United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

ENERGY EFFICIENT LIGHTING SYSTEM

CODE 670

(no)

DEFINITION

An agricultural lighting system with increased energy efficiency.

PURPOSE

This practice is used to accomplish the following purpose:

- Improve energy efficiency of an agricultural facility lighting system.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to any agricultural facility with an electrical lighting system. A lighting system may include luminaires (lamps, ballasts, and housing), controls, and wiring as appropriate.

CRITERIA

General Criteria Applicable to All Purposes

Implement a lighting system based on the lighting needs of the facility for the intended purposes for each area or space.

Plan, design, and implement the lighting system improvements to meet all Federal, State, Tribal, and local laws, codes, and regulations. Install any additional fixtures, additional circuits, or modify any wiring in accordance with National Fire Protection Association (NFPA) 70, "National Electrical Code," including Article 547, "Agricultural Buildings," which provides requirements for housing, wiring, mounting, and connections; or applicable State and local codes.

Where components will be exposed to dust, moisture, or corrosive atmosphere (such as in animal housing facilities), use noncorrosive, water-resistant light fixtures to protect lamps from environmental exposure in accordance with NFPA 70. Fixtures and exposed lamps must be rated to meet the intended purpose.

Provide an analysis that demonstrates improved energy efficiency by documenting the energy saved and the assessment methodology.

Prescriptive upgrades
Lighting system upgrades included on the State-approved prescriptive list improve energy efficiency, as such, design and implementation do not require additional specific computations for efficiency.

For lighting improvements not included on the State-approved prescriptive list, utilize the criteria below.

Lamps and ballasts
Select replacement lamps or lamp/ballast combinations that have a minimum rated efficacy of 90 lumens per watt (lm/w).

Select lamps and ballasts that meet facility requirements for starting characteristics of the light, such as warmup period and startup temperature. Use manufacturer data to select fixtures for design. See table 1 for general guidance.

Ensure ballasts or other power conditioning devices are compatible with the wattage, number, and type of lamp they support.

Fluorescent and high-intensity discharge lamps contain mercury, a toxic substance. Store the lamps to prevent breakage and the release of mercury until disposal. Dispose of lamps and ballasts in accordance with environmental laws and regulations. Document disposal of lower efficiency lighting fixtures or lamps that contain mercury (table 1) when replaced.

Controls
Lighting controls include, but are not limited to, switches, dimmers, photosensors, occupancy sensors, and timers. Use control devices to reduce operating time or input power of a lighting system if intermittent use or natural lighting makes continuous electrical lighting unnecessary.

Controls used with incandescent lights usually will not function properly with light-emitting diodes (LEDs). Design and install sensors and controls to meet their intended purpose and to ensure compatibility with the luminaires used. When automatic controls are used, install an independent manual override.

Lighting sources
Table 1 provides typical characteristics of various light sources and their energy efficiency. Choose light sources that meet the needs of the facility and the requirements of this standard.

Table 1. Typical Characteristics of Light Sources

Lamp Type	Efficacy Range (lm/w)	Useful Life Range (1000s hrs)	Color	CRI Range[1]	Color Temperature Range (1000s K)	Lowest Starting Temp. (°F)	Instant On	Contains Mercury
T-8 High output fluorescent	104	18	White	75	3–5	-20	Yes	Yes
Light-emitting diode (LED)	80–110	25–130	White	70–92	2.7–7	-40	Yes	No
T-5 (5/8”) fluorescent	95	20–30	White	85	3–6.5	0	Yes	Yes
T-8 (1.0”) fluorescent	83–93	15–40	White	60–86	3–6.5	0	Yes	Yes
High-pressure sodium	66–97	24	Yellow-orange	22–70	1.9–2.1	-40	No	Yes
T-12 (1.5”) fluorescent	62–80	9–12	White	52–90	3–5	50	Yes	Yes
T-12 High output fluorescent	70	9–12	White	52–90	3–5	-20	Yes	Yes
Pulse-start metal halide	60–74	15–32	Bluish	62–75	3.2–4	-40	No	Yes
Metal halide	41–79	10–20	Bluish	65–70	3–4.3	-22	No	Yes
Compact fluorescent	45–55	6–10	White	82	2.7	-20	Brief warm-up	Yes
Mercury vapor	26–39	24	White-bluish	15–50	3.8–5.7	-22	No	Yes
Halogen	12–21	1–6	White	100	3	-40	Yes	No

Lamp Type	Efficacy Range (lm/w)	Useful Life Range (1000s hrs)	Color	CRI Range[1]	Color Temperature Range (1000s K)	Lowest Starting Temp. (°F)	Instant On	Contains Mercury
Incandescent	7–20	1	White	100	2.8	-40	Yes	No

Additional Criteria for Greenhouse and Nursery Plant Lighting

Select replacement lamps or fixtures with a minimum photosynthetically active radiation (PAR) efficacy of 1.6 mircromoles per joule (µmol/J). Typical PAR efficacy data for various lamp fixtures are shown in table 2.

All lighting equipment must be Underwriters Laboratories (UL) labeled for damp/wet conditions.

Table 2. Typical PAR Efficacy Data for Horticultural Lamp Fixtures

Radiation Source	PAR Efficacy (µmol/J)	PAR Efficacy (mol/kWh)
Ceramic metal halide (315 W)	1.6	5.8
High-pressure sodium (mogul base, 600 W)	1.6	5.8
High-pressure sodium (double ended, 1000 W)	1.7	6.1
LED (150–650 W)	1.5–3.0	5.4–10.8

CONSIDERATIONS

Consider using the American Society of Agricultural and Biological Engineers (ASABE) S612, “Performing On-farm Energy Audits,” or equivalent, to prioritize energy conservation opportunities and estimate potential energy savings of improvements.

To reduce energy imported on a farm, consider developing and using onfarm solar, wind, or other renewable energy resources. Energy conservation and energy efficiency improvements should also consider greenhouse gas emission and ambient air pollutants.

Consider meeting the current version of ASABE Engineering Practice (EP) 344, “Lighting Systems for Agricultural Facilities,” for minimum lighting recommendations for all lighted areas by providing light uniformity based on task classification and maximum spacing-to-mounting-height ratio (s/Hp) given in the tables of ASAE EP344. Manufacturer’s uniformity data, if available, or commercial light modeling software can be used to ensure level and uniform distribution of light.

In some cases, lighting modifications may impact heating, cooling, or ventilation requirements of a building. These impacts are often minor, but they should be considered when planning for changing lamp types.

Protect switches and dimmers from environmental exposure by locating them away from damp or dusty environments, where feasible, or by using corrosion-resistant controls. Replace magnetic ballasts with electronic ballasts, where feasible, to improve energy efficiency.

The spectral quality (color) of a light source can impact the ability to distinguish colors in the lighted area and in some cases affect the mood of people and livestock. Consider installing lamps with a color rendering index (CRI) of 80 or greater in areas where inspections are occurring, such as milk room wash areas, egg inspection, milking parlor pit, etc.

Light quality, luminance, and photoperiod may be adjusted to enhance plant and animal production.

Utilizing daylight to supplement electrical light may reduce energy requirements of a lighting system and provide higher quality light.

For exterior lighting systems, the direction and intensity of the lights may affect the impact of light pollution on people and wildlife. Where possible, utilize directional lighting that will cause less light pollution and be less disruptive to plants and animals.

Some LED components can be recycled. Contact the local municipal solid waste agency for recycling guidance.

Additional Considerations for Greenhouse and Nursery Plant Lighting

Determine desired light intensity, light spectrum, and daily light integral and pattern uniformity for the crop to be grown based on the latest research data. Sources include Michigan State University, Cornell University, University of Arizona, and Rutgers University; and manufacturer's data with computer-generated design for number and layout of fixtures, mounting height, and uniformity of light pattern, or ASAE EP344.4.

The light intensity needed for crop production is usually measured across the PAR waveband (between 400 to 700 nanometers) and quantified using the units of micromoles per meter squared per second ($\mu mol/m^2s$). Total light output produced by horticultural fixtures is measured as photosynthetic photon flux (PPF; between 400 and 700 nanometers) with the units of micromoles per second (μmol/s). Fixture efficacy (efficiency) is defined as the total light output per unit of electric power consumption and has the unit μmol/J. The desired target PAR level delivered by an electrical lighting system will depend on the crop and purpose of the lighting strategy. To establish appropriate lighting quantity and quality refer to American National Standards Institute (ANSI) ANSI/ASABE S640, "Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms)," S642, "Recommended Methods for Measurement and Testing of LED Products for Plant Growth and Development," and associated standards.

The daily light integral (DLI) is the accumulated PAR sum from sunlight plus any supplemental lighting received by the plants over the period of a day (24 hours). Its units are moles per meter squared per day (mol/m^2d).

Typical greenhouse supplemental lighting systems deliver between 60 and 200 $\mu mol/m^2s$ at the top of the plant canopy. Measurements should be made in the plant growing area. Control should be with a quantum sensor/controller. The system should be able to provide the light level needed by the crop. For supplemental lighting in greenhouses, select fixtures that create the least amount of shade.

Photoperiodic lighting for daylength control (used to promote/delay flowering) should provide a minimum intensity of 2 $\mu mol/m^2s$. Consider using an efficient photoperiod control system by attaching low-wattage photoperiod lamps to a movable irrigation boom.

Consider installing movable energy/shade curtains above the crop and along the greenhouse end/sidewalls to minimize light pollution outside the greenhouse and for improved energy retention.

In indoor sole-source facilities consider the impact of heat production by the fixtures and how this excess heat can be removed.

Additional Considerations for Safety

For any space where light levels are primarily for human occupancy (such as walking, climbing, or work areas) consider worker safety ensuring that the lighting system meets the minimum recommended light quality and light levels (illuminance) in foot candles (fc or lm/ft^2) or lux (lx or lm/m^2) in accordance with ASABE EP344.4, tables 2, 5–7, and 10–11.

Also consider—

- Locating light sources to minimize shadows cast on the work area by workers and obstructions.
- Providing Illumination from more than one direction to minimize the density of shadows and to provide uniform illuminance.

- Reducing glare by selecting and installing fixtures with reflectors, refractors, and diffusing shields.
- Locating all light fixtures above the horizontal line of sight.

Additional Considerations for Life Cycle Costs and Long-term Savings

The life of an energy saving investment can significantly affect its rate of return and long-term profitability. The life of items such as a lamp with a filament will decrease with the number of on/off cycles, while an LED light's useful life is unaffected by the number of on/off cycles because it has no filament. Consider long-term cost savings and associated life cycle costs to increase long-term net income by evaluating items such as—

- Type of light and fixture used.
- Planned on/off cycles per day.
- Lumen (or PPF) depreciation over time.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for the lighting system that describe the requirements for applying the practice to achieve the intended purpose. As a minimum, include as necessary—

- Number of lamps per fixture.
- Ballast or other power conditioning device type.
- Lamp type.
- Minimum lamp efficacy.
- Lamp wattage.
- Fixture or lamp rating (dustproof, water resistance, corrosion resistance, etc.).

Describe the specific number and arrangement of fixtures to be installed as designed, along with the power source and controls.

List disposal methods for lamps or fixtures with mercury to be replaced.

Include a plan view showing the location of all components of the lighting system including an electrical wiring diagram if necessary.

OPERATION AND MAINTENANCE

Prepare an operation and maintenance (O&M) plan for the operator. The minimum requirements in the O&M plan are—

- Conduct periodic inspections of lamps, ballasts, fixtures, wiring, and controls.
- Replace burned out lamps promptly.
- Repair or replace other system components as appropriate to ensure the system functions properly.
- Clean lamps, fixtures, and room surfaces regularly to ensure a high-quality light environment is maintained.

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