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STANDBY POWER SPECIFICATIONS FOR LIGHTING SYSTEMS

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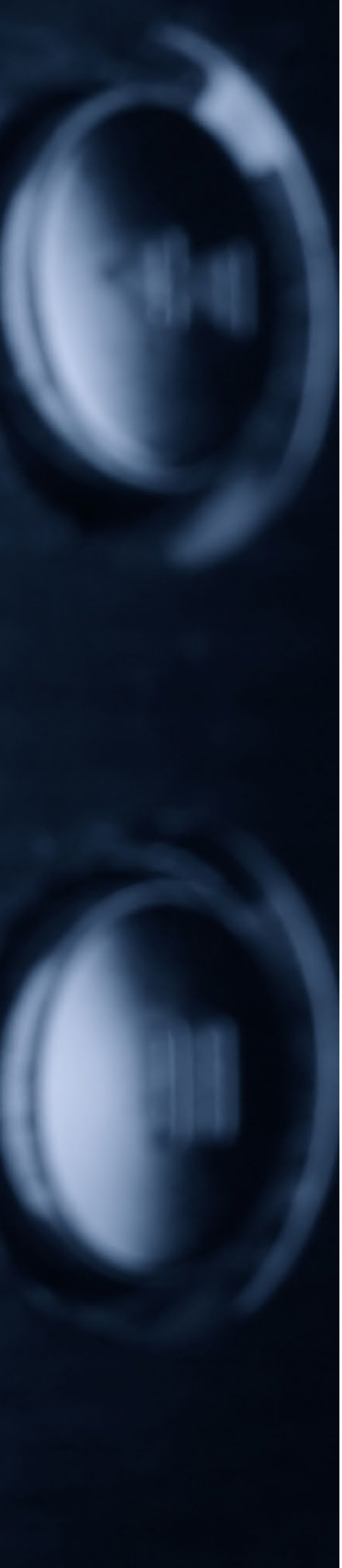

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EXECUTIVE SUMMARY

Until quite recently, standby power and lighting were two incompatible terms. It used to be that every lamp was either in an ON or an OFF binary state, being controlled by the end-user through a wired switch connected to the lighting device. However, that is now history. Today, lighting products are undergoing unprecedented changes in the way they operate and their purpose of operation. Not spared from the "smartification" and interconnection trend that is revolutionizing the world of appliances and devices in the residential and commercial sectors, lighting products are now being endowed with new functions that enhance their uses and operation. However, this enhancement comes at an energy cost primarily related to the standby power. Indeed, lighting products may now consume power even when not providing visible light in order to provide services such as sensing, networking and processing features. Lighting systems may also perform service completely unrelated to lighting, such as temperature sensing or surveillance. As more and more devices are included in what we traditionally call a lighting system, the time will come when it is more appropriate to define such products as a kind of integrated device that provides multiple services including lighting.

In most cases, these added features constitute important improvements that may contribute to diverse energy and non-energy benefits, including but not limited to greater energy savings, improved surveillance, increased lighting controllability, better building management and positive impacts on occupants' health and productivity.

Regardless of the application, one thing that the smart lighting products share is the necessity of having electronic components constantly or periodically drawing power in the background in order to remain alert and be ready to react to any received incoming signals. In absolute terms, this standby power wattage may only represent a small fraction of the lamp's input power. However, when considering the operating hours of a lamp, the total amount of energy wasted in the standby mode may be far from negligible. This is especially true for the residential sector where lamps are turned on for only 2 to 3 hours per day on average compared to the commercial sector, where this value varies between 5 and 8 hours. This standby-power issue is further exacerbated by the increasing amount of intelligent lighting products expected to flood the market in the years to come. Therefore, it was beneficial for the *CSA Technical Committee C419 on the Performance of Lighting Equipment* to look

ABBREVIATIONS

ANSI	American National Standards Institute
CEC	California Energy Commission
DOE	Department of Energy (USA)
EDNA	Electronic Devices and Network Annex
ICT	Information and Communications Technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IoT	Internet of Things
LED	Light-emitting diode
MEPS	Minimum Energy Performance Standard
SSLA	Solid State Lighting Annex
SDO	Standards Development Organization
VLC	Visible Light Communication

further into this matter in order to potentially include lighting standby energy as part of their suite of standards. This task was undertaken to encourage the continued development and deployment of energy efficient lighting products, without however hampering the innovation and developments of this lighting market.

The goal of this research report is to provide an overview of the current status of lighting standby power to the CSA TC C419 by examining a range of current regulations, test methods, guidelines and some other publicly available documents that can provide insights on how this particular topic is addressed around the world. To a larger extent, this report is intended to support and help the ongoing efforts and discussions related to the challenge that smart lighting products pose to lighting energy efficiency due to the standby power consumption of their increasing in-built functions.

This report presents five standby power definitions and three minimum energy performance standards (MEPS) approaches aimed at better clarifying and determining the scope of what should be included in the lighting standby power definition.

More specifically, the three suggested MEPS approaches are directly inspired by existing standards, one of which is currently being developed by the American National Standards Institute (ANSI). These three approaches differ not only in their degree of complexity, but also in the levels of importance they each assign to the various functions found in lighting products. For instance, the first MEPS follows a total standby power requirement approach which involves assigning a single base power allowance to all the energy consumed by the lighting system in the standby mode regardless of the functions offered by the system, whereas the other two rely on a fully functional and a semi-functional approach which assigns a power allowance according to the specific function being used in the standby mode.

Each of these three MEPS approaches has its advantages and disadvantages, which are worth considering.

INTRODUCTION

Lighting technologies (lamps, ballasts, and fixtures) are constantly evolving and lighting system features are rapidly increasing in number, providing a variety of services that go beyond lighting management such as network-connected tracking. The power requirements of these systems and features are the subject of much research, but the field requires further scoping. This increase in available features, and the likely corresponding increase in power consumption, occurs at a time when the power consumption of lighting technologies have been constantly decreasing over the last few years. This raises the need to better understand lighting standby power and the efficiency of the services provided via the lighting system.

More specifically, lighting equipment now relies on motion sensors, external power supplies, photocells, as well as remote controls, with some lamps that can now also be used as a relay to transfer information such as Wi-Fi signals. These new features inevitably increase the power demands associated to lighting technologies. Therefore, as primary loads decrease with advances in solid state lighting technology, the savings achieved by technological advances lessen, hence the need to better scope and standardize standby power.

Problematics

The lack of consensus on the definition of what constitutes lighting standby power and the lack of both power consumption and technical specifications of marketed lighting equipment all prevent an adequate assessment of this situation and the establishment of the best standards for standby power. Furthermore, with the proliferation of smart lamps, it is unclear which of these lamps' various features are to be included or not in the performance criteria of existing lighting standby power standards. Literature review results reveal a wide range of standby power specifications among similar features. There is therefore a need today for a clear definition and standard addressing the standby power of lighting devices which will help clarify the scope of such requirements.

Objective

In order to address the above-mentioned issues, this report aims to:

- Provide a definition of lighting standby power;
- Recommend a test procedure;
- Propose minimum energy performance standards (MEPS) that mainly target low performance features, but do not limit eventual new features and do not tamper with the industry competitiveness.

Methodology

The methodology consists of conducting a comprehensive literature review of publicly available information:

- Standards and guidelines;
- Test methodologies;
- Products specifications;
- White papers.

The scope of this work review was focused on the residential and commercial sectors with specific emphasis on LED products since these are the most likely to be affected by standby power standards.

1 CONTEXT

While the emergence of smart lamps and smart lighting devices[1] has enabled a great number of new opportunities, these innovations come at an energy cost. Lighting products which have for a long time been exempt from the power burden inherent to the standby mode are now encountering the same dilemma that many other appliances underwent before them. Although in many cases, the added features found in smart lamps contribute to increasing controllability and hence serve to optimize their energy usage, the power needed to provide these services might sometimes work against the current efforts to increase light efficacy (Pauli, 2014).

1.1 Features

With the advent of smart lighting systems and the Internet of Things (IoT), the lighting market is undergoing an unprecedented transformation. Until now, the evolution of this market has been mostly vertical, with an improvement of lamp efficacy through the years in accordance with Haitz's law[2] (Haitz's law, 2007). While this is still true and is expected to remain so for the next years and probably decades, lighting manufacturers are starting to shift their focus toward horizontal growth opportunities. Not only is the efficacy of lamps improving, but the features they offer are also becoming more diverse, encompassing more services than simply providing light.

These additional features, commonly referred to as smart features, are added progressively to new lighting products entering the market. A recent report from the International Energy Agency (IEA) Solid State Lighting Annex (SSLA) breaks down the smart lighting market into four categories of service (Kofod, 2016):

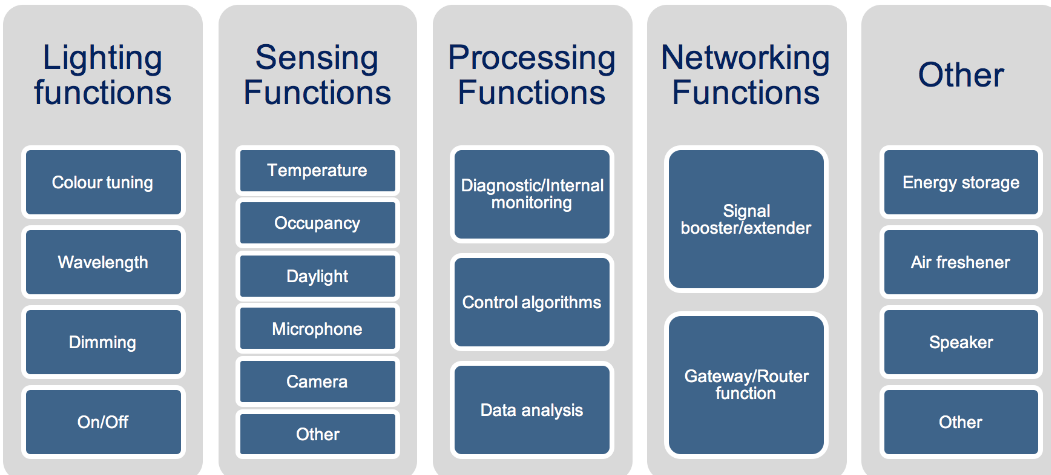
- **Domestic** – Smart lamps in this category offer features that are domestic user focused and typically controlled by the end user through a smartphone app via a network protocol (Wi-Fi, Bluetooth, ZigBee, or 6LoWPAN). Such features include wireless colour tuning and dimming, integrated audio speakers, or programmable colour and brightness-changing capabilities;
- **Data delivery** – This category of smart lamps are connectivity-enabling lamps that rely on their ubiquity to provide extended wireless range, collect data, or activate certain services based on individuals' movements in a given area (customer location monitoring in a shop for instance);
- **Professional** – The IEA defines lamps in this category as having features dedicated to prolonging the life of the lamp through active thermal control, drive current regulation, and constant flux output maintenance over time;
- **Economizing** – This group of smart lamps is characterized by features that optimize lamp operation and generate energy savings. These lamps typically have sensors that allow them to turn off or dim bulbs as a function of the environment in which they are located.

Disclaimer: In this document, the terms "lighting products" and "lighting systems" and "smart lamps" are used interchangeably and refer to lighting devices which are meant for residential and commercial applications. For the sake of simplicity, some illustrations may also appear more suitable to one sector than another, but they should all be understood as being representative of all types of LED products.

[1] These two terms are herein used interchangeably to refer to lamps and luminaires having connected functionality and enhanced features not present in traditional lamps and luminaires.

[2] Every decade the cost per lumen falls by a factor of 10 and the amount of light generated per LED package increases by a factor of 20.

FIGURE 1: CATEGORIZATION OF SMART LIGHTING SYSTEM FEATURES



While this taxonomy is useful to categorize the dedicated applications of smart lighting products currently offered on the market, the boundaries between these four categories are expected to blur, as explained in the aforementioned IEA SSLA report. To classify the different features found or expected to be found in smart lamps, an alternative categorization is proposed in this report and summarized in Figure 1. This categorization is not exhaustive, but it illustrates the variety of different features that constitutes the challenges pertaining to smart lamps very unique.

1.1.1 Lighting function

The features in the control functions category are dedicated, as the name suggests, to the control of lamp features. These features are typically remotely controlled by the end user using either a smartphone application or specific remote controller interface. Sometimes these lamps offer the possibility of being turned on/off according to a preprogramed schedule. Concretely, all these control options contain an electronic receiver module that converts an input signal into a useful application.

1.1.2 Sensing/Imaging Functions

Smart lighting products with integrated sensing and imaging functions either offer users the option of gaining increased awareness of their own environment, or enable the device to be integrated to a building automation system (BAS). These features can directly apply to lamp primary functions (lighting) for control or savings purposes (occupancy, motion, and daylight sensors), or to secondary functions such as closed-circuit television, particularly video surveillance, or location monitoring. Although it is not yet the case, some features originally dedicated to lamp primary functions are likely to be also used for secondary applications in the near future. An example of this would be using lamp integrated occupancy sensors to control not only light output, but also the HVAC systems of buildings.

1.1.3 Processing Functions

Processing functions designate additional features that enable lighting products to perform calculations and operations that run internal commands. These commands serve to monitor, control, and record lamp operation or even process information received from the user or from other devices. These functions will become more and more common as smart lamps play an increasing role in building energy management systems.

1.1.4 Networking Functions

This category of functions harnesses the ubiquity of lighting products to transform them into an extension of, booster for, or provider of wireless communication signals. The most common examples are smart lamps with a built-in Wi-Fi repeater used to improve signal coverage. In these cases, the lamp acts only as a signal amplifier. In other cases, lamps that form part of a wireless mesh network (ZigBee, Z-wave, or 6LoWPAN) have a built-in bridge function to convert the signal from one communication protocol to another (e.g. signal sent from a smartphone app onto a Wi-Fi network to a ZigBee lamp network). While most lamps using the ZigBee protocol still rely on an external hub to enable communication between the user interface and smart lamps, new lamp models now come with this built-in feature.

1.1.5 Other Functions

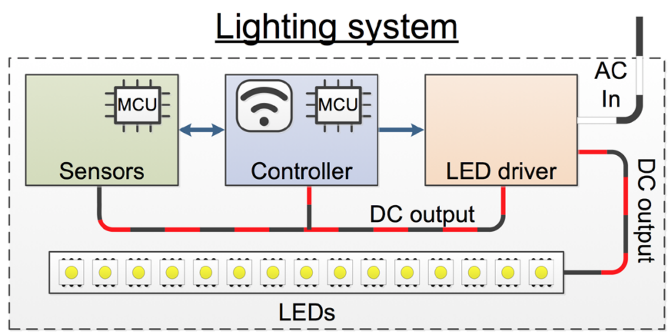
Other functions include features that do not fall into the previous categories such as integrated audio speakers, air fresheners, and energy storage services.

A clear understanding of all the features offered by smart lighting products is essential to understanding how this market is evolving and to what extent these products might be utilized by end users. In light of the different features summarized above, it is apparent that smart lamps should no longer be construed as traditional lamps given that they provide enhanced services and use power in ways that traditional lamps cannot. This applies especially to lighting products that incorporate functions for secondary applications that do not directly relate to lighting. These secondary applications could eventually become so pervasive that it would become a misnomer to refer to these devices as smart lamps because their lighting function would only be one among many applications. This must be kept in mind to orientate discussions around clearly defining lighting standby power since the existing definitions, standards, and test method often fail to coalesce all the nuances and additional features offered by smart lamps, as is further explained in the following sections.

1.2 Lighting System Configuration

In order to clearly understand the exact component of the lighting system that draws power in the standby mode, the following schematic diagram illustrates a typical LED lighting system configuration. As illustrated below, such systems mainly comprise 4 components: the LED strips, the LED driver, the controller and the sensors.

FIGURE 2: SCHEMATIC DIAGRAM OF A TYPICAL LED LIGHTING SYSTEM[3]

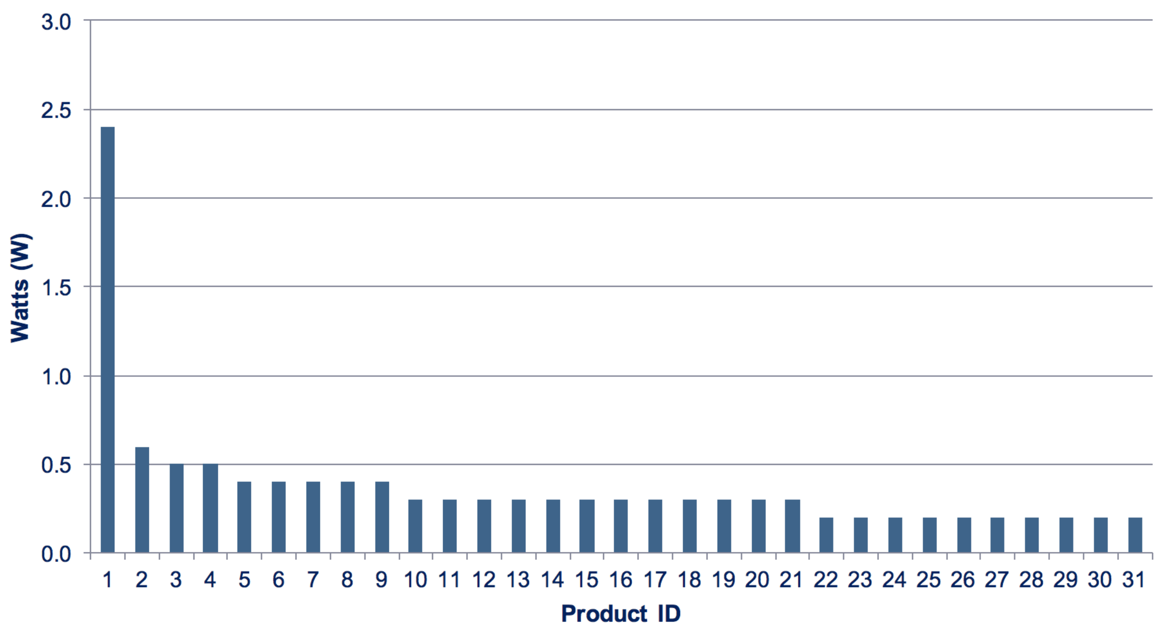


The LED strips are the equivalent of an assembly of light bulbs connected together to emit visible light when the system is turned on. These components therefore do not draw power when the lighting system is in the standby mode and shall not be covered by any standby power specifications. On the other hand, the other three system components are those that should be mainly covered by specifications in relation to the so-called vampire power.

The LED driver serves as the power supply for the system: it converts incoming AC power to the proper DC voltage and regulates the current flowing through the LED and any other system-related devices during the operation. In the standby mode, the LED driver therefore serves as a power supply for the controller and the sensors only; the LED driver continues to draw power even when the LED strips are not emitting light.

[3] The lighting system here should be understood as a general term, which also includes luminaires and other lighting products intended for both residential and commercial applications.

FIGURE 3: MEASURED STANDBY POWER OF 31 DOMESTIC SMART LAMPS (DOE, 2016)



To perform some of its functions, the driver takes instructions from the controller, which acts as the brain of the system. The control instructions sent from the controller may include voltage set points and other signals related to dimming, colour temperature and on/off sequences. To produce these control signals, the controller is equipped with one or more micro-controller units (MCUs), which perform all the necessary computing and processing functions to analyze and handle the data generated by the sensors or the signals received from the networking interface (the radio module). In smart lighting systems, the various MCUs embedded in the controller handle not only lighting applications, but also non-lighting applications, which may include space management, air quality, surveillance and indoor positioning, to name a few. Therefore, this component is the biggest concern for the lighting standby load because it is necessary for it to remain active, or at least awake, all the time in order to maintain the routing function and respond to incoming signals.

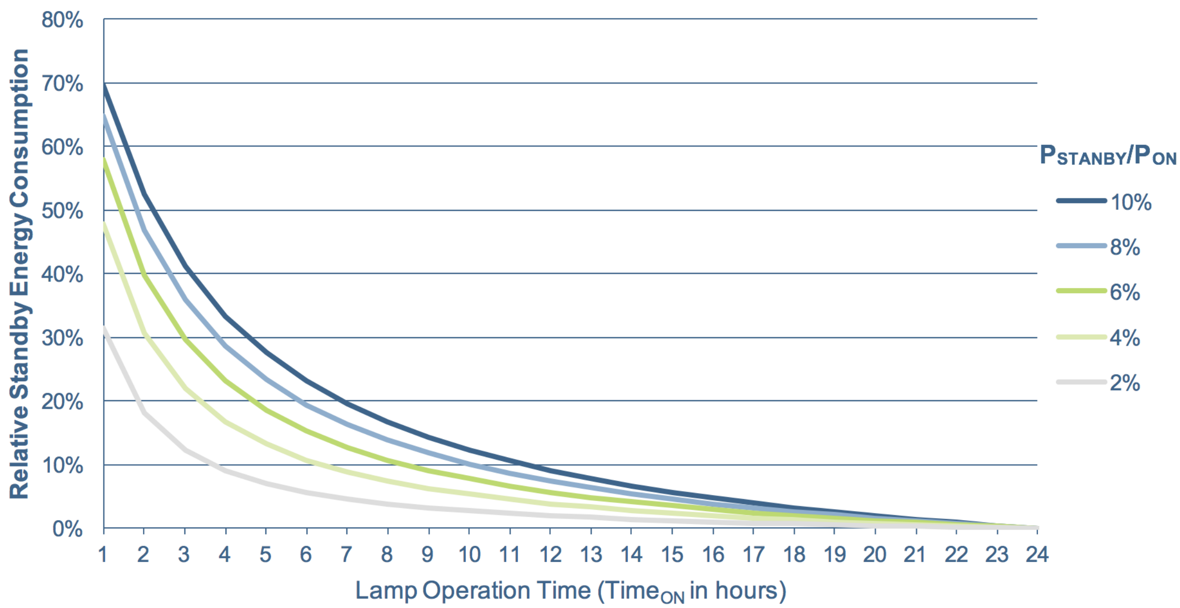
Another kind of component commonly found in lighting systems is the sensor, which may also be comprised of a dedicated embedded MCU. Since these devices are used to react to input signals from the surrounding environment, their operation needs to draw power all the time, which may in some cases account for quite a big share of the lighting system's standby power.

The use of these four kinds of components discussed here are not restricted to any specific type of system, and may therefore be found embedded in a single product in some cases (i.e., integrated LED fixtures) or scatted in several devices which collectively form part of a broader lighting system (e.g., LED luminaires with wall-mounted sensors).

1.3 Energy Use

A few studies have been undertaken to determine the standby power needed by smart lamps to remain connected to wireless networks. In fact, the most novel and enabling characteristic of smart lamps is that they can communicate wirelessly. Thus, these lamps consume energy even when not providing lighting because they await instructions in standby mode from a control device. Measurement tests performed by the IEA (Kofod, 2016) have revealed significant variations in smart lamp standby power consumption, ranging from 0.15 to 2.70 W. Based on measurements performed on readily available

FIGURE 4: RELATIVE STANDBY ENERGY CONSUMPTION FOR P_{STANBY}/P_{ON}



domestic smart lamps offered on the North American market, similar results were demonstrated by the U.S. Department of Energy (DOE), as illustrated in Figure 3 below (0.2 to 2.4 W with an average of 0.4 W), and by the National Research Council Canada (0.17 to 2.7 W with an average of 0.49 W) (Knudsen, Arsenault, & Meng Qi Zhang, 2017). The DOE tests illustrated in Figure 3 were performed on lamps having only their networking functions turned on as per the test method further described in Section 2.2.2.

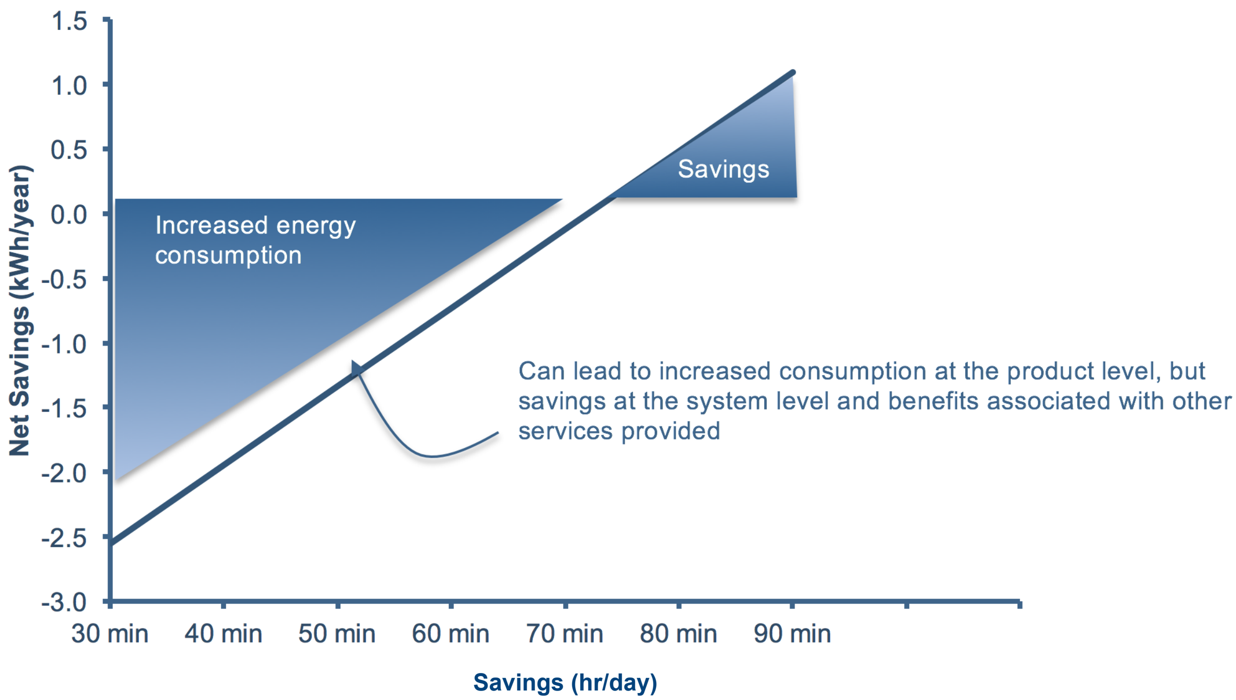
The observed disparity in standby power consumptions is mainly due to the varying wireless communication architecture inherent in smart lamps. Lamps utilizing external gateways (i.e. hubs) to connect to different lamp link protocols (e.g. ZigBee, Z-wave, 6LoWPAN) are generally the least power intensive, followed by lamps using dedicated remote controls and Bluetooth technology. Products that rely exclusively on Wi-Fi signals to communicate with user interfaces tend to use the most standby power.[4] It should, however, be mentioned that the above values do not include the power consumption of external hubs, when applicable. These gateway devices use power continuously to convert communication signals between control devices and connected lamps. Accounting for this hub power consumption would slightly increase the overall standby power of lamps with this type of architecture, although test results reveal that this additional consumption is invariable regardless of the number of hub-connected lamps. The IEA findings indicate that gateway power consumption averages 1.6 W, while National Research Council Canada (NRC) results indicate average power usage of 1.46 W.

Converting these standby power values into energy consumption reveals that, depending on the technology and its usage profile, more energy may be consumed in standby mode than when producing light as illustrated in Figure 4.

Figure 4 represents relative standby energy consumption as a function of lamps' operating time for different PSTANDBY/PON modes. The relative standby energy consumption corresponds

[4] This report is not intended for detailed discussion on varying lamp communication architecture, but readers interested in the topic are encouraged to consult the IEA Solid State Lighting Annex: Task 7 Report.

FIGURE 5: NET ENERGY SAVINGS AS A FUNCTION OF OPERATION TIME REDUCTIONS FOR A 10 W LAMP WITH STANDBY POWER OF 0.5 W



to the ratio of the energy consumed in standby mode to lamp total daily consumption. This figure illustrates two things:

- The lesser the lamp operation time (in "ON" mode), the greater the standby power contribution to total energy consumption;
- The smaller the lamp wattage, the higher the potential impact of standby power mode on total energy consumption.

These two obvious conclusions are much more relevant to the residential sector, rather than the commercial sector where lamp usage time and power are usually higher. Irrespective of the savings potential that smart features offer, this therefore means that the residential sector is more at risk of experiencing increases in lighting energy consumption pursuant to the uptake of smart lighting devices.

1.4 Energy Savings

The term intelligence efficiency was coined to designate the additional energy savings made possible through the use of information and communication technologies, including smart appliances (Elliott, Molina, & Trombley, 2012). For smart lamps intended explicitly to be used for energy efficiency gains, these savings build on enhanced control features which can help optimize operations to better suit end users' needs. For instance, some smart lamps automatically vary light intensity to maintain constant illumination and increase the benefits of daylight harvesting, while others rely on sensors or detectors to turn on and off. These examples of intelligence efficiency thus translate into overall reduced lamp operation hours, thereby leading to energy savings. In many cases, however, these savings may not be completely justified. To illustrate this, Figure 5 presents the net savings as a function of the lighting operation time reduction for a 10 W lamp with standby power of 0.5 W.

As illustrated in the figure, the lighting operation time must be reduced by more than 70 minutes to generate positive net savings. For the residential sector, knowing that typical lamp usage-time varies between three to four hours per day, a reduction of 70 minutes would thus be harder to attain. In the commercial sector on the other hand, since lighting systems generally operate during longer periods of time of approximately five to eight hours per day, energy savings are more likely to occur for this type of operation conditions even when accounting for the additional standby power use of the luminaire.

It is, however, important to put things into perspective when it comes to energy savings generated by smart lighting systems since additional standby power consumption sometimes generates more savings and provides other services than what would have been otherwise possible. As mentioned previously, this is especially true for smart lighting systems intended for use in the commercial sector, which are more prone to be utilized in interaction with other building equipment to optimize the overall savings of the environmental design. In this case, the energy consumption of the equipment controlled may be much larger than the lighting system. This is not to say that such lighting device should be able to use excessive standby power to perform such task but the complete context of operation needs to be understood.

1.5 Non-Energy Benefits and Smart Lighting Applications

1.5.1 Non-Energy Benefits

Despite the concerns related to standby energy losses, this "phantom load" may sometimes enhance other aspects of the end-user's experience, which are worth considering. These aspects of the end-user's experience may at least include maintaining a comfortable ambient lighting level conducive to staff productivity and well-being, monitoring the lamps to ensure their ongoing efficient operation and enabling the optimization of scheduled maintenance. For more complex systems, the lighting products' networking capabilities may perform other vital ongoing tasks, like maintaining indoor air quality, monitoring environmental parameters or other safety-related functions (Harrington & Nordman, 2010). Some other functions integrated into smart lighting devices also contribute in their own ways to enhancing the end-user's experience, although their potential benefits may at first appear less tangible, especially for household applications. For instance, this is the case of integrated air fresheners and audio speakers, which only serve convenience purposes.

The health benefits enabled by smart lamps are also an aspect of intelligent lighting systems that has been receiving much attention lately. Referred to as human-centric lighting (HCL), this novel segment of the lighting market relies on smart lamps' capability to dim and change colour temperatures throughout the day to mimic the Earth's natural lighting cycle. This feature has been proven to positively affect the human body's circadian rhythm, which in turn helps enhance humans' well-being, work productivity, vision and awareness (Walerczyk, 2012). This, therefore, implies that there may be more to smart lamps products than only those benefits previously realized. Together with smart lighting, HCL represents a new set of paradigms about lighting, which brings its own share of advantages and challenges. Inevitably, if this HCL trend is to gain in popularity, it should also be expected to significantly add to standby energy waste.

1.5.2 Smart Lighting Applications

The imbrication of networking and lighting applications is becoming increasingly fusional with the development of new technologies, enabling new applications which would never had been thought possible in the past. One such example is the Li-Fi technology, which relies on the modulation of light intensity to deliver high-speed communication in a manner similar to Wi-Fi. This form of visible light communication (VLC) is particularly promising for commercial applications, where the ubiquity of illumination devices combined with the high rate of data transmission achieved by this technology could unlock a myriad of possibilities. Li-Fi lighting is already being used in some retail stores and museums around the world as a positioning system to provide location-based information to visitors to enable way-finding (Oledcomm, 2017). For retailers, VLC beacons can also be used to deliver targeted information in order to increase customer loyalty and sales (Dilouie, 2014). The increasing use of this technology is a perfect illustration of a case where the use of lighting devices goes way beyond simply providing illumination, although the emitted light serves a dual purpose in this case.

Power over Ethernet (PoE) technology is yet another example of such entanglement between lighting and networking applications. By using a simple Ethernet cable to deliver both data connection and electric power to LED light fixtures, this technology provides the advanced benefits of networking the lights using the Ethernet local area network (LAN). In this way, the lighting system becomes part of a broader IT network, thus extending its reach beyond the vicinity of the user to other building elements and services. Even if wired, as opposed to their wireless counterparts, these PoE-connected lighting devices will consume power even when not providing light to send or respond to network signals.

The development of all these state-of-the-art technologies are part of a larger vision framework, which seeks to seamlessly integrate information and communication technology (ICT) and IoT technology at the heart of modern buildings and urban ecosystems. In the context of smart cities, since public lighting constitutes a kind of infrastructure which is well established and omnipresent, it will play a central role in this smartification trend. New technology rollout is already underway with smart street-lighting devices that are capable to serve as sensor networks for collecting and communicating data about transport, the environment, city management, energy, safety and security service applications (Philips Lighting, 2017). As a matter of fact, since the development of these smart street-lighting applications is happening ahead of other smart lighting applications for the residential sector, the analysis of this standby power issue and the solutions proposed for this specific commercial-market segment could be used to tackle the same challenges to be faced in every smart lighting application.

The non-energy benefits offered by smart lighting applications are not the primary concern of this document; however, these benefits may be substantial in some cases. The main point is that the context related to and the services provided by smart lighting products need to be considered if the standby mode power consumption is to be properly regulated and implemented.

1.6 Long-Term Trend

1.6.1 Market Projection

The emergence of smart lighting products on the market has been very sudden and rapid thanks to a conjunction of two market developments, first LED lighting and second wireless communication networks which allow end users to centralize and send commands from a single user interface (Page, Beletich, Jeffcott, & Kummert, 2015). This smartification, known today as the Internet of Things (IoT), is not exclusive to lighting systems but applies to a large number of appliances and devices in the residential and commercial sector including security cameras, thermostats, audio speakers, televisions, plugs, refrigerators, and much more. Lighting products, however, occupy a prominent place among such technologies because of their ubiquity which renders them perfect candidates to act as the backbone of IoT networks.

According to the IEA (Kyburz, 2016), the global smart lighting market for the residential sector is expected to grow from eight million in 2015 to 335 million units by 2025, with a compound annual growth rate of 70% until 2020 and 23% between 2020 and 2025. On the basis of this forecasted proliferation, the IEA also projects that smart lamp standby energy consumption will increase from less than 0.1 TWh in 2015 to 3.3 TWh in 2025. The standby power values used to calculate this projection is 1 W for smart bulbs and 1.6 W for gateways.

TABLE 1: IEA PROJECTED GLOBAL IMPACT OF SMART LAMPS FROM 2015 TO 2025

SMART LAMPS	**NUMBER ON THE MARKET** (MILLIONS)	**STANDBY POWER CONSUMPTION** (TWh)
2015	8	0.1
2025	325	3.3

> "A trend is starting to emerge, particularly in the commercial sector, wherein smart lighting products are used in synergy to operate and control other building systems such as heating, ventilation, and air conditioning (HVAC)."

1.6.2 Smart Lighting Systems

A trend is starting to emerge, particularly in the commercial sector, wherein smart lighting products are used in synergy to operate and control other building systems such as heating, ventilation, and air conditioning (HVAC). In these cases, lamps or luminaires should no longer be regarded as standalone products, but should rather be considered as integral components of a wider building ecosystem. In terms of standby power usage, this therefore further complicates how specifications on this parameter are set since higher standby power usage may sometimes be offset by other benefits. While these benefits are often referred to as energy savings, other advantages enabled by smart features are being praised, such as increased comfort, security, health, and productivity (Walerczyk, 2012). Therefore, it would be easy to paint an inaccurate picture of the importance of the role standby power actually plays within the context of a larger energy system.

2 LITERATURE REVIEW

2.1 Existing Standards and Guidelines

While several standards and regulations related to appliance standby power have been enacted by various countries and jurisdictions around the world, very few are specific to lighting products. Pursuant to a comprehensive literature review, this section presents a compilation of existing regional and international standards and guidelines on lighting standby power. These documents provide useful insight on the approaches that have been used to address the issue of lighting standby power.

2.1.1 Ecodesign Requirements for Directional Lamps, Light-Emitting Diode Lamps and Related Equipment, Commission Regulation (EU) No 1194/2012

The Commission Regulation (EU) No 1194/2012 implementing the 2009/125/EC Directive of the European Parliament (Official Journal of the European Union, 2012) establishes minimum energy performance standards (MEPS) for directional lamps, light-emitting diode lamps, and related equipment. This is the only European regulation that addresses the standby power consumption of lighting products, albeit with emphasis on the standby power of lamp control gears rather than the standby power of lamps itself. The regulation defines the concepts of standby mode, lamp control gear, and control devices as follows:

- **Standby mode:** "…a mode of lamp control gear where the lamps are switched off with the help of a control signal under normal operating conditions. It applies to lamp control gear with a built-in switching function and permanently connected to the supply voltage when in normal use."
- **Lamp control gear:** "…a device located between the electrical supply and one or more lamps, which provides a functionality related to the operation of the lamp(s), such as transforming the supply voltage, limiting the current of the lamp(s) to the required value, providing starting voltage and preheating current, preventing cold starting, correcting the power factor or reducing radio interference. The device may be designed to connect to other lamp control gear to perform these functions. The term does not include control devices."
- **Control device:** "…an electronic or mechanical device controlling or monitoring the luminous flux of the lamp by other means than power conversion, such as timer switches, occupancy sensors, light sensors and daylight regulation devices. In addition, phase cut dimmers shall also be considered as control devices."

TABLE 2: EUROPEAN STANDBY AND NO-LOAD POWER MEPS FOR LAMP CONTROL GEARS

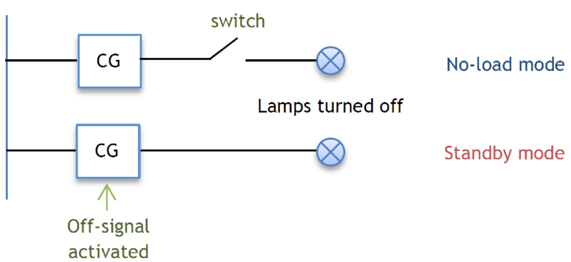
DATE	NO-LOAD POWER (W)		MAXIMUM STANDBY POWER (W)
	OUTPUT POWER P ≤ 250 W	OUTPUT POWER P > 250 W	
September 2014	1 W	1 W x P/250	–
September 2016	0.5 W	0.5 W x P/250	0.5 W

The regulation also defines the no-load mode concept as follows to make the distinction with the standby mode:

- **No-load mode: "**...the condition of a lamp control gear where it is connected to the supply voltage and where its output is disconnected in normal operation from all the primary loads by the switch intended for this purpose (a faulty or missing lamp, or a disconnection of the load by a safety switch is not normal operation)."

The difference between the standby and no-load (NL) modes is illustrated in Figure 6.

FIGURE 6: SCHEME ILLUSTRATING THE DIFFERENCE BETWEEN THE NO-LOAD AND STANDBY MODES (EUROPEAN COMMISSION, 2015)



Based on these definitions, the standby and NL power MEPS for the lamp control gear were put into force in two stages, September 2014 for the first stage and September 2016 for the second stage, as summarized in Table 2.

These requirements only apply to lamp control gears intended for use between the mains and the switch to turn lamps on/off. If a switch is located between the electrical supply and the control gear, the latter is not required to meet this standard. Moreover according to these definitions, if the control gear has additional built-in features which are more akin to a control device such as sensors, timer switches, or dimmers, such equipment does not have to comply with the above requirements. There is, however, no specific reference to the inclusion or exclusion of network connections. These last two points are very relevant for smart lamp standby power consumption because they demonstrate that the propensity of this market that is rapidly evolving and becoming prominent was underestimated when this standard was made effective in 2012. As mentioned in the previous sections, the standby power of connected smart lamps has a potential for significant additional energy consumption that might undermine attempts to save energy. The extension of the existing standby power requirements to address integrated lighting products with smart features has been pointed out in a *Preparatory Study on Light Sources* prepared for the European Commission in 2015 (VITO, 2015), but to date the ecodesign requirements have not been amended to account for these issues.

2.1.2 ENERGY STAR® Program Requirements for Luminaires V2.0

This voluntary product specification for ENERGY STAR certified luminaires is limited to residential lighting products and to luminaires with a total input power of 250 watts to be connected directly to the electric power grid (ENERGY STAR, 2015). This specification excludes LED lamps intended to replace linear fluorescent, pin-based compact fluorescent, and high-intensity discharge lamps.

Contrary to the European Commission regulation, the standby mode definition and standby power requirements put forward

TABLE 3: ENERGY STAR LUMINAIRE MINIMUM STANDBY POWER REQUIREMENTS

SCOPE		MAXIMUM STANDBY POWER
Luminaires with integral motion sensors, occupancy sensors, photosensors, or connected functionality		0.5 W
Luminaires with energy-saving features: i.e. integral motion sensors, occupancy sensors, photosensors and connected functionality		1 W
Power supplies connected to multiple luminaires		1.5 W
External power supplies employed to power luminaires	0 to < 50 W	AC-DC: ≤ 0.3 W AC-AC: ≤ 0.5 W
	≥ 50 W to ≤ 250 W	≤ 0.5 W

in this specification are much more inclusive of smart lamps functionalities. The concepts of connected luminaire and standby mode are defined as follows:

- **Connected Luminaire:** "A luminaire or retrofit which includes elements or instructions (hardware and software or firmware) required to enable communication in response to consumer-authorized energy or performance-related commands and complies with all requirements for connected in the specification. These elements may be resident inside or outside of the base luminaire or retrofit."
- **Standby Mode:** "The condition in which energy-using product is connected to a main power source; and offers one or more of the following user-oriented or protective functions: to facilitate the activation or deactivation of other functions (including active mode) by remote switch (including remote control), internal sensor, or timer; or continuous functions, including information or status displays (including clocks) or sensor-based functions."

Taking into account the internal sensing and networking potential capabilities of available smart lighting fixtures, the requirements for this voluntary labelling program is divided into different levels to account for increased standby power for integrated features such as sensors, connected functionality, and power supply as summarized in Table 3. The specific mention of luminaire-connected functionality was added in the final version of this specification to enable the combined benefits of energy-saving features and connected functionality (U.S. EPA, 2015).

2.1.3 ENERGY STAR Program Requirements Product Specification for Lamps V2.0

Similar to the program requirements for luminaires, this product specification for ENERGY STAR certified lamps addresses the standby power of lamps intended to replace incandescent lamps (ENERGY STAR, 2016). It is, however, noteworthy that the following products are excluded from the scope of this specification:

- "Lamps incorporating power-consuming features in the on or off state which are not related to control of illumination (e.g., audio functions, air fresheners, or cameras)."
- "Lamp technologies lacking applicable industry standardized methods of measurement."

This demonstrates that standards development organizations (SDOs) and incentive program administrators are aware of the current evolution of the market, but that the lack of consensus on the way to address the addition of these new functionalities has forced them to bypass the problem for the moment. The maximum ENERGY STAR standby power allowance for lamps with integral controls is stated in Table 4.

TABLE 4: ENERGY STAR LAMPS MINIMUM STANDBY POWER REQUIREMENTS

SCOPE	MAXIMUM STANDBY POWER
Lamps with integral controls (e.g. motion sensors, photosensors, wireless control, standby mode, or connected functionality)	0.5 W

This specification also includes a special mention referring to the standby power of external equipment required for lamp connectivity (e.g. gateways, hubs, and network controllers, excluding equipment typically found in the home such as Wi-Fi routers). Although it does not set a minimum standard for such equipment, it does require the lamp manufacturer to report standby power.

2.1.4 California Energy Commission: 2016 Appliance Efficiency Regulations

The current *Appliance Efficiency Regulations* of the California Energy Commission (CEC) includes mandatory standards that apply to both federally regulated and non-federally regulated appliances (Baez, Fischel, Chrisman, & Babula, 2017). Two lighting standby power requirements are formulated in this document, one with respect to state-regulated LED lamps and another for deep-dimming fluorescent ballasts. Both are defined as follows:

- **State-Regulated Light-Emitting Diode (LED) Lamp:** "Means a lamp capable of producing light with Duv between -0.012 and 0.012, and that has an E23, E17, E26, or GU-24 base, including LED lamps that are designed for retrofit within existing recessed housings that contain one of the preceding bases. State-regulated LED lamp does not include a lamp with a brightness of more than 2,600 lumens or a lamp that cannot produce light with a correlated colour temperature between 2200 K and 7000 K."

- **Deep-Dimming Fluorescent Lamp Ballast:** "Means a fluorescent ballast that is capable of operating lamps in dimmed operating modes at any number of levels at or below 50 percent of full output. The term shall only apply to lamp ballasts designed to operate one, two, three, or four T5 or T8 four-foot linear or U-shape fluorescent lamps."

The standby mode definition used by the CEC is the same as the ENERGY STAR definition which refers to the definition established by the U.S. Department of Energy (DOE). The standby power MEPS for these products are summarized in the following table.

TABLE 5: CALIFORNIA CODE OF REGULATIONS STANDBY POWER MEPS

EFFECTIVE DATE	SCOPE	MAXIMUM STANDBY POWER
July 2016	Deep-dimming fluorescent lamp ballast	1 W
July 2019	State-regulated LED lamp	0.2 W

At only 0.2 W, this Californian MEPS for the standby power of LED lamps is the most aggressive to date.

2.1.5 Voluntary California Quality Light-Emitting Diode (LED) Lamp Specification 3.0

This voluntary program developed by the California Energy Commission (CEC) aims to both promote lighting products that perform better than current mandatory requirements and prepare the market for the upcoming mandatory efficiency regulations (Pasha, Strait, & Saxton, 2016). The specification is intended for LED lamps commonly used in residential applications. The maximum standby power requirement put forward in this document, as shown in Table 6, is specific to connected LED lamps which are defined as follows:

- **Connected LED Lamp:** "An LED lamp capable of changing its lumen output or spectral power distribution in response to an external control signal other than a change in root mean square (RMS) AC supply voltage or a 0-10-volt DC control signal. Connected LED lamps include those that can be controlled wirelessly and through power line carrier digital communication."

TABLE 6: VOLUNTARY CALIFORNIA QUALITY LED LAMPS STANDBY POWER REQUIREMENTS

EFFECTIVE DATE	SCOPE	MAXIMUM STANDBY POWER
January 2018	Connected LED lamps	0.2 W

2.1.6 IEA SSLA Performance Tiers

The IEA released in November 2016, through its Solid State Lighting Annex (SSLA), a set of quality and performance tiers to address product attributes such as colour rendering, lifetime, and efficacy for different types of LED lamps and luminaires. The goal of this initiative is to provide policymakers and program administrators with a basis on which to structure voluntary and mandatory programs which are harmonized with other programs around the world.

Among the different lighting metrics addressed in these performance tiers, maximum standby power requirements are formulated for non-directional lamps, directional lamps, and downlight luminaires, as shown in Table 7. The varying requirements for the three tiers correspond to different performance levels:

- **Tier 1** represents the minimum acceptable performance level;
- **Tier 2** represents required performance levels by established quality programs; and
- **Tier 3** is intended for use by premium labelling programs on products that offer the highest commercially available performance levels.

TABLE 7: IEA SSLA STANDBY POWER PERFORMANCE TIERS

SCOPE	MAXIMUM STANDBY POWER		
	TIER 1	TIER 2	TIER 3
Non-Directional Lamps Directional Lamps Downlight Luminaires	0.2 W	0.3 W	0.2 W

TABLE 8: STANDARD POWER STANDARDS OVERVIEW

SCOPE	TYPE	SCOPE	ENACTMENT DATE	MAXIMUM STANDBY POWER (W)
Europe, Ecodesign Requirements (EU) No 1194/2012	MEPS	Lamp control gear	September 2016	0.5
California Energy Commission: Appliance Efficiency Regulations	MEPS	LED lamps	July 2019	0.2
Voluntary California Quality LED Specification 3.0	Voluntary labelling	Connected LED lamps	January 2018	0.2
ENERGY STAR, Luminaires Requirements V2.0 Final	Voluntary labelling	Luminaires less than 250 W	June 2016	• No sensor or control: 0 • With sensor or network: 0.5 • With energy-saving features (sensors and networks): 1.0 • Power supplies to multiple luminaires: 1.5 • External power supplies: must meet level V of International Efficiency Marking Protocol
ENERGY STAR, Lamps Requirements V2.0	Voluntary labelling	Lamps with integrated ballasts or drivers	January 2017	• No integral controls: 0 • With integral controls: 0.5
IEA SSLA Performance Tiers	Guideline	Non-directional, directional lamps, downlight luminaires	N/A	• Tier 1: 0.5 • Tier 2: 0.3 • Tier 3: 0.2

The proposed requirements for maximum standby power are applied to smart lamps and luminaires with activated wireless illumination control, but with all other features enabling lighting control (e.g. movement sensor) or functions (e.g. speaker) being deactivated. This corresponds to the network standby mode which only comprises those functions required for lamps to be controlled wirelessly.

2.1.7 Summary

The lighting standby power standards presented above are summarized in Table 8. Whether these requirements are mandatory or voluntary, most were made effective only in the last few years, or are about to come into force in the coming years. This demonstrates that there is clear interest and consideration from regulatory bodies and premium programs to address the lighting standby power energy-saving opportunities related to the emergence and expansion of the smart lighting market.

Most existing standards, however, remain very vague about the different functions that should be considered when talking about smart lamps or luminaire standby power. Whereas some have decided to include sensors and connected functionalities in the scope of standby power requirements (i.e. ENERGY STAR, CEC), others have preferred to exclude these functionalities for now (i.e. European Commission). This lack of homogeneity between different standardization approaches has led to the perception that some MEPS are more stringent than other premium standards.

Nevertheless, none of the current regulations or standards explain how to account for the power-consuming built-in features included in smart lamps that have nothing to do with control illumination such as the features described in Section 1.1. There is therefore a real need for a new specific definition of lighting standby power to enable future standards to align with the specificities of new lighting products.

2.2 Test Methods

For the above-mentioned standards to be applied, test methods are required to allow manufacturers to ensure that lighting products comply with standby power requirements. Again, there are but a few test methods today that provide precise procedures to measure values, and most are based on the widespread International Electrotechnical Commission (IEC) 62301 international standard for the measurement of standby power. This section provides an overview of existing test methods used to enforce standby power requirements.

2.2.1 IEC 62301 (2011): Household Electrical Appliances – Measurement of Standby Power

IEC 62301 (2011) specifies measurement methods for electrical power consumption in standby mode(s) and other low-power modes (off mode and network mode). Most definitions and procedures outlined in this measurement standard have been adopted and/or referred to by many regulatory and standard bodies in the world, including the Canadian Standards Association (CSA) and the DOE in the United States. The IEC definitions are, however, generic and irrespective of any specific product to provide enough flexibility to use them according to their standby power requirements. The IEC 62301 (IEC, 2011) broadly defines three low power categories of operation, namely the:

- **Off mode(s):** "Any product modes where the energy using product is connected to a mains power source and is not providing any standby mode, network mode or active mode function and where the mode usually persists. An indicator that only shows the user that the product is in the off position is included within the classification of off mode."

- **Standby mode(s):** "Any product modes where the energy using product is connected to a mains power source and offers one or more of the following user oriented or protective functions which usually persist to facilitate the activation or deactivation of other functions (including active mode) by remote switch (including remote control), internal sensor, or timer; or continuous functions, including information or status displays (including clocks) or sensor-based functions."

- **Network mode(s):** "any product modes where the energy using product is connected to a mains power source and at least one network function is activated (such as reactivation via network command or network integrity communication) but where the primary function is not active."

These low-power modes are defined in opposition to the active mode which corresponds to:

- **Active mode:** "a product mode where the energy using product is connected to a mains power source and at least one primary function is activated."

For lighting products, the active mode refers to the mode where the lamp is ON and providing light output.

The IEC 62301 provides clear indications on how low-power mode power consumption should be measured, including the normalized test conditions, measurement procedure, and accuracy of the measuring equipment. Depending on the device's power consumption pattern or stability, three methods of measurement are proposed in this document:

- **Sampling method:** "by the use of an instrument to record power measurements at regular intervals throughout the measurement period. Sampling is the preferred method of measurement for all modes and product types under this standard. For modes where power varies in a cyclic fashion or is unstable, or for limited duration modes, sampling is the only measurement method permitted under this standard." or

- **Average reading method:** "where the power value is stable and the mode is stable, by averaging the instrument power readings over a specified period or, alternatively by recording the energy consumption over a specified period and dividing by the time." or

- **Direct meter reading method:** "where the power value is stable and the mode is stable, by recording the instrument power reading."

2.2.2 DOE, 10 CFR Appendix BB to Subpart B of Part 430

The DOE Appendix BB to Subpart B of Part 430 (DOE Appendix BB) is one of the official federal test methods used in the United States to measure integrated LED lamp standby power consumption among seven other features including lamp input power, lumen output, lamp efficacy, correlated colour temperature, colour rendering index, and power factor and the time of failure (DOE, 2016).

The DOE Appendix BB references the IEC 62301, with an added specification to include the network mode power to measure standby power. More precisely, this test procedure clearly indicates how to perform the following step before proceeding with the measurement:

- "Connect the integrated LED lamp to the manufacturer-specified wireless control network (if applicable) and to configure the lamp in standby mode by sending a signal to the integrated LED lamp instructing it to have zero light output. Lamp must remain connected to the network throughout the duration of the test."

Every American standard that refers to this particular test method therefore includes the control networking functionalities of the lighting product as part of standby power.

A counterpart to this test method is the DOE 10 CFR Appendix BB to Subpart W of Part 430 which applies to integrated compact fluorescent lamps.

2.2.3 California Energy Commission Standby Test Method

The CEC standby power standard measurement test, which is referred to in the *Appliance Efficiency Regulations* document, builds on both the IEC 62301 and the DOE Appendix BB with some added steps to further standardize current standby power test methods. These additional requirements are specific to connected LED lamps and their networking functionalities. They provide a way to prioritize the network type to be tested if the lamp has the capacity to connect to multiple networks and also allows for test conditions to be harmonized by dictating the distance between the emitter and the lamp.

These additional specifications are formulated as follows:

- "Ensure that the lamp is connected to only one network type and the lamp is in Network Mode
- If lamp has ability to connect to multiple networks, only one network shall be tested, and the network selected for testing shall be selected using the following prioritization:
  - Wi-Fi
  - ZigBee
  - ANT
  - Bluetooth
  - RF
  - Wired
  - Other
- Measure standby power as described in section 5.3.2 of IEC 62301 (2011) for a total period of no less than 60 minutes.
  - Standby power shall be measured at a lamp that is a distance of 10 meters (+/- 0.5 meters) from the hub, or wireless controller if no hub exists. If connection is not possible at this distance, conduct testing within 1 meter of the maximum connection distance.
- To calculate standby power, divide the accumulated energy consumption in watt-hours by the duration of the test in hours. Record this value as the average Network Standby Power. For lamps that are not connected LED lamps, record this value as "not applicable."

2.2.4 EDNA Network Mode Power Measurement: Guidance Note on Measurement and Data Collection

The *Network Mode Power Measurement: Guidance Note on Measurement and Data Collection* is a document prepared by the IEA 4E Electronic Devices and Networks Annex (EDNA) in 2015, an initiative of the International Energy Agency 4E Implementing Agreement. This Annex focuses on network connected devices and is aimed at helping government policies align with the evolution of this market by keeping the participating countries informed on current developments.

In contrast to the three test methods previously described, this Annex only provides non-laboratory measurement and data collection procedures intended to facilitate uniformity of measurements across the member countries to enable them to conduct indicative and benchmarking tests of network-enabled devices. It is thus not a test method to be used for compliance activities, but rather a protocol for measuring the approximate network-mode power consumption of commercially available network-connected products. The document includes an appendix for the measurement of standby power of smart lamps, which differs substantially from the above-mentioned test methods because it provides a three-step approach mainly focused on the power consumption of lamps in network mode.

The Annex recommends measuring standby power with the lamp configured under the three following conditions:

- **Network mode 1** (Network Standby – Lamp Off): the lamp is turned "off" using the user interface but remains in network mode;
- **Network mode 2** (Network Standby – Lamp dimmed to zero): the lamp is dimmed to zero using the user interface but remains in network mode;
- **Network mode 3** (Network Standby – Lamp Off with router, gateway, hub Off): the lamp is turned "off" and the Wi-Fi router (if present) and gateway (if present) have been de-energized.

The aim of this procedure is to provide a way of investigating whether or not lamp power consumption differs under varying circumstances. Concurrently to the lamp standby power measurement, the guideline also requires that gateway power consumption be measured if it is provided with the lamp.

This guidance note was used by NRC to perform the measurements which led to the results presented in Subsection 1.3 herein. Overall, these tests did not reveal any difference in standby consumption between the three network modes.

2.3 Current Ongoing Efforts

There are at the moment a few initiatives which are underway to reach consensus on the ways and means to address standby power specifications for lighting products. This section provides an overview of such initiatives as well as a few standardization approaches which are being developed at this time.

2.3.1 IEA 4E Program

Since its inception in 2008, the IEA Efficient Electrical End-Use Equipment Collaborative Technology Programme (4E) has regularly contributed to policy efforts related to standby and network mode power consumption by providing guidance notes, as well as technical and policy information resources thereof. Two of its task forces, the Electric Device & Network Annex (EDNA) and the Solid State Lighting Annex (SSLA), are now actively involved in research on smart lighting devices, which includes standby power, among others.

EDNA

The EDNA focuses on network connected devices and is one of 4E's most active task forces as the IoT is a subject which has received great attention lately. The implications of EDNA's work and research are also far more complex than the SSLA since they encompass a greater variety of products and activities. Although not always specific to lighting devices, EDNA's work and publications are often very relevant to the standby consumption of lighting products as they provide an overview of the current approaches being envisioned to tackle this issue from the perspective of other smart appliances. The ongoing work of this organization may provide useful insights for the implementation of future smart lighting standby power requirements.

SSLA

On the other hand, the work of the SSLA is specifically dedicated to the energy performance of lighting products. One of the current research projects undertaken by the annex mostly revolves around the energy implications of additional new features to LED products. The main findings of this work are discussed in the first section herein (Subsection 1.3), but other related reports are expected to be published in the near future as research progresses.

2.3.2 ANSI C137 Lighting Systems

Since 2014, the American National Standard Institute has been working on the development of a new approach to replace current lighting component standards with standards focused on complete lighting systems (Wolfman, 2016). This initiative is motivated by the fact that most lamps today, especially in the commercial sector, are being utilized as part of a whole system that enables interactions with other lamps, but also with other non-illuminating devices. This holistic approach, which envisions lighting devices as being constituents of an entire building ecosystem, is expected to tackle some of the challenges raised by smart lighting standby power due to the high level of intricacy and interoperability between devices.

2.3.3 ENER Lot 37

Another initiative similar to the ANSI C137, ENER Lot 37 was undertaken in the European Union to examine the possibility of setting energy efficiency requirements for lighting systems, rather than simply looking at the energy efficiency of the light source (Tichelen, 2016). These requirements would apply to lighting systems comprising light sources, ballasts, luminaires, or multiple luminaires within a system with sensors and controls. Therefore, current trends seem to aim at shifting the focus of standards toward a system-based approach with the goal of harmonizing existing standards and avoiding potential unintended consequences that may arise from specifications being too specific to certain products without proper consideration of the potential impacts on the energy use of other related equipment (interactive effects).

2.3.4 Australia E3 Draft MEPS for LED Lighting

Last November, the Australia Equipment Energy Efficiency (E3) Program issued a consultation regulation impact statement (E3 Equipment Energy Efficiency, 2016) that considers policy proposals to improve the energy efficiency of residential and commercial lighting in Australia and New Zealand. As part of this RIS, new MEPS were developed to cover LED products which until then were not subject to mandatory energy efficient requirements. These MEPS include specific requirements related to the standby power of a variety of LED products including non-directional and directional lamps, linear LEDs, and integrated LED luminaires, as presented in Table 9 below.

The proposed standby MEPS introduces a novel approach, specifically a requirement based on the ratio of Standby Power to On Power (PSTANDBY/PON). This is motivated by an effort to minimize the contribution of standby energy to total lamp energy consumption, which may be particularly detrimental to the energy use of low-power lamps, as previously discussed in Subsection 1.3. Although relevant, this requirement may be impractical, as pointed out by some stakeholders (Consultations, 2017) who argue that standby losses generally occur irrespective of lamp wattage and, as a result, would discourage the development of low-power lamps with standby functionalities. For instance, the standby requirement for a 3 W lamp would be ≤ 0.15 W, whereas by 2023 the maximum requirement would be capped at 0.3 W. At the time of writing, pursuant to public consultation meetings and the receipt of stakeholder comments, decisions relative to the proposed MEPS have yet to be made known. The final draft of this document, when made available, should be scrutinized as it might pave the way for future standby power specifications.

2.3.5 ANSI C82.16 – LED Driver Standby Power (Draft)

The American National Standard Institute (ANSI) is currently developing a test procedure for the standby power measurement of LED drivers with a suggested approach to report the "true lighting related standby power consumption" of such devices. While the document is still in its preliminary draft version, it provides some insights on how the American lighting industry intends to address the unique challenges of smart lamp power consumption.

TABLE 9: AUSTRALIAN/NEW ZEALAND PROPOSED STANDBY MEPS REQUIREMENTS

SCOPE	REQUIREMENT
Non-directional lamps Directional lamps Linear LED (tube) Small integrated LED luminaires	$P_{STANDBY}/_{PON}$ ≤ 5% **Capped at:** < 0.5W < 0.3W (in 2023)
Large, planar, batten, and troffer LED (L/P/B/T) luminaires	$P_{STANDBY}/_{PON}$ ≤ 5% **Capped at:** <1.1 W <0.5 W (2023) **Note:** Where only 1 standby product/parameter is applicable, e.g. DALI, then test data from control gear/module may be used. Where a luminaire incorporates more than one standby product/parameter, e.g. DALI and sensor, luminaire is to be measured.

It is of interest to note that U.S. efforts are specifically focused on LED drivers rather than the whole lamp or luminaire. This is very similar to the European Ecodesign standard whose definition of and requirements for standby power are specifically designed for control gears, equipment that is nothing more than the actual LED drivers for LED lamps. However, while the European standard bypasses the problem of dealing with control gears with secondary functions (communications, sensing, metering, etc.) by excluding such devices from the scope of the regulation, the ANSI is proposing an alternative method to address this specific issue. The proposed approach consists of using pre-established power allowances to compensate for power consumed by all the functions included in lighting devices. The reported standby power of the LED driver would thus be equal to the total measured standby power value (the ratio of energy consumed at the time of observation) minus the power allowances of the secondary functions of the lamp as expressed in the following equation:

$$rsp = sp - \sum_{i=1}^{n} pa_i$$

Where:

- rsp = Reported standby power;
- sp = Measured total standby power;
- pai = Power allowance for non-lighting functions.

The different power allowances would be established by U.S. regulators and would cover different functions including sensors, DALI communications, wireless communication interfaces, and other possible secondary functionalities.

The main idea indirectly advocated by this method is that the power consumed by secondary functions should not be deemed part of lighting standby power because these functions provide additional useful services. While it would be ideal to be able to measure the specific power consumption of the LED driver with all its secondary functions disconnected, this is impractical. This approach thus constitutes a workaround to account for these additional features without penalizing the product for consuming more standby power because of non-lighting functions.

2.3.6 DLC's Networked Lighting Controls Technical Requirements

In addition to the specifications for the lighting device itself, some efforts are being made to standardize networked lighting controls. The DesignLights Consortium (DLC), a non-profit organization dedicated to accelerating the widespread adoption of high-performing commercial lighting solutions, has put forward a series of technical requirements for interior and exterior network lighting control systems intended for commercial and industrial buildings (DesignLights Consortium, 2017). Although these requirements currently do not include standby power specifications, this initiative demonstrates that the standardization of lighting control system is being considered as equally important as that of luminaires and lamps themselves to achieve higher energy savings. The standardization approach adopted by DLC is also interesting to look into since it favours a constructive approach, which is relatively simple to work with as an initial approach to introducing and implementing more complex and diverse specifications as the market evolves.

2.3.7 EnOcean Harvesting Wireless Technology

Throughout this document, we have kept emphasizing that approaches used to develop MEPs for standby power energy consumption should be evaluated carefully as not to temper with the market's capacity to innovate. While the examples so far given in this document illustrate the legitimacy of this statement, it should also be recognized that such requirements could also pave the way for creating opportunities for new markets and technologies. The energy-harvesting wireless technology and sensor protocols developed by the company EnOcean are examples of such innovations, which have built on the energy constraints associated with lighting control devices' standby and networking power usage to come up with state-of-the-art solutions to address this issue (EnOcean, 2015). The characteristics of the EnOcean sensor protocol allow highly energy-efficient communication, which has resulted in wireless switches, occupancy and light level sensors which can be self-powered using motion, light, temperature sensors or kinetic energy (from a person flipping a switch) as their energy source (Wright, 2017). The development of this technology clearly demonstrates that the tools already exist today to curb the standby power losses of connected devices to minimum levels without altering these same devices' capacity to serve their purposes.

3 AVENUES OF DISCUSSION

Our literature review of existing regulations and standards has revealed that most of the MEPS and definitions related to the lighting standby power were designed prior the advent of the new smart lighting products now available in the market, or the new functions offered by these types of products. In this section, some refined definitions and MEPS approaches are explored to provide a basis for discussions. The various ideas put forward below are proposed to give an overview of the possible standardisation approaches to dealing with lighting standby power.

3.1 Standby Power Definition

With the wide range of complex and diverse functions found today in smart lighting systems, there is definitely a need for refining the existing standby mode definitions to address the specificities of those new products and dismiss any ambiguity that may arise regarding their standby power usage. With multiple built in functionality in an intricate design, the problem lies in clearly defining what is included in the standby power definition. In other words, which lighting system embedded features should be considered in the lighting standby power.

A clear and concise definition will not only help in assessing smart lighting devices' energy consumption and relevant potential specifications, but also help create a favourable environment for developing this market to achieve the highest associated energy savings and other users' benefits.

3.1.1 Existing Definitions

As mentioned previously, a number of different definitions of standby power are being used today as part of various standards and guidelines. Our literature review has found four different main definitions, as summarized in Table 10 below. The most common definition used by most standard bodies in North America is the one shown in the IEC 62301 test procedure, which is not specific to lighting products but applies to all household electrical appliances. Naturally, this definition was made as general as possible so that it can be applicable to a

TABLE 10: STANDBY MODE DEFINITIONS

REFERENCES	DEFINITIONS
IEC 62301 – Household Electrical Appliances – Measurement of Standby Power	Standby mode(s) refers to any product modes where the energy-using product is connected to a mains power source and offers one or more of the following user-oriented or protective functions which usually persist: • to facilitate the activation of other modes (including activation or deactivation of the active mode) by a remote switch (including remote control), an internal sensor, or a timer; • continuous function: information or status display including clocks; • continuous function: sensor-based functions.
California Energy Commission: Appliance efficiency regulations	The DOE's standby power test method refers to both IEC 62301 standby and network modes. Network mode(s): any product modes where the energy-using product is connected to a mains power source and at least one network function is activated (such as reactivation via network command or network integrity communication), but the primary function is not active.
ENERGY STAR, Luminaires Requirements V2.0 Final	
ENERGY STAR, Lamps requirements V2.1 Draft	
Europe, Ecodesign requirements (EU) No. 1194/2012	The standby mode means a mode of lamp control gear where the lamps are switched off with the help of a control signal under normal operating conditions. It applies to lamp control gear with a built-in switching function and permanently connected to the supply voltage when in normal use.
IEA 4E Standby Power Annex: Power requirements for functions, final report	The standby mode refers to a mode where the lamp is connected to a mains power source and at least one smart network function is activated. For lighting, the standby mode occurs when the lamp is turned off by the user interface or dimmed to zero visible light but the lamp continues to use energy in order to be ready to receive the next wireless communication from the user interface.

variety of household products found in the marketplace. Until recently, this did not pose any problem for traditional lighting products since their functions were still quite limited and their modes could be easily characterized by the low power modes defined in the IEC 62301. However, this definition did not include the network mode which can represent a significant portion of the total energy consumed by the lighting system.

The DOE added the notion of network mode to the standby power definition in its adapted test methodology for measuring lamps' standby power. The IEA 4E Standby Annex's definition also follows the same principle, though in that case, the emphasis is on lamps' wireless connectivity function as if their standby power consumption were only limited to its networking capabilities. On the other hand, the European definition is very minimalist in its approach because it does not specify the exact functions to be taken into account.

3.1.2 Illuminating and Non-illuminating Functions

Because lighting systems are equipped to perform multiple functions, it is first proposed to introduce the following definitions:

- **Illuminating services:** These features are intended to provide light and control lighting levels, e.g., a presence detector to control lights.
- **Non-illuminating services:** These features are not intended to provide or control lighting levels nor any other features pertaining to lighting services, e.g., a security camera. This non-illuminating service could also be labelled according to its primary intent: Security services instead of non-illuminating.

These definitions will be useful when determining what constitutes the lighting standby power. However, these definitions alone are not sufficient since there are many devices that can be used for illuminating and non-illuminating purposes. As such, it is proposed to complement the illuminating and non-illuminating services' definitions above with the IEC 62301 primary and secondary function classifications by adding a tertiary function. This combination of qualifications will allow to capture all functions, services or devices embedded in a piece of equipment, which among other things, provides illuminating services. As features are added to a lighting system, it will become increasingly difficult to determine the primary purpose that the equipment serves. Therefore, using the generic term "equipment" seems more appropriate than "lighting system".

The definition of primary, secondary and tertiary functions are proposed below.

Primary functions encompass the intended purposes or uses of a service (e.g., to provide light).

Secondary functions serve as convenience features in addition to a primary function. Secondary functions are not necessary to a product's operation, but enhances it in some ways (e.g., remote switching, networking, sensing and protective types of functions).

Tertiary functions are not related to a primary function, but enhance the end-user's experience by providing other services.

According to the above proposed definitions, each function, service or device is an illuminating service's primary, secondary or tertiary function. At the same time, each function is also a non-illuminating service's primary, secondary or tertiary function. For example, a security camera that is primarily used for security purposes can also be used to control lighting; it is an illuminating service's secondary function as well as a primary function of a non-illuminating service (i.e., security service).

It is necessary to introduce the tertiary level in order to clearly determine what is included in the lighting standby power. This additional level will help effectively capture the lighting standby power and avoid tempering with the industrial sector's capacity to design products that centralize functions into one system to improve buildings' overall operational efficiency. Such devices as CO2 probes and temperature sensors, to name a few, cannot be labelled as either the illuminating service's primary function or its secondary function because they are not related to the illuminating service's primary function (to provide light). Hence, it is necessary to propose a third category, as mentioned above. This third category now captures these particular features, which are becoming increasingly widespread among intelligent lighting systems.

The illuminating and non-illuminating secondary and tertiary functions are developing rapidly as interconnectivity in residential and commercial buildings is gaining popularity. Such interconnectivity can improve a buildings' overall operational efficiency. It can also increase the total amount of standby power consumed by the equipment hosting multiple services; for example, such consumption impact is clear on the equipment driver which converts AC to DC to power the various devices integrated. From the illuminating service's standpoint, such a bigger driver, which needs to power multiple devices, probably consumes more power when the illuminating primary function (to provide light) is not in use. For this reason, this device encompassing multiple functions can be mistakenly classified as less energy-efficient. However, if the efficiency of each of the services is considered, probably using one driver to power several devices performing multiple services is more energy-efficient than using a few separate drivers.

Another example is communication services. A network device can be used to transmit and receive information and commands to control lighting and perform other non-illuminating services, like receiving video signals from security cameras. As more functions use the network device in the lighting system as a gateway, the more power the network device consumes. Using one piece of equipment to send all the signals is probably more efficient than equipping each of the functions or services with their respective network devices.

Another example is the controller. The controller is the equipment's "brain", which processes data from the sensors and runs algorithms to control various services. Probably, each of the services is associated with one controller performing all the tasks. As such, the controller can be characterized as an illuminating and non-illuminating primary function.

Another example is the sensor. A presence detector can be embedded in or remotely located from a lighting system. A device that efficiently embeds multiple sensors probably consumes more power than a lighting system that only receives commands from remote sensors. However, from a whole building's standpoint, it may be more efficient to have all the sensors embedded into a single piece of equipment.

Because of the challenges as illustrated by the above examples, it is difficult to define what lighting standby power really is. Does it include sensors and communication devices, or is it only focused on the mandatory components needed for a lighting system to function, in other words, the driver? Even if lighting standby power only focuses on the driver power, as illustrated above, it is not quite obvious how the driver standby power consumed by the equipment providing multiple services should be assessed and determined.

3.1.3 Lighting System Operating Modes

In the various references studied for this report, the notion of operating modes is included in the standby power definition. These operating modes include the lighting standby mode definition, the lighting active and off-modes. The following definitions of various operating modes can be used in the lighting standby power definition.

Lighting Standby mode: A mode where the equipment is connected to a mains power source, emits no light (neither active nor turned off) and has the ability to offer illuminating services secondary functions to either:

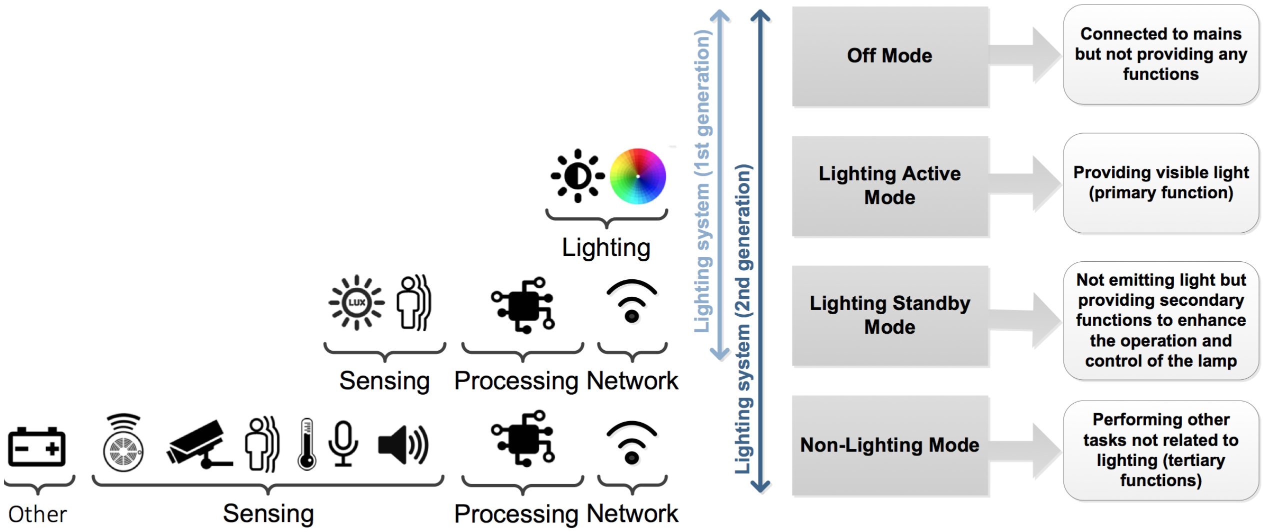
- facilitate the activation of other modes (including activation or deactivation of the lighting active mode) by a remote switch (including remote control), internal sensors or a timer;
- provide networking functions to support communication with a user interface and other lighting devices (an integrated hub/gateway);
- perform internal processing functions to support its control algorithms or to monitor and analyze its operation;
- record and communicate internal data information (lighting patterns and operating hours).

Lighting Active mode: A mode where the equipment is connected to a mains power source and provides visible light (illuminating service primary function).

Lighting Off mode: A mode where the lighting product is connected to a mains power source and does not perform any task pertaining to the lighting standby or the lighting active modes.

Non-Lighting mode: A mode where at least one non-illuminating service is activated or in standby (e.g., signal booster or extender, camera, speaker, temperature sensor, etc.)

FIGURE 7: LIGHTING MODES DEFINITIONS AND RELEVANCE FOR DIFFERENT GENERATIONS OF LIGHTING SYSTEMS[5]



Note that lighting and non-lighting modes are independent of one another.

As shown in Figure 7, non-illuminating services included in the non-lighting mode have the potential to surpass illuminating services included in the lighting active and standby mode. This means that most of the power consumed by the lighting system can be related to the non-lighting mode, which may create complex measurement issues. The figure also illustrates that lighting system components described in Section 1.2 will most likely be shared by various illuminating and non-illuminating services. For instance, the processing activities of all the functions, including sensors' data preprocessing, will most likely all be included in the lighting system controller. This means that it will become virtually impossible to isolate the power used by individual illuminating and non-illuminating services.

It has also been pointed out by some stakeholders that the characterization of the lighting standby mode should also include another level of ramification based on two levels of standby operation, namely the passive (asleep) and the active (idle) standby modes related to a product's promptness to respond to a signal and its level of "wakefulness". These two sub-modes are very common among other appliances, such as television sets, DVD players and set-top boxes which have the capacity to lower their power consumption when waiting for an external signal to wake them up from the passive mode, as opposed to the active standby mode where the product is fully awake but is not actively performing any function. For the time being, however, it may be too soon to introduce this level of detail, which would only add more complexity in dealing with the lighting standby power regulation.

3.1.4 Lighting standby power definition

Our literature review has identified two main schools of thought regarding what should be included in the lighting standby power definition. The first advocates the inclusion of both networking and sensor-based functions (such as ENERGY STAR) as part of lighting standby power specifications in standards, whereas the second favours a narrower approach that only covers the

[5] Lighting system here should be understood as a general term which also includes luminaires and other lighting products intended for both residential and commercial applications.

TABLE 11: LIGHTING STANDBY POWER DEFINITIONS

DEFINITIONS	ILLUMINATING FUNCTIONS			NON-ILLUMINATING FUNCTIONS			COMMENTS
	PRIMARY	SECONDARY	TERTIARY	PRIMARY	SECONDARY	TERTIARY	
1	Off	Driver	Off	Off	Off	Off	This definition of standby power excludes any sensors' power consumption and focuses only on the equipment driver's power consumption for its illuminating services. This definition will cause issues in the assessment of the standby power of those kinds of equipment that provide multiple services because the driver operates in a non-optimal state, or it is simply impossible to isolate the lighting's standby power from the other services' standby power. This definition implies that all the other functions can be turned off, or their power consumption levels can be isolated.
2	Off	Driver + Controller	Off	Off	Off	Off	This definition of standby power adds the power consumed by the controller to the first definition. In addition to the issues mentioned in Definition 1, this definition would be difficult to apply to real-life cases where the equipment shares a single controller with multiple services. This definition also implies that all the other functions can be turned off, or their power consumption levels can be isolated.
3	Off	Driver + Controller + Network	Off	Off	Off	Off	This definition of standby power adds the power consumed by the network device to the first and second definitions. In addition to the issues mentioned in Definitions 1 and 2, this definition would be difficult to apply to real-life cases where the equipment shares the network connection or can serve as a signal booster or a gateway. For such equipment, the power consumed by the networking function could be above the permitted threshold because it may consume more power compared to the network functions that are only dedicated to lighting control. This definition also implies that all the other functions can be turned off, or their power consumption levels can be isolated.

networking functions (such as the IEA). Currently, it seems that there is no definite way to deal with this issue since the choice actually depends on the scope and intent of the standard being developed. Indeed, the question ultimately boils down to determining what should be specifically targeted in order to curb the standby energy losses: is it enough to address only the networking functions, or should the sensor-based functions be also covered?

There has been neither consensus nor any clear answer regarding the standby power's definition. The first step in developing a clear standby power definition is to determine what should be included in the standby power.

The theoretical definitions displayed in Table 11 represent options on how to characterize standby power. They all raise some issues about how a definition can be properly applied to real-life situations and applications, especially those devices with an integrated design where power consumed by the various functions cannot be effectively isolated. It should be pointed out that none of the proposed definitions considers the power consumed by the various functions linked with non-illuminating services (illuminating services' tertiary functions). It seems obvious that such power should not be attributed to lighting standby power.

TABLE 11 (CONTINUED FROM PAGE 30): LIGHTING STANDBY POWER DEFINITIONS

DEFINITIONS	ILLUMINATING FUNCTIONS			NON-ILLUMINATING FUNCTIONS			COMMENTS
	PRIMARY	SECONDARY	TERTIARY	PRIMARY	SECONDARY	TERTIARY	
1	Off	All on	Off	Off	Off	Illuminating secondary functions all on	This definition of standby power adds the power consumed by all illuminating secondary functions to the first two definitions. It excludes all non-illuminating secondary functions. In addition to the issues mentioned in Definitions 1 and 2, this definition would be difficult to apply to real-life cases where the equipment shares the secondary functions. Also, as more and more sensors are included to control lighting, so is the standby power. A product that embeds sensors should not be penalized compared to a product designed to only receive sensor signals. Since the trend is moving towards higher integration among the pieces of equipment to improve buildings' overall efficiency, it will be easy to argue the case that none of the sensors is only dedicated to illuminating services. Because any sensor signal can be shared through the network connection, it is up to the user to determine whether the sensor signals can serve multiple purposes. This definition also implies that all the other functions can be turned off, or their power consumption levels can be isolated.
2	Off	All on	Off	Off	Secondary functions shared with illuminating services[6]	Illuminating secondary functions all on	This definition of standby power considers the power consumed by all the devices that are used for illuminating services' secondary functions. This means that the total amount of power consumed by the driver, controller, network devices and sensors used for lighting services must be characterized as lighting standby power. This definition will be easier to apply to real-life cases, but could penalize those highly integrated products offering multiple services but probably having higher standby power. This definition also implies that all the other functions can be turned off, or their power consumption levels can be isolated.

Among the above definitions, the third one seems the most appropriate. It captures the essential device use for interconnected lamps (the driver, the controller, and the network). This definition deliberately excludes all the sensors, even those that can be used to control illuminating services, since they can be located outside the equipment. As such, those product designs that receive inputs from external sensors should not be favoured or penalized compared to those product designs with embedded sensors.

This definition would be complex to apply to real-life cases, because the driver, the controller and the network device are probably always shared in integrated designs and all these devices could increase in size and power consumption as they perform more and more services. It is not practical to isolate the power consumed by each of the services; therefore, this definition will require some measurement assumptions, which are discussed in the following section.

The network's power consumption is especially challenging since a building's optimal overall efficiency may not be the optimal product networking option. A lighting system with a Wi-Fi signal booster or a gateway probably consumes more power than other networking options. However, from a whole-building standpoint, this shared device can provide a higher overall efficiency level. According to this definition, the

[6] This includes the driver, network device, controller and sensors.

network's illuminating function power is the marginal power required to share the information package associated with the illuminating functions. However, it would be impractical or unfeasible to isolate this marginal power from the overall power consumed by the network component.

3.2 Test Method and MEPS

In connection with the definitions proposed above, this section suggests three test-method and MEPS approaches. Because of the challenges associated with measuring and isolating the lighting standby power, the measurement methodology and the MEPS are closely related. Before delving into the details, it is necessary to recall that the main goal here is to propose standards aimed at limiting the inefficient usage of power in lighting systems by discouraging the market's uptake of inefficient products without impeding the market's long-term development.

Since this market is expected to develop rapidly, the standards should be allowed enough latitude to enable them to adapt quickly with minimum efforts. Based on this principle, the following MEPS and test-method approaches are suggested for future discussions.

The overall measurement approach proposed here assumes that standby power or power consumed by various features cannot be cost-effectively or technically isolated. Therefore, upstream measurement needs to be done on lighting equipment so as to cover all the illuminating and non-illuminating functions' power consumption in the various modes. There is no need to go into the measurement details in this document since the sampling requirements, the measurement protocol and other elements are all covered in IEC 62301. Furthermore, a detailed measurement process cannot be fully defined until consensus has been reached on the definition and the overall approach.

The challenge associated with the test method lies in how to isolate the lighting standby power from the total standby power measured. The following sections summarize the various options that could be used to isolate the individual modes' and functions' power consumption.

The test methods described below is based on the third definition proposed in Section 3.1.4.

3.2.1 Proposal 1: Total Standby Power Requirement Approach

The first proposal involves measuring the overall power consumed when the lighting system is in the lighting standby mode and comparing the result to a fixed overall maximum lighting standby power requirement, (e.g., a 0.5 W overall standby power level).

Test Method

For compliance purposes, a product's standby power usage could be measured as per the IEC 62301 test method and by following an additional requirement that **all illuminating tertiary functions and illuminating secondary function with the exception of the driver, controller and network functions, if any and if feasible, are to be deactivated** when the measurement is being conducted. This would mean that to comply with the MEPS, it would be up to the manufacturer to add the possibility to deactivate functions in order to be compliant with the standby power specification.

This approach is the simplest one because it can be easily implemented, which is probably the reason why it is the one being widely followed by existing standards. However, one of its potential drawbacks is that it may be impractical in some cases to deactivate functions embedded in a product. Furthermore, disconnecting these functions, where possible, may still remain problematic because the lamp driver and the internal circuitry which are designed to operate at a certain current and voltage would not operate at their optimal efficacy. The driver, controller and network power consumption for non-illuminating services cannot be isolated and would be detrimental to the product design.

FIGURE 8: ILLUSTRATION OF THE MEPS TOTAL STANDBY REQUIREMENT APPROACH

"Since this market is expected to develop rapidly, the standards should be allowed enough latitude to enable them to adapt quickly with minimum efforts."

The following example illustrates how this MEPS approach can be put into practice:

Example: An integrated LED lamp with a total measured standby power of 1.3 W includes a presence detector, a wireless communication interface, a Wi-Fi signal booster, and a temperature sensor, but none of these functions has the capacity to be deactivated. The maximum standby power according to the MEPS is 0.5 W. As illustrated in Figure 8, this lamp would not be compliant to the proposed MEPS. The manufacturer would thus face three possibilities: (1) introducing the possibility of deactivating functions; (2) reducing the power consumption of these functions; or (3) both.

3.2.2 Proposal 2: Semi-Functional Approach

This second approach is based on the allocation-by-function approach suggested by the ANSI. This approach is called semi-functional because it makes use of a total lighting standby power allowance and an additional variable representing the individual functions' allowances to determine the maximum lighting standby power on a product basis.

Two variations of this approach can be used:

1 (Measured standby power – Sum of allowances) < Total lighting standby power requirement

2 Measured standby power < (Sum of allowances +Total lighting standby power requirement)

In the first variation, allowances for functions are subtracted from the measured total standby power to calculate the system lighting standby power. Since the sum of the allowances can theoretically be bigger than the measured standby power, the result is limited to 0. The calculated lighting standby power is then compared with a fixed overall maximum lighting standby power requirement (e.g., 0.5 W). In the second variation, on the other hand, the measured standby power is compared to the sum of all allowances and a basic standby power allowance. The basic allowance equivalent to the overall lighting standby power could be set at 0.5 W and the other possible additional allowances could be set at the values listed in Table 12 for the tertiary functions (these values and functions are given for indication only and are not exhaustive).

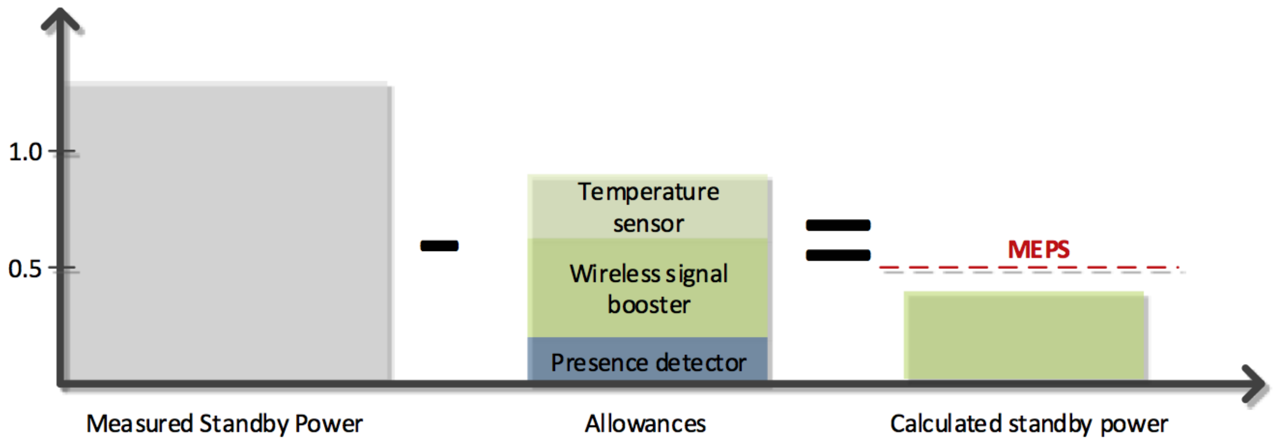
TABLE 12: LIST OF STANDBY POWER ALLOWANCES FOR LIGHTING SYSTEM FUNCTIONS

FUNCTIONS	POWER ALLOWANCES (W)
Presence detector	0.2
Photo sensor	0.2
Wireless signal booster or extender	0.4
Camera	1
Speaker	1.5
Microphone	0.8
Temperature sensor	0.3
Humidity sensor	0.2
Internal gateway	0.5
Other functions (for each individual function)	0.5

In both cases, allowances by function are required.

The list of functions with their corresponding allowances should be based on market analyses, laboratory tests, manufacturers' data or other existing standards pertaining to other devices having one of these functions as their primary function (e.g., cameras, speakers, etc.). The category "Other functions" can be included as a buffer category to allow for additional functions that were not considered at the time a standard is published. In this way, lighting product manufacturers would still have the capacity to innovate and the CSA Technical Committee C419 would not need to constantly update their standards to account for newly added functions. However, one adverse effect of this approach could be to prompt manufacturers to add functions to gain greater power allowance, instead of improving efficiency to comply with the standard. To address this potential negative effect, an overall cap could be set for the total power allowance, above which no additional allowance is to be permitted.

FIGURE 9: ILLUSTRATION OF THE MEPS SEMI-FUNCTIONAL APPROACH



Test Method

The test method for this approach would be very similar to that of the total standby power requirement approach. However, now it would be up to the manufacturer to decide whether to **use the allowance or disable those functions that can be disabled** when the product is in the lighting standby mode. The driver, the controller and the network functions should be enabled during the test.

Any function offered by the product for which allowance is used in the calculations should be enabled for the test.

As pointed out in a report prepared in 2010 for the Australian Department of Climate Change and Energy Efficiency (Harrington & Nordman, 2010), the advantage of this approach over the total standby power requirement approach is that it recognizes that products are differentiated when different functions are available and activated in the standby mode. Otherwise, products with more functions would be burdened by much more difficult, or impossible-to-meet, limits than products with fewer functions; and less functional products would have standby power limits that are too lenient.

The following example illustrates how this MEPS approach would be put into practice:

Example: An integrated LED lamp with a total measured standby power of 1.3 W includes a presence detector, a Wi-Fi signal booster and a temperature sensor. A lighting standby power MEPS is assumed in this example. As illustrated in Figure 9, the maximum standby power (MSP) allowance for this lamp is thus calculated as follows:

$$\text{Allowance} = (0.2\text{ W} + 0.4\text{ W} + 0.3\text{ W}) = 0.9\text{ W}$$

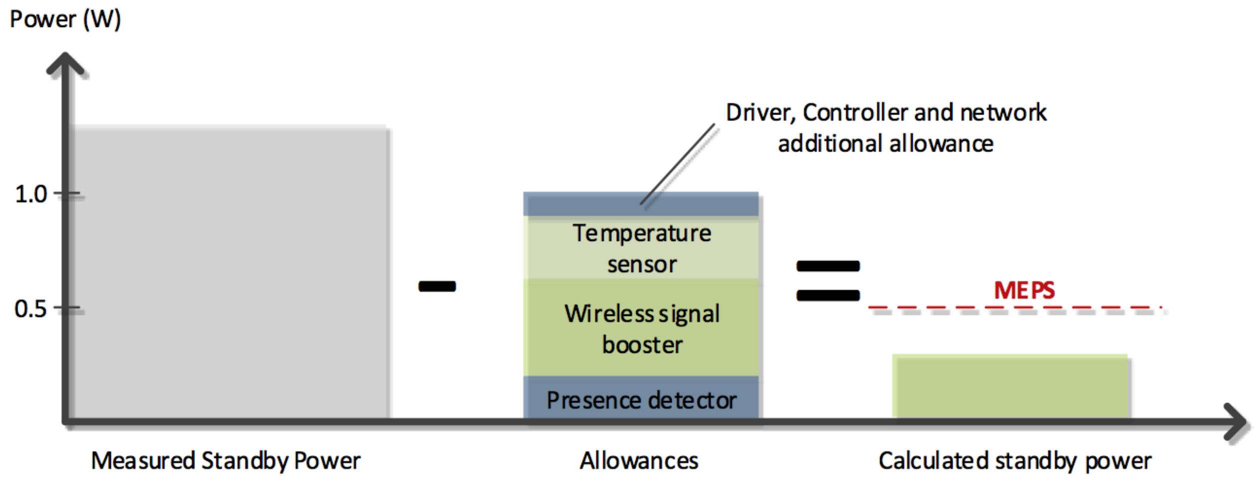
$$\text{Calculated lighting standby power} = 1.3\text{ W} - 0.9\text{ W} = 0.4\text{ W}$$

With a calculated standby power level of 0.4 W, this lamp complies with the MEPS's mandatory threshold of 0.5 W.

3.2.3 Proposal 3: Fully Functional Approach

The third proposed approach is derived directly from the second one, though with an added level of granularity concerning the driver, the controller and the network functions. Indeed, as illuminating and non-illuminating functions are added to a product, the driver, the controller and the network power consumption should be expected to increase. For these highly integrated products, it might be ill-advised and inappropriate to use only one allowance. Doing so may even hamper the energy-saving opportunities afforded by increased controllability and other intelligent energy-efficient applications, which are often directly related to those secondary functions.

FIGURE 10: ILLUSTRATION OF THE MEPS FULLY FUNCTIONAL APPROACH



This approach thus involves determining the driver, the controller and the network lighting standby power needs based on the functions' power needs. For example, the sum of the allowances could be increased by 10%.

Test Method

For this fully functional approach, the test method would be the same as the one for the semi-functional approach. In this method, the lighting standby power MEPS will be determined based on the total amount of allowances used. Thus, the driver, the controller and the network standby power will be calculated using the sum of allowances in recognition that as more functions are added, the driver, the controller and the network power consumption increases.

Any function offered by the product for which allowance is used in the calculations should be enabled for the test.

By taking into account the specificities of each product, this approach is ultimately fairer for manufacturers, while also offering potential opportunities to achieve higher energy savings thanks to standby power limits that would be tailor-made to the different lighting products available in the market.

This approach is the most versatile among the three approaches suggested, but also the most complex. The calculations used to determine the driver, the controller and the network standby power allowances may be difficult to determine and may result in unreliable results, leading to confusion among stakeholders.

The following example illustrates how this MEPS approach would be put into practice:

Example: For the same lamp mentioned in the previous examples, this MSP is calculated as follows:

$$\text{Allowance}=(0.2+0.4+0.3)\times 1.1=1\text{ W}$$

$$\text{Calculated Lighting standby power}=1.3-1.0=0.3\text{ W}$$

With a calculated standby power level of 0.3 W, this lamp complies with the MEPS's mandatory threshold of 0.5 W.

3.2.4 Summary of Proposed MEPS Approaches

The advantages and disadvantages of the three suggested MEPS approaches are summarized in Table 13.

TABLE 13: PROPOSED MEPS APPROACHES – ADVANTAGES AND DISADVANTAGES

MEPS OPTION	ADVANTAGES	DISADVANTAGES
Total standby power requirement approach	• Easy to adopt and implement • One-stop solution for every function comprised in the lighting standby power	• Does not recognize that products are differentiated according to the functions that they offer. • Not suited to products for which functions cannot be disabled. • Too broad for products with fewer functions (does not maximize savings potential)
Semi-Functional Approach	• Suited to products for which functions cannot be disabled. • Recognizes that products are differentiated according to the tertiary functions that they offer.	• Needs commitment to develop and update appropriate allowances for functional adders. • Risk of prompting the introduction of "dummy" functions to increase the total power budget. • Basic power allowance may be discouraging for products with more functions. • Does not consider the impact of multiple services on the driver, the controller and the network power consumption.
Fully functional Approach	• Offers tailor-made solutions according to the level of functionality of the product. • Suited to products for which functions cannot be disabled. • Provides allowances that are more targeted, enabling greater savings.	• Needs commitment to develop and update appropriate allowances for functional adders. • Risk of prompting the introduction of "dummy" functions to increase the total power budget. • More complex to implement.

3.3 Residential vs. Commercial MEPS

One of the questions worth asking when discussing the lighting standby power specifications is whether or not the MEPS should impose the same power limits for household and commercial lighting products. As explained previously, due to their longer operating hours, the energy performance of commercial lamps are less prone to be negatively impacted by their standby power usage. By contrast, domestic lighting products, which operate in the standby mode over longer periods of time, should be subject to more stringent specifications. Furthermore, secondary functions to be found in residential products are more likely to serve convenience purposes than to achieve energy savings. Of course, this observation may be subject to change in the future but as a matter of fact, the potential energy and non-energy benefits afforded by the standby power usage of commercial lamps are far greater than those offered by their residential counterparts.

CONCLUSION

The topic of lighting standby power is becoming increasingly complex and is quickly morphing with the fast evolution of the smart lighting market. Moreover, with more new features being added and the prominent role being played by lighting products in IoT systems, the standardization of standby power specifications may appear as an increasingly daunting task to undertake. The main challenge facing standards development organisations (SDOs) is to find an effective way to set specifications for the standby power consumption for lighting systems without unduly limiting innovation and the benefits that the growth of intelligent lighting systems can bring along.

Furthermore, as new services are provided by lighting systems, such as temperature-monitoring or surveillance, the primary role of a product becomes increasingly difficult to identify. As more and more devices are included in what we traditionally call a lighting system, the time will come when it is more appropriate to define such products as a kind of integrated device that provides multiple services including lighting. This term will avoid attributing the power consumed by the integrated device to the lighting standby power when no light is emitted.

Presently, there are not many existing standards or voluntary programs that include standby power as one of the lighting specifications for minimum energy performance.

While lighting standby power may have a negative connotation, it may in some cases be an unavoidable expense to be incurred to achieve the greater overall building efficiency. In other words, to take full advantage of the enhanced services and reap the most energy and non-energy benefits afforded by lighting systems, it should be recognized that this standby mode may sometimes be necessary. This is especially true for commercial applications where the energy savings afforded by intelligent lighting control systems may be greater at the building than at the product level, thanks to this standby consumption.

Nonetheless, it goes without saying that, regardless of the additional services provided by lighting equipment, the standby mode is expected to increase lighting energy consumption, particularly in the residential sector. For this reason, it is hence beneficial to develop practicable and effective specifications to limit the uptake by the market of inefficient products. Doing so will not only help limit the negative impact that these products could have on the market, but also encourage manufacturers to consider new strategies to better manage the energy consumption of their products in the standby mode.

Hopefully, the five standby power definitions and the three MEPS approaches suggested in this document can provide interesting insights on finding appropriate solutions to address this topic. Each of them presents some advantages and some drawbacks and limitations. This set of options may therefore not constitute complete solutions to the lighting standby power issue but should at least serve as helpful starting points for developing potential solutions to be considered in the near future.

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