

ASAE EP344.4 JAN2014
Lighting Systems for Agricultural Facilities



American Society of
Agricultural and Biological Engineers

STANDARD

ASABE is a professional and technical organization, of members worldwide, who are dedicated to advancement of engineering applicable to agricultural, food, and biological systems. ASABE Standards are consensus documents developed and adopted by the American Society of Agricultural and Biological Engineers to meet standardization needs within the scope of the Society; principally agricultural field equipment, farmstead equipment, structures, soil and water resource management, turf and landscape equipment, forest engineering, food and process engineering, electric power applications, plant and animal environment, and waste management.

NOTE: ASABE Standards, Engineering Practices, and Data are informational and advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. The ASABE assumes no responsibility for results attributable to the application of ASABE Standards, Engineering Practices, and Data. Conformity does not ensure compliance with applicable ordinances, laws and regulations. Prospective users are responsible for protecting themselves against liability for infringement of patents.

ASABE Standards, Engineering Practices, and Data initially approved prior to the society name change in July of 2005 are designated as "ASAE", regardless of the revision approval date. Newly developed Standards, Engineering Practices and Data approved after July of 2005 are designated as "ASABE".

Standards designated as "ANSI" are American National Standards as are all ISO adoptions published by ASABE. Adoption as an American National Standard requires verification by ANSI that the requirements for due process, consensus, and other criteria for approval have been met by ASABE.

Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

CAUTION NOTICE: ASABE and ANSI standards may be revised or withdrawn at any time. Additionally, procedures of ASABE require that action be taken periodically to reaffirm, revise, or withdraw each standard.

Copyright American Society of Agricultural and Biological Engineers. All rights reserved.

ASABE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA, phone 269-429-0300, fax 269-429-3852, hq@asabe.org

Lighting Systems for Agricultural Facilities

This Engineering Practice combines and therefore supersedes ASAE R286, Lighting for Dairy Farms, and ASAE R332, Poultry Industry Lighting, developed by the joint Illuminating Engineering Society—ASAE Farm Lighting Committee, EPP-46. R286 was adopted by ASAE June 1965; R332 was adopted by ASAE December 1969. This document was approved by the ASAE Electric Power and Processing Division Standards Committee and adopted by ASAE as ASAE Recommendation R344 February 1971; revised editorially and reclassified as an Engineering Practice December 1975; reconfirmed December 1980; revised March 1982; reconfirmed July 1986, December 1987; revised July 1988; reaffirmed December 1993, December 1998; December 1999; revised editorially March 2000; revised January 2005; reaffirmed January 2010; revised January 2014.

Keywords: Facilities, Lighting

1 Purpose and Scope

1.1 This Engineering Practice is intended to guide those responsible for or concerned with the design of lighting installations on or within agricultural facilities.

1.2 This Engineering Practice applies to the effective performance of workers as they accomplish specific tasks requiring various levels of illuminance and it applies to lighting installations used to change the physiological or biological properties of livestock, birds, fish and plants to alter their production capabilities.

1.3 The lighting recommendations are based on information obtained from search of current literature, from people and organizations active in this field, and from field measurements of lighting requirements for difficult seeing tasks. This document is in accordance with the latest knowledge and practice of the lighting field, and conforms to all official IESNA reports. However, future progress in agriculture and lighting will undoubtedly make revisions desirable.

1.4 Lighting systems must be installed safely. In all cases, the National Electrical Code and Building Codes, plus local codes, will take precedence. This document is primarily for effective, efficient production in agriculture.

2 Definitions

2.1 diffuser: A device used to redirect the illumination by the process of diffuse transmission.

2.2 candela: The SI unit of luminous intensity. One candela is one lumen per steradian. Formerly known as Candle. For more information on this term, see the IESNA Lighting Handbook Reference Volume.

2.3 footcandle (fc): The unit of illuminance when the foot is the unit of length. It is the illuminance on a surface one square foot in area on which is uniformly distributed a flux of one lumen. It equals one lumen per square foot.

2.4 general lighting: Lighting designed to provide a uniform level of illuminance throughout the area involved.

2.5 glare: The effect of brightness or brightness differences within the visual field sufficiently high to cause annoyance, discomfort, or loss in visual performance.

2.6 illuminance: The density of the luminous flux incident on a surface; it is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated.

2.7 local lighting: Illuminance provided over a relatively small area or confined space without any surrounding general lighting.

2.8 louver: A series of baffles used to shield a source from direct view at certain angles or to absorb unwanted light.

2.9 lumen (lm): The unit of the time rate of flow of light (luminous energy) equal to the energy emitted through a unit solid angle (one steradian) from a uniform point source of one candela.

2.10 luminaire: A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

2.11 lux (lx): The unit of illuminance when the meter is the unit of length. It is the illuminance on a surface one square meter in area on which is uniformly distributed a flux of one lumen. It equals one lumen per square meter.

2.12 Photosynthetically Active Radiation (PAR): the equivalent of illuminance when lighting for plant growth, equal to the number of micromoles of photons in the 400–700 nm wavelength range reaching a 1 m² target per second ($\mu\text{mol m}^{-2} \text{s}^{-1}$)

2.13 reflector: A device used to redirect the light from a source primarily by the process of reflection.

2.14 refractor: A device used to redirect the illuminance primarily by the process of refraction. (The bending of a ray of light as it passes obliquely from one medium to another in which its velocity is different.)

2.15 shielding angle (of a luminaire): The angle between a horizontal line through the light center and the line of sight at which the base source first becomes visible.

2.16 supplemental lighting: Lighting used to provide a specific amount or quality of illuminance which cannot be readily obtained by the general lighting system, and which supplements the general lighting system.

2.17 visual task: Conventionally designates those details and objects that must be seen for the performance of a given activity, and includes the immediate background of the details or objects.

2.18 work plane: The plane at which work is done, and on which, illuminance is specified and measured. Unless otherwise indicated, this is assumed to be a horizontal plane 0.75 m (2.5 ft) above the floor.

3 References

Agriculture and Agrifood Canada. 1993. Recommended Code of Practice for the Care and Handling of Farm Animals. Ottawa, ON.

Albrecht, J. 1996. Personal Communication on Lighting Needs for Swine. Professor and Extension Swine Specialist, Department of Animal and Veterinary Sciences, Clemson University, Florence, SC.

Albright, L. D. and A. J. Both. 1994. Comparison of Luminaires: Efficacies and System Design. Proceedings of the International Lighting in Controlled Environments Workshop, March 27–30, 1994. Madison, WI. NASA CP-95-3309. pp. 281-397.

Albright, L. D., A. J. Both, and A. J. Chiu. 2000. Controlling Greenhouse Light to a Consistent Daily Integral. Transactions of the ASAE 43(2): 421-431.

Allmond, G. W. 1986. Influence of Extended Photoperiod on Lactational and Postweaning Performance in the Sow. Paper Presented at the Annual Meeting of the American Association of Swine Practitioners. March 16-18.

- ASAE. 1997. EP344.2. Lighting for Dairy Farms and the Poultry Industry. ASAE Standards. 44th Edition. American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659.
- Beacham, T. D., and C. B. Murray. 1993. Acceleration of Maturity of Pink Salmon (*Oncorhynchus gorbuscha*) Using Photoperiod Control. *Aqua-culture*. 109: 315-325.
- Beck, L. 1995. Good Reasons for Lighting Upgrades. *Engineer's Digest*. September, pp. 34 and 38.
- Blythe, W. G., Helfrich, L. A., Libey, G., and W. E. Beal. 1994. Induced Maturation of Striped Bass *Morone saxatilis* Exposed to 6, 9, and 12 Month Photothermal Regimes. *Journal of the World Aquaculture Society*. 25(2): 183-192.
- Both, A. J., 1994. Luminaire Layout: Design and Implementation. *Proceedings of the International Lighting in Controlled Environments Workshop*. March 27-30, 1994. Madison, WI. NASA CP-95-3309. pp. 299-301.
- Both, A. J., 1994. HID Lighting in Horticulture: A Short Review. *Proceedings of the Greenhouse Systems Automation, Culture, and Environment Conference*. July 20-22, 1995. New Brunswick, NJ. Northeast Region Agricultural Engineering Service publication NRAES 72. Ithaca, NY.
- Both, A. J., L. D. Albright, R. W. Langhans, B. G. Vinzant, and P.N. Walker. 1997. Electric Energy Consumption and PPFi Output of Nine 400 Watt High Pressure Sodium Luminaires and a Greenhouse Application of the Results. *Acta Horticulturae*. 418: 195-202.
- Both, A. J., D. E. Ciolkosz, and L. D. Albright. 2002. Evaluation of Light Uniformity Underneath Supplemental Lighting Systems. *Acta Horticulturae*. 580: 183-190.
- Brandt, K. E., M. A. Diekman, D. M. Greiger, and G. E. Moss. 1990. Effect of Supplemental Lighting on Puberty, Follicular Development, Pituitary and Serum Concentration of LH and Hypothalamic Content on Gn RH in Gilts. *Animal Production*. 51: 365-373.
- Chastain, J. P. 1992. Lighting Requirements for the Milking Centre. In: *Milking Centre Design, Proceedings from the National Milking Centre Design Conference (NRAES-66)*, Harrisburg, PA. Nov. 17-19. pp 214-229.
- Chastain, J. P. 1994. On-Site Investigation of Indoor Lighting Systems for Dairy Facilities. ASAE Paper No. 945507, American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659.
- Chastain, J. P., L. D. Jacobson, and J. Martens. 1997. Lighting Design for Livestock Buildings. In *Livestock Environment V, Proceedings of the Fifth International Symposium*. American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659. II: 816-826.
- Ciolkosz, D. E., A. J. Both, and L. D. Albright. 2001. Selection and Placement of Greenhouse Luminaires for Uniformity. *Applied Engineering in Agriculture*. 17(6): 875-882.
- Ciolkosz, D. E. 2008. Design Daylight Availability for Greenhouses Using Supplementary Assimilative Electrical Lighting. *Biosystems Engineering*. 100(2008)571-580.
- Clarke and Devine. 1984. Supplementary Lighting for Research Greenhouses. *Canadian Journal of Plant Science*. 64(July): 337-339.
- Clause, R., and U. Weiler. 1985. Influence of Light and Photoperiodicity on Pig Prolificacy. *Journal of Reproductive Fertility*. 33(Supplement): 185-197.
- Dahl, G. E., B. A. Buchanan and H. A. Tucker. 2000. Photoperiodic effects on dairy cattle: A review. *Journal of Dairy Science*. 83:885-893.
- Dahl, G. E., T. L. Auchtung, J. L. Salak-Johnson and D. E. Morin. 2003. Photoperiod and immune function in dairy cows. Published as pp. 20-25 in the *Proceedings of the 5th International Dairy Housing Conference*, American Society of Agricultural Engineers, K. A. Janni ed. and as pp. 175-181 in the *Proceedings of the 42nd Annual Meeting of the National Mastitis Council*.
- de Graaf-van der Zande, M. T., and Tjeerd Blacquiére. 1992. Light Quality During Longday Treatment for Poinsettia and China Aster. *Acta Horticulturae*. 327:87-93.
- Dietzer, G., R. Langhans, J. Sager, A. Spomer, and T. Tibbitts. 1994. Guidelines for Lighting in Controlled Environments. *Proceedings of the International Lighting in Controlled Environments Workshop*, March 27-30, 1994. Madison, WI. NASA CP-95-3309. pp. 391-393.

- Duston, J., and R. L. Saunders. 1995. Advancing Smolting to Autumn in Age 0+ Atlantic Salmon by Photoperiod, and Long Term Performance in Sea Water. *Aquaculture*. 135: 295-309.
- Ehret, D. L., P. A. Jolliffe, and J. M. Molnar. 1989. Lighting for Greenhouse Vegetable Production — An Overview. *Canadian Journal of Plant Science*. 69(Oct. 1989): 1409-1426.
- Evans, J. W., A. Borton, H. Hintz, and L. D. Van Vleck. 1990. *The Horse*. 2nd Edition, W. H. Freeman and Company, New York, NY, p. 409.
- Evans, M., F. D. Evans, R. R. Hacker, J. R. Morris, and R. Friendship. Studies on Behavioral Estrus. Ridgetown College, University of Guelph, Guelph, ON.
- Evans, M., J. Morris, V. Osborne, R. R. Hacker, and C. Okere. 1996. Inseminating Sows at a Specific Hour with Regards to Weaning Time and Eliminating Estrus Detection. *Ontario Swine Research Review*. 38-39.
- Feddes, J. J. R., B. A. Young, and J. A. DeShazer. 1988. Feeding Behavior in Pigs: Influence of Light and Temperature. ASAE Paper No. 88-4502. American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659.
- Frier, J. P. 1987. Principles of Lighting Design as Applied to Agriculture. ASAE Paper No. 87-3538, American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659.
- Hart, P. R., Hutchinson, W. G., and G. J. Purser. 1996. Effects of Photo-period, Temperature and Salinity on Hatchery-Reared Larvae of the Greenback Flounder (*Rhombosolea tapirina* Gunther, 1862). *Aquaculture*. 144: 303-311.
- Hoagland, T. A., M. A. Diekman, and P. V. Malven. 1981. Failure of Stress and Supplemental Lighting to Affect Release of Prolactin in Swine. *Journal of Animal Science*. 53(2).
- Hudson, L. 1996. Personal Communication on Effects of Photoperiod on Estrus in Brood mares and Sperm Production in the Stallion. Professor and Extension Equine Specialist, Department of Animal and Veterinary Sciences, Clemson University, Clemson SC.
- Illuminating Engineering Society of North America. 2000. *Lighting Handbook: Reference and Application*. 9th Edition. Illuminating Engineering Society of North America, 120 Wall Street, 17th Floor, New York, NY, 10005-4001.
- King, S. S. 1993. Reproductive Anatomy and Physiology of the Mare (HIH 910). In: *Horse Industry Handbook*, American Youth Horse Council, 4093 Iron Works Pike, Lexington, KY 40511-8434.
- Krakenes, R., Hansen, T., Stefansson, S. O., and G. L. Taranger. 1991. Continuous Light Increases Growth Rate of Atlantic Salmon (*Salmo salar* L.) Postmolts in Sea Cages. *Aquaculture*. 95: 281-287.
- Leech, J. F. and H. L. Person. 1993. Housing for Horses (HIH 320). In: *Horse Industry Handbook*, American Youth Horse Council, 4093 Iron Works Pike, Lexington, KY 40511-8434.
- MacDonald, R. and G. Henderson. 1991. Applications of Energy Efficient Lighting Systems in Livestock and Poultry Facilities. ASAE Paper No. 913545, American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659.
- Mason, E. G., Gallant, R. K., and L. Wood. 1991. Productivity Enhancement of Rainbow Trout Using Photoperiod Manipulation. *Bulletin of the Aquaculture Association of Canada*. 91(3): 44-46.
- McCree, K. J. 1972. Test of Current Definitions of Photosynthetically Active Radiation Against Leaf Photosynthesis Data. *Agricultural Meteorology*. 10:443-453.
- Miller, A. R. E., L. W. Douglass, R.A. Erdman and G. E. Dahl. 2000. Effects of photoperiodic manipulation during the dry period of dairy cows. *Journal of Dairy Science*. 83:962-967.
- Mpelkas, C. C. 1981. Horticultural Light Sources. *Sylvania Engineering Bulletin* 0-352. Sylvania Lighting, Danvers, MA.
- Mpelkas, C. C., 1984. Horticultural Lighting Design. *Sylvania Engineering Bulletin* 0-361. Sylvania Lighting, Danvers, MA.
- Mutton, W. J. 1987. The Influence of Photoperiod and Light Intensity on the Farrowing Sow and Litter. Pig Housing and Environment. *British Society of Animal Production*. Occasional Publication No. 11.
- MWPS. 2005. *Horse Facilities Handbook*. MWPS-60, Midwest Plan Service, 122 Davidson Hall, Ames, Iowa.

- MWPS. 2013. Wiring Handbook for Rural Facilities. MWPS-28. Midwest Plan Service, Ames IA 50011.
- RERC. 2009. Agricultural Wiring Handbook (15th ed.). Rural Electricity Resource Council, Wilmington, OH.
- Ntunde, B. N., R. R. Hacker and G. J. King. 1979. Influence of Photo-period on Growth, Puberty and Plasma LH Levels in Gilts. *Journal of Animal Science*. 48(6)
- Ontario Hydro. 1992. Lighting Reference Guide. 5th Edition. Ontario Hydro, 700 University Ave. Toronto, ON.
- Perera, A. N. M., and R. R. Hacker. 1984. The Effects of Different Photoperiods on Reproduction in the Sow. *Journal of Animal Science*. 58(6).
- Petchey, A. M. 1987. Supplementary Light and Pig Performance. *Farm Building Progress*. 88(April).
- Peters, R. R. 1994. Photoperiod and Management of Dairy Cows: A Practical Review. In: *Dairy Systems for the 21st Century, Proceedings of the Third International Dairy Housing Conference*. American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659. pp. 662-666.
- Philips Lighting. 1992. Artificial Lighting in Horticulture. Application Document #3222 634 00681. The Netherlands: Philips Lighting Co.
- Radenko, V. N., and I. A. Alimov. 1992. Significance of Temperature and Light for Growth and Survival of Larvae of Silver Carp, *Hypophthalmichthys molitrix*. *Journal of Ichthyology*. 32(1): 16-27.
- Sigholt, T., Jarvi, T., and R. Lofthus. 1989. The Effect of Constant 12-Hour Light and Simulated Natural Light on Growth, Cardiac-Somatic Index and Smolting in the Atlantic Salmon (*Salmo salar*). *Aquaculture*. 82: 127-136.
- Skewes, P. 1996. Personal Communication on Lighting Programs Used for Broiler and Egg Production. Professor and Extension Poultry Specialist. Department of Poultry Science, Clemson University, Clemson SC.
- Spaargaren, J. J. 2001. Supplemental Lighting for Greenhouse Crops. Published by P. L. Light Systems Inc., Beamsville, ON. 178 pp.
- Stevenson, J. S., D. S. Pollmann, D. L. Davis, and J. P. Murphy. 1983. Influence of Supplemental Light on Sow Performance During and After Lactation. *Journal of Animal Science*. 56(6).
- Taylor, N. 2010. Lighting for Pig Units, a review. BPEX division of Agriculture and Horticulture Development Board. Stoneleigh Park, Kenilworth, Warwickshire, United Kingdom.
- Thimijan, R. W., and R. D. Heins. 1983. Photometric, Radiometric, and Quantum Light Units of Measure: A Review of Procedures for Interconversion. *Hortscience*. 18(6): 818-822.
- Thorarensen, H., Clarke, W. C., and A. P. Farrell. 1989. Effects of Photo-period and Various Intensities of Night Illumination on Growth and Seawater Adaptability of Juvenile Coho Salmon (*Oncorhynchus kisutch*). *Aquaculture*. 82: 39-49.
- Ting, K. C., and G. A. Giacomelli. 1987. Availability of Solar Photosynthetically Active Radiation. *Transactions of the ASAE*. 30(5): 1453-1457.
- Vogelsang, M. M. 1993. Detection of Estrus and Manipulation of Estrous Cycle (HIH 930). In: *Horse Industry Handbook*, American Youth Horse Council, 4093 Iron Works Pike, Lexington, KY 40511-8434.
- Weir, J. 1975. Artificial Lighting for Commercial Horticulture. *Lighting Research and Technology*. 7(4): 209-225.
- Wheelhouse, R. K., and R. R. Hacker. 1982. The Effect of Four Different Types of Fluorescent Light on Growth, Reproductive Performance, Pineal Weight and Retinal Morphology of Yorkshire Gilts. *Canadian Journal of Animal Science*. 62(June): 417-424.
- Mitchell, C.A., A. J. Both, C. M. Bourget, J. F. Burr, C. Kubota, R.G. Lopez, R. C. Morrow, and E. S. Runkle. 2012. LEDs: The future of greenhouse lighting! (feature article) *Chronica Horticulturae* 52(1):6-12.
- Sager, J.C., W. O. Smith, J. L. Edwards, and K. L. Cyr. 1988. Photosynthetic efficiency and phytochrome photoequilibria determination using spectral data. *Transactions of the ASAE* 31(6): 1882-1889.

4 Introduction

4.1 Lighting equipment

4.1.1 Lamps. Light sources available for agriculture lighting applications include incandescent, fluorescent, low pressure sodium and high intensity discharge (HID). HID sources include mercury, metal halide and high-pressure sodium lamps. HID lamps are more efficient, have longer rated lives, and generate 2 to 5 times more light than the incandescent filament for the same amount of electrical energy. Refer to IESNA Lighting Handbook, Part II Lighting Engineering, Chapter 6 Light Sources.

Incandescent Lamps. These lamps come in a variety of types and sizes. They are a high brightness source and should be used in appropriate luminaire to minimize glare. No auxiliary electrical equipment is required. These lamps can be dimmed.

Fluorescent Lamps. These lamps provide a large light source. Even though surface brightness is relatively low, fluorescent lamps should always be housed in a suitable luminaire to minimize glare. In high humidity environments or areas subject to wash down, gasketed or weatherproof housings are required to prevent corrosion and premature failure of the light system. Fluorescent lamps are available in different sizes, types, and colors, which can provide good color rendering, cool or warm colors. Light output is highly dependent on operating temperature.

At very high or extremely low ambient temperatures, light output drops. Cold start or low temperature starting ballasts along with an enclosure to maintain to temperature should be used in cold areas. Refer to IESNA Lighting Handbook, Part II Lighting Engineering, Chapter 6 Light Sources.

High Intensity Discharge Lamps. HID lamps are used both outdoors and indoors. Ballasts are required for their operation. HID lamps differ in their color rendering ability, generally being lower than fluorescent or incandescent lamps. These lamps are not suited to applications where lights operate intermittently for a short duration due to their slow warm up time.

Light Emitting Diodes. LED lamps are relatively new to the lighting market, and can provide either colored or white light at efficacies exceeding those of incandescent lamps. As they are an emerging technology, their performance characteristics continue to develop.

4.1.2 Luminaires. Light is emitted from most lamps in many directions. A luminaire is designed to control the direction at which light is emitted so glare will be reduced and light directed more effectively on the objects to be seen. In most cases, luminaires should direct light downward to minimize losses. In some applications, it is desirable to have a portion of the light directed toward the ceiling. Some of the light striking a light-colored ceiling is reflected back to the visual tasks.

Luminaires control light distribution with reflectors (enamel, aluminum, glass, or plastic), refractors (glass or plastic diffusing lenses), or diffusers (glass or plastic diffusing shields). One or more of these devices might be used in the same luminaire. Reflectors and refractors direct light for more efficient utilization. Reflectors, refractors, and diffusing shields prevent glare. Refer to IESNA Lighting Handbook, Part II Lighting Engineering, Chapter 6 Light Sources.

A luminaire prevents water from striking hot lamps when used in damp locations, outdoor areas or areas which are washed. Weatherproof or gasketed housings are available for lamps used in humid environments, areas where water spray is a problem or when lamps are exposed to the weather.

4.1.3 Controls. Electric lighting systems in agricultural applications can be controlled electronically. There are several reasons for equipping a lighting system with an electronic control.

- **Visual and Production Performance:** match light intensity to the application. Occupant visual performance may depend on the quantity and quality of the light; for example, visually inspecting livestock for health or produce for quality purposes is a demanding visual task. The application may be specific to the reproductive, growth or behavioral needs of the plant or livestock.
- **Energy Management:** matches light application to demand; thereby, reducing unnecessary energy, time of use and/or demand charges.

A wide variety of controls are used in agricultural operations depending on the application. These controls include switches, dimmers, photosensors, occupancy sensors, and timers. The information provided in this section comes from IESNA Lighting Handbook, Part V Special Topics, Chapter 27 Lighting Controls. For details on any of the areas discussed, please refer to the Handbook.

Switching. Switching control allows lights to be switched on and off manually with simple wall-box switches, or remotely with relays, switchable circuit breakers, a control system, or occupancy sensors. The choice of switching control will depend on the application. Local manual switching controls give control over light levels according to their needs or the task are inexpensive.

Central switching controls are well suited to scheduled activities such as occupation of a space during prescribed hours of the day and week. Control systems are ideal for applications with multiple zones and changing lighting requirements over time. Greenhouse operations, for example, employ lighting control systems to match light requirements to the crop being grown in a particular zone.

Occupancy or motion sensors are used in applications where lights are required only during occupancy of a space. These sensors are ideally suited to walkways, hallways, entrances to buildings, or to spaces where the user's hands are not free to activate a switch.

Dimming. Dimming control allows the illuminance in an area to be adjusted smoothly and continuously to meet the lighting requirements of the occupants. Dimming systems are employed in the poultry industry for example to control daily light levels and light levels during the growout period of a crop of broiler chickens for instance.

Most incandescent lamp dimmers currently rely on solid-state switching components. These components can generate electromagnetic and audible noise as well as harmonic distortion, which requires filtering. The light output, life and color temperature of the lamp are affected by dimming. By reducing light output by 25%, lamp life triples. The lamp color appears warmer with reduced voltage.

Fluorescent lamps can be controlled with dimmers. Dimming is not as simple as reducing the input voltage, which eventually extinguishes the arc and reduces lamp life. Dimmers are available for lamps operated with standard magnetic ballasts, magnetic dimming ballasts, or electronic dimming ballasts. There are many factors affecting the reliability, stability and cost of dimming systems.

High intensity discharge lamps can be dimmed; however, the restrike delay, long warm-up, and color shift limit their use in agricultural applications. Multi-level ballasts allow illuminance to be changed in steps. Continuous dimming to less than 20% full light output is available with certain equipment. Metal halide lamps shift color toward blue-green, and high-pressure sodium to yellow. The color shifts become noticeable below 60% of rated lamp power for metal halide and 40% for high-pressure sodium lamps.

Timing Devices. Timers control lighting based on known or scheduled events, ideal for poultry, swine and dairy operations. They range from simple integral timers (spring-wound) to microprocessors. Microprocessors can be programmed for a sequence of events or multiple events and lighting effects for years in advance. An override is required in order to deviate from the preset schedule.

Sensing Devices. Sensing devices include photosensors and occupancy or motion sensors. A photosensor transforms visible radiation (light) into an electrical signal, which controls a lighting system or lamp. The photosensor generally does not respond to UV and IR radiation. Design, placement, and calibration of interior photosensors are critical to ensure high quality lighting.

Occupancy or motion sensors provide local on-off control of luminaires automatically based on the presence or absence of occupants. Energy consumption is reduced and demand may be reduced as well.

4.1.4 Energy Efficient Lighting. Energy efficiency varies with the type of light source. Table 1 shows the approximate efficiency of a number of light sources compared to a regular life incandescent source. Fluorescent, metal halide, and high-pressure sodium lighting systems have significantly higher first costs compared to incandescent. However, the energy cost savings combined with longer lamp life offsets the higher initial costs for energy efficient lighting systems. The energy efficient alternative will typically pay for itself in two years or less in applications where the lights are operated 8 hours per day or more (Chastain, 1992).