Testing and Reporting Requirements for LED-based Horticultural Lighting

Version 2.1 – Draft 1

Proposed Effective Date: July 1, 2021

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", "Hort QPL"). Products eligible for DLC qualification must be complete LED light fixtures. That is, they must be electromagnetic radiation-generating devices analogous to luminaires (or fixtures) as defined by ANSI/IES RP-16 sections 6.8.5 and 10.3.1.

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

Products designed and intended to operate with standard North American nominal AC line voltages (typically 120V – 480V) are eligible for DLC qualification. The following are further eligibility rules for horticultural lighting equipment:

- Products that are 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 for qualification at this time.
- Fixtures that incorporate light sources other than LED, whether as sole-source or as LED-hybrid fixtures, are not eligible for qualification at this time.

- Manufacturers must list full and complete model numbers that clearly demonstrate all qualified product options offered.
    - "Full and complete model numbers" means model numbers that include all performance-affecting and non-performance-affecting variations offered, and which do not omit any option that is available to customers in the market. In general, options that do not affect the performance of the product can be submitted as a single model number, and the multiple options can be denoted by bracketing them in the model number.

      For example, a product that has multiple exterior paint color options or mounting options that do not affect performance may include all color and mounting options in brackets (e.g. "[WH, BLK, SLV, GRY]") within a single model number. Low and high voltage options may be submitted as a single model number (e.g. "ABC 300 [120V-277V, 347V-480V] WH") with the worst-case performance reported. Multiple driver variations may be included in single product applications, as noted above, and listed in a single model number as long as they perform nominally the same. If the drivers perform nominally differently – that is, they are not presented to customers as having the same performance other than voltage input and result in different ordering codes – then the unique drivers must be listed in separate model numbers. Options that affect the flux output, presence or lack of dimming capabilities, or spectral tuning options cannot be bracketed and submitted as a single model number.
    - DLC reviewers may check web listings and other marketing materials and reserve the right to request additional information to demonstrate the full and complete model number. A lack of clarity in model numbers will result in delayed application processing; misrepresentation of model numbers in the application process discovered outside the application process will generally be considered a violation of the DLC program and trademark rules.
    - Each model number can only represent the fixture under a single brand. If the fixture can be sold under multiple brands, model numbers must be listed separately for each brand.

Testing Methods and Requirements

The DLC Technical Requirements for LED-based Horticultural Lighting are as follows. Details explaining each item follow **Table 1**.

58 **Table 1: DLC Horticultural Lighting Technical Requirements**

Parameter/Attribute/Metric	Requirement	Requirement Type	Method of Measurement/Evaluation
Photosynthetic Photon Flux (Φ_p or PPF) ($\mu mol \times s^{-1}$)	n/a	Reported	(ANSI/IES LM-79) 400-700nm range, with 400-500nm, 500-600nm, and 600-700nm bins reported alongside the total
Far-Red Photon Flux ($\Phi_{p,fr}$ or PF_{FR}) ($\mu mol \times s^{-1}$)	n/a	Reported	(ANSI/IES LM-79) 700-800nm range
Photon Flux (PF_{PBAR}) ($\mu mol \times s^{-1}$)	n/a	Reported (Optional)	(ANSI/IES LM-79) 280-800nm range
Spectral Quantum Distribution (SQD) ($\mu mol \times s^{-1} \times nm^{-1}$)	n/a	Reported	(ANSI/IES LM-79) (ANSI/IES TM-33-18) 400-800nm range
Photosynthetic Photon Intensity Distribution (I_P or PPID) ($\mu mol \times s^{-1} \times sr^{-1}$)	n/a	Reported	(ANSI/IES LM-79) (ANSI/IES TM-33-18) 400-700nm range
Photosynthetic Photon Efficacy (K_p or PPE) ($\mu mol \times J^{-1}$)	≥1.90 $\mu mol \times J^{-1}$	Required/Threshold	(ANSI/IES LM-79) 400-700nm range
Photon Efficacy (PE_{PBAR}) ($\mu mol \times J^{-1}$)	n/a	Reported (Optional)	(ANSI/IES LM-79) 280-800nm range
Photon Flux Maintenance, Photosynthetic (PFM_P)	Q_{90} ≥36,000 hours	Required/Threshold	(ANSI/IES LM-80 / IES TM-21 or IES LM-84 / IES TM-28) 400-700nm range, fixture technical specification sheet, and *In-Situ Temperature Measurement Test* (ISTMT)

Parameter/Attribute/Metric	Requirement	Requirement Type	Method of Measurement/Evaluation
Photon Flux Maintenance, Far-Red (PFM_{FR})	Report time to Q_{90}	Reported	(ANSI/IES LM-80 / IES TM-21 or IES LM-84 / IES TM-28) 700-800nm range
Driver Lifetime	≥50,000 hours	Required/Threshold	Driver technical specification sheet, fixture technical specification sheet, and *In-Situ Temperature Measurement Test* (ISTMT)
Fan Lifetime	≥50,000 hours	Required/Threshold	Fan technical specification sheet, fixture technical specification sheet
Warranty	5 years	Required/Threshold	Legal warranty terms & conditions
Power Factor (PF)	≥0.9	Required/Threshold	Benchtop electrical testing or ANSI/IES LM-79
Total Harmonic Distortion, Current (THDi)	≤20%	Required/Threshold	Benchtop electrical testing or ANSI/IES LM-79
Safety Certification	Horticultural Lighting designation by OSHA NRTL or SCC-recognized body	Required/Threshold	ANSI/UL 8800 (ANSI/CAN/UL 8800)

Output Characteristics:

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

- **Photosynthetic Photon Flux (Φ_p or PPF), (µmol × s^{-1})**
  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 fixture and contains no spectral or directional information.

  The DLC Horticultural QPL reports on both the total and ~100nm-wide "bins" of flux within this range to allow end users to understand the fixture's relative proportions. Test information must provide output in these ranges specifically, in addition to the total 400-700nm output.

- **Far-Red Photon Flux ($\Phi_{p,fr}$ or PF_{FR}), (µmol × s^{-1})**
  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 fixture and contains no spectral or directional information. This metric is reported only and does not have a qualifying threshold.

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

- **Photon Flux (PF_{PBAR}), (µmol × s^{-1})**
  This is the output of the product over a plant's "photobiologically active radiation" (PBAR) wavelength range (280-800nm). This metric is an integrated value for the entire fixture and contains no spectral or directional information. This metric is optionally reported only and does not have a qualifying threshold.

  The DLC Horticultural QPL reports on the total flux of this PBAR band specifically for end users' informational needs. PF_{PBAR} is intended to convey UV, PAR, and FR radiation, which are often associated with photomorphological effects in plants. PF_{PBAR} is not an ASABE S640 defined term and is not required for DLC qualification, though it can be reported and listed if desired by applicants.

- **Photon Efficacy (PE_{PBAR}), (µmol × J^{-1})**
  This is the output of the product over a plant's "photobiologically active radiation" (PBAR) band (280-800nm) divided by the total electrical input watts to the fixture, including any other ancillary loads (controllers, sensors, cooling fans, etc.) used within the lighting system. This metric is an integrated value for the entire fixture and contains no spectral or directional information. This metric is optionally reported only and does not have a qualifying threshold.

  The DLC Horticultural QPL reports on the total flux of this PBAR band specifically for end users' informational needs. PE_{PBAR} is intended to convey luminaire efficacy in converting electrical energy into UV, PAR, and FR radiation, which are often associated with photomorphological effects in plants. PE_{PBAR} is not an ASABE S640 defined term and is not required for DLC qualification, though it can be listed if desired by applicants.

- **Spectral Quantum Distribution (SQD), (µmol × s^{-1} × nm^{-1})**
  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). The DLC will also accept the distribution of photon flux per photon wavelengths over the PBAR range (280-800nm). When reporting either of the optional PBAR metrics (i.e. PF_{PBAR} and PE_{PBAR}), distribution of photon flux over the PBAR range is required. This distribution is measured and reported as integrated in all directions from the fixture and contains no granular directional information itself. This distribution must be measured and reported from an appropriately accredited facility.

  An image of this distribution must be submitted within the application in a .jpg graphical file format, at a size of 300x300 pixels or larger. This image will be accessible to users on the QPL. The DLC intends to utilize the required .xml file per ANSI/IES TM-33-18 to generate these images in the future.

Please refer to the TM-33-18 Reporting and Photometric/Spectral Reporting Alternatives section for additional information.

- **Photosynthetic Photon Intensity Distribution (I_P or PPID), (µmol × s^{-1} × sr^{-1})**
  This is the distribution of photosynthetic photon intensity per unit solid angle leaving the fixture. This distribution is measured and reported as integrated for all wavelengths across the 400-700nm range leaving the fixture and contains no spectral distribution information itself. This distribution must be measured and reported from an appropriately accredited facility.

  An image of this distribution is to be submitted within the application in a .jpg graphical file format, at a size of 300x300 pixels or larger. This image will be accessible to users on the QPL. The DLC intends to utilize the required .xml file per ANSI/IES TM-33-18 to generate these images in the future.

  Please refer to the TM-33-18 Reporting and Photometric/Spectral Reporting Alternatives section for additional information.

  Note: The DLC will no longer accept distribution data that are developed through in-house assessments. Products that were qualified prior to the V2.0 effective date must provide TM-33-18 documents by December 31, 2021 to requalify to the V2.0 Technical Requirements, or the products will be delisted.

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 the total electrical input watts to the fixture, including any other ancillary loads (controllers, sensors, cooling fans, etc.) used within the lighting system.

All products are required to have a PPE of ≥ 1.90 µmol × J^{-1}. In both submitted applications and under surveillance testing, the DLC allows an absolute tolerance of -5% to this threshold value. The result of this is the DLC's acceptance of any test report showing an efficacy of 1.81 µmol × J^{-1} or higher, and the disqualification of any product, either during submission or surveillance testing, with a test report showing an efficacy less than 1.81 µmol × J^{-1}, at any point in the product's specified operating voltage range. All evaluations and listings of this measurement will be rounded to the nearest hundredth.

If a product contains multiple drivers:

- All driver specification sheets must be provided.
- For each unique driver used, manufacturers must provide electrical testing to document which driver variation results in the overall minimum K_p (PPE) or worst-case driver efficiency, as well as which variation results in the overall worst-case power quality (THDi and PF).
  - This testing must 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) benchtop electrical testing is sufficient for demonstrating the driver variation that yields the overall minimum K_p (PPE) and

minimum power quality 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 LM-79 testing by an accredited testing lab.
- For questions about testing requirements for family grouping applications, please refer to the Family Grouping Application Requirements for LED-based Horticultural Lighting policy.

- Drivers that result in explicitly different nominal fixture performance (for example, if a driver change results in different flux output by the product, determined at the DLC's discretion) are not permissible variations within a single model number and are required to submit a family grouping application for QPL listing. If alternate driver variations result in different input wattage, worst-case will be published on the QPL.
  - Please refer to the Family Grouping Application Requirements for LED-based Horticultural Lighting policy for specific testing and reporting requirements for product families.

Long-Term Performance:

The DLC requires the following performance data to characterize the long-term performance of the fixture:

- **Flux Maintenance, Φ_p (PPF) and $\Phi_{p,fr}$ (PF_{FR})**
  This is a characterization of the ability of the device to maintain its output within the given parameters over time. Given that device output of interest is measured in quanta of photons, and not in lumens, the DLC will use the general engineering term for quanta, "Q", instead of the more-familiar "L" prefix used within general illumination applications.
  - The DLC requires either LED device-level or whole-fixture testing and projections in accordance with the (LM-80 and TM-21) or (LM-84 and TM-28) industry standards sufficient for a Q_{90} of ≥36,000 hours within the Φ_p (PPF) range (400-700nm).
    - The "Q" in the Q_{90} value is based strictly on the value shown in cell I42 of the ENERGY STAR TM-21 calculator or cell I45 of the ENERGY STAR TM-28 calculator.
  - All TM-21 or TM-28 projections must be made at the maximum ambient temperature on the fixture's specification sheet. See *In-Situ Temperature Measurement Testing (ISTMT)* information below for additional details.
  - The DLC requires testing and projections to report Q_{90} for the $\Phi_{p,fr}$ (PF_{FR}) range of 700-800nm, but does not make determinations or qualifications based on this data. Please see a description of PFM_{FR}-specific testing requirements in the "For fixtures using multiple types of LEDs" section below.
  - To support PFM_P and PFM_{FR} projections, LM-80/LM-84 information must be provided for both the 400-700nm and the 700-800nm range.

- All new product submissions using the LM-80/TM-21 approach are required to provide LM-80 data in appropriate (PPF, PF_{FR}) units, measured as such at all time points in the LM-80 procedure. The DLC reserves the right to request additional information for all reports referring to "photon flux" that are ambiguous (based on product SQD) about the division of said flux between the PPF and PF_{FR} categories to determine approval.
    - Products qualified with non-PPF units that were converted into PPF units during the provisional period (i.e. prior to V1.2) will be required to provide LM-80 data in appropriate units to requalify under the V2.0 Technical Requirements.
    - Provisionally qualified products will be allowed to update their listings to remove any caveats by submitting actual data by December 2021. The DLC will process these update applications through the month of December, 2021.
- Products may not be qualified and listed on the QPL without long-term performance data for flux degradation. Products that use LEDs for which no LM-80 data is available are required to undergo LM-84 testing for TM-28 projections.

- *In-Situ Temperature Measurement Testing (ISTMT):*
    - ISTMTs must be conducted and provided for the hottest LED in the fixture, and LED-device level drive current must be reported.
    - ISTMTs must be conducted and reported in the same manner as thermal testing for safety certification. Specifically, applicants must report the operating temperature of the LED at the fixture's highest rated ambient temperature within the ISTMT report. This must be done in accordance with acceptable procedures from safety certification standards for measuring and projecting operating temperatures. For example, if a fixture is rated for operation at 40°C ambient, ISTMTs are not accepted if they only show the temperature of the LED when measured during a 25°C ambient condition. In this example, appropriate steps must be taken to characterize the LED operating temperature when the fixture is in a 40°C ambient environment, as defined by the thermal portions of the relevant safety standards.
- 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 fixture.
        - For DLC evaluations, LED "type" is differentiated by the nominal output of the LED device or the manufacturer of that LED device. For example, a fixture incorporating four different LEDs, with nominal emissions of 440nm, 660nm, 730nm, and a 5000K "white", is required to provide four LM-80s and associated information for TM-21 projections, corresponding to each of these nominal designations. Some limited

cross-applicability of LM-80 data is allowed within phosphor-converted white LEDs of the same series; see LM-80 applicability information below.

- ISTMT testing must be provided on the hottest of each LED type (for example, the hottest blue, white, and red LED in the fixture, respectively).
- Maximum LED drive current must be reported for each LED type.
- For PFM_P (400-700nm), each LED type present in the fixture that has at least 25% of its per-device flux in the PPF range must independently meet the $Q_{90} \geq$ 36,000 hours requirement, as shown by a TM-21 calculation. The DLC does not require device-level SQD data from applicants and will typically accept the applicant's descriptions of a device's relative PPF while reserving the right to request explanation.
- The DLC requires calculated PFM_{FR} for all fixtures with a PF_{FR} output that is equal to or greater than 5% of the fixture's flux from 400-800nm. For PFM_{FR} (700-800nm), each LED type present in the fixture that has at least 25% of its per-device flux in the PF_{FR} range must report its Q_{90} duration in hours. The DLC does not require device-level SQD data from applicants and will typically accept the applicant's descriptions of a device's relative PF_{FR}, while reserving the right to require explanation. There is no threshold performance requirement across this far-red range; it is a reported value only.

  - LM-80 applicability:
    - For phosphor-converted "white" LEDs within the ANSI nominal chromaticity range, the DLC follows the *ENERGY STAR Requirements for the Use of LM-80 Data* published September 2017. Consistent with the ENERGY STAR requirements, for narrow-band emitters, the DLC generally requires an LM-80 for each distinct nominal product offered by an LED device manufacturer. Devices of the same type but with different optical codes for beam spread are allowed to cross-apply LM-80 testing. This also applies to products that are in the same series with differences in nomenclature due to marketing changes (see series provisions of ENERGY STAR requirements document). The DLC reserves the right to require additional information to approve all claims of LM-80 applicability.

- **Warranty**

  Products must have a manufacturer-provided product warranty of at least five years. The warranty terms and conditions must be provided as part of the submittal for qualification. The warranty must cover the complete luminaire and must clearly explain the terms and conditions associated with the warranty. Note that "luminaire" includes light source, housing, heat sink, power supplies, and other electrical components, optics, and any other components such as cooling fans or controls (if present).

  Warranty terms and conditions can vary widely from manufacturer to manufacturer. The DLC explicitly defines a warranty period of five years and does not have specific requirements for

warranty claim terms (e.g. labor, recommissioning, etc.) other than those listed above. The DLC does not verify or validate a manufacturer's terms, conditions, or process for customer warranty claims. The DLC does not monitor field failure rates of qualified products or warranty policy redemption or history among manufacturers. Industry stakeholders are urged to review warranty terms and conditions as part of the purchasing decision process.

- **Driver ISTMT**

  Applicants must supply a technical specification sheet for the driver(s) 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. 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 specification sheet information and demonstrating that the driver will have a lifetime of at least 50,000 hours when operating at or above 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 certification. Specifically, applicants must report the operating temperature of the driver at the fixture's highest rated ambient temperature within the ISTMT report. This must be done in accordance with acceptable procedures from safety certification standards for measuring and projecting operating temperatures. For example, if a fixture is rated for operation at 40°C ambient, ISTMTs are not accepted if they only show the temperature of the driver when measured during a 25°C ambient condition. In this example, appropriate steps must be taken to report the driver operating temperature when the fixture is operating in a 40°C ambient environment, as defined by the thermal portions of the relevant safety standards.

  - For products that may use multiple drivers, specification 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. If a product uses multiple drivers from the same manufacturer product line or series, then the single worst-case thermal ambient environment of the product line or series requires a driver ISTMT. The DLC will operate with the expectation that the operating condition at the highest wattage in the driver manufacturer's product line or series is the worst-case thermal ambient environment, but the DLC may ask the manufacturer to provide detailed evidence to document the worst-case driver thermals.

- **Fans**

  Products that employ on-board cooling fans must provide a technical specification sheet for each fan type employed in the product, family group, or spectral sub-group, as applicable. The fan specification sheet must state the lifetime of the fan and a reference operating temperature rating for that lifetime claim. The lifetime must be at least 50,000 hours, at an operating temperature at or above the fixture's highest rated ambient temperature.

  If the product is available with multiple fan models:

- If fan model variations result in substantively different component temperature or wattage consumption by the fixture (determined at the DLC's discretion), a family grouping application is required with model numbers to represent the different fan variations. DLC reviewers will examine fan model power levels and flow rate to determine this distinction. Products that offer fan variations without substantively different component temperature or wattage consumption by the fixture are allowed to qualify using bracketed variations within a single model number.
- Multiple fan variations require a similar testing and reporting plan to multiple driver variations, as noted in the efficacy section.

Electrical Performance/Power Quality:

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

- **Power Factor**
  Products must have a measured power factor of ≥0.90 at any rated input voltage at full output or non-dimmed state.
- **Total Harmonic Distortion, current (THDi)**
  Products must have a measured THDi of ≤20% at any rated input voltage at full output or non-dimmed state.

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 and maximum designed output power. Testing to demonstrate that products are compliant with the power factor and total harmonic distortion requirements may be done on an in-house or benchtop setup for practical simplicity, and results must be documented and included in the application materials. Please see the efficacy section regarding the use of this electrical testing for worst-case efficacy driver variation determination. Please refer to the Family Grouping Testing Requirements for LED-based Horticultural Lighting policy for specific testing and reporting requirements for product families.

Safety:

Products must be certified by an OSHA NRTL or SCC-recognized body to ANSI/UL 8800 (ANSI/CAN/UL 8800) which is applicable for *horticultural lighting products* by that safety organization.

For illustrative and reference purposes, practices of acceptable safety organizations are described below:

- **UL**
  Fixture manufacturers who use UL for safety certification purposes are required to be listed on the UL Certification Directory under the designation IFAU.

- **ETL/Intertek**
  Fixture manufacturers who use ETL for safety certification are required to be listed on the ETL Certification Directory, specifically as Horticultural Fixtures.
- **CSA Group**
  Fixture manufacturers who use CSA for safety certification are required to be listed under CSA Group's Classes defined for horticultural lighting equipment in Canada and the US.
- **TÜV SÜD**
  Fixture manufacturers who use TÜV SÜD for safety certification are required to be listed on the TÜV SÜD Certification Directory, specifically as a light fixture for use on horticulture purposes.
- **SGS**
  Fixture manufacturers who use SGS for safety certification are required to be listed on the SGS Certification Directory, specifically as horticultural lighting equipment.
- **Other safety organizations**
  To be added to the DLC's approved list of safety organizations who certify horticultural lighting equipment per ANSI/CAN/UL 8800 requirements, please contact horticulture@designlights.org.

Special Considerations

Special Considerations for Spectrally-Tunable Products

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

- The threshold-qualifying state to be tested must 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 indicate that the product is operated in this "maximum power" condition 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, applicants must perform PPF testing for each control channel, in which the channel under test must be set to the maximum designed output, while all other channels must be set to their minimum designed output for this state. The test report must present an identifying name of this channel and setting, the PPF (400-700nm total and 400-500nm, 500-600nm, and 600-700nm "bins" PPF) and PF_{FR} (700-800nm) for each of the single-channel scenarios, and a description of the control narrative to achieve each setting. For each channel tested, a corresponding graphic for the SQD produced in that setting must be provided in the application. Refer to the SQD section for reporting requirements.
    - The flux output of each specific channel testing is displayed on the DLC Horticultural QPL, with the per-channel test outcomes and identifying information for each setting. These data are intended to support standardized communication of information about the product's spectral tuning range, aiding product selection and user acceptance.

- Applicants must provide user-facing documentation narrating the control protocol and input parameters employed in controlling the output.
- For PFM_P and PFM_{FR} evaluation:
    - Provisions for products utilizing multiple types of LEDs must be followed as described in the For fixtures using multiple types of LEDs section.
    - ISTMT testing must be provided on the hottest of each of the LED types. For each unique LED type, ISTMT testing must occur at the operating mode that produces the highest operating temperature in the fixture, for this LED type.
    - The DLC asks any applicants considering LM-84-based maintenance testing on a spectrally-tunable fixture to contact horticulture@designlights.org to discuss their proposed testing plan.

PROPOSED Special Considerations for DC-Powered Fixtures

Eligibility Information

Horticultural lighting fixtures powered by direct current (DC) are eligible for listing on the Horticultural QPL. DC-powered fixtures include two types:

- **Modular fixtures where one AC-to-DC power source supplies power to multiple fixtures.** The power source may have a minimum as well as a maximum number of fixtures that it may serve. The AC-to-DC power source may be attached to one of the fixtures or may be located remotely from the fixtures. The fixtures may be offered with more than one power supply option. The power source must be available to purchase through the fixture manufacturer for that specific fixture model or family.
- **Fixtures that operate on DC power, where one or more AC-to-DC power source may or may not be sold with the fixture.** These fixtures may be wired to an AC-to-DC power source outside the fixture or in a separate room, or may be part of an off-grid, DC-only horticulture facility.

Technical Requirements Information

All V2.0 Horticultural Lighting Technical Requirements described in **Table 1** must be met in addition to the following requirements.

The following requirements apply to applications for DC-powered fixtures, in place of the equivalent AC testing and reporting:

- **DC-Powered "All-on" Photon Flux Test Report**: Applicants must provide an LM-79 report in PDF format from an accredited third-party test lab with all required photon flux and power values for verification, including DC voltage, current and power. For dimmable or tunable products, this is the test report of the product at its maximum (non-dimmed) power state. Additionally, to better capture worst-case operating conditions, including losses over cabling, LM-79 testing must be conducted while using the longest cabling option allowed if specified by the fixture

manufacturer. Performance measurements shall be made at the cabling input so that losses over the length of the cabling are included in LM-79 measurements.

- **Tested Power Source Report**: For both types of DC-powered fixtures, if power sources are offered for sale with the DC-powered fixture, applicants must provide a table of the following performance values for all drivers offered for sale with the DC fixture. A power source specification sheet or other documentation from the power source manufacturer with numerical values listed for each load point may satisfy this requirement, in place of testing. These values may come from benchtop testing (measurements performed by a manufacturer that are not from a certified testing lab). All values must be provided at the minimum and maximum AC input voltages for each driver, as well as at each DC output voltage utilized by the DC-modular fixture (if multiple).
    - Performance values must be provided at each of four load points:
        - The driver's maximum rated power load
        - 50% of maximum load
        - 20% of maximum load
        - The minimum power source load if specified by the fixture manufacturer
            - For example: The minimum driver load is the load represented by one fixture, e.g. 30% load for a 100W power source that may power one to three 30W fixtures, or by the minimum number of fixtures per power source specified on the fixture spec sheet, e.g. 60% load for a 100W power source that may power either two or three 30W fixtures.
    - Performance values to be reported in the benchtop test report:
        - Consumed input power, shown to the nearest hundredth of a watt
        - DC output power, shown to the nearest hundredth of a watt
        - Electrical efficiency (driver power output divided by driver power consumed), shown to the nearest hundredth
        - Power factor, shown to three significant digits
        - Total harmonic distortion of the current waveform as a percentage, shown to three significant digits at minimum

- The following example shows this table for a single power supply:

Manufacturer Name		Model Number		AC Input Voltage Range (V)		DC Output Voltage Range (V)	
ABC Corp.		*ABC123*		*120-277*		*48V*	
Input Voltage (V)	**Output Power Range (W)**	**Loading Percentage**	**Input Power (W)**	**Tested Output Power (W)**	**Tested Efficiency (%)**	**Power Factor**	**Total Harmonic Distortion (current)**
120	*30-300*	**100%**	*315.2*	*300*	*95.18*	*0.932*	*0.05*
		50%	*161.1*	*150*	*93.11*	*0.928*	*0.041*
		20%	*65.9*	*60*	*91.05*	*0.911*	*0.04*
		minimum %	*35.1*	*30*	*85.47*	*0.908*	*0.038*
277	*30-300*	**100%**	*314.8*	*300*	*95.30*	*0.932*	*0.05*
		50%	*160.9*	*150*	*93.23*	*0.928*	*0.041*
		20%	*65.5*	*60*	*91.60*	*0.911*	*0.04*
		minimum %	*36.2*	*30*	*82.87*	*0.908*	*0.038*

  - Fixtures that are not offered for sale with any AC-to-DC power source are not required to provide a tested driver report. These products will be listed with an assumed AC-to-DC conversion efficiency—see below.

- Consistent with the Horticultural Technical Requirements, Driver ISTMT Reports are required for all horticultural products sold with AC-to-DC or DC-to-DC power sources.
  - Fixtures that are not offered for sale with any AC-to-DC power source are not required to provide a Driver ISTMT report.

QPL Listing Information

DC-powered fixtures will be listed on the Horticultural Lighting QPL with the following differences from AC-powered fixtures:

- New fields will be reported:
  - **"System Type"** will be distinguished between AC and DC products.
  - **"DC Input Voltage"** and **"DC Input Current"**, from DC-powered LM-79 for both DC-powered fixture types.
  - "**DC Input Power"** and **"DC Photosynthetic Photon Efficacy: 400-700 nm, µmol/J (DC PPE)"** will display the values from the all-on DC photon flux report.
    - Optional new field **"DC PE_{PBAR}"** will be reported if PE_{PBAR} is reported.
  - Additionally, new fields will display **"AC De-rated Input Power"** and **"AC De-rated PPE"** only for DC-powered fixtures.
    - DC-powered fixtures offered for sale with any AC-to-DC power source will reflect the power efficiency of the AC-to-DC conversion at the load condition that creates the worst-case efficiency. For example, a 100W lightbar with PPE of 2.5 and a power supply showing a worst-case efficiency of 85% at 20% load, would be listed on the QPL at 2.13µmol/J and 118W.
    - DC-powered fixtures that are not offered for sale with any AC-to-DC power source will display values in the AC de-rated fields based on an assumed 87.5%

conversion efficiency. 87.5% is informed by the Federal Standard per 10 C.F.R. § 430.32(w) for minimum efficiency for External Power Supplies greater than 250W.

  - Optional new field **"AC De-rated PE_{PBAR}"** will be reported if PE_{PBAR} is reported.

- The fields currently used for "**AC Input Power**" and **"AC PPE"** will not be populated.
- The worst-case values of THD and Power Factor will be shown in the existing fields.

Key Questions for V2.1 Draft 1, DC-Powered Fixtures

1. Is the proposed method for listing de-rated values for fixtures offered for sale with one or more power sources appropriate? Should any other information (beyond power draw at the worst-case load condition) be displayed on the Hort QPL to assist QPL users? Is the 87.5% conversion efficiency the right assumption?
2. Is the proposed method for listing de-rated values for fixtures not offered for sale with any power source appropriate?
3. Is it beneficial to list de-rated AC values for Input Power and PPE, in addition to DC values? Are AC values for a worst-case configuration useful in evaluating proposed hort lighting systems? Or are system evaluators, such as custom incentive program engineers, more likely to use manufacturer-provided information to calculate power and PPE at the actual load conditions, driver configuration, and input voltage of the system under consideration?
4. Are the power source performance data required for the table available from power source manufacturers?
5. If no maximum cabling length is specified at the luminaire level, how could worst-case power losses over cabling be considered during LM-79 testing? If cabling gauge varies to account for longer cabling, should higher gauge, longer cable runs or lower gauge, shorter cables runs be tested?
6. The proposed requirements would offer no information on power source efficiency below 20% load condition. Is it important to capture power source efficiency below 20% loading, and if so where does this load condition exist in horticultural lighting applications? What minimum loading percentage would reflect this real-world use for AC-de-rated reporting?

PROPOSED Special Considerations for Externally-Supplied Actively Cooled Fixtures

Eligibility Information

- LED horticultural fixtures that employ externally-supplied ducted forced-air are not eligible. LED horticultural fixtures that employ externally-supplied circulating-liquid are eligible with the following conditions described below.
- The DLC defines externally-supplied circulating-liquid cooled horticultural fixtures to be products in which liquid, often water or a water/glycol solution, flows through input and output ports of each fixture in the system, being channeled through a cooling plate or other heat exchanger within the fixture.

Technical Requirements Information

- All V2.0 Horticultural Lighting Technical Requirements described in **Table 1** must be met in addition to the following requirements and clarifications:
    - Manufacturers must specify the range of allowable operating conditions that should be supplied to or affect the LED product performance, including:
        - Solution type/concentration
        - Flow rate
        - Inlet fluid temperature
    - The threshold-qualifying state to be tested must be the manufacturer designated state with the *worst-case* operating conditions for inlet fluid temperature, flow rate, and solution concentration.
        - Average and highest inlet fluid temperature, measured at the manufacturer specified Test Measurement Location (TML), must be measured and reported during ISTMT and LM-79 testing.
        - ISTMT reports must report the operating temperature(s) at the fixture's highest rated ambient temperature.
    - Inlet fluid temperature must also be measured and reported during benchtop electrical testing.
    - To support the qualification of *externally*-supplied circulating-liquid cooled horticultural fixtures, the DLC will accept LM-79 gonioradiometer testing with methods or equipment from other gonioradiometer types in addition to Type C.
        - All *externally*-supplied circulating-liquid cooled horticultural fixtures seeking qualification by the DLC must test the fixture per ANSI/IES LM-79, including requirements specific to, but not limited to, stabilization and optical measurements, while employing active cooling.

- Electrical testing must be provided to document the maximum input power and input voltage to the externally-supplied cooling mechanism when operating at the highest voltage in an "All On" (i.e. max flow rate, highest fluid temperature, etc.) state.
    - In-house (i.e. non-accredited lab) benchtop electrical testing is sufficient.
- Additionally, applicants must provide documentation describing the *externally*-supplied cooling mechanism with the following reporting and threshold requirements:
    - Rated lifetime of the cooling system must be a minimum of 10 years, as stated on the cooling mechanism manufacturer's specification sheet.
    - Range of acceptable inlet and outlet fluid temperature, flow rate, and solution type/concentration must be defined.

QPL Listing Information

In addition to the existing fields, *externally*-supplied actively cooled fixtures will have the following information listed on the QPL:

- **"Product Category"**
    - *Externally*-Supplied circulating-liquid horticultural fixture
- **"Tested Inlet Fluid Temperature"**
    - Maximum and average measured temperature per ISTMT and LM-79 testing
- Allowable operating conditions supplied to fixture including:
    - **"Solution Concentration"**
    - **"Flow Rate Range"**
    - **"Inlet Fluid Temperature Range"**
- Per cooling mechanism in-house benchtop electoral test report:
    - **"Maximum Input Voltage"**
    - **"Maximum Input Power"**
    - **"Power Factor"**
    - **"Total Harmonic Distortion (current)"**

Key Questions for V2.1 Draft 1, Externally-Supplied Actively Cooled Fixtures

1. The DLC has proposed that *externally* supplied circulating-liquid horticultural fixtures meet the same efficacy requirements as V2.0 luminaires without considering power consumption of the cooling system. Should the power consumed by the cooling system be considered in evaluation of luminaire PPE? If so, how should it be considered and reported on the QPL?

2. The DLC has proposed a rated lifetime requirement of 10 years for the cooling system. Is the proposed rated lifetime requirement reasonable?

3. How does the rated input power for an externally-supplied cooling system differ when considering environment? i.e. Is performance substantially different if located within a greenhouse or set outside a grow facility? Is benchtop testing needing to consider "worst-case" conditions for the cooling system?

4. What, if any, additional considerations should be made for listing eligibility of *externally*-supplied circulating-liquid cooled horticultural fixtures?

PROPOSED Special Considerations for LED Replacement Lamps

Eligibility Information: Linear Replacement Lamps

LED replacements for linear fluorescent lamps are eligible with the following conditions:

- LED replacements for linear fluorescent lamps seeking qualification to the DLC Horticultural Lighting QPL must meet the definitions, eligibility requirements, supporting documentation, and distribution requirements of the SSL V5.1 Testing and Reporting Requirements for Linear Replacement Lamps.
    - Linear replacement lamps seeking horticulture lighting qualification *do not* need to meet the following performance criteria under the solid-state lighting program:
        - Luminous efficacy (lumens per Watt)
        - Initial bare lamp light output (lumens)

Technical Requirements Information: Linear Replacement Lamps

- Linear replacement lamps seeking horticultural lighting qualification must test the bare lamp according to LM-79 to meet all V2.0 Horticultural Lighting Technical Requirements as described in **Table 1**.
    - The DLC defines bare lamp as the performance characteristics of a replacement lamp, including the effects of an external ballast (for Type A and Dual Mode lamps) or driver (for Type C lamps), if applicable, when operated outside of a luminaire or retrofit kit.

Eligibility Information: Screw-Base Replacements for HID Lamps

LED replacements for mogul-base high intensity discharge (HID) lamps are eligible with the following conditions:

- The DLC accepts Horticultural QPL applications for mogul (E39 and E40) screw-base replacement lamps. UL Type B products, which require removal of the existing ballast from the circuit and the lamp holder to be wired with line voltage, are eligible.
    - Other base types and UL Types are not eligible at this time.

- Field-adjustable light distribution products are not eligible at this time.

- Screw-base LED replacements for HID lamps seeking qualification to the DLC Horticultural Lighting QPL must meet the definitions, eligibility requirements, and supporting documentation requirements of the SSL Testing and Reporting Requirements for Screw-Base Replacements for HID Lamps.
  - Screw-base replacements for HID lamps seeking horticultural lighting qualification *do not* need to meet the following performance criteria under the solid-state lighting program:
    - In-Luminaire minimum efficacy (lumens per Watt)
    - In-Luminaire light output (lumens)
    - Reference Housing requirements
  - ISTMT testing shall be conducted similarly to the SSL V5.1 Linear Replacement Lamp policy.

Technical Requirements Information: Screw-Base Replacements for HID Lamps

- Screw-base replacements for HID lamps seeking horticultural lighting qualification must test the bare lamp according to LM-79 to meet all V2.0 Horticultural Lighting Technical Requirements as described in **Table 1**.
- Screw-base replacements for HID lamps must be generally omni-directional (the DLC defines omni-directional to be a product that emits radiation in all directions except in the base direction).

QPL Listing Information: All Replacement Lamps

In addition to existing fields, replacement lamps will have the following information listed on the Horticultural Lighting QPL:

- **"Product Category"**
  - Options include: Linear Replacement Lamp or Screw-Base Replacements for HID Lamps
- **"Base Type"**
  - Options include: G13, G5, E39, E40
- **"Product Size Information"**
  - Linear replacement lamps must include the nominal length in inches
  - Screw-base replacements for HID lamps must include product dimensions as Maximum Overall Length (including base) x width x height
- **"UL Type"**
  - Options include: A, B, AB, C

Key Questions for V2.1 Draft 1, LED Replacement Lamps

1. The DLC has proposed that lamps must meet the same efficacy requirements as V2.0 luminaires of 1.9 umol/J. Is the proposed efficacy reasonable? If not, please provide justification (i.e. data) to support this rationale.
2. The DLC has not proposed requirements for lamps in a fixture housing (i.e. "in-luminaire"), but instead uses distribution requirements for the bare lamp. Is this approach reasonable? If not, please provide justification to support this rationale.
3. Should there be different distribution requirements for horizontally and vertically mounted Screw-Base Replacements for HID Lamps?
4. Should the DLC include reporting requirements for mounting criteria, such as lamp orientation? If so, which criteria specifically is critical to report?

Tolerances

The DLC accepts measurement tolerances to most metrics listed in the Technical Requirements. Please refer to **Table 2** below for additional tolerance information.

Table 2: DLC Horticultural Lighting Technical Requirements Tolerances

Parameter/Attribute/Metric	V2.0 Tolerances
Photosynthetic Photon Efficacy	-5%
Power Factor	-3 percentage points
Total Harmonic Distortion	+5 percentage points
ISTMT Temperature Measurements	1.1°C or 0.4%, whichever is greater
LM-80 Drive Current	-5%

Tolerances are intended to account for all testing variation, rounding, and significant digits. The requirement values and tolerances will be interpreted by DLC review staff as exact requirements. While test labs will be expected to follow the requirements of their accreditation and relevant test standards,

DLC staff will not employ additional "rounding" to interpret values below the absolute thresholds as passing. For example, if a horticultural lighting product is required to have a PPE of 1.9 with an efficacy tolerance of -5%, any value for efficacy less than 1.81 will be interpreted as a failing value. It is the applicant's responsibility to check all data presented in an application before submission to ensure compliance with the DLC requirements.

Supporting Documentation

Test Reports

The DLC requires that all testing be conducted at appropriately accredited laboratories except where noted otherwise. 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 follow the DLC requirements for LM-79 labs.
- Labs conducting testing of device-level and/or fixture-level photon flux maintenance must also follow 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:
    - 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

TM-33-18 Reporting and Photometric/Spectral Reporting Alternatives

The DLC requires all applicants to submit accompanying .xml files per ANSI/IES TM-33-18 for each parent or single product to represent the spatial and spectral distribution of the tested fixture.

- The .xml file must be based on measured data from an accredited lab, accompanying the LM-79 testing requirements for spectral and spatial measurements.
- The .xml file must include the spectral power distribution data, with an interval resolution of 5nm or smaller over the photosynthetic and far-red range of wavelengths defined by ANSI/ASABE S640 (400-800nm). The DLC also requires the distribution of photon flux per photon wavelengths over the PBAR range (280-800nm) in the case that applicants provide PF_{PBAR} and PE_{PBAR} data. Spectral data in 1nm intervals are acceptable. The spectral measurement represents the integrated flux in all directions from the fixture, without directional spectral information. Per TM-33-18, the data is reported in W/nm, not spectral quantum distributions.

All DLC developed and interim manufacturer submitted SQD images will report in µmol × s^{-1} × nm^{-1}.

- The .xml file must also include the Photosynthetic Photon Intensity Distribution (PPID), reported in µmol × s^{-1} × sr^{-1}, over the photosynthetic wavelengths defined by ANSI/ASABE S640 (400-700nm). PPID is the distribution of photosynthetic photon intensity per unit solid angle leaving the fixture. Each measurement is integrated across the 400-700nm range leaving the fixture and contains no granular spectral distribution information (i.e. color over angle).

To facilitate time for accredited labs to develop or purchase TM-33-18 reporting software, the DLC offers a 9-month grace period for applicants to provide .xml files compliant with TM-33 reporting for parent products. If TM-33-18 reports are not available, applicants must submit LM-63 and TM-27 (i.e. .ies and .spdx files, respectively) for parent products or single products.

- For manufacturers choosing to submit .ies and .spdx files instead of .xml files in the interim period, they must resubmit data compliant with TM-33-18 reporting requirements by December 31, 2021, or the products will be delisted.
- The .ies files must contain [_OTHER] keywords to describe the units of intensity values and a conversion factor relating photosynthetic photon intensity to luminous intensity (conversion factor = PPF/lumens).

Additional Application Details

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

- A completed web-based application form
- Specification sheets (or “cut sheets”) for the product that include maximum ambient temperature
- Specification sheets for all drivers and fans employed in the product, including lifetime-at-temperature information
- Safety certificates of compliance as issued by the relevant safety body, attested to by the DLC self-certification statement
- 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 testing on the product submitted, with only limited variations permitted as detailed in the sections above. Given the multiple options within product families, the DLC offers the Family Grouping Application Requirements for LED-based Horticultural Lighting policy, which describes a method to determine “worst-case” product family members.