Harvesting the Benefits of Horticultural Lighting
Horticultural Lighting

• As legislation expands across the country, horticultural grow facilities are becoming the fastest-growing load for DLC-member utilities.
  – New facilities → New load

• More and more facilities are coming online.
  – Addressing product performance and energy consumption is critical.
Near-Term Plans

- Participate in industry working groups on standards development and track industry activities and publications
  - ASABE
  - IES
  - LRC
  - GLASE
  - Others

- Create home on DLC website to explain technology and market status, highlight product considerations, and provide DLC updates
  - Launching in August

- Investigate (interim) approach for qualifying products and reporting performance data
  - Draft proposal Q1 2018
Potential Market Paradigm

1. Industry-developed guidance document will lay out parameters that need to be known/considered to determine installation/lighting needs

2. Grower/Specifier will take this information to build a spec for product selection

3. DLC QPL will have verified list of products meeting minimum thresholds
   a) Published performance data
   b) Enable utility incentives
Potential Market Paradigm

Industry-developed guidance document will lay out plant, space, and fixture parameters that need to be known and considered to determine lighting needs.

Growers/Specifiers will take this information to build specs for product selection.

DLC QPL will have verified list of products meeting minimum thresholds.
- Published performance data
- Enable utility incentives
What Goes In To a DLC Spec?

1. What types of products need to be covered?
   a) How should they be structured?

2. What are the metrics?
   a) Which metrics should have minimum thresholds?

3. Where to set the minimum thresholds?
   a) What performance will meet customer needs and save energy?

4. Is there a standardized test procedure?
   a) Are there labs accredited to that standard?
Beyond the Spec

• Determining energy savings
  – How will utilities set baselines?

• Informing product selection
  – Will the growers know what their plants’ needs are?
    ▪ Various stages of cultivation
    ▪ Different crops

• Driving adoption
  – Will energy savings be the motivating factor?
Panelists

Philip Smallwood
Strategies Unlimited

Travis Williams
Fluence Bioengineering

Doug Oppedal
Evergreen Consulting
NORTH AMERICAN HORTICULTURAL LIGHTING MARKET OVERVIEW
LEDs for Horticultural

Small Form Factor and Heat
- LED’s small form factor provides a fixture manufacturer a degree of design freedom that they didn’t have before. This enables:
  - Indoor lighting applications
  - Vertical farming applications
  - Use of secondary optics
  - Unique population patterns
- Temperature 1000W HPS vs 400W LED grow lamp at equal distance

Tunable Spectrum
- Traditional light sources (HPS, MH, Fluorescent) only offer static spectrum solutions
- LEDs allow you to custom tune the spectrum to suit the plant’s needs

Longer Operating Life
- A major parameter in calculating ROI when deciding what type of light technology to purchase is lifetime or how often you need to replace or service the fixture.

Disadvantages of LEDs in Horticultural
- High capital expenditure + other related incremental costs
- Optimal light recipes for specific crops & varieties still largely unproven
- PPF and PPFD of LED vs. incumbent technology is not equal (Especially important for plants with higher DUI)
- Lack of Quality Standards
Greenhouse Lighting Market
How do You Measure the Market Cont’d?

• Installed base

• What You’re Measuring
  • $/Sq. Ft Light Installations by End Application

• Incumbent
  • Cost of market (Replacement Lamps and Luminaires)

• LED
  • Mostly Luminaires replacing canopy lights (For Now)
    • New form factors could have a huge impact on production!
N. A. Installed Base

Total Sq. Ft Greenhouses

Total Sq. Ft Greenhouses Lit vs. Unlit

- Cannabis
- Ornamental
- Fruits/Vegetables

Lit
Unlit
Total N.A. Illuminated Sq. Footage of Greenhouses

- Million Sq. ft
- 2015 to 2021

Types:
- Cannabis
- Ornamental
- Fruits/Vegetables
How do You Measure the Market Cont’d?

• Most likely Product
• Needs of Product
  • Costs of Production
• Lighting Qualities
  • Incumbent
  • LED
• Market Dynamics
• Geographic Dynamics
• Payback and ROI
N.A. Sq. Foot area of Lighting Installations

![Graph showing sq. foot area over years with different lighting options]

- **2015**: 160 sq. ft. (Hybrid: 20 sq. ft., Traditional: 140 sq. ft., LED: 5 sq. ft.)
- **2016**: 170 sq. ft. (Hybrid: 25 sq. ft., Traditional: 150 sq. ft., LED: 5 sq. ft.)
- **2017**: 180 sq. ft. (Hybrid: 30 sq. ft., Traditional: 160 sq. ft., LED: 5 sq. ft.)
- **2018**: 190 sq. ft. (Hybrid: 35 sq. ft., Traditional: 170 sq. ft., LED: 5 sq. ft.)
- **2019**: 200 sq. ft. (Hybrid: 40 sq. ft., Traditional: 190 sq. ft., LED: 5 sq. ft.)
- **2020**: 220 sq. ft. (Hybrid: 50 sq. ft., Traditional: 200 sq. ft., LED: 5 sq. ft.)
- **2021**: 240 sq. ft. (Hybrid: 60 sq. ft., Traditional: 220 sq. ft., LED: 5 sq. ft.)
N.A. Greenhouse Lighting Market Forecast

![Graph showing revenues forecast from 2015 to 2021 for Hybrid, Traditional, and LED lighting systems.]
N.A Horticultural Lighting Market by Application

![Graph showing revenue growth by application over years from 2015 to 2021. The categories are Cannabis, Fruits/Vegetables, and Ornamental.]
Application Focus Cannabis

Legend:
- **Green**: Legalized for Adult Recreational & Medical Use
- **Blue**: Legalized for Medical Use Only
- **Red**: Expected to Legalize in 2017
- **Gray**: Illegal

Source: Money Morning Staff Research
N.A. Cannabis Grow houses (Installations and Market)
Market Indicators for Growth

• 2 major indicators
  • Quality of light
  • Decreasing prices (Payback period under 3 years and ROI)

• What will speed up/slow down the market?
  • Increased Education
    • End Users
    • Manufacturers
  • Product/technology development
    • Decreased prices
    • Increased ease of use
    • Market acceptance

Standards play a major role in all of this!
Thank You!

Philip Smallwood
Director of Research
Strategies Unlimited
Philips@pennwell.com
HORTICULTURE LIGHTING

NUANCES & THE NEED FOR STANDARDS

Travis Williams
Vice President of Marketing & Research, Fluence Bioengineering
PHOTOBIOLOGY

WAVE + PARTICLE (PHOTON)

- Gamma Rays: 0.0001 nm - 0.01 nm
- X-Rays: 0.01 nm - 10 nm
- Ultraviolet: 10 nm - 400 nm
- Infrared: 700 nm - 0.01 cm
- Radio Waves: 0.01 cm - 100 m

PAR/Visual Light

400 nm - 700 nm
Photopic Vision
• Lumens
• LUX/Foot Candles
• Lumens/Watt

Photobiology
• PAR
• PPF
• PPFD
• µmol/J
PHOTOBIOLOGY

PHOTOSYNTHESIS
SERIES OF LIGHT & DARK REACTIONS THAT OCCURS IN THE CHLOROPLASTS USING LIGHT ENERGY (PHOTOSYNTHETIC PHOTON FLUX) TO GENERATE CARBOHYDRATES FROM CO2 AND H2O.

PHOTOMORPHOGENESIS
LIGHT-CONTROLLED PROCESSES THAT REGULATE PLANT PHYSIOLOGICAL DEVELOPMENT OF FORM AND STRUCTURE

PHOTOPERIODISM
PHYSIOLOGICAL RESPONSE TO RELATIVE LENGTHS OF LIGHT AND DARK PERIODS

FLOWER/FRUIT MANIPULATION
Photobiology requirements in commercial agriculture

PPF | PPFD | UNIFORMITY | SPECTRUM | EFFICACY | SIZE | PROXIMITY

The amount of light emitted by a light source. Measured in: micromoles per second (µmol/s)
HORTICULTURE vs. VISION

Photobiology requirements in commercial agriculture

The amount of light reaching your canopy. Measured in:
micromoles per meter squared per second (µmol/m²/s)
Photobiology requirements in commercial agriculture

The average, maximum and minimum amount of ppfd. Measured with:

a PAR map
HORTICULTURE vs. VISION

28' x 58' ROOM

20' x 4' CANOPY

4' x 4' CANOPY

PPFD
- Average: 1844 μmol/m²/s
- Maximum: 1532 μmol/m²/s
- Minimum: 684 μmol/m²/s

28' x 58' ROOM

20' x 4' CANOPY

4' x 4' CANOPY

PPFD
- Average: 415 μmol/m²/s
- Maximum: 167 μmol/m²/s
- Minimum: 33 μmol/m²/s
HORTICULTURE vs. VISION

Photobiology requirements in commercial agriculture

PPF | PPFD | UNIFORMITY | SPECTRUM | EFFICACY | SIZE | PROXIMITY

The proportions of different wavelengths. Measured with: a spectral power distribution chart
HORTICULTURE vs. VISION
**Petunia ‘Classic Purple Wave’**

57 Days After Transplant at 61 °F

<table>
<thead>
<tr>
<th>Light Source and PPE of 4-h night interruption:</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-h Short day</td>
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<tr>
<td>Incandescent</td>
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<tr>
<td>0.627</td>
</tr>
</tbody>
</table>

- 92

**Flowering Percentage**

- 58

- 92

- 56

**Days to Flower**

- 61

- 58

-
### Celosia ‘Dragon Breath’

57 Days After Transplant at 61 °F

<table>
<thead>
<tr>
<th>Light Source and PPE of 4-h night interruption:</th>
<th>9-h Short day</th>
<th>Incandescent</th>
<th>LED 1</th>
<th>LED 2</th>
<th>LED 3</th>
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</thead>
<tbody>
<tr>
<td>0.627</td>
<td>100</td>
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<td>100</td>
<td>100</td>
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</table>

<table>
<thead>
<tr>
<th>Flowering Percentage</th>
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<tbody>
<tr>
<td>34</td>
</tr>
<tr>
<td>61</td>
</tr>
<tr>
<td>61</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Days to Flower</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
</tr>
<tr>
<td>61</td>
</tr>
<tr>
<td>61</td>
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</table>
## African Marigold ‘Antigua Yellow’

46 Days After Transplant at 61 °F

<table>
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<th>Light Source and PPE of 4-h night interruption:</th>
<th>Incandescent</th>
<th>LED 1</th>
<th>LED 2</th>
<th>LED 3</th>
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</thead>
<tbody>
<tr>
<td>9-h Short day</td>
<td>0.627</td>
<td>0.631</td>
<td>0.711</td>
<td>0.700</td>
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</table>

<table>
<thead>
<tr>
<th>Flowering Percentage</th>
<th>Days to Flower</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td>100</td>
<td>42</td>
</tr>
<tr>
<td>100</td>
<td>44</td>
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<tr>
<td>100</td>
<td>51</td>
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<tr>
<td>100</td>
<td>52</td>
</tr>
<tr>
<td>100</td>
<td>47</td>
</tr>
</tbody>
</table>
Photobiology requirements in commercial agriculture

How energy efficient a light fixture is at converting electrons into photons. Measured in: Micromoles per joule (µmol/J)
EFFICACY

DATA FROM PEER REVIEWED JOURNAL – DR. BUGBEE

μmol/j

- Fluence RAZRx: 2.2
- DE HPS: 1.7
- LED: 1.7
- LED: 1.4
- Cycloptics CMH: 1.46
- T8 Fluorescent: 0.84
Photobiology requirements in commercial agriculture

How much space does your lighting system require? Measured in:

inches, centimeters, millimeters, etc.
Photobiology requirements in commercial agriculture

Space requirements from light to canopy? Measured in:
inches, feet, centimeters, millimeters, etc.
HORTICULTURE vs. VISION
Factors to consider when designing or deploying a horticulture lighting solution

RH | TEMPERATURE | RADIANT HEAT | CO2 | IRRIGATION | & SO MUCH MORE
LIGHTING TECHNOLOGIES

A quick look at what’s in use

LED | CMH | HPS | FLUORESCENT | PLASMA | & SO MUCH MORE
LIGHTING TECHNOLOGIES

Today and tomorrow

GREENHOUSE TOP LIGHT | GREENHOUSE INTRACANOPY |
GREENHOUSE VERTICAL | VERTICAL FARMING | GROWTH CHAMBERS | & SO MUCH MORE
FUTURE

EMPOWERED BY TECHNOLOGY

LED efficiency gains

Thermal management

Automation & big data
FUTURE

EMPOWERED BY

SCIENCE

Custom spectra

Environmental optimizations

Genetic optimizations

DLC STAKEHOLDER MEETING

FLUENCE

JULY 2017
OPPORTUNITIES

SAVING ENERGY AND/OR MAKING MONEY

Maximize yield per cubic foot

Minimize operating cost/pound

Augment pricing power (quality/consistency/forecast)
FOR NEXT TIME

NOW THAT
THE BASICS
ARE COVERED

Degradation
Maintenance, loss, inconsistency

Rohs
Avoiding mercury and other harmful contaminants

CU
Don’t waste photons
SUMMARY

Plants use light might much differently than humans

Growers/KDMs are largely uneducated when it comes to photobiology

There are myriad factors for CEA. No one-size fits all.

Horticulture lighting *should be* revenue-generating, not cost-saving.

WE (ALL OF US) WILL BENEFIT FROM INDUSTRY STANDARDS.
What's Growing on in Oregon
Grow Light Options

Utility perspective from the front lines
Legacy Technologies
Baseline or industry standard

1,000 watt High Pressure Sodium, single ended lamp (one socket)

*INDUSTRY RULE OF THUMB* – 16 S.F. per grow

*Provides approximately 700 to 800 PPFD µmol/m2 S*
Step up from a Singled Ended HPS

1,000 watt High Pressure Sodium
Double ended lamp

Provides approximately 800 to 1,000 PPFD μmol/m² S
• **Single Ended (SE).** Mogul base The arc tube connects to the base of the bulb with a metal frame wire holding it by each end

• **Double Ended (DE).** Connects on each end at the lamp much like a fluorescent tube

• Because of the support and shapes, the DE is much thinner than SE which improves optical properties. Exposing the arc tube to the bulb without any metal framing in the way, increases light delivery. The symmetry of the DE bulbs allows you to create an even spread of light.

• **Hours:** It would appear that SE bulbs last longer than DE bulbs but in reality, you need to change the SE bulb every 6,000 hours and every DE bulb every 10,000 hours to maintain optical properties

• **Efficiency:** SE bulbs are vacuum, DE bulbs are full of nitrogen gas. The gas allows the bulb to operate at higher temperatures, which increases it’s efficiency. But, any air movement (fans) can cool the lamp decreasing efficiency.

Hightimes.comBy Sirius J, May 24, 2016
Induction

Race track style
Load 440 watts
Life of lamp 100,000 hours

Provides approximately 300 to 400 PPFD µmol/m² S
Light Emitting Ceramic (LEC)
Ceramic Metal Halide (CMH)

2/315 watt CMH lamps

Load 630 watts/240 volts @ 100%

Provides approximately 700 to 800 PPFD µmol/m² S
One 315 watt lamp is ½
Light Emitting Plasma

1/270 watt Plasma

Load 270 watts/240 volts @ 100%

Life of lamp – 50,000

Provides approximately to 200 to 300 PPFD µmol/m² S
Tube LED (TLED)

54 watt T5 HO fluorescent baseline

28 watt T5TLED
Works off existing fluorescent ballast
Life of lamp – 50,000 hours

Provides approximately to 500 to 600 PPFD µmol/m² S
(8-lamp luminaire)
Hybrid
LED (dimmable, tunable)

- Average around 600 watts
- Life of LED: 50,000 hours @ 70% output
- Some provide approximately 1,000 to 1,200 PPFD µmol/m² S
What manufacturers should provide

- Height above the canopy: 7’ 4”
- PPFD: 138 (average), 166 (max), 75 (min)
- Light loss Factor: 0.99

PPFD: Photosynthetic Photon Flux Density (units: μmol/m²/s)
Reducing your operational costs
Time is money – cent’s per kWh

Indoor

Clone - 18 to 24 hours 7 days per week (8,760)
Vegetative stage - 18 hours 7 days per week (6,570)
Flowering stage - 12 hours 7 days per week (4,380)

Green house

2,118 annual hours for supplemental electric lighting
Lighting is the largest load in an indoor grow operation

Less lighting load means...

- Less HVAC load
- Less fan load
- Less electrical service costs
- Less insulation
- And more
- The gift that keeps on giving
Virtual case study

3,500 S.F. canopy grow operation

Flower room

218, 1,000 watt HPS virtual grow lights (3,500/16 SF)
$200 ea.
4,380 annual hours

218, 640 watt LED grow lights $1,200 ea.
<table>
<thead>
<tr>
<th>Estimated Annual Energy Savings</th>
<th>429,835 kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Annual Cost Savings</td>
<td>$ 44,224 per year</td>
</tr>
<tr>
<td>Estimated Energy Trust of Oregon Incentive</td>
<td>$ 107,414</td>
</tr>
<tr>
<td>Additional Estimated Incentive, if applicable</td>
<td>$ -</td>
</tr>
<tr>
<td>Estimated Installation Cost</td>
<td>$ 218,000</td>
</tr>
</tbody>
</table>

Based on your proposed retrofit and estimated installation cost, we show the following financial analysis:

| Estimated Installation Cost     | $ 218,000 |
| minus Energy Trust of Oregon incentive | $ (107,414) |
| Net Installation Cost           | $ 110,586 |
| Energy Savings Payback (in years) | 2.5 |
| % of installed cost paid for by incentives | 49% |
| Rate of Return                   | 40% |

Estimated cost for every year the project is delayed $ 44,224  PROFIT after 2.5 years!!

*This project requires a pre-installation inspection.*

This is an estimate only, as actual savings and incentives will vary based on final installed measures and costs, actual area operating hours, energy rates and building usage.

**Green Project Box:** *(Estimate for informational purposes only. The carbon footprint from electricity generation is calculated from a regional average, which may be different than the national average.)*

This proposed project could offset approximately 204 tons of CO2 generated by fossil fuels, equal to taking more than 29 cars off the road.
QPL lists for Horticulture

- Needs to be cognizant of growers methodology, designs and procedures that produce high yields
- Utilities: Should there be a list or should there be specifications to meet?
Thank you

Doug Oppedal, LC
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503.382.9359
Thank You!

Irina Rasputnis
DLC

Philip Smallwood
Strategies Unlimited

Travis Williams
Fluence Bioengineering

Doug Oppedal
Evergreen Consulting