

# Codes and Standards Enhancement (CASE) Initiative For PY2008: Title 20 Standards Development

**Title:**  
Analysis of Standards Options for  
High-Intensity Discharge Lighting Fixtures

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## 1 Executive Summary

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for high-intensity discharge (HID) lighting fixtures.

Approximately 2% of lamps installed in commercial and industrial facilities are HID. HID lighting systems (i.e., lamps and ballasts) account for 16% of the total lighting electricity consumed indoors in these sectors, equaling more than 80 billion kWh per year. The 54.9 million HID systems in outdoor stationary applications consume an additional 50 billion kWh per year. Although HID technology has evolved in recent years, widespread adoption of more efficient products has lagged behind the mainstream introduction of these products, particularly in the retrofit market. Federal regulation of HID lighting systems has taken effect only recently, with the ban on mercury vapor (MV) ballasts set to take effect in 2008, and the adoption of minimum ballast efficiency requirements for metal halide (MH) fixtures scheduled for January 2009. The federal standard for metal halide fixtures is based somewhat on standards effective in California beginning in 2006. Furthermore, federal law explicitly allows California a one-time opportunity to set new standards for MH fixtures that exceed the federal standards taking effect in 2009. Additional energy savings could be realized in California with adoption of expanded standards on HID lighting systems.

In this analysis, we evaluate standards options for MH and high pressure sodium (HPS) fixtures based on the energy savings and costs associated with available replacement options. Our findings suggest that the energy savings and performance benefits of MH fixtures with higher efficiency ballasts outweigh the retrofit costs, with a benefit-cost ratio of approximately 2.65. Existing MH systems can be upgraded to high-efficiency products for an average net present value of \$95 in savings per unit.

We recommend that the current ballast efficiency requirement for MH fixtures be revised to require electronic or equivalent efficiency ballasts. Specifically, we recommend minimum ballast efficiency of 90% for 150W to 274W fixtures, and 92% for fixtures of 275W to 500W. Standards for HPS fixtures are not warranted at this time, but should be reevaluated at a later date. We project this standard will save 173 to 538 GWh of electricity, and avoid 31 to 96 MW of peak demand in California.

## 2 Product Description

The predominant HID light sources are metal halide and high pressure sodium.<sup>1</sup> We will cover each source in turn and then discuss HID luminaires.

### 2.1 Metal Halide Lighting Systems

#### 2.1.1 Metal Halide Lamps

MH lamps were introduced in the 1960s. The lamps consist of a quartz or ceramic arc tube (or discharge tube) containing a starter gas, mercury, and metal halide salts. An outer envelope or bulb contains the arc tube, which operates at high temperature and pressure. The metal halide arc tube requires a high voltage (higher than the voltage supplied by building electrical systems) to start the lamp. As a result, a ballast is required to supply the correct starting voltage and to regulate the starting and operating currents. As the temperature and pressure within the arc tube increase, the compounds in the arc tube vaporize to emit light. The glass outer envelope encapsulating the arc tube provides an inert or vacuum atmosphere to prevent high temperature oxidation of the arc tube components, and limits the amount of ultraviolet radiation emitted from the lamp.

MH lamps are available with either probe-start or pulse-start technology. Probe-start lamps are started when a discharge is created across the small gap between the starter electrode (or starting probe electrode) and one of two operating electrodes, causing electrons to jump across the arc tube to the second operating electrode. A resistor is required to prevent burn up of the probe and a bi-metal switch removes the starting electrode from the circuit once the lamp is started.

Pulse-start MH lamps rely on a high-voltage ignitor pulse to replace the need for the starter electrode. The ignitor and ballast start the lamp through a series of high-voltage pulses. By eliminating the starting probe electrode, the life of the lamp is increased and the seal area at the base of the arc tube can be reduced in area relative to a probe-start arc tube, and in turn heat loss is reduced. In addition, the higher fill gas pressure of the pulse-start arc tube leads to a reduction in the build up of tungsten that blackens the arc tube and reduces lamp performance in probe-start lamps.

Traditionally, probe-start lamps have been more common except for medium-base MH lamps, where pulse-start is used because of arc tube size limitations that will not accommodate the starter electrode required in probe-start lamps. As of January 2008, probe-start ballasts are no longer permitted in 150-500 watt MH fixtures manufactured for sale in California (the same requirement for fixtures with a vertical base-up MH lamp position went into effect in January 2006).

Ceramic MH lamps, which also utilize pulse-start technology, use ceramic rather than quartz arc tubes. Ceramic arc tubes can tolerate a higher temperature, resulting in improved color rendering and color temperature, and in some cases, better efficacy. The

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<sup>1</sup> Another HID source is mercury vapor. The market share for mercury vapor lamps has been declining steadily since 1990 and in January 2008 sales of mercury vapor ballasts will be banned under the federal Energy Policy Act of 2005. As a result, mercury vapor lighting systems are not addressed in this report.

improvements in color performance make ceramic MH particularly attractive in retail and other color-sensitive environments. Ceramic MH lamps use mostly the same ballasts as pulse-start MH lamps.

Pulse-start MH lamps are available with rated lamp power ranging from 20W to 1000W. At this time, ceramic MH lamps of 20W to 400W are available. This CASE report focuses on mid- to high-wattage pulse-start MH lamps (i.e., 150W and higher).

It should be noted that metal halide lamps come in three major configurations—lamps designed for vertical operation (base up and/or base down), lamps designed for horizontal operation, and “universal” position lamps (that can be operated in any orientation). Lamps designed for vertical and horizontal operation are optimized for these positions and have better efficacy and life than universal position lamps operating in these same positions. Pulse-start metal halide lamps are most widely available for vertical operation, but the availability of horizontal and universal pulse-start products has grown in preparation for state standards slated to take effect in 2008.

**Figure 1: Metal Halide Lamps**



Pulse-start MH lamp

Ceramic MH lamp

### 2.1.2 Ballasts for Metal Halide Lamps

A range of ballasts are available for use with MH lamps. Both magnetic and electronic ballasts are available for pulse-start MH lamps, however electronic ballasts currently account for only an estimated 3-5% of pulse-start ballasts. Magnetic pulse-start ballast systems include constant-wattage autotransformer (CWA), linear reactor, HX lag, and regulated lag. CWA are lead-style ballasts for pulse-start lamps, comparable to the CWA ballasts common in probe-start systems. Pulse-start CWA technology offers good power regulation with modest ballast losses, handling voltage dip variations of up to 45%. These ballasts reduce ballast losses by 5-10 watts relative to probe-start CWA ballasts. Linear reactors (or “reactor” ballasts) and HX lag ballasts are both lag-style ballasts, offering improved ballast efficiency and lamp performance relative to CWA but less power regulation. Reactor ballasts are only available in 277 volts and are suited for areas with

very little variation in line voltage. Compared to CWA ballasts, reactor ballasts can reduce power input by up to 35 watts; however, their sensitivity to power quality and specific voltage requirements limit their applicability. Regulated lag ballasts have the most sophisticated design of the magnetic pulse-start ballasts providing good power regulation as well as improved lumen maintenance. Drawbacks of this design are a large physical size, lower efficiency, and higher cost compared to other MH ballasts.

Electronic ballasts for MH lamps can offer several advantages over magnetic ballasts, but higher costs, lamp/ballast compatibility, reliability and limited availability have limited their use. Benefits of electronic ballasts can include reduced size, higher power factor, reduced ballast losses (greater efficiency), cooler operation, improved lamp lumen maintenance, better color stability, longer lamp life, and improved dimming capability. Electronic ballasts for mid-wattage MH lamps typically operate at high frequency, although low-frequency square wave ballasts (common for lamps of 150W and under) are being introduced for mid-wattage lamps to address concerns about acoustic resonance and electromagnetic interference. Although still a small fraction of pulse-start ballast sales, the market for electronic ballasts has been growing and accounts for roughly 3 to 5 percent of the current pulse-start ballast market at power levels below 150W. The number of manufacturers producing electronic ballasts is on the rise, and the range of products has grown to include lower-cost, non-dimming ballasts, as well as dimming ballasts for select lamps.

In order to compete with T5 and high-output T8 fluorescents and high-wattage CFLs, manufacturers continue to conduct research and introduce improved MH lighting systems, including quartz and ceramic pulse-start MH lamps optimized for use with electronic ballasts.

### **2.2 High Pressure Sodium Lighting Systems**

[Note: we plan to add descriptive information on high pressure sodium lamps and ballasts in subsequent versions of this CASE report. At this time, there has been little improvement in magnetic ballasts for HPS systems and concerns persist about the performance of electronic HPS ballasts on the market so we are not recommending standards for HPS products at this time. However, there are some early indications with new products that electronic HPS ballasts may prove more reliable than electronic MH ballasts in some applications, but this needs to be borne out with further development and use of the technology. Given concerns about the performance and reliability of current electronic MH ballasts in outdoor applications, we are recommending some exclusions for these applications to prevent backsliding from MH to HPS in outdoor fixtures. HPS ballasts may warrant more detailed examination and consideration in the next round of standards rulemaking.]

#### *2.2.1 High Pressure Sodium Lamps*

2.2.2 Ballasts for High Pressure Sodium Systems

2.3 HID Fixtures

Metal halide and other HID lamps are used in a variety of fixtures, including recessed fixtures (particularly for lamps of less than 150 Watts), wall-mounted fixtures (often called wall packs), streetlights and pole-mounted fixtures, sports-lighting luminaires, and interior industrial- and commercial-type fixtures. These latter fixtures are particularly common in such applications as warehouses, manufacturing facilities, malls and “big box” retail, and gymnasiums. Industrial- and commercial-type fixtures generally come in *high-bay* and *low-bay* types, where high-bay fixtures are designed for installation 20 or more feet above floor level and low-bay for lower mounting heights. Low-bay fixtures generally have special drop lenses to distribute light over a wider distribution angle, a consideration that is much less important for high-bay fixtures due to their higher mounting height. High-bay fixtures are generally made out of spun-aluminum, but products are also available with more reflective surfaces or with prismatic outer shells. Conventional spun-aluminum, high-bay fixtures typically have a *luminaire efficiency* of about 75%, meaning about 75% of the light from the lamp exits the fixture and the remaining 25% becomes trapped in the fixture and ultimately converted from light to heat. Fixtures with more reflective surfaces or prismatic fixtures (whose outer shell is transparent or translucent, permitting some light to escape upwards to illuminate the ceiling) typically have efficiencies of 90% or more. Clear and translucent fixtures partially illuminate the ceiling, reducing the “cave effect” (making a room look like a cave) glare, and improving contrast ratios.

Figure 2: Typical high-bay and low-bay MH fixtures



High-bay: Open die-cast aluminum



Low-bay: Enclosed die-cast aluminum

### 3 Manufacturing and Distribution Channel Overview

The U.S. market for HID lamps is highly concentrated. Three manufacturers—General Electric (GE), OSRAM Sylvania, and Philips Lighting—account for the majority of HID lamp sales with EYE Lighting, Ushio America, and Venture Lighting making up the remainder. A larger number of manufacturers produce ballasts for the U.S. market. The number of companies making electronic HID ballasts has grown in recent years; however, two manufacturers left the market in 2007. Leading manufacturers include:

- *Electronic and magnetic ballasts* Advance Transformer, GE, Holophane, OSRAM Sylvania, Universal Ballast, Venture Lighting
- *Electronic ballasts only* AMF Technology, Green Earth, IEPC, Metrolight, Romlight
- *Magnetic ballasts only* EYE Lighting

The luminaire market is also fairly concentrated with three manufacturers—Cooper Lighting, Acuity Brands Lighting and Genlyte Thomas Group—representing over half of the domestic market. More than 20 other manufacturers produce HID luminaires for the U.S. market.

Major distribution channels for HID lighting systems include large electrical distributors selling to contractors, and larger customers including building managers, maintenance contractors, developers, utilities, municipalities, and mail-order distributors serving smaller businesses and contractors. Large maintenance companies and other customers may buy directly from manufacturers.

## 4 Energy Usage

### 4.1 Test Methods

#### 4.1.1 Current Test Methods

A widely used test method for MH and other HID lamps is LM-51-00, published by the Illuminating Engineering Society of North America (IESNA). This standard is titled *Electrical and Photometric Measurements of High Intensity Discharge Lamps*. It is regularly updated, with the most recent version published in 2000.

The American National Standards Institute (ANSI) publishes test methods for magnetic and electronic ballasts. Magnetic ballasts are covered in ANSI C82.6-2005 *Ballasts for High Intensity Discharge Lamps – Method of Measurement*. For electronic ballasts, ANSI/ANSLG C82.14-2006 *Low-Frequency Square Wave Electronic Ballasts for Metal Halide Lamps* provides specifications and operating characteristics for low-frequency electronic MH ballasts including reference to the test methods outlined in ANSI C82.6. Standards for high-frequency electronic MH ballasts have not been published, but are now being developed with completion anticipated in approximately 3 years.

#### 4.1.2 Proposed Test Methods

We recommend using the current test methods referenced above for magnetic and low-frequency electronic ballasts. The new test method under development for high-frequency electronic ballasts should be adopted once it is published. Enactment of a standard for mid- to high-wattage MH fixtures could put pressure on the process and ensure publication of the new test method to meet the effective date of the standard.

### 4.2 Baseline Energy Use Per Product

Baseline energy consumption varies depending on the specific lamp/ballast combination and the application. Table 2 summarizes per fixture energy use for mid-wattage MH systems meeting the current California standards for metal halide fixtures (i.e., pulse-start metal halide system with minimum ballast efficiency of 88%).

**Table 2. Baseline MH Energy Use**

Baseline Lamp (Wattage)	Input Power (W) <sup>a</sup>	Annual Energy Consumption (kWh/yr) <sup>b</sup>
175W	199	871
200 W	227	995
250 W	284	1244
320 W	364	1593
350 W	398	1742
400 W	455	1991
450 W	511	2240

Source: Manufacturer catalogs unless noted.

<sup>a</sup> Assumes pulse-start lamp with ballast efficiency of 88% per California Title 20 standards.

<sup>b</sup> Assumes typical operating hours of 12 hours/day per weighted average commercial, industrial, and outdoor stationary usage (DOE 2002).

### 4.3 Efficiency Measures

Improvements in MH fixture efficiency can be realized through increases in luminaire efficiency or ballast efficiency. Common spun-aluminum, high-bay fixtures have a luminaire efficiency of about 75%, whereas comparable fixtures incorporating reflective surfaces or prismatic outer shells typically have luminaire efficiencies of 85% or higher. Higher luminaire efficiency permits the use of lower wattage lamps, while maintaining desired light levels.

The efficiency of the base case MH system described above can be improved through the use of higher efficiency ballasts. High-efficiency/low-loss CWA ballasts now on the market have ballast efficiencies of 91% to 92%, thereby reducing power consumption by 5W to 20W per fixture depending on lamp wattage. In applications with a single line voltage and good power quality, dedicated 277 voltage (or even 240 voltage) linear reactor ballasts (with efficiencies of 93% to 94%) can reduce power consumption by

10W to 30W per fixture. Additional energy savings can be realized through the use of electronic ballasts and improved reflectors/fixtures. Electronic ballasts can have efficiencies of up to 94% for some lamp wattages and some designs can yield additional energy savings by improving lamp lumen maintenance and allowing for the use of dimming.

Further efficiency improvements can be realized through the use of lamps with better lumen maintenance. Reported lumen maintenance values for pulse-start MH lamps range from 55% to 85%, with most lamps in the range of 75% to 81% mean lumens after 40% of rated lamp life. Better lumen maintenance not only extends the useful life of the lamps, but allows for the installation of lower wattage lamps to yield the desired level of light over the life of the lamp.

#### **4.4 Standards Options Energy Use Per Product**

For this CASE study, we focused our analysis on revised standards for new MH fixtures. Specifically, we looked at options for revising the current ballast efficiency requirements for MH fixtures that took effect in January 2006 and 2008 to account for improvements in ballast efficiency. We initially considered system efficacy requirements (i.e., lamp/ballast system lumens per watt) and lamp lumen maintenance requirements, such as a mean maintained lumens requirement, which would account for lamp and ballast efficiency as well as lamp lumen maintenance; however, we ultimately decided to concentrate on ballast efficiency. System approaches combining lamp efficacy and ballast efficiency are very complicated given the wide range of lamps available on the market. Standards establishing system efficacy requirements would require fixture manufacturers to test all possible lamp and ballast combinations, or shipping fixtures with lamps as well as ballasts to ensure compliance. As a result, a system efficacy standard or other approaches incorporating lamp efficacy, are much more difficult and costly to implement. Stronger ballast efficiency requirements will reduce ballast energy consumption and are easier to establish and implement since fixtures are routinely shipped with ballasts. In many cases, higher efficiency ballasts also yield lumen maintenance improvements.

Figures 1 and 2, respectively, illustrate the distribution of electronic and magnetic pulse-start ballasts currently available by wattage and manufacturer reported ballast efficiency. Figure 1 shows that almost all of the electronic ballasts on the national market exceed the current California ballast performance standards for MH fixtures according to manufacturer literature. In fact, for all lamp wattages above 150W there are products available with reported efficiencies exceeding 90%. Above 250W, all electronic ballasts exceed 92% ballast efficiency. In contrast, the number of magnetic ballasts meeting or exceeding the current standards is limited, although magnetic ballasts are the only type listed in the CEC database of certified products exceeding 90% efficiency as of February 2008 (two magnetic pulse-start ballasts are listed with efficiencies of 94% and 93.7%).

Figure 1: Available Electronic Pulse-Start MH Ballasts

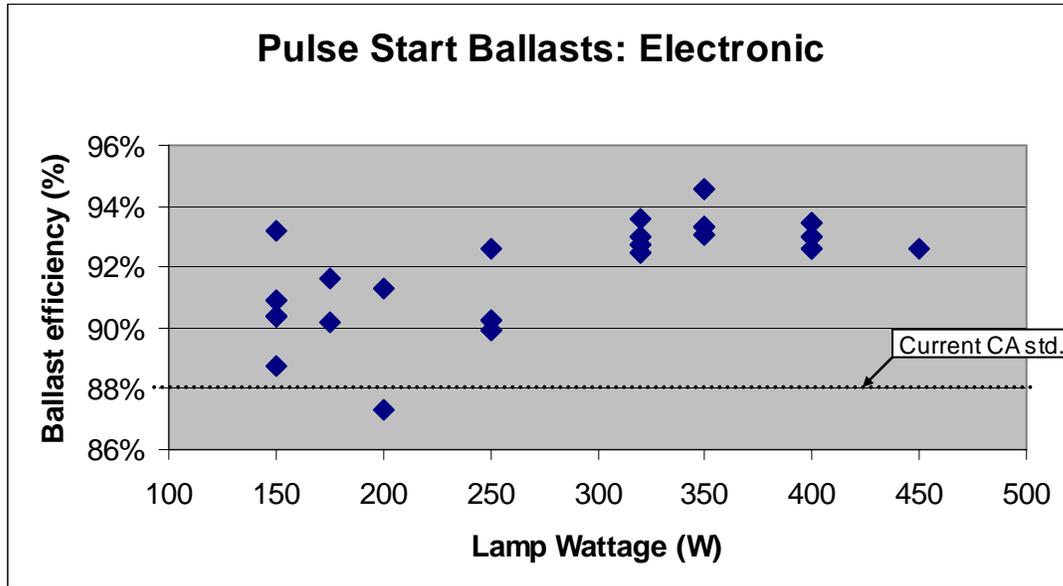
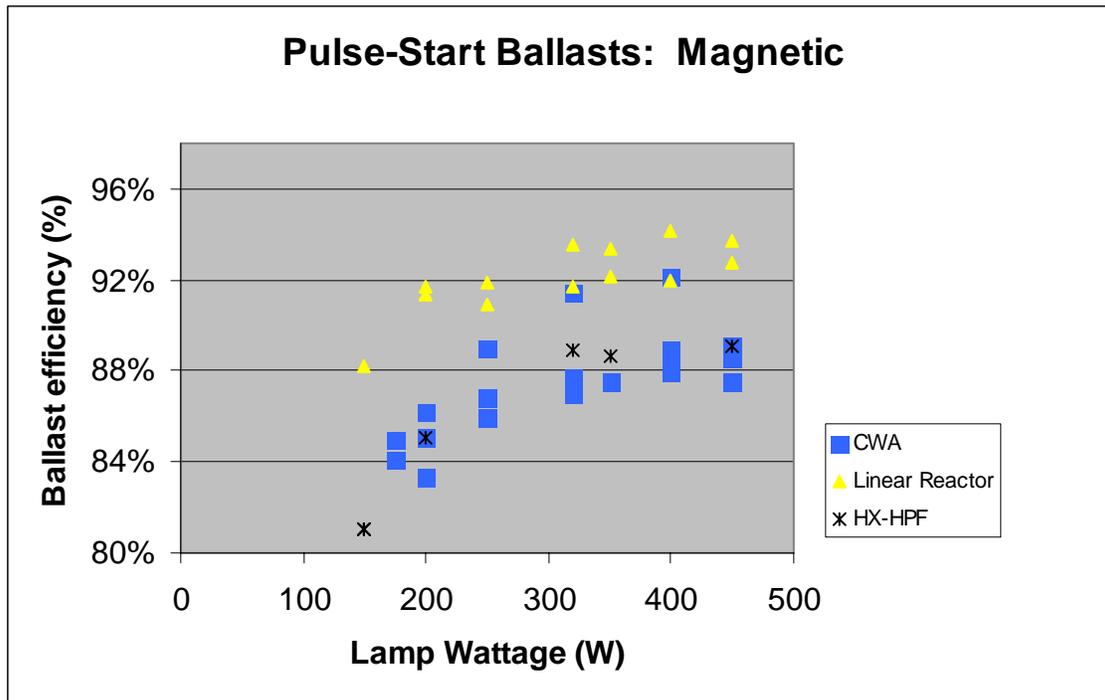


Figure 2: Available Magnetic Pulse-Start MH Ballasts by Type



Given these findings, we analyzed energy savings from a standard requiring electronic ballasts or equivalent efficiency for MH systems in California. Since pulse-start systems offer a range of benefits, such as improved lumen maintenance, that can contribute additional energy savings, we did not consider reversing the ban on probe-start ballasts in

California. Table 3 presents the standards option evaluated and estimated per fixture energy use. Energy use is reported with the low-end of the range incorporating an estimated 10% improvement in lumen maintenance associated with electronic MH ballasts; the high-end of the range does not include any lumen maintenance benefits.<sup>2</sup> In practice, lumen maintenance savings would be achieved through reduction in lamp wattage or number of fixtures used.

**Table 3. Energy Use for Standard Option Requiring Electronic Ballast or Equivalent**

Lamp	Ballast Efficiency Requirement (%)	Input Power (W)	Annual Energy Consumption (kWh/yr)
175W	90%	194	767 - 852
200 W	90%	222	876 - 973
250 W	90%	278	1095 - 1217
320 W	92%	348	1371 - 1523
350 W	92%	380	1500 - 1666
400 W	92%	435	1714 - 1904
450 W	92%	489	1928 - 2142

Source: Manufacturer catalogs unless noted.  
Assumes typical operating hours of 12 hours/day (DOE 2002)

## 5 Market Saturation and Sales

### 5.1 Current Market Situation

#### 5.1.1 Baseline Case

The 2002 U.S. Lighting Market Characterization (DOE 2002) estimates that there are a total of 34.8 million MH lamps operating in commercial, industrial, and outdoor stationary applications, accounting for 33% of the installed base of high-intensity discharge (HID) luminaires. This translates into an existing stock of 3.3 million MH lamps in operation in California since the state accounts for about 9.6% of U.S. commercial building floor area (CEC 2003). MH lamps are the most common HID source in the commercial and industrial sectors, accounting for 63% and 71% of installed luminaires, respectively. MH lamps make up a smaller portion of outdoor stationary HID, accounting for only 9% of the installed HID base, which is predominately high-pressure sodium (67%). Mercury vapor makes up the remaining 24%, but its overall market share has been declining steadily since 1990, and will continue to erode with the January 2008 federal ban on MV ballasts. The 2003 Commercial Buildings Energy Consumption Survey (EIA 2005) reports that 33% of lit commercial building floorspace in the five states of the Pacific census division includes some use of HID lighting.

<sup>2</sup> According to a leading manufacturer's product literature, electronic ballasts increase mean lumens to 86% relative to 75% for magnetic pulse-start systems, an improvement of more than 14%.

## Analysis of Standards Options for HID Lighting Systems

According to the National Electrical Manufacturers Association (NEMA), annual U.S. shipments of MH lamps totaled 18.6 million in 2001 and 19.2 million in 2002 (DOE 2003). If California also accounts for 9.6% of U.S. MH lamp sales, California sales totaled 1.79 million MH lamps in 2001 and 1.84 million MH lamps in 2002 (U.S. Census Bureau 2002). Shipments of MH lamps have increased every year since 1992. In contrast, shipments of high pressure sodium lamps have leveled off since the late 1990s, and shipments of mercury vapor have steadily declined since the early 1990s.

HID fixture sales in 2000 and 2001, as compiled by the U.S. Census Bureau, total 12.6 million and 11.7 million, respectively.<sup>3</sup> These numbers include fixtures used for all HID sources, not just MH. Sales are greater in 2000 than in 2001 due primarily to the recession that took hold in 2001. As noted in the paragraph above, California accounts for about 9.6% of U.S. fixture sales, or roughly 1.1 million HID fixtures sold in 2001, including approximately 363,000 MH fixtures. Table 4 presents estimated statewide baseline sales, stock, and energy use for MH fixtures in California.

Data on the relative proportion of high-bay versus low-bay fixtures are not widely available, but discussions with lighting distributors suggest that 90% of industrial-type fixtures are high-bay designs and 10% are low-bay. Sales of low-bay fixtures have been on the decline in recent years as a result of the growing popularity of high-output fluorescent lighting systems for low-bay applications.

**Table 4. California Statewide Baseline Sales, Stock and Energy Use**

Weighted Average System <sup>a</sup>	California Annual Sales <sup>b</sup>	California Stock <sup>c</sup>	Annual Operating Hours <sup>d</sup>	% On at Peak <sup>e</sup>	California Energy Use and Demand	
	Units	Units (millions)			MW	GWh/year
398W MH system	254,100	2.3	4,380	78%	690	4,027

<sup>a</sup> Base case determined using current CA standard for typical 350W lamp with 88% efficient pulse-start ballast.

<sup>b</sup> National sales data from U.S. Census Bureau, 2002. California sales estimated at 9.6% of U.S. Commercial sales based on commercial floor area data from CBECS (EIA 2005) and 2002 population data from the U.S. Census Bureau. Assumes 70% of MH lamps sold are 150W to 1000W.

<sup>c</sup> California existing stock data from CEC 2003 and EIA 2005

<sup>d</sup> Daily operating hours averaged for MH lamps in commercial and industrial from DOE 2002

<sup>e</sup> Peak coincidence 78% for commercial sector (based on PG&E 2000)

As of January 2006, all new MH fixtures with vertical, base-up lamps of 150W to 500W can no longer include probe-start ballasts. In addition, ballasts included in the fixtures must meet a minimum ballast efficiency requirement of 88%—this last requirement applies to all new fixtures, regardless of lamp-burning position, as of January 2008. While this has not had a big impact on the new construction and large-scale renovation markets, where the majority of projects in California have been using pulse-start MH

<sup>3</sup> The Census Bureau no longer collects and reports data on HID fixture shipments – 2001 is the last year for which this data is available.

technology for at least 4 or 5 years (Nelson 2003), it is causing a big shift in retrofit and replacement markets where penetration rates of pulse-start MH have been much lower. Over time, this will also lead to an increase in sales of pulse-start metal halide replacement lamps.

In the new construction, renovation, and retrofit markets, MH faces competition from other lighting technologies. Building owners interested in investing in new technology are installing high-output T5 fluorescent lighting, T8 fluorescents, CFLs, induction lighting, and LEDs, or retrofitting their existing HID systems with these alternatives. These technologies have advantages over MH in applications where occupancy sensors can yield substantial savings. Even with electronic ballasting, the restrike time for pulse-start MH is too long to allow occupancy sensors to completely turn the MH lamp and ballast off. In contrast, fluorescent and induction lighting have instant-on capability allowing sensors to completely turn lights off in unoccupied spaces, saving additional electricity.

### *5.1.2 High Efficiency Options*

At present, the majority of ballasts sold for pulse-start MH systems are magnetic CWA ballasts with efficiency in the range of 83% to 89%. High-efficiency/low-loss CWA ballasts with efficiency in excess of 90% are available from one manufacturer, but sales are still relatively low. Linear reactor ballasts are limited by their sensitivity to power quality and specific voltage requirements. Overall, higher efficiency alternatives have yet to capture significant market share, but the technology continues to improve. At the present time, experts estimate that electronic ballasts account for only about 3-5% of pulse-start MH ballast sales; however, this figure is expected to grow with interest in the higher efficiency, energy savings from lamp dimming and the other performance benefits associated with electronic ballasts. The number of manufacturers producing electronic ballasts continues to grow.

As for fixtures, data on fixture sales by efficiency level are not compiled. However, it is estimated that 20-25% of current high-bay fixture sales have a luminaire efficiency of 85% or more.

## **6 Savings Potential**

### **6.1 Statewide California Energy Savings**

Using the standards option outlined in Section 4.4, Table 5 estimates annual statewide energy savings. The range of savings accounts for savings with and without lumen maintenance benefits.

**Table 5. California Statewide Energy Savings From Proposed Standards**

Weighted Average System	California Fixture Sales	Percent Existing Fixtures with Electronic Ballast <sup>a</sup>	Watts Saved per Fixture	Percent on at Peak	For First-Year Sales		After Entire Stock Turnover	
					Coincident Peak Demand Reduction (MW)	Annual Electricity Savings (GWh/yr)	Coincident Peak Demand Reduction (MW)	Annual Electricity Savings (GWh)
398W MH system	254,100	5%	18 – 56	78%	3 - 11	19 - 59	31 – 96	173 - 538

<sup>a</sup> ACEEE estimates based on discussions with industry experts.

## 6.2 Other Benefits and Penalties

As noted above, electronic ballasts offer advantages beyond greater efficiency and improved lumen maintenance. Additional benefits can include reduced size, higher power factor, cooler operation, better color stability, longer lamp life, and improved dimming capability. The ability to incorporate dimming strategies for MH lighting can yield additional energy savings and help MH compete with linear fluorescent, CFL, and LED technologies.

Electronic ballasts can have disadvantages as well. They must be kept cooler than electromagnetic ballasts. Whereas magnetic ballasts can reliably operate at temperatures between 130° and 180°C, electronic ballasts generally must operate at component temperatures no higher than 85° to 115°C. As a result, electronic ballasts may be larger than their magnetic counterparts and almost always have a different form factor. Differences in form factor and limitations in operating temperature require luminaires designed specifically for electronic ballasts and do not generally allow for interchangeable luminaire designs. The proposed standards would establish efficiency levels that can be met by electronic or magnetic ballasts to help address these issues.

The proposed standards options analyzed here have the potential to impact future federal standards rulemakings as required by law. Details of the scheduled rulemaking process are discussed in Section 8.3.

## 7 Economic Analysis

### 7.1 Incremental Cost

Electronic MH ballasts are more expensive than magnetic ballasts, although the price has dropped some in recent years. At present, electronic ballasts incur an incremental cost from \$60 to as much as \$150. The most common products from the major manufacturers carry an incremental cost of \$100 relative to magnetic pulse-start ballasts. However, as more manufacturers enter the market, the number of available models grows, and sales increase prices should continue to drop. Over the next few years, the incremental costs relative to other pulse-start MH ballasts can be expected to approach \$75.

### 7.2 Design Life

The rated lamp life for pulse-start MH lamps typically ranges from 15,000 to 25,000 hours. MH magnetic ballasts have a longer life, generally around 60,000 hours. Electronic ballasts typically have a shorter life of 30,000 to 50,000 hours depending on operating temperature. Ten hours is the daily burn time used in the test procedure. For this analysis, we have assumed a lamp design life of 20,000 hours or 4.5 years with an average burn time of 12 hours per day. In most applications, typical burn time is 12 hours per day. Using these same assumptions, a 60,000-hour magnetic ballast will have a life of 13.5 years and an electronic ballast can be expected to have a life of 9 years. As noted above, the typical fixture will have a life of 20 years but to make the calculations much easier, we use even multiples of lamp and ballast life and thus assume an average fixture life of only 9 years.

### 7.3 Lifecycle Cost / Net Benefit

Table 6 summarizes the projected life cycle cost savings based on incremental cost and present value of lifetime energy savings calculations. Net present value estimates are based on average statewide present value electricity prices, as supplied by the California Energy Commission.

**Table 6. Costs and Benefits Per Unit**

Basecase Fixture (system wattage)	Annual Energy Savings per unit (kWh)	Life (yrs)	Incremental Cost (\$) <sup>a</sup>	PV of Lifetime Energy Savings (\$) <sup>b</sup>	Lifecycle Benefit / Cost Ratio <sup>c</sup>	NPV per unit (\$) <sup>d</sup>
398W Pulse-Start MH	159	9	\$75	\$152	2.65	\$95

<sup>a</sup> Incremental cost for electronic pulse-start MH ballasts based on manufacturer and distributor data at effective date of standard.

<sup>b</sup> Calculated using the CEC's average statewide present value statewide energy rates that assume a 3% discount rate (CEC 2004).

<sup>c</sup> Total present value benefits divided by total present value costs.

<sup>d</sup> Positive value indicates a reduced total cost of ownership over the life of the appliance

## **8 Acceptance Issues**

### **8.1 Infrastructure Issues**

In response to California's current standards for MH fixtures, pulse-start MH lighting is becoming the norm in the retrofit market, and increasing its gains in new construction and major renovations. The growing availability of electronic MH ballasts, including the introduction of product lines from major manufacturers, should increase the market share of electronic versus magnetic ballasts particularly in applications where the other benefits of electronic ballasts outweigh their higher first costs. However, MH fixtures are expected to experience greater competition from other light sources in the coming years. In addition to competition from linear fluorescent and CFLs, new LED products designed for typical MH applications are coming into the market. The efficacy of these products is improving rapidly and costs are dropping. These products also offer much longer lifetimes, better dimming capability, and other benefits.

### **8.2 Application Issues**

As noted above, there are concerns that the proposed standards could result in some reversion to HPS in outdoor installations where more efficient MH systems would otherwise be used. This would increase outdoor lighting energy use and reduce lighting quality due to the poor scotopic properties of HPS lamps. A limited range of fixtures for outdoor applications are excluded from the existing California standards for MH luminaires. Specifically, excepted luminaires must be rated only for 150W lamps, be rated for use in wet locations, and contain a ballast rated to operate at ambient air temperatures above 50°C.

To address concerns about the performance of electronic and high efficiency magnetic ballasts in outdoor environments, we recommend continuation of the current exceptions and of the current standards requirements (i.e., pulse-start ballasts with 88% of higher ballast efficiency) for outdoor luminaires that do not meet the current exception.

### **8.3 Existing Standards**

#### *8.3.1 Federal Standards*

The Energy Independence and Security Act of 2007, signed into law in December 2007, establishes federal standards for MH fixtures to take effect in January 1, 2009. The federal standard applies to fixtures for 150W to 500W MH lamps. The standard sets a minimum pulse-start MH ballast efficiency of 88%. Unlike California's MH fixture standard, the federal standard does not prohibit the use of probe-start ballasts; rather, magnetic probe-start ballasts must meet a stringent efficiency requirement of 94%. Non-pulse-start electronic ballasts must meet a minimum efficiency of 92% for wattages greater than 250W, or 90% for wattages less than or equal to 250W. The law explicitly excludes California's MH fixture standards from preemption and provides an opening for the California Energy Commission to adopt revised standards by January 1, 2011.

Furthermore, the statute requires DOE to determine whether to revise the federal standards by January 2012; if a positive determination is made, the amended standards must be published at that time and will take effect by January 2015. A second determination must be published by January 2019, with an effective date of any amended standards required by January 2022. Any revised MH fixture standard adopted by California prior to the 2011 deadline will likely influence the federal rulemaking process.

### 8.3.2 *Interaction with Title 24 of California's Building Code*

The standards proposed here affect new fixtures in commercial applications. Based on discussions with industry experts, it appears that the majority of new fixtures do not use the electronic ballasts proposed here and thus, this proposed standard will save a substantial amount of energy beyond the energy saved by Title 24.

## 8.4 Stakeholder Positions

[This section will be completed after NEMA review of the draft and our meeting]

## 9 Recommendations

### 9.1 Recommended Standards Options

Based on the cost-effective energy savings available from the use of electronic MH ballasts, a revised standard for new MH fixtures is warranted. We recommend that the current ballast efficiency requirement for MH fixtures be revised to require electronic or equivalent efficiency ballasts. Specifically, we recommend minimum ballast efficiency of 90% for 150W to 274W fixtures, and 92% for fixtures of 275W to 500W.

Standards for HPS fixtures are not warranted at this time, but should be reevaluated at a later date.

### 9.2 Proposed Changes to the Title 20 Code Language

[To be prepared later]

## 10 References

- [CEC] California Energy Commission. 2004. *Update of Appliance Efficiency Regulations*. CEC Publication # 400-04-007D; Appendix A, Table 22. July 2004 California Energy Commission.
- \_\_\_\_\_. 2003. *2003 Integrated Energy Policy Report, Appendix I*. October. Available online at [www.energy.ca.gov/energypolicy/documents/index.htm](http://www.energy.ca.gov/energypolicy/documents/index.htm). Sacramento, CA: CEC.
- [DOE] Department of Energy. 2002. *US Lighting Market Characterization. Volume I: National Lighting Inventory and Energy Consumption Estimate*. Washington, D.C.: Navigant Consulting, Inc.
- \_\_\_\_\_. *Draft Framework for Determination Analysis of Energy Conservation Standards for High Intensity Discharge Lamps*. June 30. Washington, DC: U.S. DOE.
- [EIA] Energy Information Administration. 2005. *Commercial Building Energy Consumption Survey 2003*. Washington, DC: U.S. DOE.
- Harding, Tom (ADLT/Venture Lighting). 2008. Personal communication with Jennifer Amann. February.
- Nelson, Tom (Philips Lighting). 2003. Personal communication with Jennifer Thorne. August.
- [PG&E] Pacific Gas & Electric Company. 2000. *2001 Energy Efficiency Programs Application, Attachment K, Workpapers*. San Francisco, CA: PG&E.
- U.S. Census Bureau. 2003. Electric Lighting Fixtures: 2001. *Current Industrial Reports*. MA335L(01)-1(RV). Washington, DC: U.S. Census Bureau.
- \_\_\_\_\_. 2002. Census 2000, Summary File 3 (SF 3). Available online at [www.census.gov/Press-release/www/2002/sumfile3.htm](http://www.census.gov/Press-release/www/2002/sumfile3.htm). Washington, DC: U.S. Census Bureau.