Advanced High-Resolution Controls for Dimmable LED Lighting

Performance Specification

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Summary

The U.S. Department of Energy's (DOE) Better Buildings Alliance (BBA) has developed this specification for advanced lighting controls. The purpose of the specification is to provide a description of requirements that will result in energy savings for dimmable lighting control systems, reliable performance, and energy cost savings. It also includes requirements for emergency lighting. This specification was developed through collaboration with Better Buildings Alliance Lighting & Electrical Team members and with input from manufacturers and other interested parties.

This specification defines the performance characteristics for a product that is in the top efficiency tier – which is considered approximately less than the top 10% of the current market. The specification can be used in a request -for-proposal by copying the language on the following pages.

DOE and BBA are promoting this specification because dimmable, controllable lighting is quickly becoming the norm in commercial buildings as industry segues toward light emitting diode (LED) lighting sources. With operating hours of 10+ hours per day – lighting collectively consumes nearly 97 billion kilowatt-hours (kWh) of electricity annually, worth approximately 9.9 billion dollars; this is as much energy as 8.9 million homes consume in a year. By adopting this specification, building owners can save up to 75% with controls. If all lighting in the nation complied with this specification, the nation could save approximately 39 billion kilowatt-hours (kWh) of electricity annually, worth approximately 4 billion dollars.

Additional information on the DOE and BBA activities, including other energy saving purchase specifications and demonstration case studies can be found on the BBA website (http://eere.energy.gov/BetterBuildingsAlliance)

Specification requirements start on the next page. The cover page and summary should not be submitted to the manufacturer. Note that there are sections where you must select a specific "option" or "tier". Higher-level tiers are generally preferred (as indicated).

1. **Light level target values and energy goals:**

   a. Task illuminance: at full light output, the lighting system will produce a minimum of 30 average horizontal maintained footcandles (fc) on task surfaces (assuming no daylight contribution). *[Note that the new Illuminating Engineering Society Handbook, 10th Edition, lists many different target illuminance values depending on the specific visual task. In office environments where the predominant visual task is the computer screen, the Handbook lists target levels as low as 3.75 fc. Review with the owner and, if desired, select a lower value.]*

   b. Lighting power density (LPD) shall not exceed 0.75 W/ft^2. *[Note that this corresponds to the current LPD limit for office lighting in the most restrictive state energy code – California Title 24-2013. However, reducing LPD levels is easily achievable using state-of-the-art LED luminaires, depending on target task illuminance values. Review with the owner and, if desired, select a lower value.]*

2. **Overhead light fixtures for ambient light:**

   a. Dimming – all overhead light fixtures shall be dimmable in a continuous range between 1-100% of full light output.

   b. Control system components – modify existing lighting scheme to incorporate dimming and any other required control system components as follows: *[select one]*

      i. *[Option 1]* Retrofit existing luminaires to incorporate LED lamps, LED matrices or use complete "retrofit kits", incorporating dimmable LED drivers as required. Incorporate additional control system components and new optical control media (e.g., lenses or diffusers) as required. Leave existing luminaire housings and primary power feeds in place. Connect new low-voltage network wires as required for communication with the lighting control system.

      ii. *[Option 2]* Replace existing luminaires one-for-one with new LED luminaires incorporating dimmable drivers for LEDs, with any required control system components factory-installed. Reuse existing primary power feeds and connect to new luminaires. Connect new low-voltage network wires as required for communication with the lighting control system.

      iii. *[Option 3]* Remove existing luminaires and install new LED luminaires with a new layout. Provide new luminaires incorporating dimmable drivers for LEDs, with any required control system components factory-installed, using appropriate spacings/locations to achieve the target illuminance levels. Patch ceiling and/or replace tiles as required. Reroute primary power feeds to new luminaires as required. Connect new low-voltage network wires as required for communication with the lighting control system.

   c. Light source color: *[select one]*

      i. *[Option 1]* Correlated color temperature (CCT) – LEDs shall have a published CCT of *[3500K or 4100K – select one]*. Actual CCT for LEDs as shown on IES LM-79 tests may have a tolerance of ±100K. Therefore they must be in the range of *[3400-3600K (for nominal 3500K) or 4000-4200K (for nominal 4100K) – select one]*. Coloring rendering index (CRI) – LEDs or LED lamps shall have a published CRI of 80 or greater.

      ii. *[Option 2]* Correlated color temperature (CCT) – LEDs shall have a published CCT of *[3500K or 4100K – select one]*. Actual CCT for LEDs as shown on IES LM-79 tests may have a tolerance of ±100K. Therefore they must be in the range of *[3400-3600K (for nominal 3500K) or 4000-4200K (for nominal 4100K) – select one]*. Coloring rendering index (CRI) – LEDs or LED lamps shall have a published CRI of 80 or greater. However, the CCT may be continuously increased up to 5000K at the user's discretion, either by manually adjusting the color temperature or by setting the desired CCT in the control system software. Fade rate for any such change in CCT may range from 0-59 seconds, or up to 60 minutes.

   d. Glare and luminance limits – to minimize direct glare from fixtures, restrict luminance as follows for any azimuth angle: *[select one]*

i. *[Tier 1]* Restrict luminance at any vertical angle at or above 55° from nadir (from 55-90°) to 2000 candelas/square meter (cd/m^2).

ii. *[Tier 2 (preferred)]* Restrict luminance at the following vertical angles to:

1. 850 cd/m^2 at 55° from nadir.
2. 350 cd/m^2 at 65° from nadir.
3. 175 cd/m^2 at or above 75° from nadir.

3. Wiring:

a. Wiring to and between luminaires – method of wiring: *[select one]*

i. *[Option 1]* Reroute existing power wires and/or run additional power or control wires as necessary from existing or new luminaires locations to a centrally located electrical room(s). Terminate in existing or new distribution panels, depending on the control system.

ii. *[Option 2]* Distribute controllers in the plenum and run power and/or control wires as necessary to luminaires, or to distinct zones. Controllers shall not require "homeruns" back to a centrally located electrical closet(s) for either power or control wiring. Communicate between controllers, from controllers to server, from sensors to server, and to user access points (terminal, switches, etc.) via *[a new data bus, company local area network (LAN), or wirelessly using radio frequency (RF) or other method of communication – select one method of communication]*.

iii. *[Option 3]* Use existing power wires to luminaires. Luminaires shall be "self-contained", with on-board components required to switch and dim fixtures, to communicate with the lighting control system (dimming drivers, controllers, radios, etc.), and to reconfigure the zoning. The luminaires shall communicate wirelessly with a gateway. No additional wiring is required to luminaires.

b. Wire colors – luminaire vendors shall use industry-standard wire colors for all line-voltage power feeds as well as low-voltage control connections.

4. Lighting control system for overhead luminaires:

a. Dimming – as previously noted in 2a, all overhead luminaires shall be dimmable.

b. Minimum power at lowest light output: *[select one]*

i. *[Tier 1]* – At the lowest light output, input power to the luminaire shall be no greater than 20% of the input power at maximum light output.

ii. *[Tier 2 (preferred)]* – At the lowest light output, input power to the luminaires shall be no greater than 10% of the input power at maximum light output.

c. Control zones for overhead luminaires. *[For any of the options shown, if occupancy sensors with specific coverage areas (or shapes) are desired, include those specific amounts or shapes in the specification language and/or attach diagrams showing the coverage area/shape as appendices, or by including manufacturer's catalog sheets.] [select one]*

i. *[Option 1]* Low granularity occupancy zones: create zones corresponding to the coverage pattern of the occupancy sensors to be used (e.g., 500, 1000 or 2000 ft^2).

ii. *[Option 2]* Medium granularity occupancy zones: create zones that are smaller than the coverage pattern of the occupancy sensors to be used (e.g., 200 ft^2). This may be accomplished by masking portions of a ceiling-mounted sensor. *[Alternately, use occupancy sensors that have smaller coverage patterns than typical ceiling-mounted sensors (e.g., 200 ft^2).]*

iii. *[Option 3]* Maximum granularity occupancy zones: create zones that correspond to individual luminaires.

d. Control strategies – the lighting control system shall be capable of implementing the following lighting control strategies:

i. **Daylight harvesting** – the availability and amount of daylight shall be determined by the use of photosensors. Luminaires in areas with sufficient daylight shall dim and/or turn off in response to available daylight if those options are selected in the control profile in use at a specific time. Photosensors shall meet the following criteria:

1. Photosensor type *[select one]*:

   a. Closed-loop.

   b. Open-loop.

   c. Dual-loop.

2. Signal transmission method *[select one]*.

   a. Analog.

   b. Digital.

3. Viewing cone – closed-loop photosensors shall be *[ceiling- or fixture-mounted – select one]* with a viewing cone limited to an angle of *[e.g. 30-60°; edit and provide a specific angle]*. Open-loop photosensors shall have a viewing angle that limits its cone of view to *[provide a specific angle]*° and the width of its view parallel to the window wall to *[provide a specific angle; determine these desired angles based on plans and section drawings]*°.

4. Spectral filtering – photosensors shall incorporate a photodiode to measure light levels that can be correlated to the desktop illuminance. The photodiode shall be spectrally filtered (color-corrected) to measure light that approximates the photopic response of the human eye.

5. Range – photosensors shall operate within a range of 0-300 fc of incident light on the task surface *[or greater; increase this amount if the setpoint <target> illuminance level is higher]*. This may be modified to a more limited range either by physical adjustment at the photosensor, or (preferably) by changing settings in the control system software.

6. Accuracy – photosensors shall be accurate to within 1% of reading in an operating environment between 15-30°C.

7. Calibration *[select one]*:

   a. *[Option 1]* – Nighttime calibration. Calibrate the photosensors by adding a "photosensor calibration" event to the schedule in the system's software. The calibration will be scheduled to take place during nighttime hours (with no available daylight). The control system will turn luminaires on and leave them at full output for 10 minutes to insure that all luminaires are fully warmed up. Then the system will dim luminaires by 10% every 5 minutes (allowing light levels to stabilize with temperature), recording the resulting levels measured by the photosensors. The final dimmed levels shall be 5% and 1% once the photosensors have been calibrated for all levels in 10% increments. Once the calibration is done, the system will use these recorded values to determine the appropriate mix of daylight and electric light to achieve the target illuminance levels during daylight hours when daylight harvesting profiles are active.

   b. *[Option 2] – [Other methods of calibrating the photosensors may be proposed by a lighting control system vendor. Consult with the vendor and add appropriate language describing the calibration method.]*

8. Deadband – a range of values shall be set in the control system software that achieves the following:

a. Maximum setpoint – task illuminance target level plus 10%. *[Edit and list specific maximum setpoint amount; e.g., if the task illuminance target level is 30 fc., add 10% (3 fc) and list 33 fc as the maximum setpoint value.]* When a combination of daylight and electric light exceeds this setpoint (for a period of time specified in the software), the control system will dim luminaires (or turn them off).

b. Minimum setpoint – task illuminance target level minus 10%. *[Edit and list specific minimum setpoint amount; e.g., if the task illuminance target level is 30 fc., subtract 10% (3 fc) and list 27 fc as the maximum setpoint value.]* When a combination of daylight and electric light fall below this setpoint (for a period of time specified in the software), the control system will increase the level of the luminaires (or turn them on if they were previously off).

c. Time delay – 5 minutes. Set variables in the system software so that luminaires will not dim up or down until 5 minutes after a change in light level registers at the photosensor. *[Edit value; time delays may be set in the control system software for dimming luminaires up or down.]*

d. Fade rate – *[Specify length of time. Fade rates may be set in the control system software for dimming luminaires up or down.]*

ii. **Occupancy/vacancy sensing** – occupancy/vacancy shall be determined by the use of *[passive infrared (PIR), ultrasonic (US), dual-technology or other types of occupancy sensors (microwave, acoustic, etc.); if a specific type of occupancy sensor is desired, select that type and delete the others.]*

1. Signal transmission method. Occupancy/vacancy sensors shall be *[analog or digital – select one]*.

2. Adjustment of sensors shall be as follows *[select one]*:

a. *[Tier 1]* – Adjustment for "sensitivity" may be preset at the sensor before installation, or field-adjusted at the sensor after installation. "Time delay" may be set at the sensor as well as in the system software.

b. *[Tier 2 (preferred)]* – Adjustments for "sensitivity" as well as "time delay" shall be made in the system software. Time delays can be different for different control "profiles" or during different "schedules".

3. Programming of system behavior based on occupancy and vacancy sensing *[select one]*:

a. *[Tier 1]*:

i. Upon sensing occupancy, turn luminaires on to a predetermined level set in the lighting control system software. Allow for a "transition" time (to fade luminaires up) of 3 seconds. *[Many control systems allow fade rates of up to 60 minutes. This variable can be modified if desired.]*

ii. Upon sensing vacancy, and after a 5-minute time delay, turn luminaires off or dim to a predetermined level set in the lighting control system software according to the control profiles. Allow for a "transition" time (to fade luminaires down) of 3 seconds. Note that time delay and fade rate variables can be different for occupancy sensing versus vacancy sensing, and for different zones, and in different control profiles.

b. *[Tier 2 (preferred)]* – In addition to the behavior as described in *[Tier 1]*, after sensing vacancy, allow for *[1, 2 or unlimited – select one]* "intermediate step" where luminaires dim to a different predetermined level after a specified time delay. Alternately, allow lights to "blink" off then on as a visual indication to occupants that the occupancy sensors have already timed out – before reducing light levels based on settings for the "vacant" state. Fade rates for this intermediate step may be different than for the base behavior as described in Tier 1. *[If this option is selected, append this language to the language noted for Tier 1.]*

4. "Daylight hold off" – if sufficient daylight is present in the space, allow the lighting control system to "hold off" luminaires in certain zones (keeping those luminaires off or at a minimum light level preset in the system software, based on the prevailing control profile).

iii. **Scheduling** – control system shall allow the creation of a schedule that will determine which "control profiles" are in effect at what times, including:

1. Normal schedule – allows creation of "typical" schedules.
2. Temporary schedule – allows creation of atypical or one-time events that would override the normal schedule.
3. Format:
   a. The lighting control system shall utilize a Microsoft Outlook-style calendar for the creation of "normal" as well as "temporary" (or "exception") schedules. Any "temporary" schedule shall override the "normal" schedule in effect at that time.
   b. "Default" behavior – default behavior may be created without selecting specific blocks of time to determine when the default behavior is in effect.
   c. Individual events for either "normal" or "temporary" schedules may be any duration of time based on increments of 1 minute, and as short as 2 minutes in duration.
   d. The control system shall be capable of creating "overnight" events (spanning midnight).
   e. Events may be created that repeat indefinitely (with no end date).
   f. Provide automatic system time adjustments for Daylight Savings Time as well as for leap years. This may be achieved *[internally, or by reference to an external NTP (Network Time Protocol) server. If an NTP server is available and can be linked to the lighting control system, keep that language and delete reference to this being achieved internally.]*

iv. **Tuning** – the control system shall allow for presetting a reduction in light levels (by setting a maximum light output) throughout any specific zone. This variable will be set in each control profile and will be active when a given profile is active based on the schedule.

v. **Demand response/demand reduction (DR)**:

1. Methods of activation: *[select one]*
   a. *[Tier 1]* – The lighting control system shall allow programming of manual or scheduled reduction of light levels based on preprogrammed values.
   b. *[Tier 2 (preferred)]* – Provide all of the options for preprogramming a reduction of light levels as mentioned for Tier 1. In addition, provide an interface to an Automated Demand Response (ADR) server to automatically activate demand response/demand reduction functions in the lighting control system as described above. *[Note that certain jurisdictions now require the availability of ADR functionality; e.g. California Title 24. Verify these requirements based on the project location.]*
2. Severity of events – regardless of whether demand response events are activated manually or by a signal from an ADR server, allow for preprogramming demand response/demand reduction events with at least three degrees of severity.
3. "Opting out" – the lighting control system must allow any zone to "opt out" of a manual or automated demand response event.

vi. **Manual overrides** – the following devices or methods may be used to manually control any zone or combination of zones:

1. Types/methods of manual override: *[include those required and delete the rest]*

a. Wallbox switches/dimmers.

b. Preset scene selector panels (for example, used in a conference room to dim all zones to predetermined levels by pushing a single button for each scene).

c. Touch screens.

d. Smartphone apps.

e. Software-based control.

f. Input from a BMS (for example to turn all luminaires to full on in an emergency situation other than during loss of normal power).

2. "Logic" for override behavior – variables can be set in the system software to control the behavior of manual override devices or methods. *[If specific behaviors as described below are required in your project, make sure to include them. Examples of/issues regarding override behavior logic:*

a. The default system logic may dictate that after a zone is manually overridden, it will automatically revert to the preprogrammed behavior after the next change in the normal schedule – or it may not. Applicable codes may limit the duration of any manual override period.

b. A time delay may be set in the system software that causes an overridden zone to revert to the default behavior based on the schedule after a specified period of time. It may be desirable to set different time delay periods for different profiles or schedules. For example, a wallbox switch/dimmer may override the operation of a zone for up to 2 hours during normal daytime use, but only for 1 hour during evening or nighttime use to provide enough light for cleaning crews before reverting to default operation.

c. A hierarchical structure may be created such that different devices and/or methods have greater levels (and/or longer periods) of control over the default system behavior. For example, an "emergency" input signal from a BMS may override all default system behavior and prevent the system from automatically reverting to normal operation until the BMS and/or authorized personnel have cleared the emergency condition.

d. It is incumbent upon the vendors to clearly indicate and explain the sequence of control logic in operation manuals and on-line help screens. If this is not clearly explained, then the system may exhibit behavior that is confusing. For example, what happens if you switch a zone off using a wallbox switch/dimmer? Does the zone switch back on after the specifed "manual override time delay" is over? Does the zone remain off irrespective of the "manual override time delay" as programmed in the system, only turning back on if occupancy is sensed, or only at the next normal schedule change? Verify system operation with the manufacturer.]

e. Control profiles:

i. Control system software shall allow for creation of "profiles" that contain variables for controlling the behavior of luminaires. Control profiles may be activated automatically by creating blocks of time in the schedule during which a specific profile is in effect. The software shall also allow for creation of a "default" – when a specific control profile is active unless a separate scheduled event is created that overrides the default control profile. These variables shall include (but are not limited to):

1. Occupancy sensor input – whether or not occupancy/vacancy sensors are used, time delays upon sensing occupancy or vacancy before lights turn on or off (or dim), sensitivity, transition times (fade rates) between states, etc.

2. Daylight harvesting – high and low setpoints to create a deadband for dimming or switching fixtures in response to available daylight, time delay before change of electric lighting is allowed, fade rate(s) for dimming lights up or down, etc.

3. Daylight "hold off" – keeps lights off if there is enough available daylight even if there is occupancy in the space, and allows setting the threshold for the "hold off" function.

4. Manual override – allows for occupant override of the preprogrammed control profile, and for setting the maximum override time period before luminaires revert to preprogrammed operation.

ii. Control profiles (also called "control narratives" or "sequences of operation") shall contain values for all of the variables provided by the system. The control system shall be commissioned based on these control profiles. *[Unless there is already a company-wide standard for typical lighting control profiles, the specifier must create these control profiles. They should be issued as an attachment to these specifications. Before finalizing these documents, they need to be submitted to the owner for review and approval.]*

f. Power metering – the lighting control vendor shall provide a means to measure instantaneous power use on a per-luminaire or per-zone basis. *[Verify the availability of power metering functions with the manufacturer, and how they operate. If this function is desired, indicate the granularity required for the measured power use data and the accuracy of the available metering devices.]*

g. Node licenses or additional recurring costs. *[Verify with the manufacturer whether licenses or other charges are assessed based on the quantity of system components or for any other reason at all].*

h. BACnet integration – the lighting control system shall have some means of integration with another building or energy management system. *[If this is desired, verify the availability of this function with prospective vendors, and how the interface works. Also note that additional charges may be required; e.g. for BACnet node licenses, etc.]*

i. Graphic user interface (GUI): *[select one]*

1. *[Tier 1]* – Display "near real time" status of zones (for example – on, off, dimmed level) overlaid onto a floor plan of the space. "Near real time" is defined as the status of zones being updated at intervals of no greater than 1 minute.

2. *[Tier 2]* – In addition to the display of "near real time" status of the zones as described in Tier 1, allow for manual override of a zone(s) directly from the graphic user interface.

j. Emergency (EM) lighting – for overhead luminaires: *[If this is a design-build job, then include the following text in the specification. If not, then the owner/ project team should conduct the following tasks prior to issuance of the specification:*

i. A licensed electrical engineer shall determine which new or retrofitted luminaires (or which fixture segments in continuous rows) require EM power feed or integral batteries for emergency lighting, in accordance with applicable code requirements.

ii. EM luminaires designated by the electrical engineer shall provide emergency lighting functions upon loss of normal power.

iii. When normal power is available, all EM luminaires shall operate according to the control profiles as set in the system for normal operation in their respective zones.

iv. If required by code, bypass control system wiring (power and/or control wiring) to maintain code-compliant emergency egress lighting functions.

v. A licensed electrical engineer shall determine if a change to the normal or emergency operation of EM luminaires will require submission of documents to an "authority having jurisdiction" (AHJ), to verify that they will still provide emergency lighting according to applicable codes.

vi. *A licensed electrical engineer shall determine if new or retrofitted luminaires will change the light levels or power draw on emergency power sources in an emergency lighting situation, and if any such changes prevent the lighting system and luminaires from operating according to code requirements or within the capacity of the EM power source.]*

k. System failures – *[Develop specification language so that during the bid process, the owner/ project team can verify with the manufacturer what will happen when each component fails, considering (but not limited to) the following questions:*

i. *Server – for example, if a centrally located server fails or loses power, will other system components continue to operate normally? Will there be a loss of usage data during the time that the server was down?*

ii. *Gateways – for example, if wired or wireless gateways fail or lose power, will luminaires still operate normally? Will usage data be lost during that time?*

iii. *On-board controllers – for example, if controllers fail or lose a signal from the control system, will they still operate normally, or shut off, or turn on to full output?*

iv. *Sensors and switches – for example, if sensors or switches fail, will luminaires still operate based on default behavior as determined by the server/software?*

v. *Software – for example, similarly to any complex computerized system, software for lighting control systems may be regularly updated by the manufacturer. What happens if the software is updated and causes the system to operate abnormally? Is there a way to force the software to revert back to a previous version that is known to make the system work as specified? What is the procedure used by the manufacturer to correct bugs in the software or firmware in devices (and how regularly is that done)? How will bug fixes affect the operation of the system in the space?*

vi. *Normal vs. abnormal operation – if there are critical tasks being performed in a space, it's essential to know how the system will operate under "normal" as well as "abnormal" conditions. Any manufacturer with a proven track record of having deployed their system for at least three years should have a clear understanding of what happens based on various configurations and topologies and under different conditions.*

vii. *"Failsafe" operation – if the system starts to behave erratically for any reason at all, is there a method available to entirely bypass the system and operate luminaires manually? Will local switches (or any other components or methods) still control luminaires even if the rest of the system is disabled? How about occupancy sensors or photosensors?]*

l. Standby power – if "standby power" in luminaires is necessary to maintain continuity in on-board control circuitry, that power usage shall be limited to a maximum of 1 Watt per luminaire.

m. Reporting – information to be reported/saved/stored by the control system shall include:

i. Peak demand (kW) in any 15-minute period.

ii. Energy use for every 15-minute period (measured in kWh).

iii. Occupancy for every 1-hour period (in both minutes of occupancy and percentage).

iv. Demand response/demand reduction condition (if any, including level of severity).

v. Alarms, alerts or error messages for any equipment not performing as required (including control system communication errors).

vi. Event logs – record logs of all events in the system (schedule changes, occupancy or vacancy, dimming lights in response to photosensor input, manual overrides, alarms, errors, etc.).

vii. Storage – store all historical data indefinitely in server, including energy usage and event logs. *[Depending on the control system, capacity of the storage drives, and granularity of event or usage data, it may be desirable to regularly download/offload data files to free up space on the system's storage drives. Discuss with each vendor.]*

viii. Data format – CSV (comma separated values) or Microsoft Excel. Data files may be exported from the system on an as-needed basis, and/or (if desired) on a regular schedule set up in the control system's software.

ix. Access to historical data. *[If data cannot be accessed through the graphic user interface, allow data to be accessed through standard menu options in the control system software – verify with the manufacturer.]*

x. Reports and graphs. *[Verify with the manufacturer what types of reports and graphs the system can create, display, store (and presumably also export) during design and specification.]*

n. Notifications:

i. The lighting control system shall have some method of sending notifications about errors, alarms, alerts, warnings, etc.

ii. E-mail or text notifications – the lighting control system's notification function shall send e-mails and/or texts *[specify which are desired]* to designated staff. *[Determine if the system can be programmed to send notifications to only one or more than one person, and if each recipient can receive different forms of alerts, warnings, error messages, etc.]*

iii. Daily reports – send daily reports of equipment requiring servicing or replacement. *[Verify with potential vendors if such a function is available, and if so, how it operates.]*

o. Backup – provide a means to automatically backup programming (schedules, control profiles, etc.), usage data files and event logs on a regularly scheduled basis, using at least one of the following methods (preferably both):

i. Backup files on the system's server.

ii. Provide some method to backup files to a USB drive and/or remote storage device, or to e-mail backup files. In the event of loss of program or usage data on the server, backup files may be uploaded to the server to restore normal operation (for control profiles and schedules, in addition to usage and event logs). *[Verify with potential vendors if such a function is available and, if so, how it operates.]*

p. Energizing system before commissioning – provide a means to energize all luminaires at full output prior to commissioning the lighting control system.

q. Connecting control system components and connecting to the system: *[Review all the considerations in this section with the owner at the outset of the project then write specific language describing the desired (or allowable) methods of connection.*

i. Connections between system components:

1. Most (but not all) lighting control systems have a centrally located server. This will usually be installed in an IT server room or electrical closet. Typically, some of the components are connected to the server – such as gateways to luminaires, controllers, sensors, switches, touch panels, DALI ballasts or drivers, etc.

2. Most systems allow for connection between some or all of these components and the server via the owner's existing communications network (intranet) – if the owner allows that. For example, gateways connected to luminaires are often provided with IP addresses and can therefore be connected to an existing communication network (intranet). If the server is also connected to the network, then it can communicate with the gateways without the need for additional wiring.

3. *If the owner will not allow for using any of their internal communications networks (intranets) to connect system components, then they will need to be connected with additional dedicated wiring, unless the system is designed to allow some or all of these connections to be made wirelessly.*

ii. *Connecting to the system (remote access):*

1. *Most lighting control systems are designed to allow remote access to the operating software as previously described, usually residing on a centrally-located server. A common method is to access a webpage or program on the server from a remote location.*

2. *If the owner allows the server (and/or other system components) to reside on an internal communications network (intranet), then it may be possible to access the system's software from any computer on the owner's network. It may also be possible to access the software from any remote location. In some cases, this may require a VPN (virtual private network) to access the server from outside the owner's internal network. It is essential to make this determination during the design and specification of the lighting control system.*

3. *If the owner will not allow for using their internal communications network to access the software residing on the server (or other system components), then it may be necessary to install a dedicated wireless access point (for example, using a 3G modem, aircard, etc.) – or some other method of communicating with the system without accessing the existing building network – in order to gain remote access.]*

4. Access to the system's software shall be provided to the following *[delete any that don't apply in your project]*:

a. System operator/administrator. *[This is usually someone on the building operation/engineering staff.]*

b. Lighting control system manufacturer (this may be required for troubleshooting, software updates, commissioning, recommissioning, rezoning, etc.).

c. Lighting designer/electrical engineer/others.

d. Users (occupants) – allow individual occupants to control luminaires and/or other devices connected to the system.

e. "Dashboards" *[Many systems have methods to allow for displaying system usage (e.g., kWh/hour, kW <load> in percent or amount, usage compared to baseline <actual kW/max kW>, demand response event status, if any, etc.). A common method is for a remotely located monitor to connect to the server's software by accessing its URL for the dashboard display. If this function is desired, verify its availability and operation with prospective vendors.]*

r. User access levels – allow different users to access different functions in the system. *[Verify whether the system allows for different access levels during design and specification and, if so, how.]* Examples of different levels of access and functionality might include: *[Include those required by the owner and delete the others.]*

i. System administrator – has access to all functions and control over all luminaires (and/or other devices) on the system.

ii. Tenants – if a system is used to control luminaires in a multi-tenant space, tenants may be given access only to luminaires in their space.

iii. Individual users – occupants may be given control over the luminaires in their own private office, or luminaires that are located over their workstation in an open office area.

iv. Guests – other people may be given access to monitor the system, without being able to make any changes.

s. Commissioning (Cx). *[Note that some of the steps in the Cx process may be performed by the installing contractor, some by the vendor, and some by an independent Cx agent. Determine which steps are performed by whom and list those responsibilities as part of each step as shown below.]* The Cx process shall include the following steps:

i. Verification of correctly installed wiring and components.

ii. Creating zones in the lighting control system software (including graphic overlays for the graphic user interface).

iii. Discovery of lighting control system components including gateways, controllers, sensors, switches, wall panels, etc.

iv. Creating profiles and schedules for typical operation, as well as atypical events like testing after initial start-up, daylight calibration, demand response events, etc.

v. Assignment of luminaires/groups of luminaires to appropriate zones as created above.

vi. Calibration of photosensors.

vii. Correction of any faults, warnings, alerts, alarms, etc.

viii. Verification that all aspects of the control system software are operating properly and that the system is recording data as described above.

ix. Setting appropriate values to establish baselines. These include any or all of the following:

1. Hours of operation.
2. Fixture types and wattages. *[Note that it may be desirable to have a "pre-install" baseline as well as a "post-install" baseline if the luminaires are replaced or retrofitted.]*
3. Electricity cost (per kWh, which may vary based on time of day).
4. Percentage of occupancy *[this can be established beforehand by using loggers and analyzing the data]*.
5. Cost of CO_2 (carbon dioxide emissions rate, based on electricity or gas cost). *[In some cases, CO_2 emission reductions are taken into account when considering financial incentives, payback, etc.]*

x. Resetting all usage and event data recorded since initial system installation to zero, if desired.

xi. Clearing all active alarms, warnings, alerts, etc. (after insuring that the system is functioning normally).

t. User training:

i. Lighting control system vendor shall provide *[specify amount]* hours of on-site training for designated representatives of owner and design team to learn how to operate the system.

ii. Lighting control system vendor shall provide reference manuals in *[print and/or PDF form – specify which]*, as well as context-sensitive help screens in the control system software itself.

u. Technical support:

i. Allow remote access to the lighting control system server (with appropriate safeguards including firewalls, passwords, etc.).

ii. Within *[specify period of time, e.g., one month, one year, etc.]* from initial system power-up, the lighting control system vendor will make site visits at their own expense in order to correct any problems with the lighting control system.

iii. The selected vendor shall provide ongoing technical support during any warranty period including the following: *[After reviewing these questions with potential vendors, include these answers in the specification text.*

1. *Does the vendor typically allow time to meet with the electrical contractor in advance of installation to review wiring terminations, topology of cable runs, and/or other issues specific to their system? Note that many electrical contractors are unfamiliar with advanced lighting control systems and their associated technology – such as DALI, 0-10V, other protocols, topologies, emergency transfer methods, etc. It's important for someone to provide a minimum amount of education to the installing electrical contractor in advance of actual installation to reduce errors and eliminate delays.*
2. *Does the vendor provide a "factory start-up" (meaning that someone from the factory will be on-site to initially power-up the system)?*
3. *What will happen if the vendor is on-site for initial power-up, but finds that the system hasn't been installed as shown in the submittal documents?*
4. *What will happen if any system components fail upon initial installation or do not operate as expected? How (and when) will they be replaced? How will the replacement components be shipped to the job site, and at whose cost?*
5. *What will happen if there are problems with the software not behaving as expected? Who will troubleshoot and resolve those?*
6. *How quickly will the vendor address problems that arise during or after initial commissioning? Will the vendor only remotely investigate system problems or will a designated representative be available to troubleshoot on-site if necessary? If so, will the vendor make a commitment to getting their staff to the job site within a specific period of time (one day, one week, etc.)?*
7. *How will problems be addressed and handled that arise after any initial warranty period has expired?]*

v. Vendor experience – any prospective lighting control system vendor must have at least three years of experience in supplying and successfully implementing advanced lighting control systems with similar features and operation as described above.

w. Procurement process issues for luminaires:

i. Submittals – luminaire vendors shall submit the following for approval before fabrication and shipping equipment to the job site. *[Verify how long the manufacturer will need to produce these drawings and whether they will require any materials from the owner or specifier (such as CAD background drawings, control schedules, etc.). Determine who will review and approve these materials prior to releasing a purchase order.]* The submittals must include (but are not limited to) the following:

1. Luminaire detail drawings – showing all views necessary to fully describe the luminaire. This may include plan views, section drawings, run configurations, mounting details and/or any other drawings necessary to show every aspect of the luminaires to be installed.
2. Integral controls components – besides the LED driver(s), which may or may not be part of the lighting control system itself, any additional on-board or remote-mounted components must be shown on the drawings, as well as all associated wiring (cord sets, individual conductors, etc.). These may include fixture controllers, on-board sensors, UL924 relays and/or other components required by the lighting control system.
3. Quantities – the luminaire vendor shall indicate quantities required for each fixture type (based on different fixture types, different mounting conditions, lengths, different on-board control equipment, normal vs. EM, etc.).

ii. Samples – luminaire vendors shall provide a working sample of each fixture type for review and approval by the owner and design team. Each sample shall be a complete, functional unit ready to be energized, including any on-board lighting control equipment required.

x. Procurement process issues for lighting control systems:

i. Submittals – lighting control system vendors shall submit the following for approval before fabrication and shipping equipment to the job site. *[Verify how long the manufacturer will need to produce these drawings and whether they will require any materials from the owner or specifier (such as CAD background drawings, control schedules, etc.). Determine who will review and approve these materials prior to releasing a purchase order.]* The submittals shall include (but are not limited to) the following:

1. Plans – showing location of all lighting control system components and how they are connected.
2. One-line diagrams – showing all lighting control system components and how they are connected (but not showing exact locations on a plan of the space).
3. Wiring diagrams – the lighting control system vendor shall provide drawings showing every wiring connection for all system components.
4. Control schedules – indicating what resides in each control zone, including but not limited to:
   a. Luminaires – including quantity of each fixture type in that zone, wattage for each fixture type, type of load (incandescent, fluorescent, LED, low-voltage magnetic, etc.).
   b. Total wattage for the entire zone.
   c. Emergency lighting.
   d. Occupancy sensors associated with that zone.
   e. Photosensors associated with that zone.
   f. Dimmer switches or touch screens associated with that zone.
5. Manufacturer's catalog sheets of all equipment.

ii. Samples – the lighting control system vendor shall provide the following sample equipment: *[The topology and wiring methods for many new lighting control systems are different than the existing topology and wiring in most buildings. It is advantageous for the installing contractor to acquire samples of certain equipment in advance of the installation. These may be provided as free samples by the manufacturer prior to received a purchase order, or subsequent to receiving a purchase order, or the manufacturer may want to provide these samples only as part of an actual order. Verify with the lighting control vendor. Consider creating a mockup of wired components to obtain more informed bids.]*

1. LED drivers – these may be 0-10V, DALI and/or other types. (Not all electrical contractors have experience installing ballasts that contain more than just a hot wire, neutral wire, and a ground.)
2. On-board controllers.
3. Centrally located load controllers.
4. Sensors – wired or wireless occupancy sensors or photosensors.
5. Wall-mounted dimmer switches or touch panels.
6. Emergency transfer devices (such as UL924-compliant components).

iii. Takeoffs/Bill of Materials – the lighting control system vendor shall provide a Bill of Materials for review by the project team based on takeoffs prepared by the electrical contractor. Takeoffs (counting number of luminaires and other components such as sensors, switches, etc.) shall be created by the electrical contractor based on drawings and a walk-through of the existing space and submitted to the luminaire and lighting control system vendors to aid them in preparing Bills of Materials for the project.

iv. Spares – the lighting control system vendor shall provide limited quantities of spare components for certain items. *[Specify which (e.g., LED drivers, on-board controllers, sensors, switches, etc.) and quantities or percentages of additional spares required.]*

v. Service plans – the lighting control system vendor shall offer a plan to cover on-going service of the lighting control system after the warranty period ends. *[Verify the availability and details of such plans with the manufacturer prior to placing a purchase order.]* These service plans shall cover the following: *[Keep items desired in a service plan and delete the others.]*

1. Troubleshooting – after the warranty period ends.
2. Training – beyond what is provided immediately upon completion of system commissioning (for example, training new building engineers after the warranty period ends).
3. Software and firmware upgrades:
   a. Manufacturer shall provide upgrades for system software and component firmware for a period of *[specify time period]* from the date of completion of the on-site commissioning process.
   b. *[Lighting control system software is typically upgraded by the manufacturer by remotely accessing the server. Component firmware may be upgraded by remotely accessing the component, or directly via a USB drive and/or other external method. Verify the methods of upgrade with the manufacturer.]*
4. Recommissioning – changing or adding control zones, recalibrating sensors, adding any additional equipment or components, etc.

5. Warranties – vendors shall provide the following warranty periods from date of final acceptance:
   a. Luminaires – Ten (10) years.
   b. LED drivers – Five (5) years.
   c. Lighting control system – Five (5) years.

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