Technical Requirements for LED-Based Horticultural Lighting Version 4.0

DRAFT 1

Released for Comment: November 7, 2024

This draft of the Technical Requirements document contains proposed updates and clarifications. These updates are denoted by yellow highlighted line numbers, table rows, or text.

Contents

1.0 Introduction

Horticultural lighting products using LEDs must comply with the provisions of this document to be eligible for listing on the DLC Horticultural Lighting Qualified Products List (Horticultural QPL, Hort QPL). Products eligible for DLC qualification must be complete LED light fixtures or modules. That is, they must be electromagnetic radiation-generating devices analogous to luminaires (or fixtures) as defined by *ANSI/IES LS-1-22*.

In North America, increasing demand for locally produced food combined with the legalization of medical and/or recreational cannabis and the desire for resilient supply chains are fueling the growth of controlled environment agriculture (CEA).[*] The DLC Horticultural Lighting Technical Requirements are designed to help guide the industry toward sustainable growth in concert with decarbonization efforts.

Relying on industry standard nomenclature, testing, and reporting methodologies, the DLC Technical Requirements establish minimum performance baselines for horticultural LED fixtures. The requirements support the successful adoption of energy efficient practices in CEA through the implementation of LED luminaires and controls. Since the implementation of Hort V1.0, the average efficacy of listed products has increased by 17.5%.

Hort V4.0 is designed to further support and accelerate the adoption of energy efficient lighting and controls in CEA. This is accomplished through the following key revisions to the previous technical requirements:

- **Proposed efficacy increase**
  Hort V4.0 proposes to increase the PPE threshold to a minimum of 2.5 µmol × J^{-1}, which is an 8.7% increase over the Hort V3.0 PPE threshold. This increase will set the DLC efficacy threshold for LED-based horticultural lighting at more than 45% above the most efficacious non-LED option, the 1000W double-ended high pressure sodium luminaire. Please let us know if you have any questions or concerns with the proposed efficacy threshold for Hort V4.0 and be specific to whether that concern exists for all product types, or for products with certain characteristics or designed for specific applications.

- **Proposed removal of lamp categories**
  In 2021, Hort V2.1 introduced several new product qualification pathways for DC-powered products, liquid cooled products, and several lamp types. Since then, all new categories have seen participation and QPL listings have been actively growing, except for lamps. With the lack of uptake around lamps, Hort V4.0 proposes to simplify the overall Technical Requirements and application process by removing the qualification pathway for lamps. Please let us know if you think lamp categories should remain eligible.

- **Proposed clarifications to various requirements**
  To improve clarity of the Horticultural Technical Requirements, a variety of clarifications have been proposed throughout the document. For example, clarifications to what the DLC considers

[*] *Where marijuana is legal in the United States*. (2022, November 9). MJBizDaily. https://mjbizdaily.com/map-of-us-marijuana-legalization-by-state

"nominally distinct wavelength band" have been included in the LM-80 applicability section, language has been added to clarify testing requirements for spectrally tunable products based on their spectral tunability and to better define what the PPE-tested qualifying state should be, and other clarifications have been made to various requirement details. Please review these clarifications and let us know if you have any questions or concerns and provide suggestions for addressing these concerns.

2.0 Definitions

2.1 Horticultural and Lighting Terminology

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-45-21, Recommended Practice: Horticultural Lighting* and *ANSI/IES LS-1-22, Lighting Science: 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.

3.0 Eligibility

Products designed and intended to operate with standard North American nominal AC line voltages (typically 120 V to 480 V) or with DC voltages below 600 V are eligible for DLC qualification. In addition:

- Ineligible products include:
    1. Products that are light engines (see definition of "LED light engine" in *ANSI/IES LS-1-22*) or identified as retrofit kits intended to replace the light sources or other structures within an existing fixture.
    2. Products that incorporate light sources other than LED, whether as sole-source or as LED-hybrid fixtures.
    3. AC products that are dynamically configurable (i.e., having no defined configuration or set of configurations) and whose form factor may vary in the grow facility, are not eligible as an AC product and must qualify through the DC product pathway with the exception noted below.
        a. Products that are sold as a static set of components whose light emitting components are not rigidly connected can follow the AC **or** DC pathway. Additional details can be found in section **24.**
    4. Lamps (integrated or non-integrated), as defined in the DLC Glossary
        a. Hort V4.0 proposes to remove technical requirement details and qualification pathways for all lamps; i.e., previously eligible lamps will no longer be eligible under V4.0.

- Manufacturers must list full model numbers that clearly demonstrate all qualified product options offered.
    - "Full model numbers" means model numbers that include all performance-affecting and non-performance-affecting variations offered, and that 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 may be submitted as a single model number, and the multiple options may be denoted by bracketing them in the model number.

      For example, the submittal for 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 Level 1 (formerly 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 may not 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 model number. A lack of clarity in model numbers will result in delayed application processing; misrepresentation of model numbers discovered outside the application process will generally be considered a violation of the DLC program and trademark rules and may result in delisting.
    - Each model number may only represent the product under a single brand. If the product can be sold under multiple brands, model numbers must be listed separately for each brand. If brand name is not provided, the manufacturer name will be used to represent the brand name on the QPL.

4.0 Testing Methods and Requirements

The DLC Technical Requirements for LED-based Horticultural Lighting are shown in **Table 1**. Additional information is provided in **Sections 4.1** through **4.5**. Further requirements, exceptions, and special considerations for some kinds of fixtures are discussed in **Section 7, Special Considerations.**

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Parameter, Attribute, or Metric	Requirement	Requirement Type	Method of Measurement and Evaluation
Photosynthetic Photon Flux (Φ_P or PPF) ($\mu mol \times s^{-1}$)	n/a	Reported	(ANSI/IES LM-79) 400-700 nm range, with 400-500 nm, 500-600 nm, and 600-700 nm 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) 700-800 nm range
Photon Flux (PF_{PBAR}) ($\mu mol \times s^{-1}$)	n/a	Reported (Optional)	(ANSI/IES LM-79) 280-800 nm range
Spectral Quantum Distribution (SQD) ($\mu mol \times s^{-1} \times nm^{-1}$)	n/a	Reported	(ANSI/IES LM-79) (ANSI/IES TM-33) 400-800 nm 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) 400-700 nm range
Photosynthetic Photon Efficacy[1,2] (K_P or PPE) ($\mu mol \times J^{-1}$)	≥2.5 $\mu mol \times J^{-1}$	Required/ Threshold	(ANSI/IES LM-79) 400-700 nm range
Photon Efficacy (PE_{PBAR}) ($\mu mol \times J^{-1}$)	n/a	Reported (Optional)	(ANSI/IES LM-79) 280-800 nm range
Photon Flux Maintenance, Photosynthetic (PFM_P)	Q_{90} ≥ 36,000 hours	Required/ Threshold	(ANSI/IES LM-80 and ANSI/IES TM-21, or ANSI/IES LM-84 and ANSI/IES TM-28) 400-700 nm range, fixture specification sheet, and In-Situ Temperature Measurement Testing (ISTMT) results
Photon Flux Maintenance, Far-Red (PFM_{FR})	Report time to Q_{90}	Reported	(ANSI/IES LM-80 and ANSI/IES TM-21, or ANSI/IES LM-84 and ANSI/IES TM-28) 700-800 nm range

Parameter, Attribute, or Metric	Requirement	Requirement Type	Method of Measurement and Evaluation
Driver Lifetime	≥50,000 hours	Required/ Threshold	Driver specification sheet, fixture specification sheet, and In-Situ Temperature Measurement Testing (ISTMT)
Fan Lifetime	≥50,000 hours	Required/ Threshold	Fan specification sheet, fixture specification sheet
Warranty	Fixtures: ≥5 years	Required/ Threshold	Legal warranty terms and 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	ANSI/UL 8800 (ANSI/CAN/UL 8800)
Application Information	Intended controlled environment(s) and lighting scheme(s)	Reported	Product specification sheet
Controllability	Dimming capability	Required or reported, depending on product attributes	Product specification sheet
	Dimming range	Reported	Manufacturer reported
	Dimming and control methods	Reported	Product specification sheet or supplemental material
	Integral control capabilities	Reported	Product specification sheet or supplemental material

Table notes:

1. DC-powered fixtures must meet the PPE threshold requirement at their AC de-rated PPE value. See “Special Considerations for DC-Powered Fixtures” for more information on AC de-rating.

4.1 Output Characteristics

The DLC requires testing and reporting of the following characteristics of the output of horticultural lighting devices. (*Exception:* PF_{PBAR} is optionally reported, as described below.)

- **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 (400-700 nm). 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 approximately 100-nm-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 400-700 nm 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* (700-800 nm). 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 100-nm-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 (280-800 nm). 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 Lighting QPL reports on the total flux of this PBAR band specifically for end users' informational needs. PF_{PBAR} is intended to convey information regarding ultraviolet (UV) radiation, photosynthetically active radiation (PAR), and far-red (FR) radiation, all of 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.

- **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* (400-800 nm). The DLC will also accept the distribution of photon flux per photon wavelength over the PBAR range (280-800 nm). 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.

  The DLC has released a publicly available tool to generate distribution images, which is accessible through a free MyDLC account. An image of this distribution generated by the DLC tool must be submitted within the application in a PNG graphical file format. This image will be accessible to users on the QPL.

For additional information, please refer to **Section 9.2, ANSI/IES TM-33-18 Reporting**.

- **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 400-700 nm range and contains no spectral distribution information itself. This distribution must be measured and reported by an appropriately accredited facility.

  The DLC has released a publicly available tool to generate distribution images, which is accessible through a free MyDLC account. An image of this distribution generated by the DLC tool must be submitted within the application in a PNG graphical file format. This image will be accessible to users on the QPL.

  For additional information, please refer to **Section 9.2, ANSI/IES TM-33-18 Reporting**.

4.2 Efficacy

The requirements for testing and reporting of the output characteristics of horticultural lighting devices are described below. (*Exception:* PE_{PBAR} is optionally reported, as described below.)

- **Photon efficacy (PE_{PBAR}), (µmol × J^{-1})**
  This is the output of the product over a plant's "photobiologically active radiation" (PBAR) band (280-800 nm) divided by the total electrical input watts to the fixture, including any other ancillary loads (e.g., controllers, sensors, cooling fans) 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.

  Additional information regarding PBAR may be found in the definition of "photon flux" in **Section 4.1, Output Characteristics**.

- **Photosynthetic photon efficacy (K_p, PPE) , (µmol × J^{-1})**
  This is the output of the fixture over the specific range of wavelengths defined by *ANSI/ASABE S640* for PPF (400-700 nm) divided by the total electrical input watts to the fixture, including any other ancillary loads (e.g., controllers, sensors, cooling fans) used within the lighting system.

All products must have a PPE of at least 2.5 µmol × J^{-1}. In both submitted applications and under surveillance testing, the DLC allows an absolute tolerance of -5% for this threshold value. The result of this is the DLC's acceptance of any test report showing an efficacy of 2.38 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 2.38 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 one-hundredth.

The following requirements apply to products that contain 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 PPE or worst-case driver efficiency, as well as which variation results in the overall worst-case power quality (THDi and PF). In addition:

- 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 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.
- Additional information may be found in the Level 2 Application (formerly Family Grouping Application) requirements for LED-based horticultural lighting.

- Drivers that result in explicitly different nominal fixture performance (for example, a driver change which results in different flux output by the product, determined at the DLC's discretion) are not permissible variations within a single model number, and a Level 2 application for QPL listing must be submitted. If alternate driver variations result in different input wattage, the worst case will be published on the QPL.

  The Level 2 application requirements for LED-based horticultural lighting provide specific testing and reporting requirements for product families.

4.3 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 photons, which are quanta (i.e., packets) of energy, and not in lumens, the DLC will use the general engineering term "quantum," or "Q," instead of the more-familiar "L" prefix used in general illumination applications. In addition:
- 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 at least 36,000 hours within the Φ_p (PPF) range (400-700 nm). A complete and accurate copy of the June 18, 2018 version of the ENERGY STAR TM-21 calculator OR a complete and accurate copy of the ANSI/IES TM-21 Calculator report in both PDF and JSON format is required for submission. 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, or Flux maintenance Q_{90} value from a complete and accurate ANSI/IES TM-21 Calculator report.
- In response to ENERGY STAR retiring its TM-21 calculator, the DLC intends to transition away from all pathways requiring ENERGY STAR TM-21 calculators to requiring use of the ANSI/IES TM-21 calculator. ENERGY STAR pathways are acceptable throughout V4.0.

- All TM-21 and TM-28 projections must be made at the maximum ambient temperature on the fixture's specification sheet. (See **In-Situ Temperature Measurement Testing (ISTMT)** bullet below for additional details.) All temperature values must be reported in degrees Celsius.
- The DLC requires testing and projections to report Q_{90} for the $\Phi_{p,fr}$ (PF_{FR}) range of 700-800 nm but does not make determinations or qualifications based on this data. (See a description of PFM_{FR}-specific testing requirements in the **For fixtures using multiple types of LEDs** bullet below.)
- To support PFM_P and PFM_{FR} projections, LM-80/LM-84 information must be provided for both the 400-700 nm and the 700-800 nm ranges.
    - All new product submissions using the LM-80 and TM-21 approach must provide LM-80 data in appropriate (PPF, PF_{FR}) units, measured as such at all time points during 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 will 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 must undergo LM-84 testing for TM-28 projections.
- In-Situ Temperature Measurement Testing (ISTMT) (ISTMT):
    - ISTMTs must be conducted, and results provided, for the hottest LED in the fixture, and 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 an ambient condition of 25 °C. In this example, appropriate steps must be taken to characterize the LED operating temperature when the fixture is in an ambient environment of 40 °C, 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 spectral output of the LED device, or the manufacturer of that LED device. For example, the submittal for a fixture incorporating four different kinds of LEDs, with nominal

emissions of 440 nm, 660 nm, 730 nm, and a phosphor-converted white (pc-white) of 5000K, is required to provide four LM-80 reports 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 pc-white LEDs of the same series; see the **LM-80 applicability** bullet below.

- ISTMTs must be provided on the hottest of each LED type (for example, the hottest blue, pc-white, and red LED in the fixture, respectively).
- Maximum LED drive current must be reported for each LED type.
- For PFM_P (400-700 nm), 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 requirement of $Q_{90} \geq 36{,}000$ hours, 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 400-800 nm. For PFM_{FR} (700-800 nm), 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 further explanation. There is no threshold performance requirement across this far-red range; it is a reported value only.

  - LM-80 applicability:
    - For pc-white LEDs within the ANSI nominal chromaticity range (i.e., 2200K-6500K), 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 report for each product with a nominally distinct wavelength band (e.g., 650 nm, 620 nm, 590 nm) 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 the series provisions of the above-mentioned ENERGY STAR requirements document). The DLC reserves the right to require additional information to approve all claims of LM-80 applicability.

- Based on a review of publicly available specification sheets, industry outreach, and a review of existing and upcoming standards, LM-80 applicability will not be restricted within manufacturing tolerances or binning options for distinct colors. The DLC relies on LED manufacturers to appropriately claim LM-80 applicability between LEDs that are nominally the same peak or dominant wavelength (i.e., distinct colors) as defined by the LED manufacturer for appropriate use of LM-80 test data.

- LM-80 applicability claims where the difference from the nominal peak or dominant wavelength of the LM-80 tested LED to the nominal peak or dominant wavelength of a different LED is beyond +/- 15nm will be rejected.

- **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. All temperature values must be reported in degrees Celsius.

    - As noted in the **ISTMT** description under the flux maintenance bullet at the beginning of **Section 4.3, Long-Term Performance**, driver ISTMTs must be conducted and the results 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 an ambient condition of 25 °C. In this example, appropriate steps must be taken to report the driver operating temperature when the fixture is operating in an ambient environment of 40 °C, as defined by the thermal portions of the relevant safety standards.

    - For products that may use multiple drivers, a specification sheet 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, as determined by the DLC, then the single worst-case thermal ambient environment of the product line or series requires a driver ISTMT. Typically, 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.

    - Manufacturers of products with custom and integrated drivers must provide documentation equivalent to that required for drivers from third-party vendors. Manufacturers must supply documentation indicating the maximum acceptable temperature for the driver for a 50,000-hour life, as well as the TMP to be used during thermal testing and evaluation.

- **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 Level 2 Application (formerly Family Grouping Application) is required with model numbers to represent the different fan variations. DLC reviewers will examine fan model power levels and flow rates 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 **Section 4.2, Efficacy**.

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

  The DLC does not have specific requirements for warranty claim terms (e.g., labor, recommissioning) 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.

4.4 Electrical Performance and 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 at least 0.90 at any reported input voltage at full output or a non-dimmed state.

- **Total harmonic distortion, current (THDi)**
  Products must have a measured THDi no greater than 20% at any reported input voltage at full output or a 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 THDi 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. **Section 4.2, Efficacy** provides additional information on the use of this electrical testing for worst-case efficacy driver variation determination. Specific testing and reporting requirements for product families may be found in the Level 2 Application (formerly Family Grouping Application) testing requirements for LED-based horticultural lighting.

4.5 Safety

Products must be certified by an Occupational Safety and Health Association (OSHA) Nationally Recognized Testing Laboratory (NRTL) or by a Standards Council of Canada (SCC)-recognized body to *ANSI/UL 8800 (ANSI/CAN/UL 8800*), which is applicable for horticultural lighting products.

5.0 Application (Intended Product Use) Information Requirements

All products are required to report product-level application (intended product use) information, as shown in **Table 2**. Additional information on these requirements, including definitions of terms, can be found in **Sections 5.1** and **5.2**.

Table 2. Application Information Reporting Requirements

<table>
<tr><th colspan="2" rowspan="2">Controlled Environment[1]</th><th colspan="2">Lighting Scheme[1]</th><th rowspan="2">Product Image and Dimensions[2]</th><th rowspan="2">Requirement Type</th><th rowspan="2">Method of Measurement and Evaluation</th></tr>
<tr><th>Position</th><th>Use Case</th></tr>
<tr><td rowspan="2">Indoor</td><td>(Stacked)</td><td rowspan="2">Top light, intra-canopy, other (text)</td><td rowspan="2">Sole-source or Supplemental</td><td rowspan="3">All product submittals are required to include:
• A representative image of the qualifying product or family
• Product physical dimensions</td><td rowspan="3">Reported</td><td rowspan="3">Product specification sheet or supplemental materials</td></tr>
<tr><td>(Non-stacked)</td></tr>
<tr><td colspan="2">Greenhouse</td><td>Top light, intra-canopy, other (text)</td><td>Supplemental</td></tr>
</table>

Table notes:

1. For verification and evaluation, the respective Controlled Environment information must be clearly stated on the provided specification sheet for each product. Additionally, Lighting Scheme information must be clearly stated on the provided specification sheet for each product or in supplemental materials.
2. A representative image and dimensions of the product or product family must be clearly provided on the submitted specification sheet or in supplemental materials for each product.

5.1 Controlled Environment

The DLC considers controlled environments to be buildings or structures wherein electric lighting and other inputs (e.g., air temperature, humidity, and water consumption) can be controlled to grow crops.

The following are controlled environments considered in Version 4.0:

- **Indoor (Stacked or Non-stacked)**
  Indoor controlled environments are fully enclosed controlled environments with single or multitier layers of crops.
  - Stacked indoor controlled environments are typically synonymous with vertical farms, and products listed in this controlled environment should be intended for crops that have a short stature, short production cycle, and high yield. Products intended for stacked indoor controlled environments are often highly customizable and scalable.
  - Non-stacked indoor controlled environments are indoor facilities with a single canopy, and that do not have multiple vertical layers of crops. Products listed in this category may be intended for a broader variety of crops with varying statures, production cycles, and yields.
- **Greenhouse**
  Greenhouse controlled environments rely on sunlight as a primary light source, but often utilize supplemental electric lighting (defined below) while still taking advantage of available daylight throughout the year to maintain a consistent daily light integral (DLI) incident on the plant canopy.

The controlled environment(s) for which the product is intended must be explicitly and clearly stated in the product specification sheet.

Applicants must report product physical dimensions and provide a representative image of the fixture (PNG format). Style guidance for representative product images is available here. The dimensions and representative image of the product will be published on the QPL for all listed products. Level 2 Applications (formerly Family Grouping Applications) are allowed to use a representative image for the family and are not required to provide individual images for each listed variation.

5.2 Lighting Scheme

Along with the controlled environment information described in **Section 5.1**, applicants must report the intended lighting scheme of listed products. Lighting schemes provide insight into how listed horticultural lighting fixtures are intended to deliver optical radiation to the crop or canopy in terms of both direction and duration.

The following are lighting schemes considered with Version 4.0:

- **Lighting Scheme (Position): Top Light, Intra-canopy, or Other (text)**
  This information must be reported to convey the mounting position and directionality by which listed products deliver optical radiation.

  Products reported to be a top light must be intended to be mounted with the emission area facing downward, toward the plant canopy.

  Products reported to be an intra-canopy light must be intended to be mounted within the plant canopy.

To account for innovative technologies in this developing field, the "other (text)" option supports products that do not fit within the top lighting or intra-canopy lighting categories. Examples: "other (ground-mounted lighting)" or "other (side lighting)."

- **Lighting Scheme (Use Case): Sole-Source and/or Supplemental**
  Products reported to be sole-source must be intended for applications where the lighting fixture is the primary source of optical radiation for inducing photobiological effects in crops.

  Products reported to provide supplemental lighting must supplement daylight or another product that is the primary light source. Supplemental products must be intended for applications where the lighting product is not the primary source of optical radiation for inducing photosynthesis but is instead intended to provide supplemental light, and overall energy usage is not as high (e.g., a specialty product that is intended to provide a specific light spectrum to induce a specific growth action in addition to daylight in a greenhouse, or a higher-output product with a broadband spectrum to fully supplement daylight in a greenhouse).

The lighting scheme(s) for which the product is intended must be explicitly and clearly stated in the product specification sheet.

Submittals for products designed for a variety of controlled environments and lighting scheme applications may report multiple options for a single QPL listing. For example, a product intended for an indoor, stacked, top lighting, sole-source application may also be intended for use in a greenhouse, top lighting, supplemental application.

6.0 Controllability Requirements

All products must meet the controllability requirements shown in **Table 3**. Details explaining each item follow in **Sections 6.1** through **6.4**. Further requirements, exceptions, and special considerations for some kinds of fixtures are discussed in **Section 7, Special Considerations**.

Table 3. Controllability Requirements

Parameter, Attribute, Metric		Requirement	Requirement Type	Method of Measurement, Evaluation
Dimming Capability	**All DC products**	Products must be dimmable	Required	Product specification sheet[1]
	AC luminaires with PPF ≥ 350 µmol × s^{-1}			
	AC luminaires with PPF< 350 µmol × s^{-1}	Report whether the product is dimmable or non-dimmable	Reported	
Dimming Range[2]		Report: minimum input wattage, minimum PPF, default input wattage, default PPF	Reported	Manufacturer reported
Dimming and Control Methods[2]		Report: dimming or control method designation to the product, connector, or transmission hardware[3]	Reported	Product spec sheet or supplemental material[1]
Integral Control Capabilities		N/A	Reported	Product spec sheet or supplemental material[1]

Table notes:

1. For verification and evaluation, the corresponding characteristic must be clearly stated on the provided specification sheet for each product and/or supplemental material as specified in the table. There will be no further evaluation against any other document. For DC-powered products, this information may be included on the specification sheet for the power source, if applicable.
2. Reporting of dimming range or dimming and control method is not required for non-dimmable products.

6.1 Dimming Capability

- **For DC-powered products and AC-powered luminaires with a reported PPF greater than or equal to 350 µmol × s^{-1}:**
  Products must be capable of dimming via a line voltage, low voltage, or wireless signal. Products that are dimmable via a knob or switch mounted on the fixture (manual dimming) are not acceptable unless an additional external control signal is available. For verification, the product technical specification sheet (or other documentation stated in Note 1 for **Table 3**) must state that the product is dimmable.
- **For AC-powered luminaires with a reported PPF less than 350 µmol × s^{-1}:**
  Dimming capability is not required for this subset of products, but this information should be reported. The QPL will display whether the product is capable of dimming. For verification, the product technical specification sheet (or other documentation stated in Note 1 for **Table 3**) must state whether the product is dimmable or non-dimmable.

6.2 Dimming Range

To describe the dimming range of the product, each of the following values must be reported on the application. (Dimming range information is not required for non-dimmable products.) If multiple drivers are offered for a single product, each with a unique dimming range, these options will each be represented by an individual line item on the QPL, not bracketed into a single catalog number.

- **Minimum input wattage**
  This is the input power (in watts) to the product at the minimum dimming level. If the product is capable of being turned off via the control signal (i.e., dim to off), this value must include any standby power consumed while the product is in the "off" state. If there is no standby power consumed while the product is in the "off" state, this value should be zero.

- **Minimum photosynthetic photon flux**
  This is the photosynthetic photon flux at the minimum dimming level, in $\mu mol \times s^{-1}$. If the product is capable of being turned off via the control signal (i.e., dim to off), this field may be reported as zero.

- **Default input wattage**
  The default wattage occurs at the default setting, i.e., the setting at which the product is shipped with no adjustments, expressed in watts. Beyond the required photometric testing detailed in **Section 4, Testing Methods and Requirements**, no additional testing is required at the default wattage level.

- **Default photosynthetic photon flux**
  The default photosynthetic photon flux occurs at the default setting, i.e., the setting at which the product is shipped with no adjustments, expressed in $\mu mol \times s^{-1}$. Beyond the required photometric testing detailed in **Section 4, Testing Methods and Requirements**, no additional testing is required at the default photosynthetic photon flux level.

6.3 Dimming and Control Methods

- **Dimming and control method designations to the product**
  All available dimming and control method designations between the product and other devices must be reported and stated on the product technical specification sheet or supplemental material (see Note 1 for **Table 3**). Reporting of dimming and control method designations to the product is not required for non-dimmable products.

  Options for reporting are shown in **Table 4**. The "Acceptable Terms" column includes terms that may appear on the submitted documentation to indicate the use of the corresponding dimming or control method. Any dimming or control method not included in this table, including proprietary options, may be reported as "Other Wired" or "Other Wireless" as applicable. Multiple selections may be made. If multiple driver options are offered for a single product, each with a unique dimming or control method, these options must each be represented by an individual line item on the QPL; they may not be bracketed into a single catalog number.

Modifications may be made for DC-powered products. Additional information is provided in **Section 7, Special Considerations**.

Table 4. Dimming and Control Method Designations to the Product

	Control Type (as displayed on the QPL)	Definition	Acceptable Terms
Wired	**0-10V**		
	0-10V IEC 60929 Annex E	Wired analog low-voltage control that varies DC voltage between 0 and 10 volts to produce varying light output.	0-10V, 10V, 10V0
	0-10V ANSI C137.1 (8-Volt)		
	0-10V ANSI C137.1 (9-Volt)		
	0-10V Other		
	Phase Cut		
	Phase Cut (Forward Phase)	Modification, or cutting, of the leading edge of the AC mains sinusoidal waveform to produce varying light output.	Phase-cut, forward phase, leading edge, TRIAC, magnetic low-voltage (MLV)
	Phase Cut (Reverse Phase)	Modification, or cutting, of the trailing edge of the AC mains sinusoidal waveform to produce varying light output.	Phase-cut, reverse phase, trailing edge, electronic low-voltage (ELV)
	DALI		
	DALI	Digital Addressable Lighting Interface Protocol, a wired digital communication protocol registered by the DALI Alliance.	DALI
	DALI2	Digital Addressable Lighting Interface Protocol, a wired digital communication protocol registered by the DALI Alliance.	DALI2, DALI-2
	Ethernet		
	Power Over Ethernet	Power over Ethernet (PoE) products are a specific subset of DC products that comply with the IEEE 802.3 standards for carrying both power and communication signals on Ethernet cables.	Power Over Ethernet, PoE
	Ethernet TCP/IP	Wired networking technology defined by IEEE 802.3 standards.	Ethernet
	Ethernet Proprietary		
	Other		
	Other Wired	Other wired communication protocol as specified by the manufacturer.	N/A

Control Type (as displayed on the QPL)		Definition	Acceptable Terms
Wireless	**Zigbee**		
	Zigbee 3.0	Wireless digital communication protocol developed by the Connectivity Standards Alliance.	Zigbee 3.0, ZB3
	Zigbee – Manufacturer Specific		ZigBee
	Bluetooth		
	Bluetooth® Sig MESH and MMDL Layers	Wireless digital mesh communication protocol developed and maintained by the Bluetooth Special Interest Group (SIG). Product utilizing and qualified with the Bluetooth mesh specification in the networking and application layer.	Bluetooth SIG MESH, Bluetooth MESH Technology
	Bluetooth® - Manufacturer Specific	Any Bluetooth implementation not described above and not utilizing the Bluetooth specification in both the networking and application layers.	Bluetooth
	Wi-Fi		
	Wi-Fi	Wireless networking protocol based on IEEE 802.11.	Wi-Fi, WIFI, IEEE 802.11, Wi-Fi Certified
	EnOcean		
	EnOcean	Wireless digital communication protocol developed by EnOcean.	EnOcean
	Other		
	Other Wireless	Other wireless communication protocol as specified by the manufacturer.	N/A

- **Connector or transmission hardware**

  This is the hardware integrated into the product that enables it to physically connect with and receive control signals from a controller or other device. In addition to the dimming or control method designation to the product, all available connectors and transmission hardware must be reported and stated on the product technical specification sheet or supplemental material (as stated in Note 1 for **Table 3**), using one or more of the terms from the "Acceptable Terms" column in **Table 5**. Reporting of connector or transmission hardware is not required for non-dimmable products.

  Any connector or transmission hardware not included in **Table 5** may be reported using the "Other Wired" or "Other Wireless" options shown in **Table 5**. Multiple selections may be made. If variations are offered for a single product, each with a unique connector or transmission

hardware option, these options must each be represented by an individual line item on the QPL; they may not be bracketed into a single catalog number.

Table 5. Connectors and Transmission Hardware

Type of Hardware		Acceptable Terms
Wired	**RJ-11**	RJ-11, RJ11
	RJ-12	RJ-12, RJ12
	RJ-14	RJ-14, RJ14
	RJ-45	RJ-45, RJ45
	USB	USB
	Flying Leads	Flying Leads
	Terminal Block	Terminal Block
	Other Wired	N/A
Wireless	**Wireless Radio**	Any of the acceptable terms from the Wireless section of **Table 4**
	Infrared Receiver	
	Other Wireless	N/A

6.4 Integral Control Capabilities

All available integral control capabilities listed in **Table 6** must be reported. If applicable, this information must be included on the product technical specification sheet or supplemental material (as stated in Note 1 for **Table 3**), using one or more of the terms from the "Acceptable Terms" column. Multiple selections may be made. If a product does not include any of the capabilities in **Table 6,** this field may be left blank.

Table 6. Integral Control Capabilities

Integral Control Capabilities	Definition	Acceptable Terms
Dim to Off	The ability for a product to be turned on or off via a dimming control signal.	Dim to off, Dimming: 0%-100%
Energy Monitoring	The capability of a driver to report the energy consumption of a luminaire.	Energy (or Power) Monitoring, Energy (or Power) Metering, Energy (or Power) Measurement, Energy (or Power) Reading
Manual Dimming	A knob or other control device integrated into the fixture and used for manual dimming.	Manual Dimming, Knob Dimming, Dimming Knob, Fixture Integrated Dimming, Rotary Switch

7.0 Special Considerations

7.1 Special Considerations for Spectrally Tunable Products

Spectrally tunable products vary spectral output options beyond simple dimming of the whole product. Spectrally tunable products are categorized as having either:

- Customizable Spectra - This category of spectrally tunable products allows precise and dynamic control over the spectral output by allowing the user to adjust individual control points. These control points can be adjusted continuously through a variety of user interfaces such as physical or digital sliders representing LED type or wavelength, a color wheel, or other approaches. For purposes of this document, the variety of interfaces used for custom spectral control will be referred to as “custom spectral controllers”.
- Predefined Spectra – This category of spectrally tunable products allows the user to select from a set of predefined spectral options, often referred to as "spectral recipes," that have been design by the manufacturer with intentions for specific plants, plant growth stages or desired outcomes (e.g., vegetative growth, flowering, fruiting).
- Products that are capable of both (customizable and predefined spectral options) are qualified as having customizable spectra.
- If control mechanisms other than those described in this section are utilized to adjust spectrum, please reach out to horticulture@designlights.org

Spectrally-tunable products are eligible with the following conditions:

- The PPE threshold qualifying state to be tested must be the manufacturer-designed state with the highest power consumption (“maximum power”).
    - The threshold qualifying state is the spectral setting or option that results in the highest input power to the product.
        - This may or may not be the same as all LEDs within the product at maximum output, since products may not be designed to use all their LEDs 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 spectral tuning characterization via Full LM-79/SQD testing for specific conditions noted below:
    - For products with customizable spectra, each setting representing the maximum power for each individually-controllable channel.
        - Tested custom spectral settings must be set to the maximum designed output for each individually-controllable channel, while all other individually-controllable channels are set to their minimum designed output.
        - The test report must sufficiently describe the conditions for custom spectral controllers as well as include a setting name to be used for publishing on the QPL.
    - For products with predefined spectra, each predefined spectral must be tested.

        - The test report must include the predefined spectral option name that will be used for publishing on the QPL.
    - This data is intended to support standardized communication of information about the product's spectral tuning range, thus aiding in product selection and user acceptance.
- Additionally, each test report must include:
    - The photon flux (PPF: 400-700 nm, 400-500 nm, 500-600 nm, and 600-700 nm PF "bins") and PF_{FR} (700-800 nm)
    - The flux output of each manufacturer provided configuration name will be displayed on the DLC Horticultural QPL.
- Applicants must provide user-facing documentation narrating the control protocol and input parameters employed in controlling the output.
    - If the user-facing documentation does not clearly describe technical limitations of the product, and the relationship between the control settings and electrical conditions of each LED device present in the product, this information must be provided in a supplementary document. The documentation must be sufficient for the DLC team to understand the capabilities of the product in all possible end-use applications, and not simply a set of presets designed for one particular customer.
- For PFM_P and PFM_{FR} evaluation:
    - Provisions for products utilizing multiple types of LEDs must be followed as described in the bullet titled **For fixtures using multiple types of LEDs** in **Section 4.3, Long-Term Performance**.

      In-Situ Temperature Measurement Testing (ISTMT) must be performed on the hottest of each of the LED types. For each unique LED type, the ISTMT must occur in the operating mode that produces the highest operating temperature in the fixture for this LED type. Test reports must specifically indicate that the product is operated in this "highest operating temperature" condition during the test, with a description of the control narrative to ensure that the power state is at its highest operating temperature designed level.

      To ensure worst-case evaluation of each LED for flux maintenance, models for which an ISTMT is performed must be tuned to produce the hottest thermal environment for each of the LED types. This will likely result in the same model being tested multiple times at different settings in order to generate the hottest setting for each of the LED types.
    - 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.

7.2 Special Considerations for DC-Powered Fixtures

7.2.1 Eligibility Information

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

- **Modular and/or dynamically configurable fixtures where one or several AC-to-DC power sources (e.g., drivers) supply power to multiple fixtures or modules.**
    - The power source(s) may have a minimum as well as a maximum number of fixtures that they may serve.
    - The AC-to-DC power source(s) may be attached to one of the fixtures or may be located remotely from the fixtures.
    - The power source(s) must be marketed by the fixture manufacturer as the intended power source(s) for that specific fixture model or family.
- Fixtures that are sold as a static set of components whose light emitting components are not rigidly connected can be considered a modular and/or dynamically configurable fixture, i.e. as a DC product, **or** as an AC product.
    - Model numbers included for qualification must be specific to the input power type utilized for qualification, i.e. a product seeking qualification as an AC-powered fixture must include a complete set of components.
- **Fixtures that operate on DC power, where an AC-to-DC power source (e.g., driver) is not marketed by the fixture manufacturer as the intended power source.** 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 a DC-only horticultural facility.

7.2.2 Technical Requirements for DC-Powered Fixtures

All requirements described in **Table 1** (see **Section 4.0, Testing Methods and Requirements**) must be met, in addition to the following requirements, with exceptions as noted. The requirements listed here 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. This is the test report of the product operated in its maximum (non-dimmed) power state.
- **Power source test report**:
  If power sources (e.g., drivers) are marketed with the DC-powered fixture, applicants must provide a table of the following performance values for all power sources offered for sale with the DC fixture. 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 reported minimum and maximum AC input voltages for each power source, as well as at each DC output voltage utilized by a DC modular fixture (if multiple). A power source specification

sheet or other documentation from the power source manufacturer with numerical values listed for each load point may be used to satisfy this requirement, in place of testing.

- Performance values must be provided at each of two load points, as determined by the fixture manufacturer:
  - Maximum power load, i.e., the load representing the maximum number of light fixtures that can be powered by this power source.
  - The load point of the power source between maximum power load and 20% of maximum load that results in the worst-case power source efficiency.
    - Only load points achievable with multiples of this fixture at full output need to be considered in identifying the worst-case power source efficiency. For example, for a 100-watt power source that may power either two or three 30-watt fixtures, only the 60% and 90% loading conditions must be compared to determine the worst-case efficiency.
    - A lower limit on load points may also be set by the loading requirement for a given power source listed on the fixture specification sheet. For example: “Required operating range of 15 W to 90 W of output at 100 W of input power.”
- The following performance values must be reported in the power source test report:
  - Nominal AC input voltage
  - Maximum output power of the power source at the specified input voltage, shown to the nearest whole watt
  - Minimum and maximum output power for the specific combination of power source and horticultural fixture at full output, shown to the nearest whole watt
  - Loading percentage (the ratio of tested DC output power to maximum output power with this fixture), shown to the nearest tenth of a percent
  - Tested AC input power, shown to the nearest hundredth of a watt
  - Tested DC output power, shown to the nearest hundredth of a watt
  - Electrical efficiency (power source output power divided by power source input power), shown as a percentage to two decimal places
  - Power factor, shown to three decimal places
  - Total harmonic distortion of the current waveform as a percentage, shown to one decimal place
- **Figure 1** shows an example for a single power source.

Manufacturer Name			Model Number				AC Input Voltage Range (V)		DC Output Voltage Range (V)	
ABC Corp.			*ABC123*				*120-277*		*48*	
Nominal AC Input Voltage (V)	**Power Source Maximum Output (W)** [Output rating irrespective of fixture]	**Minimum Output Power with this fixture type (W)** [fixture type at full output]	**Maximum Output Power with this fixture type (W)** [fixture type at full output]	**Loading Scenario**	**Loading Percentage (%)** [Relative to maximum for this fixture type-power source combination]	**Tested AC Input Power (W)**	**Tested DC Output Power (W)**	**Tested Efficiency (%)**	**Power Factor**	**Total Harmonic Distortion (current) (%)**
120	3100	300	3000	Full	**100.0**	3115.23	3000.00	96.30	0.932	5.0
				Worst-Case Efficiency	**20.0**	677.63	600.00	88.54	0.914	4.0
277	3100	300	3000	Full	**100.0**	3098.02	3000.00	96.84	0.932	5.6
				Worst-Case Efficiency	**20.0**	665.19	600.00	90.20	0.911	5.9

Figure 1. Example of a performance report for a single power source.

- Fixtures where no AC-to-DC power source is marketed by the fixture manufacturer as the intended AC-to-DC power source are not required to provide a power source test report. These products will be listed with an assumed AC-to-DC conversion efficiency (see below).

- **Power source (e.g., driver) ISTMT report**:
  Consistent with the report requirements for drivers (see the **Power source test report** bullet above), power source ISTMT reports are required for all horticultural products sold with AC-to-DC and DC-to-DC power sources, as applicable. DC-to-DC power source ISTMT reports are required for both DC fixture types described in **Section 7.2.1, Eligibility Information**.
  - DC-to-DC power sources include any component that modifies the current or voltage input to the LED chips, either in value relative to input (e.g., a voltage converter) or value over time (e.g., a constant-current power source).
  - AC-to-DC power sources, in the context of DC-powered products, include components external to the listed product that convert AC power to DC power.

- **Information or specifications for DC cabling**:
  Manufacturers must provide information or specifications for DC cabling on the fixture specification sheets or supplemental marketing documentation. Guidance for maintaining cabling losses to less than 2% for a fully loaded power supply (e.g., driver) must be detailed.
  - The fixture wattage in the cabling guidance must match the input power of the submitted fixture, and the cabling losses must reflect the copper resistance values listed in NFPA 70 National Electrical Code, 2020 Edition. Applicants may choose their own tradeoff of cabling gauge and length as long as it conforms with cabling information provided on the fixture specification sheet.

7.2.3 Controllability Interactions with DC-Specific Requirements

Because DC-powered products are often designed such that multiple light bars may be combined into a larger light source, all DC-powered products must be dimmable, regardless of PPF. All controllability requirements from **Table 3** (see **Section 6.0**) must be met, with the following adjustments and clarifications:

- For DC-powered products controlled via a specific central AC-to-DC power source marketed for use with the product, as shown in the example in **Figure 2**, the phrase "Dimming and Control Method Designations to the Product" in **Table 4** (see **Section 6.3**) refers to communication between the power source (e.g., driver) and the controller, received at point "A" in **Figure 2**. In addition, the phrase "Connector or Transmission Hardware" in **Table 5** (see **Section 6.3**) refers to the port or terminal on the power source that a control cable connects to, depicted as "A" in **Figure 2**. The options given in **Tables 4** and **5** apply. If multiple power sources are available for a single DC-powered product, each with a unique dimming or control method or unique transmission hardware, these options must each be represented by an individual line item on the QPL; they may not be bracketed into a single catalog number.
- In cases where no power source (e.g., driver) is marketed for use with the product, or where dimming is not controlled via an external power source, "Dimming and Control Method Designations to the Product" in **Table 4** (see **Section 6.3**) refers to the signal received by the product at point "B" in **Figure 2**, and "Connector or Transmission Hardware" in **Table 5** (see **Section 6.3**) refers to the port or terminal on the product that a control cable connects to, depicted as "B" in **Figure 2**. The options given in **Tables 4** and **5** apply.

Other than the adjustments and clarifications stated above, all requirements in **Section 6, Controllability Requirements** must be met.

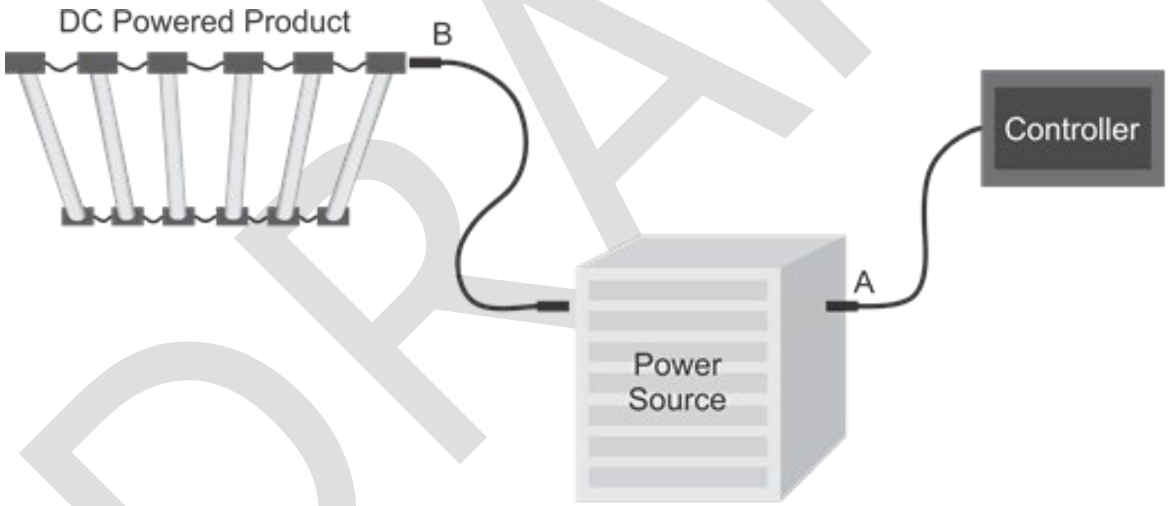

Figure 2. Depiction of a DC-powered luminaire connected to a central AC-to-DC power source (e.g., a driver). Connector "A" is the point where the power source connects and receives a control signal from the controller, and connector "B" is the point where the luminaire connects and receives a control signal from the power source.

7.2.4 QPL Listing Information for DC-Powered Fixtures

DC-powered fixtures will be listed on the Horticultural Lighting QPL with differences from AC-powered fixtures as described below.

The following new fields will be listed on the QPL. Unless noted below, all DC numerical fields below will have an equivalent tested value and **a** reported, or nominal, value provided by the submitter in the review.

- **"Input Power Type"** will be distinguished between AC and DC products.
- **"Tested Voltage"** and **"Tested DC Input Current"** will display the values from the all-on DC-powered LM-79 photon flux report for both DC-powered fixture types. Nominal values for "Reported Maximum Input Voltage," "Reported Minimum Input Voltage," and "Reported DC Input Current" are provided by the submitter during application submittal.
- "**DC Input Wattage"** and **"DC Photosynthetic Photon Efficacy (µmol/J) (400-700 nm)** will display the values from the all-on DC-powered LM-79 photon flux report.
    - Values for an optional new field **"DC PE_{PBAR} (µmol/J) (280-800 nm)"** will be reported if "DC PF_{PBAR} (µmol/J) (280-800 nm)" is reported.
- New fields will display **"AC Derated Input Wattage"** and **"AC Derated PPE (µmol/J) (400-700 nm)"** only for DC-powered fixtures.
    - DC-powered fixtures must meet the PPE threshold requirement at their AC derated PPE value. For example, a 100-watt lightbar with a DC-powered PPE of 2.5 µmol/J and a power source with a worst-case efficiency of 90% at 20% load would be listed on the QPL at 2.25 µmol/J AC Derated PPE and 105 W AC Derated Input Wattage. The fields currently used for "Photosynthetic Photon Efficacy: 400-700 nm, µmol/J (PPE) (AC)" would not be populated.
    - DC-powered fixtures marketed 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 100-watt lightbar with a PPE of 3.0 µmol/J and a power supply (e.g., driver) showing a worst-case efficiency of 85% at 20% load, would be listed on the QPL at 2.55 µmol/J and 118 W.
    - DC-powered fixtures that are not marketed with any AC-to-DC power source will display values in the AC derated fields based on an assumed 87.5% conversion efficiency. This value is informed by the standards set in (U.S.) Federal Standard 10 C.F.R. § 430.32(w) for minimum efficiency for external power supplies greater than 250 W.
    - Values for an optional new field **"AC Derated PE_{PBAR} (µmol/J) (280-800 nm)"** will be reported if "DC PE_{PBAR} (µmol/J) (280-800 nm)" is reported.
    - **"Power Source Loading Percentage"** will display the fixture loading that creates the worst-case efficiency used in the derating calculations and the power source load point that creates that worst-case condition, in the format "AC-derated performance is 91.12% efficiency at 20% loading on a 3,000-W power source at 120 V."
- **"Cabling Loss Example"** will show an example of cabling length and gauge that results in cabling losses less than 2% for a fully loaded power supply (e.g., driver).

- For example: “Nine 300 W fixtures parallel-wired with 100 feet of 10AWG cabling to a 3,000 W power supply channel.”
- This field will be populated only for DC-powered fixtures marketed with an AC-to-DC power source.

- The worst-case values of total harmonic distortion (current) (THDi) and power factor (PF) from the Tested Power Source Table (see example in **Figure 1**, **Section 7.2.2**) will be shown in the existing fields for **“Total Harmonic Distortion”** and “**Power Factor**.” The THDi and power factor fields will be populated only for fixtures marketed with an AC-to-DC power source.

7.3 Special Considerations for Externally Supplied, Actively Cooled Fixtures

7.3.1 Eligibility Information

LED horticultural fixtures that employ externally supplied circulating liquid are eligible with the following conditions:

- The DLC defines “externally supplied circulating-liquid-cooled horticultural fixtures” as products in which liquid, often water or a water-glycol solution, flows through the input and output ports of each fixture in the system, being channeled through a cooling plate or other heat exchanger within the fixture.
- LED horticultural fixtures that employ externally supplied ducted forced air are not eligible at this time. For simplicity, this document may refer to eligible externally supplied actively cooled fixtures as simply “actively cooled”.

7.3.2 Technical Requirements for Externally Supplied Actively Cooled Fixtures

All requirements described in **Table 1** (see **Section 4**) must be met, in addition to the following requirements and clarifications:

- Manufacturers must specify information regarding allowable operating conditions that affect product performance, including:
  - **Solution type or concentration**
    - Restrictions or limitations to the allowable solution type or concentration must be described in marketing material and/or specification sheets and will be reported on the Hort QPL.
  - **Inlet fluid temperature range:**
    - Minimum and maximum allowable operating inlet fluid temperatures must be stated in marketing material and/or specification sheets and will be reported on the Hort QPL.
    - Data describing the performance impact of varying inlet fluid temperature on measured PPF and measured input power of the fixture, reported in increments of 5 degrees Celsius (or smaller) and covering the complete allowable inlet fluid

temperature range, must be provided. A template file will be available for actively cooled applications to capture this data. The template file will be used to generate and report an image of this data on the QPL.

- Flow rate must be held constant across the allowable temperature range and must be reported.
- Measured PPF as a function of inlet fluid temperature data and measured input power as a function of inlet fluid temperature data, must be provided and will be reported on the Hort QPL.

        - All temperature values must be reported in degrees Celsius.
    - **Self-protect cutoff functionality**
        - Fail-to-off functionality must be present to turn off the actively cooled fixture before a maximum inlet fluid temperature is reached, in the event that the external cooling system fails.
        - The self-protect cutoff temperature must be stated in the manufacturer-provided marketing material and/or specification sheet and will be reported on the Hort QPL.

- All inlet fluid temperatures must be maintained within a tolerance of ±2.5 degrees Celsius from the target temperature during LM-79 testing and ISTMTs.
- LM-79 testing must employ water as the cooling liquid at an appropriate flow rate to maintain the targeted median inlet fluid temperature (i.e., middle operating inlet fluid temperature in the allowable range) as defined by the luminaire manufacturer.
- The average and maximum inlet fluid temperature measured during LM-79 testing (measured at fixture-level stabilization per LM-79), within the allowable 5-degree Celsius range, must be provided and will be reported on the Hort QPL.
- ISTMTs must employ water as the cooling liquid at an appropriate flow rate to maintain the targeted worst-case inlet fluid temperature (i.e., maximum allowable operating inlet fluid temperature) as defined by the luminaire manufacturer. The average and maximum inlet fluid temperature measured during an ISTMT (at stabilization), within the allowable 5-degree Celsius range, must be provided and will be reported on the Hort QPL.
- Flow rate, measured in gallons per minute (GPM), must be recorded during LM-79 testing and ISTMTs, with the average and highest flow rate measurements being provided; these will be reported on the Hort QPL.
- Outlet fluid temperature must be measured during LM-79 testing, with the average and highest outlet fluid temperature reported on the Hort QPL.
- To support the qualification of externally supplied circulating-liquid-cooled horticultural fixtures, the DLC will accept LM-79 gonioradiometric testing with methods or equipment performed with Type C goniometers or other gonioradiometer types.

- All externally supplied circulating-liquid-cooled horticultural fixtures for which qualification by the DLC is sought must be tested per ANSI/IES LM-79, including requirements specific to, but not limited to, stabilization and optical measurements, while employing active cooling.
- The DLC reserves the right to require additional information on all LM-79 test reports derived from non-Type C gonioradiometer types.

7.3.3 QPL Listing Information

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

- **Active Cooling Presence**
  - Externally supplied circulating-liquid-cooled horticultural fixtures will be distinguished as having "active cooling presence" and will be designated as such on the Hort QPL (e.g., as a filterable field)
- **Tested Inlet Fluid Temperature** and **Tested Flow Rate**
  - Maximum measured inlet fluid temperatures and flow rates per ISTMTs and LM-79 testing
  - Average measured inlet fluid temperatures and flow rates per ISTMTs and LM-79 testing
- **Tested Outlet Fluid Temperature**
  - Maximum measured outlet fluid temperature per LM-79 testing
  - Average measured outlet fluid temperature per LM-79 testing
- Additional reporting fields, relating to the allowable operating conditions for the system, including:
  - **Solution Concentration Restrictions**
  - **Minimum Allowable Inlet Fluid Temperature** and **Maximum Allowable Inlet Fluid Temperature**
  - **Self-Protect Cutoff Temperature**
  - Reported data depicting PPF and wattage as a function of inlet fluid temperature.

7.4 Tolerances

The DLC accepts measurement tolerances to most metrics listed in **Section 4.2, Efficacy** and **Section 7.3, Special Considerations for Externally Supplied, Actively Cooled Fixtures**. **Table 8** provides additional tolerance information.

Table 8. DLC Horticultural Lighting Technical Requirements Tolerances

Parameter, Attribute, Metric	Tolerance
Photosynthetic Photon Efficacy	-5%
Power Factor	-3 percentage points
Total Harmonic Distortion (THDi)	+5 percentage points
ISTMT Temperature Measurements	1.1 °C or 0.4%, whichever is greater
Drive Current, per LM-80	-5%
Dimming Capability PPF threshold for AC-powered luminaires with Tested PPF > 350 µmol/s	+10%

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 beyond the absolute thresholds as passing. For example, if a horticultural lighting product is required to have a PPE of 2.5 with an efficacy tolerance of -5%, any value for efficacy less than 2.38 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.

8.0 Supporting Documentation

8.1 Test Reports

The DLC requires that all testing be conducted at appropriately accredited laboratories, except where noted otherwise. Specifically:

- Testing of flux, luminous 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 Mutual Recognition Arrangement (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 a Nationally Recognized Testing Laboratory (NRTL)
    - 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

9.0 Additional Reporting Requirements for ANSI/IES LM-79 and ANSI/IES TM-33

Complete information must be included in all LM-79 test reports (including information that may not have been required in the past). The subsections below specify additional reporting requirements for all submitted LM-79 test reports and accompanying TM-33 XML documents. Test reports that do not comply will not be accepted.

For measurements that are made under conditions that are nonstandard per ANSI/IES LM-79, including measurements related to externally supplied actively cooled products, the nonstandard conditions must be identified in a prominent location on the test report. If the submitter intends to test a product using non-standardized methodologies per ANSI/IES LM-79 and the product is not actively cooled, they should contact the DLC at: horticulture@designlights.org.

9.1 ANSI/IES LM-79 Reporting

Horticultural lighting products or family groupings must be tested according to the guidelines in the relevant ANSI/IES Lighting Measurement (LM) documents (e.g., LM-79, LM-80, LM-84). LM-79 Test reports generated by a test lab that complies with the DLC LM-79 Testing Requirements will be accepted only if all optical and electrical performance characteristics are tested and documented as described below.

- Only tests performed according to the 2019 version or newer of LM-79 (i.e., ANSI/IES LM-79-19) will be accepted for new applications. All tests must be conducted at the full output or non-dimmed state, and corresponding test reports must be in PDF format.
- Configurations tested to produce LM-79 reports will be listed as “parent” products on the QPL, with the test performance data based on the QPL listing information in each applicable section. If a full LM-79 report describing both spectral and spatial distribution performance is provided for the same configuration, the tested performance listed on the QPL will be for the worst-performance data set.
- Generally, test reports that require spectral performance information (generally expected to be from testing in an integrating sphere, though gonio-spectroradiometer testing is also acceptable) do not require distribution performance information. These spectrum-specific test reports are generally referred to within this document as “full LM-79/SQD reports” and must include, but are not limited to, the following:
    - Electrical characteristics (wattage, input voltage, THDi, and PF)
    - Total photosynthetic photon flux (PPF)
    - Photosynthetic photon efficacy (PPE)

- Accompanying XML document (following ANSI/IES TM-33-18 or -23 format) with spectral power distribution data from 400-800 nm in increments ≤5nm
  - The product model number must be present and must match in both the TM-33 and LM-79 documents
  - When reporting either of the optional PBAR metrics (i.e., PF_{PBAR} and PE_{PBAR}), distribution of photon flux over the PBAR range (280 to 800 nm) is required

- All information listed above, except the accompanying TM-33 XML document, must be included in a single LM-79 test report. (Please refer to **Section 9.2, ANSI/IES TM-33-18 Reporting** for additional information.)

- Generally, test reports that require photosynthetic photon intensity distribution (PPID) performance information (generally expected to be from testing with a goniophotometer) do not require spectral performance information. These distribution-specific test reports are generally referred to within this document as "full LM-79/PPID reports" and must include, but are not limited to, the following:
  - Electrical characteristics (wattage, input voltage)
  - Photosynthetic photon intensity distribution (PPID array)
  - Accompanying TM-33 XML document (following ANSI/IES TM-33-18 or -23 format) with photosynthetic photon intensity distribution data
    - The product model number must be present and must match in both the TM-33 and LM-79 documents

- Test reports containing only a partial set of LM-79 metrics (for example, an integrating sphere test report without photosynthetic photon flux reported) will not be accepted for application review purposes. For clarity, even if a test is needed only for the purpose of verifying input wattage, it must be a full LM-79/SQD report as described herein, with all required metrics reported.

Additional TM-33 reporting requirement information may be found in **Section 9.2**.

9.2 ANSI/IES TM-33 Reporting

The DLC requires all applicants to submit accompanying XML documents per ANSI/IES TM-33-18 or -23 for each parent or single product, to represent the spatial and spectral distribution of the tested fixture.

- The XML document must be based on measured data from an accredited lab, following the LM-79 testing requirements for spectral and spatial measurements.

- The XML document must include the spectral power distribution data, with an interval resolution of 5 nm or smaller, over the photosynthetic and far-red range of wavelengths defined by ANSI/ASABE S640 (400-800 nm). The DLC also requires the distribution of photon flux per photon wavelengths over the PBAR range (280-800 nm) only in the case that applicants provide PF_{PBAR} and PE_{PBAR} data. Spectral data in 1-nm intervals are acceptable. The spectral dataset represents the integrated flux in all directions from the fixture, without directional spectral information. Per ANSI/IES TM-33-18 or -23, the data is reported in watts per nanometer

(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 document 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* (400-700 nm). (PPID is the distribution of photosynthetic photon intensity per unit solid angle leaving the fixture. Each measurement is integrated across the entire range and thus contains no granular spectral distribution information, i.e., color over angle.)
- TM-33 documents are separated into six elements: Version, Header, Luminaire, Equipment, Emitter, and Custom Data. In addition to all "required" elements per ANSI/IES TM-33-18 or -23, the following are the elements required by DLC:
    - Header Element Required Fields
        - Manufacturer
        - Catalog Number
        - Laboratory
        - Report Number
        - Report Date
    - Luminaire Element Required Fields
        - Dimensions
        - Number of Emitters
    - Emitter Element Required Fields
        - Quantity
        - Description
        - Catalog Number
        - Input Wattage
        - Power Factor
        - Data Generation – Intensity Scaling element field must be "false." Scaling with respect to laboratory measurements will not be accepted. Angle interpolation element must be "true" or "false," not blank.
        - Photon Data – Photon Intensity data fields must include *only* PPF (400-700 nm) data. Photon Flux data field must report *only* PPF (400-700 nm) data.
        - Spectral Data – Spectral Intensity must be reported. Additionally, Emitter Name is required for spectrally tunable products.
    - Custom Data Element Required Fields
        - A custom data element called "Radiant Power to PPF Scalar Multiplier" must be reported for the ratio of PPF to radiant watts within the PAR range (400-700 nm). The Any Data field must describe this scalar multiplier. The Unique Identifier data field must contain a Universally Unique Identifier (UUID), as defined by RFC 4122.

- It is acceptable to report element fields described in ANSI/IES TM-33-18 or -23 that are not detailed above. All data must be reported to the required number of decimal places per the applicable standard or as defined within these DLC Horticultural Lighting Technical Requirements.
- The DLC reserves the right to provide enhancements to the Horticultural Technical Requirements and program tools, such as the TM-33 Pre-Submission tool, to support revisions and enhancements made to ANSI/IES TM-33.

9.3 Additional Application Details

In addition to the test data noted in **Sections 9.1** and **9.2**, 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 rating
- Specification sheets for all drivers and fans employed in the product, including lifetime-at-temperature information
- Certificates of safety 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 lifetime projection calculation per ANSI/IES TM-21-21 for each LED device present in the fixture, along with the applicable LM-80 and ISTMT information for that LED device. If demonstrating flux maintenance at the fixture-level, a completed lifetime projection calculation per ANSI/IES TM-28-20 must be provided for the fixture, with the applicable LM-84 information accompanying it.

The DLC will only accept product applications that are accompanied by the required product test reports, with only limited variations permitted as detailed in **Sections 9.1** and **9.2**. Given the multiple options within product families, the DLC offers the Level 2 Application (formerly Family Grouping Application) requirements for LED-based horticultural lighting, which describes a method to determine "worst-case" product family members.

10.0 Surveillance Testing

This document is accompanied by specific surveillance testing requirements that will protect the integrity and value of the QPL for all stakeholders. The Horticultural Lighting Surveillance Testing Policy outlines the process for selection of products from the QPL for surveillance testing. The DLC may seek to implement additional efforts toward these objectives in future policy development cycles.

11.0 Policy Clarifications and Updates

As the DLC processes applications for horticultural lighting products and interacts with stakeholders, we encounter opportunities for minor corrections, terminology clarifications, and policy interpretations. In

order to be as transparent as possible, the V4.0 policy documents will be updated as needed, and the changes will be tracked in the table below. Table 9 shows the corrections or clarifications and where they can be found in the document.

Table 9: Corrections and clarifications

Date Updated	Subject	Change Type	Description	Affected Page(s)