SECOND DRAFT Testing and Reporting Requirements for LED-based Horticultural Lighting

Horticultural lighting products using LEDs must comply with the provisions of this document to be eligible for listing on the DLC Solid-State Horticultural Lighting Qualified Products List (Horticultural QPL). Products eligible for DLC qualification must be complete LED light fixtures. That is, they must be electromagnetic radiation-generating devices analogous to luminaires as defined by ANSI/IES RP-16 sections and 6.8.5 and 10.3.1. Only products designed and intended to operate with standard AC line voltage are eligible, but the DLC intends to issue regular updates to these requirements and does not exclude the possibility of including DC and PoE-based systems in future revisions.

Definitions

Unless otherwise noted, DLC policy nomenclature directly references the definitions from the American Society of Agricultural and Biological Engineers (ASABE) *ANSI/ASABE S640: Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms)*, and, where applicable, the Illuminating Engineering Society (IES) *ANSI/IES RP-16: Nomenclature and Definitions for Illuminating Engineering,* with key deviations or interpretations noted. Each mention of the term "LED device" in this document is meant to reference LED packages, modules, or arrays.

Eligibility

The following are eligibility rules for horticultural lighting products:

- Products that are lamps (analogous to RP-16 sections 6.8.5.3, and 6.8.5.4), light engines (analogous to RP-16 section 6.8.5.5), or identified as retrofit kits intended to replace the light sources or other structures within an existing fixture, are not eligible.
- Fixtures that incorporate light sources other than LED, whether as sole-source or as LED-hybrid fixtures, are not eligible.
- Fixtures that employ externally-supplied active cooling systems, including circulating-liquid and ducted forced-air, are not eligible. Those that incorporate internal active cooling systems that can be measured via standardized fixture test procedures, such as on-board fans, are eligible.

Testing Methods and Requirements

The DLC intends to require testing of horticultural luminaires in accordance with a standard under development in the ASABE ES-311 committee: ASABE X642: Recommended Methods for Measurement and Testing of LED Products for Plant Growth and Development. As this draft standard is under development, its contents could change before being finalized, published, and made publicly available. In this document, the DLC refers to the nearest similar IES-standard methods of measurement as a means of understanding the potential scope of work involved in testing.

The DLC Technical Requirements for LED-based Horticultural Lighting are as follows. Details explaining each item follow below the table.

Table 1: DLC Horticultural Lighting Technical Requirements

Parameter/Attribute/Metric	Requirement	Requirement Type	Method of Measurement/Evaluation
Photosynthetic Photon Flux (PPF), (µmol/s)	n/a	Reported	(LM-79-08) 400-700nm range, with 400-500nm, 500-600nm, and 600-700nm bins reported alongside the total
Far Red Photon Flux (PF_{FR}), (µmol/s)	n/a	Reported	(LM-79-08) 700-800nm range
Spectral Quantum Distribution (SQD) (µmol/s/nm)	n/a	Reported	(TM-27-14 or TM-33) 400-800nm range
Photosynthetic Photon Intensity Distribution (PPID) (µmol/s/sr)	n/a	Reported	(TM-33 or adapted LM-63) 400-700nm range
Photosynthetic Photon Efficacy (PPE), (µmol/J)	≥1.8 µmol/J, with -5% absolute tolerance	Required/Threshold	(LM-79-08) 400-700nm range
Photosynthetic Photon Flux Maintenance (PPFM)	Q_{90} ≥36,000h	Required/Threshold	(LM-80-15 / TM-21 or LM-84 / TM-28) 400-700nm range
Photon Flux Maintenance (PFM_{FR})	Report time to Q_{90}	Reported	(LM-80-15 / TM-21 or LM-84 / TM-28) 700-800nm range

Parameter/Attribute/Metric	Requirement	Requirement Type	Method of Measurement/Evaluation
Driver Lifetime	≥50,000 hours	Required/Threshold	Driver Technical Specification Sheet and *In-Situ Temperature Measurement Test* (ISTMT)
Fan Lifetime	≥50,000 hours	Required/Threshold	Fan Technical Specification Sheet
Warranty	5 years	Required/Threshold	Legal Warranty Terms & Conditions
Power Factor (PF)	≥0.9	Required/Threshold	(LM-79-08)
Total Harmonic Distortion, Current (THDi)	≤20%	Required/Threshold	(LM-79-08)
Safety Certification	Appropriate Horticultural Lighting designation by OSHA NRTL or SCC-recognized body	Required/Threshold	Per safety certification body (see below)

Output Characteristics:

The DLC requires testing and reporting of the following characteristics of the output of horticultural lighting devices:

- **Photosynthetic Photon Flux (PPF), (µmol/s)**
  This is the total output of the product, over the specific range of wavelengths defined by ANSI/ASABE S640 for PPF (400-700nm). This metric is an integrated value for the entire device, and contains no granular spectral or directional information.

  The DLC will report on both the total and 100nm-wide "bins" of flux within this range to allow end users to understand the fixture's relative proportions of "blue," "green," and "red" light.

- **Photon Flux, Far Red (PF_{FR}), (µmol/s)**
  This is the output of the product, over the "far red" band defined by ANSI/ASABE S640 (700-800nm). This metric is an integrated value for the entire device, and contains no granular spectral or directional information. This metric is a reported field only.

  The DLC will report on the total flux of this 100nm-wide band separately for end users' informational needs.

- **Spectral Quantum Distribution (SQD), (µmol/s/nm)**
  This is the distribution of photon flux per photon wavelength, over the photosynthetic and far-red range of wavelengths defined by ANSI/ASABE S640 (400-800nm). This distribution is measured and reported as integrated in all directions from the device, and contains no granular directional information itself. This will be required in IES TM-27 (or pending TM-33) formats with a resolution of no coarser than 5nm.

  The DLC will require this data to be submitted with applications, and will make it available on the QPL. Please see the Key Questions document for an outline of the ways QPL users might access this data.

- **Photosynthetic Photon Intensity Distribution (PPID), (µmol/s/sr)**
  This is the distribution of PPF intensity per unit solid angle leaving the device. This distribution is measured and reported as integrated for all wavelengths across the 400-700nm range leaving the device, and contains no granular spectral distribution information itself. This will be required in a PPF-only LM-63 (or pending TM-33) format, at an angular resolution of no less than prescribed in ANSI/IES LM-79.

  The DLC will require this data to be submitted with applications, and will make it available on the QPL. Please see the Key Questions document for an outline of the ways QPL users might access this data.

Efficacy:

The DLC requires testing and reporting of Photosynthetic Photon Efficacy (PPE), which is the output of the fixture over the specific range of wavelengths defined by ANSI/ASABE S640 for PPF (400-700nm), divided by all electrical input watts to the device, including any other ancillary loads (controllers, sensors, cooling fans, etc.).

All products will be required to have a PPE of ≥ 1.8 µmol/J. In both initial applications and surveillance testing, the DLC will allow an absolute tolerance of -5% to this threshold value. The result of this will be the DLC's acceptance of any test report showing an efficacy of 1.71 µmol/J or higher, and the disqualification of any product with a test report showing an efficacy less than 1.71 µmol/J.

While, in general, family grouping approaches are not allowed (i.e. products must all have their own testing), limited variations for alternate drivers will be allowed within the same product listing. If the product contains multiple drivers, or is capable of operating at multiple input voltages:

- All driver spec sheets must be provided.
- For each unique driver used, manufacturers must provide electrical testing to demonstrate which driver variation will result in the overall worst-case efficiency (and therefore efficacy), as well as which variation will result in the overall worst-case power quality (Total Harmonic Distortion, current or THDi, and Power Factor, or PF).
    - This testing shall include the input current and wattage, the output voltage, current, and wattage, and the THDi and PF, for each driver, at each nominal input voltage.

- In-house (i.e. non-accredited lab) bench-top electrical testing is sufficient for demonstrating the driver efficiency at the applicable loading conditions and at the applicable input voltages.
- From this electrical characterization testing, the product and conditions representing worst-case efficacy must undergo formal whole-fixture testing by an accredited lab.

Long-Term Performance:

The DLC requires the following performance items to characterize the long-term performance and reliability of the device:

- **Flux Maintenance, PPF and PF_{FR}**
  This is a characterization of the ability of the device to maintain its output within the given ranges over time. Given that device output of interest is measured in quanta of photons, and not in lumens, the DLC is using the general engineering term for quanta, "Q", instead of the more-familiar "L" prefix used within general illumination applications.
  - The DLC will require either LED device-level or whole-fixture testing and projections in accordance with the (LM-80-15 and TM-21) or (LM-84 and TM-28) industry standards sufficient for a Q_{90} of ≥36,000 hours within the PPF range (400-700nm).
  - The flux maintenance point is set at a 10% reduction from initial product output due to the increased sensitivity of plant metabolism to reduced flux. While human vision can tolerate a 30% loss of output across a fixture's life (the intent of the L_{70} extrapolation), the reduced plant growth resulting from reduced flux is a significant factor in end users' economic calculations.
  - All TM-21 or TM-28 projections must be made at the maximum environmental temperature on the fixture's specification sheet. See ISTMT information below for additional details.
  - The DLC will require testing and projections to report Q_{90} for the PF_{FR} range of 700-800nm, but will not make determinations or qualifications based on this data.
  - To support PPF and PF_{FR} maintenance projections, LM-80-15 / LM-84 information must be provided for both the 400-700nm and the 700-800nm range.
    - For applicants who decide to use the LM-80/TM-21 approach, the DLC will allow qualification of products that have LM-80 data from historical testing in differing units than desired for PPF maintenance projections, <u>for the first 12 months of the program (until October 2019)</u>.
    - Data will be accepted if stored from historical tests in radiometric power or lumens, with appropriate conversion factors to PPF based on the measured SQD of the device. Data in other units will be addressed on a case-by-case basis as needed, and applicants will be expected to give detailed technical justifications:

        - For these provisional paths to be utilized by applicants, both appropriate SQD testing of the LED device (following provisions of LM-85) and conversion formulas must be provided.
    - Any products qualified using alternative LM-80 data will be designated as such on the QPL, using a provisional listing status asterisk to note Q_{90} performance, or other method to be determined.
        - Products initially qualified using this provisional approach will be allowed to update their listings to remove any caveats by submitting actual data whenever it becomes available.
    - Beginning in October 2019, all new product submissions using the LM-80/TM-21 approach will be required to provide LM-80 data in appropriate (PPF) units.
        - Products qualified with non-PPF units during the October 2018 – October 2019 provisional period will have until April 2020 to update their listings with actual PPF maintenance data, or will be delisted.
    - Products will not be listed without long-term performance and flux degradation data. Products which use LEDs for which no LM-80 data is available, in any units, will be required to undergo LM-84 testing, for TM-28 projections.
- *In-Situ Temperature Measurement Testing* (ISTMT) must be conducted and provided for the hottest LED in the fixture, and LED-device level drive current must be reported.
    - ISTMT testing must be conducted and reported in the same manner as thermal testing for safety purposes. Specifically, appropriate steps must be taken to characterize the operating temperature of the LED at the highest rated ambient temperature. This must be done in accordance with acceptable procedures from safety testing for measuring and projecting operating temperatures generally.
- For fixtures using multiple types of LEDs:
    - LM-80 reports (if being used instead of whole-fixture LM-84 data) must be provided for each type of LED device present in the luminaire.
    - ISTMT testing must be provided on the hottest of each of the LED types (For example, the hottest blue, white, and red LED in the fixture, respectively).
    - Maximum drive current must be reported for each of the LED types.
    - Completed TM-21 calculators must be provided for each LED type, corresponding to the LM-80 and ISTMT for that LED type.
    - For PPF maintenance (400-700nm), each LED type present in the fixture must independently meet the $Q_{90} \geq 36{,}000$ hours requirement. As this is a normalized and relative maintenance requirement, it is required that all LED types meet this maintenance threshold, irrespective to the portion of output they produce within the PAR range. The DLC will report the minimum PPF maintenance value out of all submitted values on the QPL.

- For the PF_{FR} maintenance (700-800nm), the DLC will report the minimum PF_{FR} Q_{90} projection out of all submitted for each LED type present in the fixture on the QPL. There will be no threshold performance requirement across this broader range.

- **Warranty**
  Products must have a manufacturer-provided warranty of at least 5 years. The warranty terms and conditions must be provided as part of the submittal for qualification. Terms and conditions must not exclude key components such as the LED, driver, cooling fans (if present) or optics.

- **Driver ISTMT**
  Applicants must supply a technical specification sheet for the driver they use in their product, showing the lifetime of the driver based on operating temperature and the temperature measurement point (TMP) for monitoring the operating temperature of the driver during operation. In-situ temperature measurement testing must be conducted, and a report must be provided with the application showing an operating temperature consistent with the driver spec sheet information and demonstrating that the driver will have a lifetime of at least 50,000 hours when operating at the highest rated ambient temperature on the fixture's specification sheet.

  As noted in the ISTMT description within the flux maintenance section, driver ISTMTs must be conducted and reported in the same manner as thermal testing for safety purposes. Specifically, appropriate steps must be taken to characterize the operating temperature of the driver at the fixture's highest rated ambient temperature. This must be done in accordance with acceptable procedures from safety testing for measuring and projecting operating temperatures generally.

  - For products that may use multiple drivers, spec sheets for each driver must be provided with the details above. Testing must be conducted on each driver, at its appropriate worst-case input voltage.

- **Fans**
  Products that employ on-board cooling fans must provide a technical specification sheet for each fan type employed in the product. The fan specification sheet will specifically state the lifetime of the fan, which must be at least 50,000 hours, when operating at the fixture's highest rated ambient temperature.

Electrical Performance/Power Quality:

The DLC requires the testing and reporting of the following to characterize the electrical performance of the device:

- **Power Factor (PF)**
  Products must have a measured power factor of ≥0.90 at any rated input voltage.

- **Total Harmonic Distortion, current (THDi)**
  Products must have a measured THDi of ≤20% at any rated input voltage.

For products with driver variations, including input voltage variations, electrical testing of each product must be performed, sufficient to characterize the power quality of each driver, at its

applicable nominal input voltages. Worst-case variations identified must be tested in an accredited laboratory. Characterization testing may be done on an in-house or benchtop set up for practical simplicity, and results must be documented and included in the application materials.

Safety:

The DLC requires products to be appropriately safety certified by a relevant safety certification body in the United States or Canada. Specifically, products must be certified by an OSHA NRTL or SCC-recognized body to a set of safety requirements and standards deemed applicable to horticultural lighting products by that safety organization.

As an ANSI-accredited safety standard for horticultural lighting products does not currently exist, the DLC will remain in contact with relevant safety organizations to understand how they are certifying these products and to ensure that certifications are in accordance with those bodies' relevant practices. If an ANSI-accredited safety standard for horticultural lighting does become available after these requirements are published, the DLC will require it for new applicants only after consulting with safety certification bodies to ensure the industry is ready to meet end user volume needs.

For illustrative purposes, practices of relevant safety organizations are described below:

- **UL**
  UL has defined a preliminary Outline of Investigation (OOI), currently identified as UL 8800, for the review and certification of horticultural lighting products. Device manufacturers who use UL for safety certification purposes will be expected to be listed on the UL Certification Directory under the designation IFAU.
- **ETL/Intertek**
  ETL has defined an internal set of guidelines for certifying horticultural fixtures. Although there is not a reference number for ETL's guidelines, they generally harmonize with UL 8800, with minor additions. Device manufacturers who use ETL for safety certification will be expected to be listed on the ETL Certification Directory, specifically as Horticultural Fixtures.
- **Other safety organizations**
  The DLC will work with other safety organizations to understand their rules for horticultural products as necessary.

Special Considerations for Spectrally Tunable Devices

Spectrally tunable products (those with varying output channels beyond simple, single-axis dimming of the whole product) will be eligible with the following conditions:

- The threshold-qualifying state to be tested will be the manufacturer-designed state with the highest power consumption ("maximum power"). This may or may not be the same as an "all channels on" condition, since fixtures may not be designed to use all their channels simultaneously. Test reports must specifically state that the product is operated in this "maximum power" mode during the testing, with a description of the control narrative to ensure that the power state is at its maximum designed level.

- In addition to the "maximum power" condition, products will repeat a portion of the overall testing for each control channel, in which the channel under test will be set to the maximum designed output, while all other channels will be set to their minimum designed output for this state. Additionally, the test report will present the name, PPF (400-700nm, with total and 3, 100nm-wide "bins"), and PF_{FR} (700-800nm) for each of the single-channel scenarios, along with that of the "maximum power" condition.
    - The output of this specific channel testing will be displayed in a QPL table, with the per-channel test outcomes alongside those of the "maximum power" state. These data will support uniform presentation of information about the product's spectral tuning range, aiding product selection and user acceptance.
- Products will provide user-facing documentation narrating the control protocol and input parameters employed in controlling the output.
- For PPF and PF_{FR} maintenance evaluation:
    - Provisions for products utilizing multiple types of LEDs (above) must be followed.
    - ISTMT testing must be provided on the hottest of each of the LED types. This testing must be conducted in the hottest operating mode of the fixture, corresponding to the "maximum power" condition (i.e. full-output). If a type of LED is *not* illuminated during the designated "maximum power" condition, then an additional ISTMT report will be required from the highest-power designed fixture state that *does* use the LED type.

Technical Requirements Update Intervals and Product Qualification Duration

Major Update Interval

The DLC Horticultural Requirements intends to follow a 24-month update cycle on its major efficacy requirements and structure. Six months prior to the new requirements' scheduled start date, the DLC will announce a new efficacy threshold for the upcoming requirements revision. The new threshold will be based on a query of all qualified products in its Horticultural QPL and determine the fifteenth percentile of PPE – that value which is the dividing line between the least efficacious 15% of products, and the more efficacious upper 85% of products.

All manufacturers of products below this fifteenth percentile will receive a notification and an invitation to update their product with current information and re-submit for a review. If the product does not receive an update that clears the new efficacy threshold, it will be delisted after a six month grace period following the change in requirements (twelve months after the percentile announcement).

The potential exists for other structural changes to the requirements (for example: application designations, family grouping, or output distribution/uniformity requirements) that may carry additional qualification implications at the end of this 24-month cycle. In each case, the DLC will make these changes with maximum notice and thorough stakeholder engagement, with the intent to accommodate existing listed products through any structural changes to the maximum extent possible.

Minor Update Interval

The DLC may also carry out minor technical updates before the 24-month update cycle. These will not materially alter the main requirements, and are aimed at improving the overall functioning of the program. These will be posted publicly and will be subject to the DLC's stakeholder input process. The DLC intends to carry out the following minor updates at the twelve-month mark, but others may also emerge if needs warrant it.

- Requiring true PPF-based LM-80 data for TM-21-based flux longevity calculation purposes.
- If conditions allow, requiring the usage of an ANSI-accredited safety certification for horticultural fixtures.
- If conditions allow, requiring TM-33-based data for PPID and SQD, and potentially PPF/PPE, and associated purposes.
- Adding "update product" capabilities to a self-service, web-based application.
- Adding "private labeling" capabilities to a self-service, web-based application.

Product Qualification Duration

The DLC proposes to allow products qualified during a major revision cycle to remain on the QPL for the duration of a technical requirements cycle, plus a grace period of six months. Those products meeting the requirements of the following cycle will have a means of easily confirming their continued commercial availability, and those requiring an update to their tested performance will have a means of easily updating their existing product. Those products that are not re-confirmed or updated for the following revision cycle's requirements will be delisted at the end of the six-month grace period following the onset of the new requirements becoming active.

Example Time Table

To review the structure of this proposed revision update and qualification duration, please see the companion document, "Horticultural Lighting Requirements Revision Schedule" posted as a companion to this DRAFT Requirements document.

Supporting Documentation

Test Reports

The DLC requires that all testing be conducted at appropriately accredited laboratories. Specifically:

- Testing of flux, intensity, and electrical characteristics must be conducted at laboratories that are accredited to ISO 17025 and the appropriate reference test standard by accreditation bodies that are signatories to the ILAC-MRA.
    - Labs conducting whole-fixture performance testing must also be acceptable via the DLC requirements for LM-79 labs in the SSL QPL program.

    - Labs conducting testing of device-level and/or fixture-level lumen maintenance must also be acceptable via the DLC requirements for LM-80/LM-84 labs.

- Labs conducting *In-Situ Temperature Measurement Testing* (ISTMT) must meet at least one of the following, consistent with requirements for SSL for general illumination:
    - Approved by OSHA as Nationally Recognized Testing Laboratories (NRTLs).
    - Approved through an OSHA NRTL data acceptance program or OSHA Satellite Notification and Acceptance Program (SNAP).
    - Accredited for ANSI/UL 1598 or CSA C22.2 No. 250.0-08, including Sections 19.7, 19.10-16, by an accreditation organization that is an ILAC-MRA Signatory.

Additional Application Details

In addition to the test data noted in the sections above, the DLC will require for all submissions:

- A completed web-based application form
- Specification sheets (or "cut sheets") for the product
- Marketing brochures used to describe and sell the product
- Specification sheets for all drivers and fans employed in the product, including lifetime-at-temperature information
- A self-certification statement, in the form of a digital signature made during the application process
- Safety certificates of compliance as issued by the relevant safety body, attested to by the self-certification statement above
- If demonstrating flux maintenance at the device-level, a completed TM-21 calculator must be provided for each LED device present in the fixture, with the applicable LM-80 and ISTMT information for that LED device. If demonstrating flux maintenance at the fixture-level, a completed TM-28 calculator must be provided for the fixture, with the applicable LM-84 information accompanying it.

The DLC will only accept applications for products with their own testing, with only limited variations for drivers allowed, as specified in the "Efficacy" section above. Additional grouping or "family" approaches will be considered if market conditions warrant as the sector matures. Given the multiple different axes of performance and product variability in this application, the DLC will be observing product data to determine equitable ways to determine "worst case" product family members, which would be a prerequisite for family grouping approaches.

Listing on the QPL

Information noted in the requirements and testing above will be noted on the QPL.

For SQD and PPF Intensity Distributions, the QPL will allow users of the QPL to link, download, or view the data array directly for use in calculating specific metrics or modeling their intended lighting layout. Please see the Key Questions document released alongside this draft document for more information.