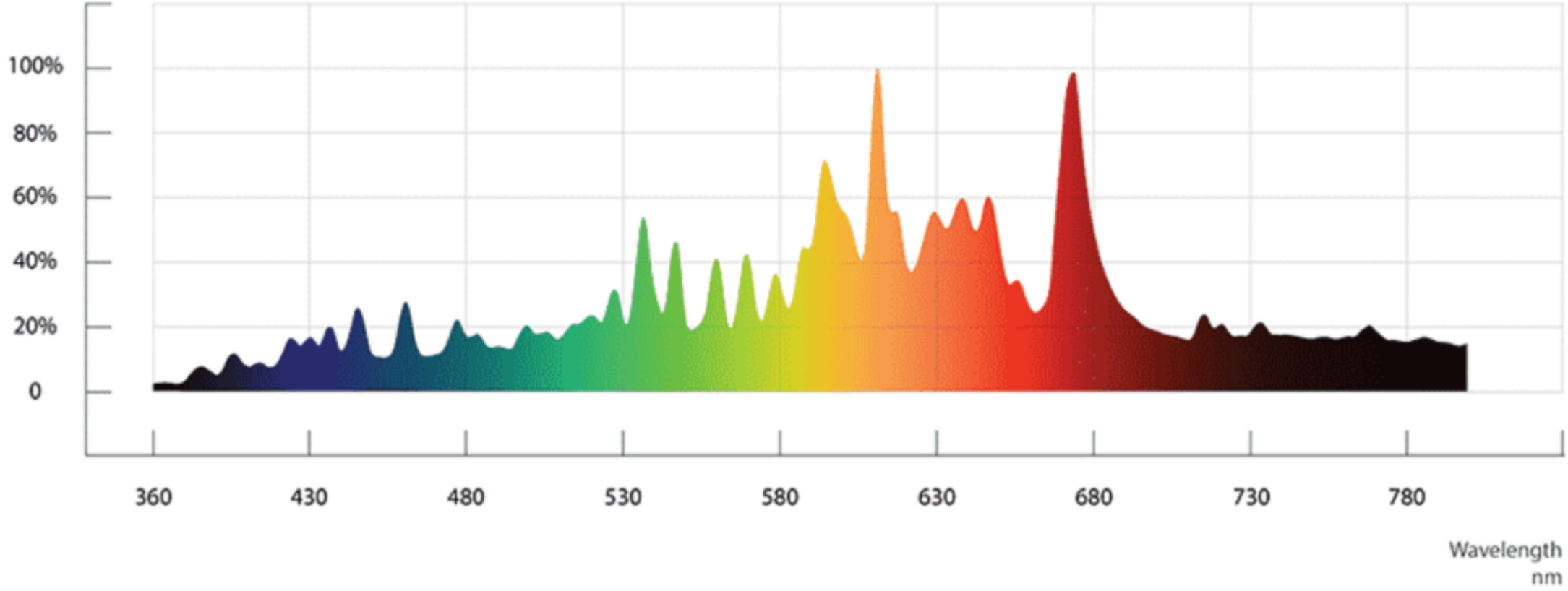


COMPARISON OF PHOTOMETRIC OUTPUT: CMH

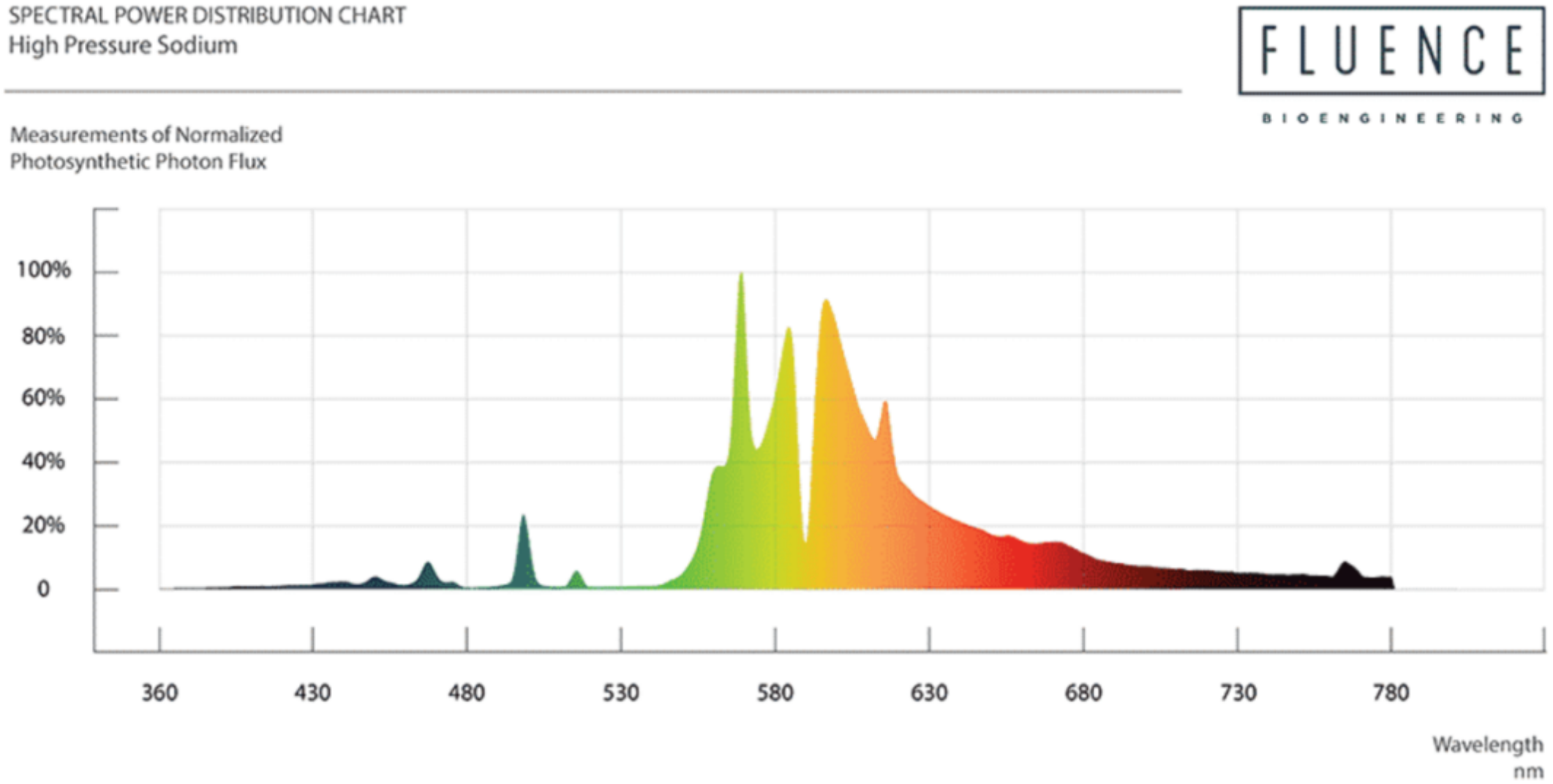
SPECTRAL POWER DISTRIBUTION CHART
Ceramic Metal Halide

FLUENCE
BIOENGINEERING

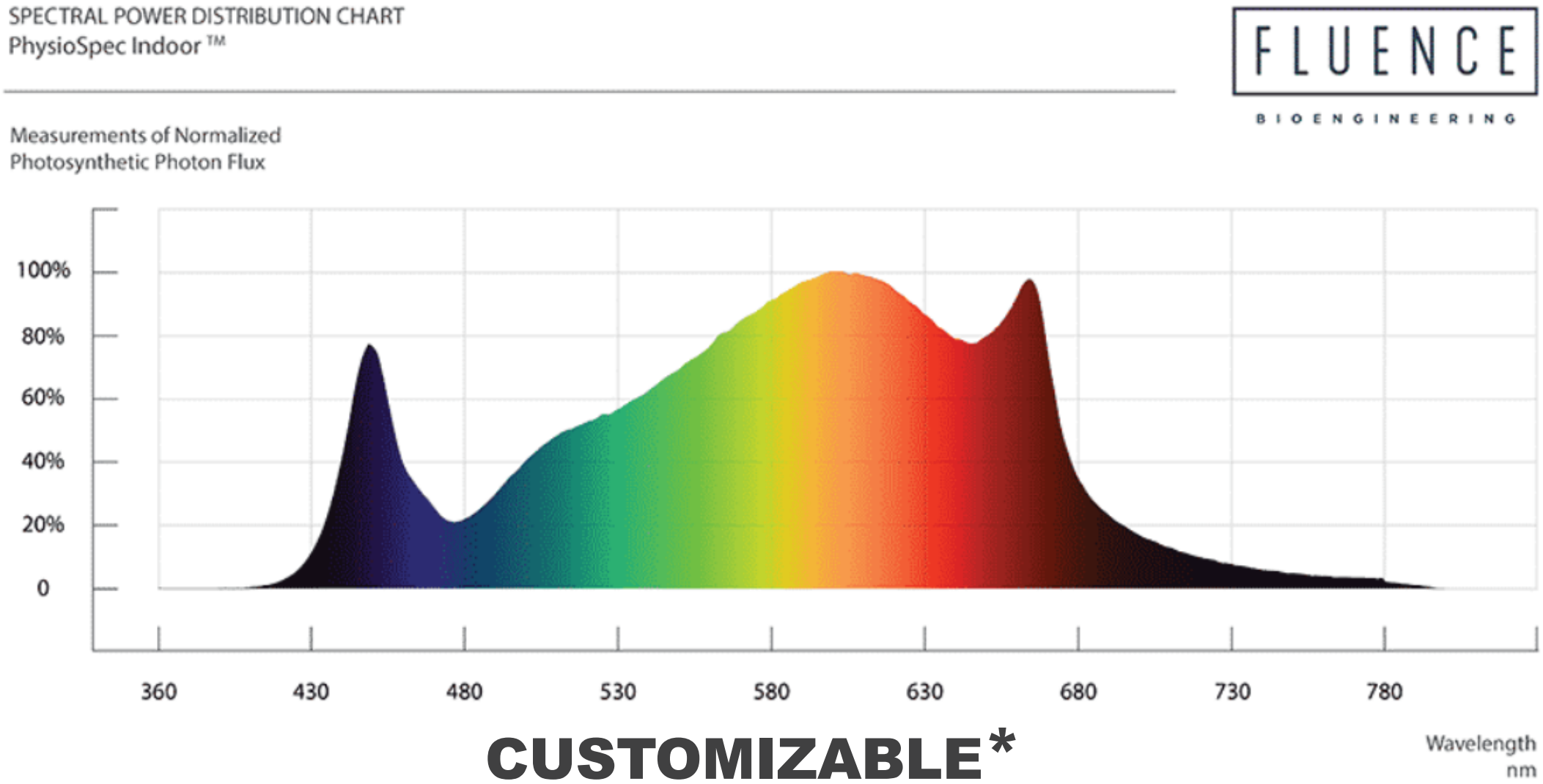
Measurements of Normalized
Photosynthetic Photon Flux



COMPARISON OF PHOTOMETRIC OUTPUT: HPS



COMPARISON OF PHOTOMETRIC OUTPUT: LED



CUSTOMIZABLE*

PPF: PHOTONS EMITTED

Light emitted by a fixture

Varies widely depending on intended use

- 600–2,000

Should be reported in range bins along spectrum

(µMol/s)

PPFD: PHOTONS AT CANOPY

Light received by plants

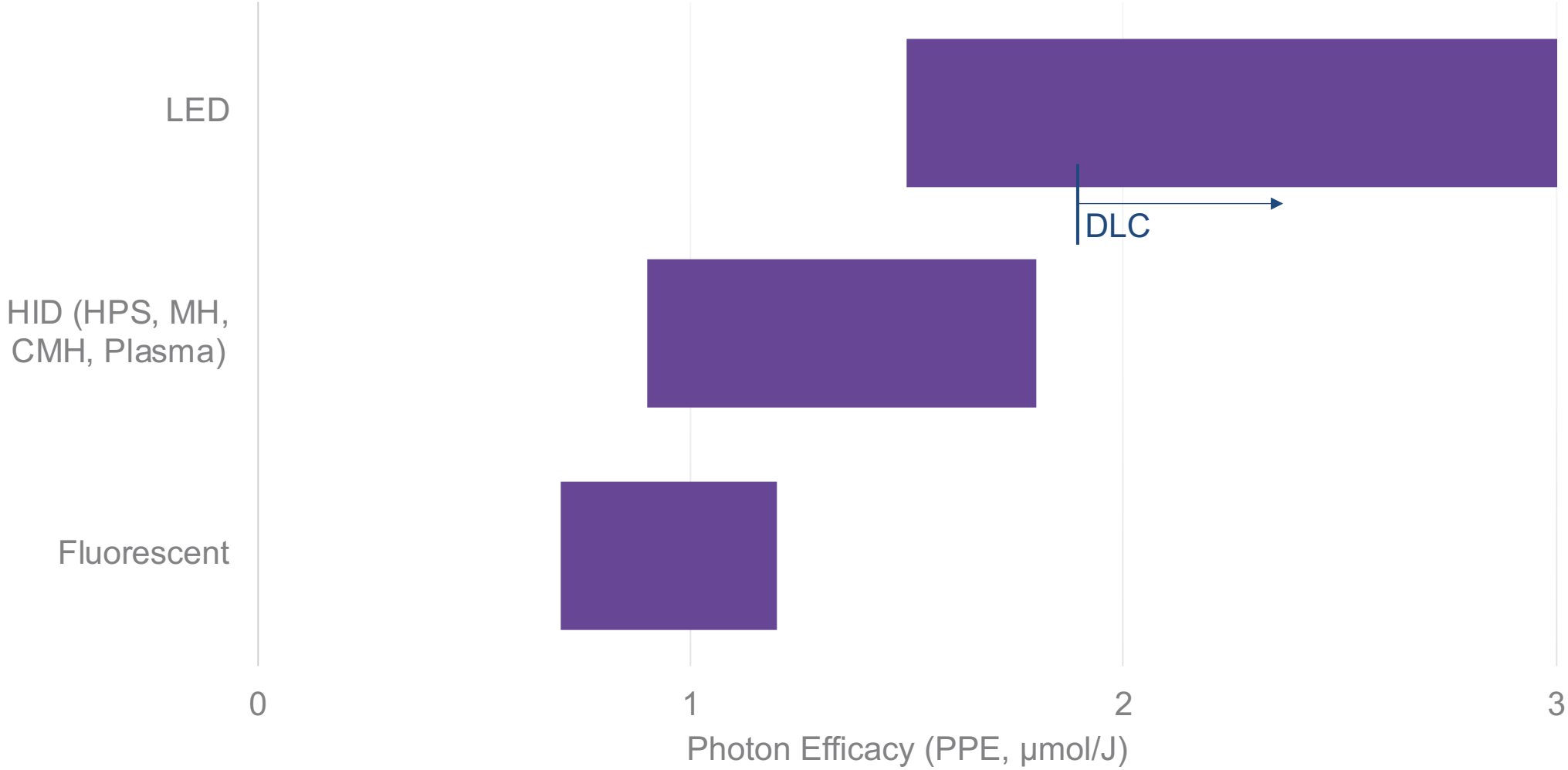
- Design requirements should be dictated in PPFD

Requirement varies by plant, growth phase, time in cycle

- Nursery <300 µmol/s/m^2
- Vegetative growth 300-600 µmol/s/m^2
- Flowering/fruiting 600-1000 µmol/s/m^2

PPFD varies by fixture PPF, number of fixtures, mounting height, wall and ceiling reflectivity…

PPE: PHOTONS PER INPUT POWER



energy & resource solutions

http://www.doctorgreenhouse.com/

LED Impacts on Growing

LEARNING CURVE

- Key: Proactive Cultivator
- *Anecdotally*, 1 grow cycle to adjust
- *Anecdotally*, different or improved quality / flavor / cannabinoids

https://www.iaesconference.com/

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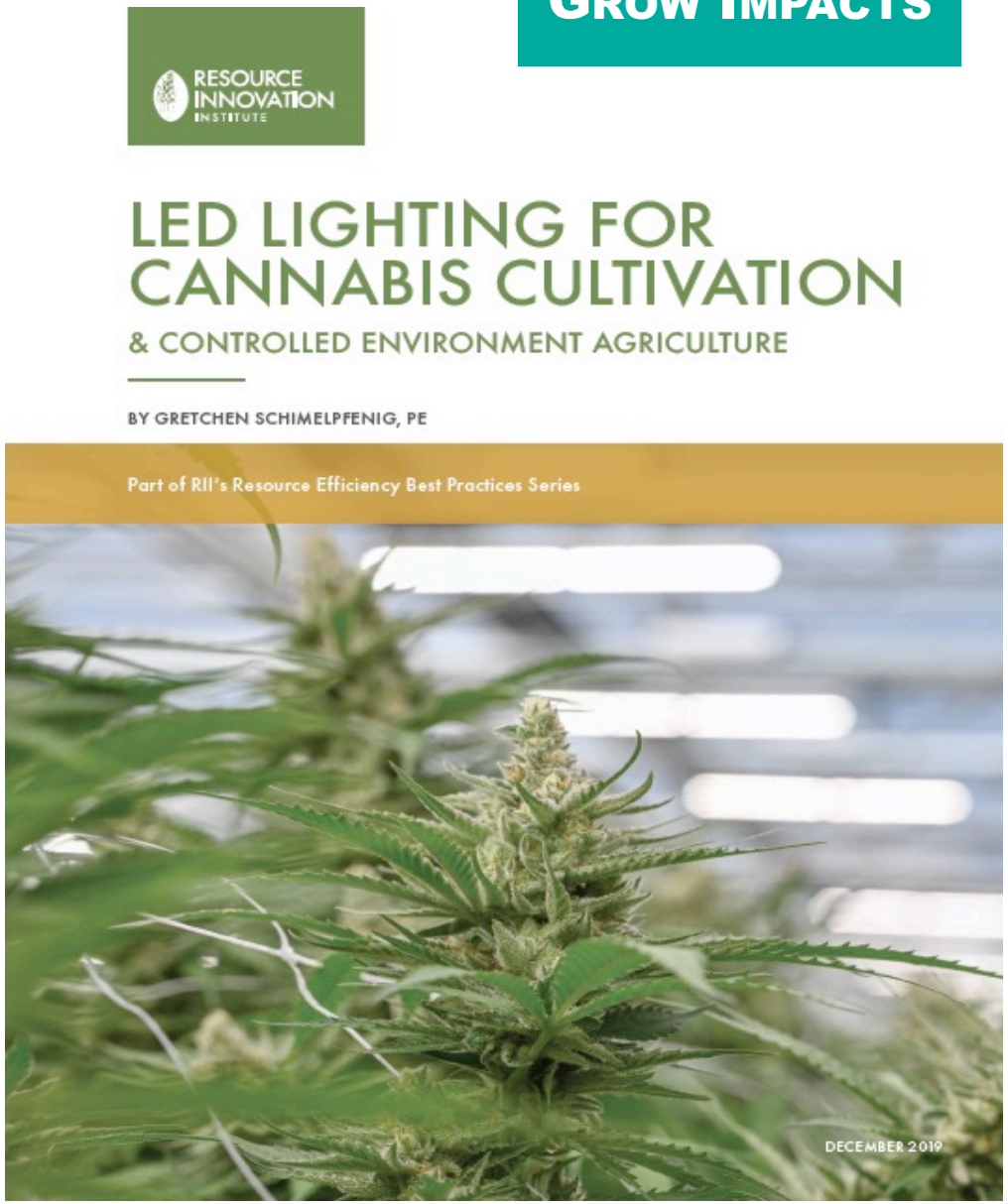
RECONSIDER

- **A** Watering rates
- **B** Nutrient recipes, schedules
- **C** Room air temperature, RH
- **D** CO_2 levels



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Resources

- https://resourceinnovationinstitute.wildapricot.org/RII-REPORTS/
- https://www.designlights.org/horticultural-lighting/
- https://elibrary.asabe.org/
- https://assets.bouldercounty.org/wp-content/uploads/2020/05/EIOF-BC-Cultivation-Assessment-Summary-Report_Final-5_4_20.pdf
- https://zondits.com/?s=cannabis

- Massachusetts Utilities Technical Assistance and Commissioning - ongoing
- Massachusetts Cannabis Cultivation Facility Industry Standard Practice (ISP) study - ongoing
- Efficiency (Nova Scotia) Cannabis Baseline Lighting Study - complete
- California Title 24 Controlled Environment Horticulture CASE Calculations - ongoing

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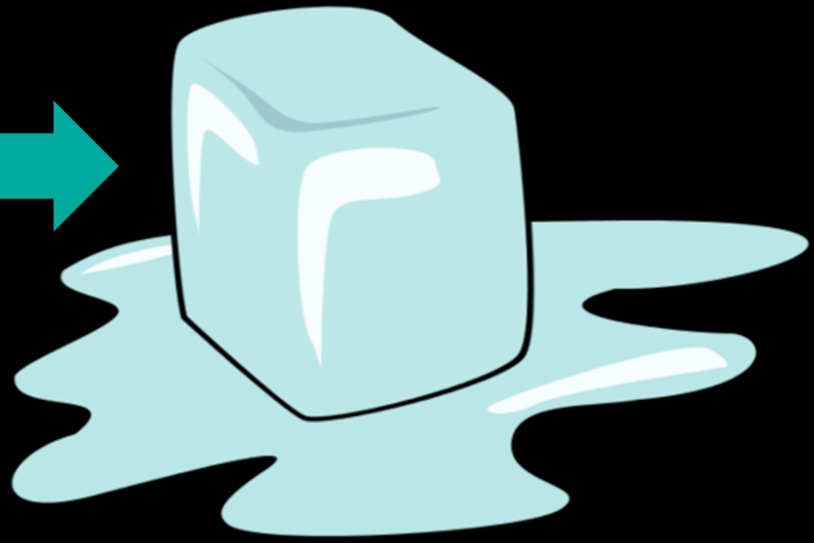
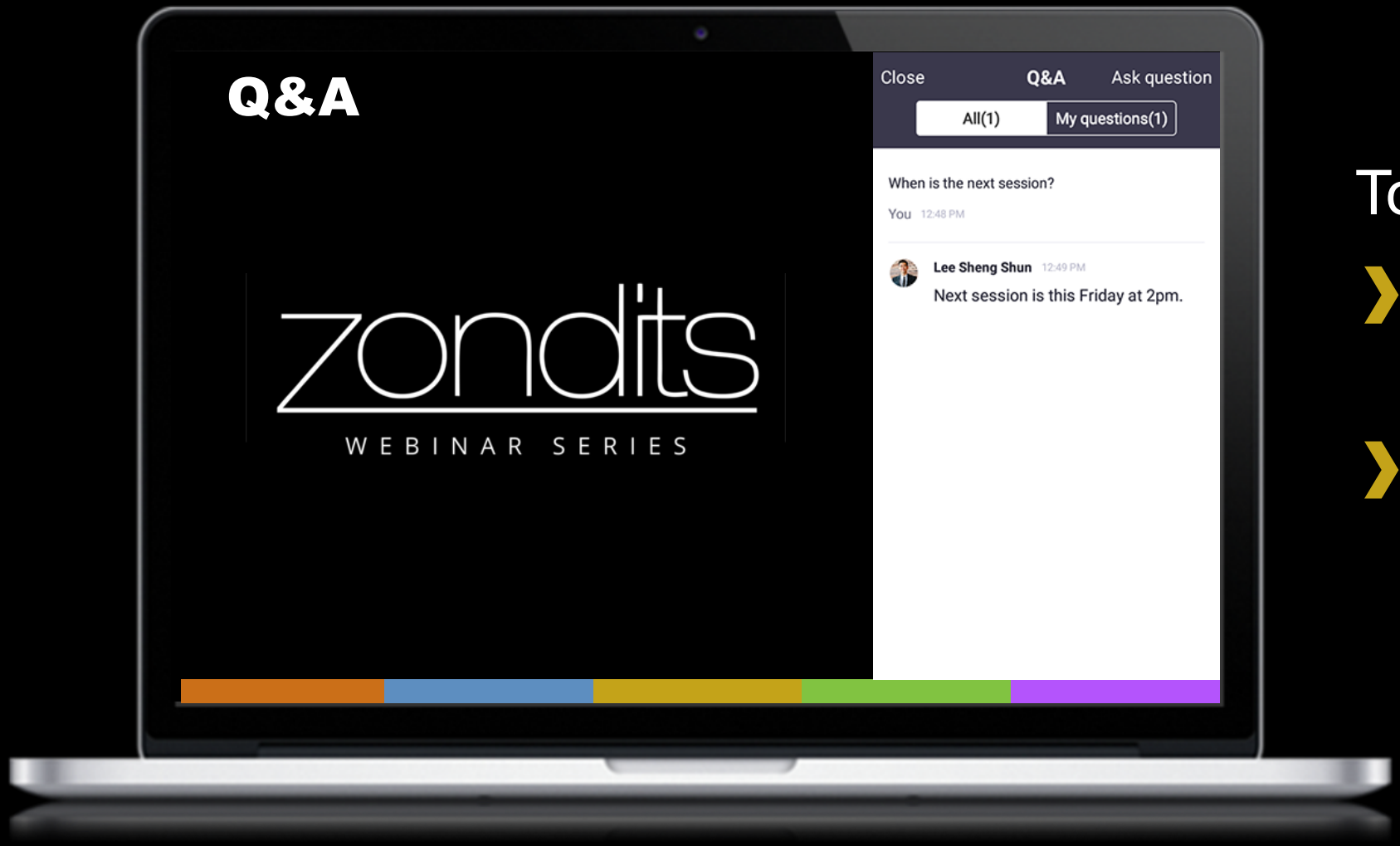
Part 2: HVAC for Controlled Environment Agriculture – *Energy and Efficiency*

August 19, 2020

- The need for environmental control
- HVAC loads in indoor and greenhouse facilities
- HVAC energy use and efficiency opportunities



Register for our August 19 webinar on HVAC for Controlled Environment Agriculture:
https://bit.ly/30JM5VU



To ask a question:

- Type your question into the Q&A box.
- Click Send.

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Next Webinar:

6/24: Assessing Key Delivery Practices for Large C&I Program Success