Analysis of Background Illuminance Levels During Television Viewing

December 2011

BY

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The Collaborative Labeling and Appliance Standards Program (CLASP)

This report has been produced for the Collaborative Labeling and Appliance Standards Program (CLASP).

December 2011

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Executive Summary

The Collaborative Labeling and Appliance Standards Program (CLASP) – the primary resource and voice for appliance, lighting and equipment energy efficiency worldwide – initiated a study to collect field data on background lighting levels during television viewing. Data was collected from sixty residences over a 7-day time period in October 2011 in both the Washington, DC and Sacramento, CA metro areas.

This study acts on the recommendation of a previous CLASP-funded study, "Analysis of Television Luminance and Power Consumption," (Jones, 2011) to collect data on actual background lighting levels during television viewing and support the improvement of the television test procedures used by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA). The results of this study will assist domestic and international energy efficiency initiatives to develop a television test procedure that measures the energy consumption associated with the automatic brightness control (ABC) feature in a manner more representative of expected consumer usage.

CLASP worked in partnership and collaboration with the California Lighting Technology Center (CLTC) to develop a test plan for collecting data. CLASP engaged Shugoll Research to identify homes and develop screening criteria. Shugoll coordinated installation and removal of equipment with CLTC entering the homes and physically installing and removing the equipment. Keith Jones, from Digital CEnergy Australia, joined CLASP and CLTC to analyze data and identify key findings and conclusions.

Key findings of this study are summarized below:

1. Typical daytime room illuminance levels can be characterized by three illuminance profiles;
2. Typical nighttime room illuminance levels can be categorized by two illuminance profiles;
3. An insignificant amount of television viewing occurs at 0 Lux;
4. The majority of television viewing occurs between 0 and 100 Lux; and,
5. The consistency between results for the majority of houses sampled suggests that the results may be representative of houses in the Northeastern and Northwestern regions of the United States

Key conclusions and recommendations of this study are summarized below:

1. The 0 Lux and 300 Lux test points specified in the ENERGY STAR test procedure should not be used to measure television energy consumption with the ABC feature enabled;
2. Three test points should be used to measure television energy consumption: these three points should be between 10 Lux and 100 Lux;
3. Further analysis is needed to determine if differences in the amount of time televisions are viewed during the daytime verses the nighttime has a material impact on television energy consumption; and
4. Additional data collection is recommended, including data collection in regions outside of the United States.

This study is part of CLASP's larger effort to support energy efficiency testing and compliance initiatives worldwide by providing technical assistance for the development and revision of test procedures; helping to establish and improve test facilities; supporting the improvement of testing practices and compliance; and supporting the harmonization of test procedures regionally or globally.

Background

Television energy consumption is a significant and growing portion of residential energy use. Globally, televisions account for more than 3-4% of residential energy consumption (Park, Phadke, Shah, & Letschert, 2011). In the United States, televisions consume approximately 50 billion kWh of energy each year (US Department of Energy) or 4% of total residential energy use. Energy efficiency standards and labeling (S&L) programs have responded to the growth in television energy consumption with the development of efficiency standards and labels.

Since 1998, the EPA has managed an ENERGY STAR endorsement-labeling program for televisions. This program saves significant energy by endorsing products with greater energy efficiency than the average product sold on the market. ENERGY STAR qualified televisions consume 40% less energy than standard televisions (US Environmental Protection Agency). At the time of this study, ENERGY STAR is in the process of revising the stringency of their specification to encourage further market transformation toward efficient products.

In addition to the endorsement label, in 2010 the U.S. DOE appliance standards program began analysis on a range of policies to reduce the energy consumption of televisions, including mandatory standards. A federal efficiency standard has the potential to save substantial energy by removing the most inefficient products from the market. If a federal standard were implemented for televisions in 2012, it would have the potential to save 7.3 TWh of energy cumulatively through 2020 (Park, Phadke, Shah, & Letschert, 2011).

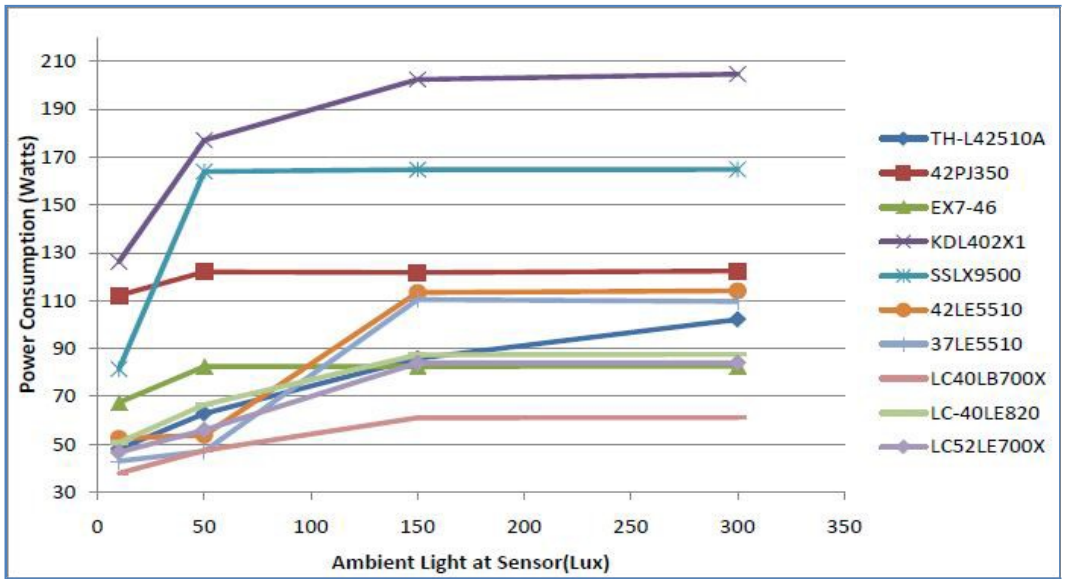
Test procedures describe how to measure the energy consumption of a product and form the foundation of energy efficiency standards and labels. Before an efficiency level for a federal standard or endorsement label can be set, test procedures (characterized by their ability to represent typical usage conditions and their repeatability, reproducibility and accuracy) must be established. Currently, the DOE is developing a federal test procedure for televisions that will allow the implementation of a federal standard. At the same time, the EPA is revising the ENERGY STAR test procedure for the endorsement label.

To support these efforts, CLASP launched a study in 2010 to assess the energy performance of televisions and the existing ENERGY STAR test procedure. This study, “Analysis of Television Luminance and Power Consumption,” (Jones, 2011) addressed multiple issues concerning television energy performance, including the ability of the existing ENERGY STAR test procedure to accurately represent the energy consumption of a television when its automatic brightness control (ABC) feature is enabled. The ABC feature adjusts the brightness level of a television’s screen in response to ambient light levels in order to reduce television energy consumption. The study found that the current ENERGY STAR test procedure, which calculates energy consumption as an average of consumption at 0 and 300 lux, does not accurately represent energy consumption associated with the ABC feature. A measurement at 0 Lux is not representative of actual television energy use as 0 Lux corresponds to a complete absence of background light during television viewing including the background light produced by the television screen itself.

As a part of CLASP’s study, fourty televisions were tested using the ENERGY STAR test procedure at 10 Lux, 50 Lux, 100 Lux, 150 Lux, 200 Lux, 250 Lux, and 300 Lux to assess how the energy consumption of the television changed with the ABC feature enabled (see Figure 1). The results showed that the ABC

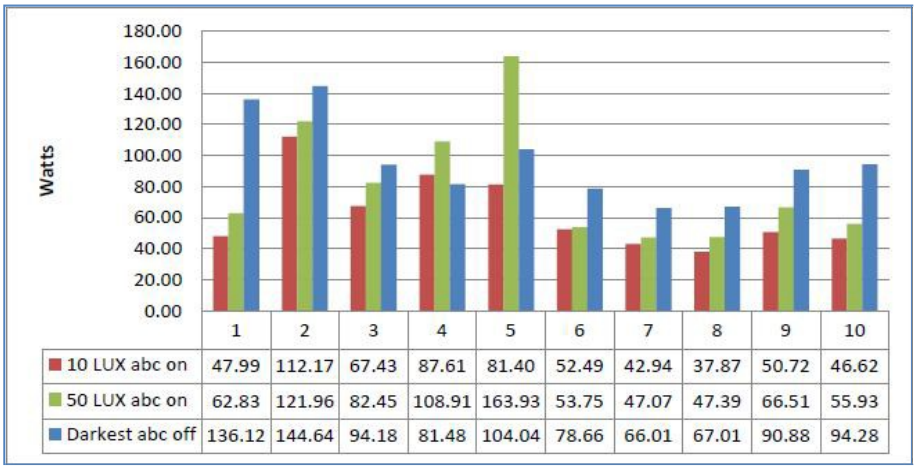
feature of certain televisions (e.g. television model SSLX9500) reacted only slightly when illuminance levels were between 300 Lux down to 50 Lux, and only exhibited the expected response at very low illuminance levels (<50 Lux).

Figure 1: Power Consumption vs. Ambient Light



Testing also showed that television energy consumption in the dimmest user-selectable picture mode (often recommended for watching films) was in most cases slightly higher than energy consumption at the 10 Lux level with the ABC feature enabled (see Figure 2).

Figure 2: Dimmest Selectable Picture Mode Compared to ABC Power Consumption



	1	2	3	4	5	6	7	8	9	10
10 LUX abc on	47.99	112.17	67.43	87.61	81.40	52.49	42.94	37.87	50.72	46.62
50 LUX abc on	62.83	121.96	82.45	108.91	163.93	53.75	47.07	47.39	66.51	55.93
Darkest abc off	136.12	144.64	94.18	81.48	104.04	78.66	66.01	67.01	90.88	94.28

These findings suggest that manufacturers have designed ABC to reduce energy consumption dramatically at very low levels of ambient light – thus the simple two-point ABC test specified by ENERGY STAR could be exploited to skew reported power consumption of ABC-enabled televisions.

CLASP's report recommended additional research to collect data on actual background lighting levels during television viewing. This data would be used to improve the television test procedure by setting test points at levels corresponding to background lighting levels during actual television viewing.

In an effort to act on the recommendation of the study to collect data on actual background lighting levels during television viewing and further support the improvement of the television test procedure used by EPA, CLASP funded this additional field study in 2011 to collect data on background ambient light levels during in-home television viewing. A summary of this most recent study's methodology, data analysis, key findings, and conclusions are described below.

Methodology

Introduction:

CLASP worked with experts in market research and lighting to obtain measurements from a broad range of lighting conditions. CLASP worked with the California Lighting and Technology Center (CLTC) at U.C. Davis to develop a comprehensive test plan to collect measurements of illuminance levels. CLTC has extensive expertise in lighting and illuminance measurement; they are affiliated with major lighting manufacturers and utility efficiency programs. CLASP also worked with Shugoll Research, a market research firm with substantial field research experience, to identify a diverse sample of homes for study participation.

Data Collection:

The test plan developed by CLASP and CLTC included procedures for installation and removal of energy and illuminance recorders and for data retrieval. In-home data collection specifications are summarized below:

- Each of the television viewing environments were photographed and sketched to document the general arrangement of the room including light sources, windows, doors, and other major physical characteristics.
- A five point baseline illuminance map of each room was completed profiling the illuminance conditions without electric light and with electric light. Points of the illuminance map were marked on the sketch of the room.
- Each TV was outfitted with an illuminance meter and a power meter. The illuminance meter was located near the middle of the bottom bezel to simulate the location of television illuminance sensors.
- Following seven complete days of data collection the power meter and illuminance meter were recovered. The data were downloaded and synced up with time stamps for analysis.

CLTC selected and special ordered high quality equipment in order to guarantee the accuracy of measurements. The following equipment was used to complete the study:

- Eagle 120 – Wireless Receptacle Recorder (30 Ea.)
- T and D Illuminance Meter and Data Logger – Model No. TR-74Ui (30 Ea.)
- Hand Held Illuminance Meter – Minolta T-10

- Digital Camera
- Hand-Held Electric Tape Measure

Participant Selection:

CLASP worked with Shugoll Research to select a diverse sample of homes in order to obtain a broad range of lighting conditions. Shugoll assisted in the development of screening criteria used to identify and achieve a demographic mix of household size, age, gender, and income as well as a variety of housing types including single-family homes, apartments, and row houses (see Appendix A: Specifications & Demographics for more information). A total of sixty households were selected for the study, at test sites in each of two markets: Washington, DC metro area and Sacramento, CA metro area.

Data Analysis

Initial Data Review:

To determine background lighting levels during television viewing, sixty homes were monitored continuously over a 7-day time-period. Of the sixty homes monitored, fifty four were analyzed for this study. The other six homes were eliminated from analysis for the following reasons:

- Recorder error resulted in no recorded television energy consumption data.
- Participants did not view television during the data collection time period.

Illuminance Graphs:

To better understand background lighting levels over the time that data was collected, illuminance graphs were created for each of the fifty four homes used in the analysis (see Appendix B for graphs). Illuminance graphs show background lighting levels over the course of each day that data was collected. The following types of illuminance graphs were made for each home:

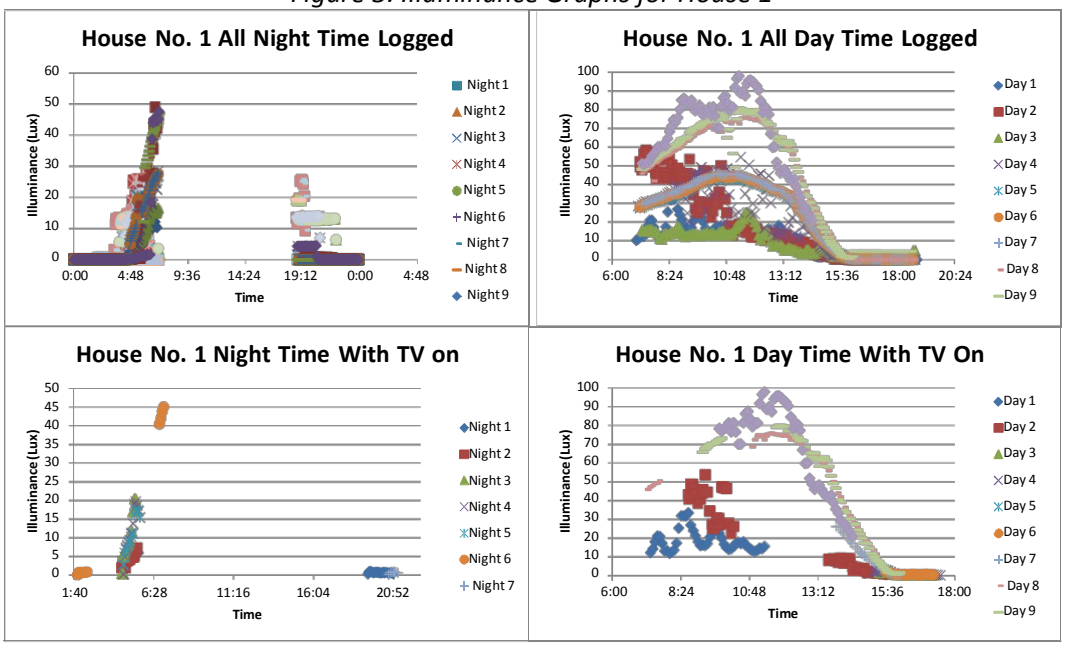
- Illuminance levels in the room where the television was located during the entire data collection period.
- Illuminance levels during television viewing periods.

Daytime and Nighttime Split:

Data has been divided between daytime and nighttime based on an assumption that the presence of natural light would produce marked differences in lighting conditions. Daytime and nighttime were determined based on the U.S. Department of Commerce National Oceanic and Atmospheric Administration (NOAA) calculations for sunrise and sunset in each metro area during the data collection period.

By dividing data between daytime and nighttime, separate graphs for room illuminance levels and illuminance levels during television viewing were created. As a result of this data analysis plan, four illuminance graphs were developed for each home (see Figure 3).

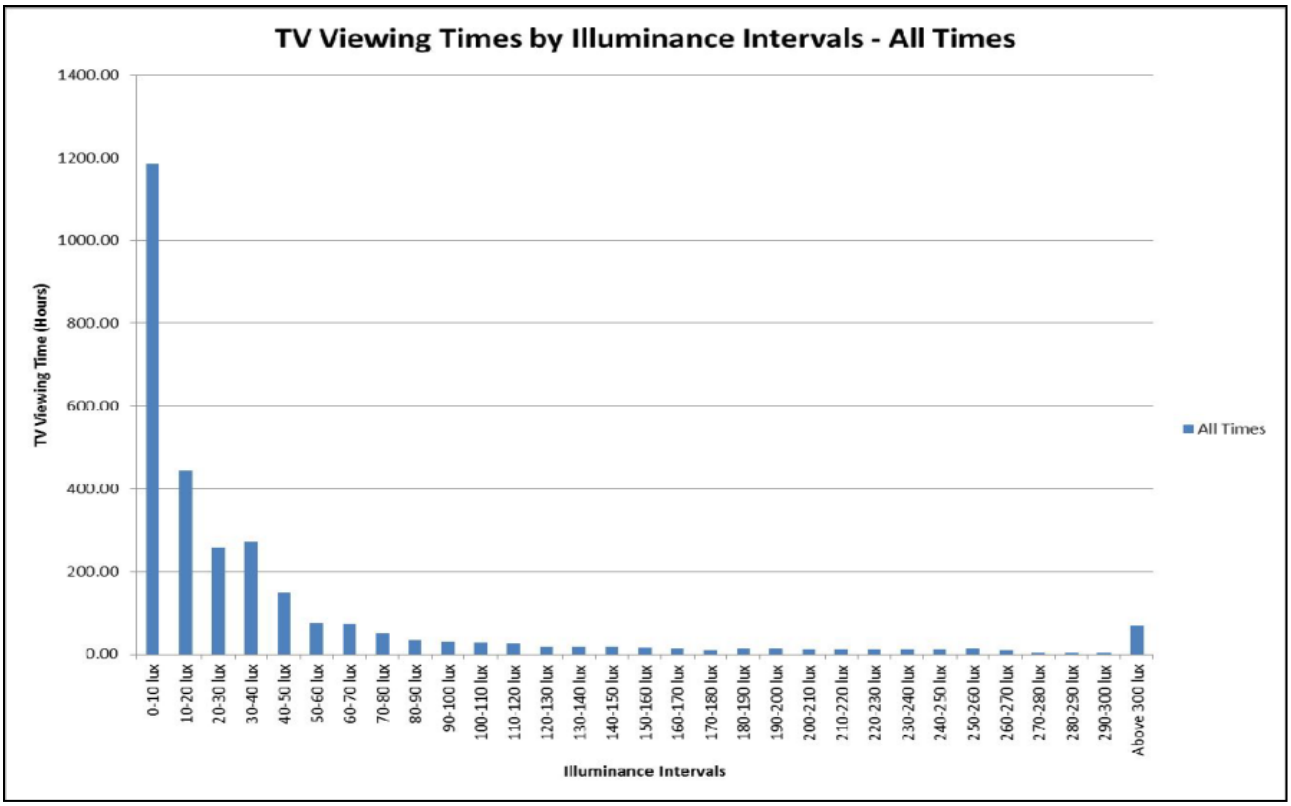
Figure 3: Illuminance Graphs for House 1



Illuminance Interval Graphs:

To visualize how often televisions were viewed at different background lighting levels, illuminance interval graphs were created (see Figure 4). These graphs depict the total number of hours televisions were viewed at different intervals of background lighting levels.

Figure 4: Illuminance Interval Graphs


TV Viewing Times by Illuminance Intervals - All Times
TV Viewing Time (Hours)
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
0-10 lux
10-20 lux
20-30 lux
30-40 lux
40-50 lux
50-60 lux
60-70 lux
70-80 lux
80-90 lux
90-100 lux
100-110 lux
110-120 lux
120-130 lux
130-140 lux
140-150 lux
150-160 lux
160-170 lux
170-180 lux
180-190 lux
190-200 lux
200-210 lux
210-220 lux
220-230 lux
230-240 lux
240-250 lux
250-260 lux
260-270 lux
270-280 lux
280-290 lux
290-300 lux
Above 300 lux
Illuminance Intervals
All Times

Television Viewing Room Sketch and Photos:

During installation of measurement equipment, photos were taken and sketches made of the rooms where the televisions are viewed. During analysis of the data, these photos and sketches were used to explain how the presence of windows and artificial light sources may impact measured room illuminance levels.

House 47 is a good example of using the room sketch and photos to explain measured illuminance levels. The daytime television viewing illuminance graph for House 47 shows Day 2 and Day 3 television viewing at significantly high illuminance levels (300 Lux and 250 Lux) between 14:00 and 16:00 and decreasing levels between 16:00 and 18:00 (see Figure 5). This can be explained by the presence of a window near the television where bright direct sunlight enters the room between 14:00 and 16:00 and dims as the sun sets between 16:00 and 18:00 (see Figure 6). The daytime illuminance graph also shows substantially lower illuminance levels on Day 6 and Day 7 between 14:00 and 16:00. This can be explained by photos of the room which show the blinds drawn on Day 6 and Day 7 to block direct sunlight (see Figure 7).

Figure 5: Daytime Illuminance Graph of Lighting Levels in the Room for House 47

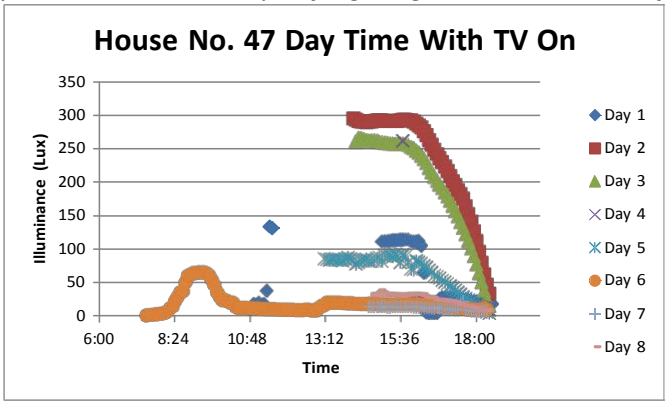


Figure 6: Room Sketch for House 47

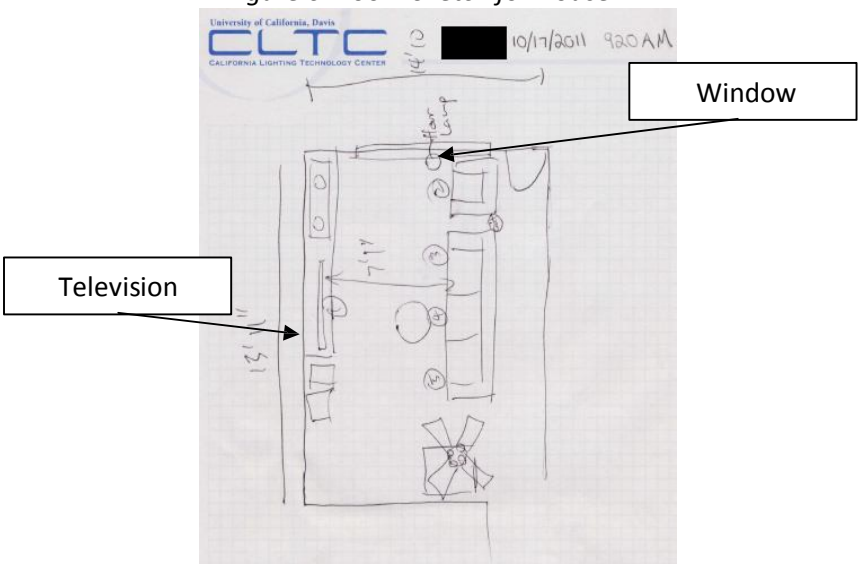


Figure 7: Television Viewing Room for House 47

Key Findings

Room Illuminance Profiles

Introduction:

To obtain a robust sample of room lighting conditions, this study monitored a variety of housing types in two metro areas. Analysis of data collected during this study indicates that almost all of the houses monitored can be categorized by a daytime and a nighttime room illuminance profile. Although this study had a small sample size, data consistently fit into one of three daytime profiles and one of two nighttime profiles suggesting that the results may be representative of houses in the Northeastern and Northwestern regions of the United States.

Daytime Room Illuminance Profiles:

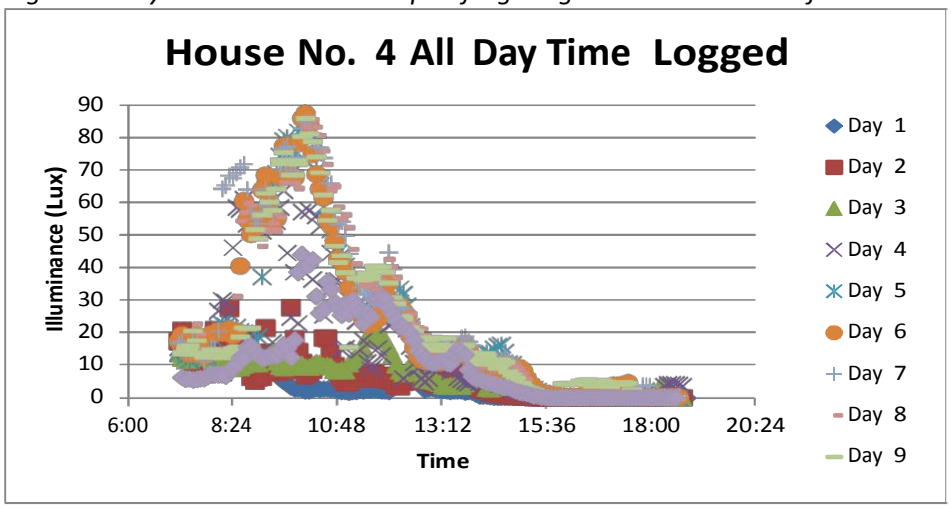
Room illuminance levels vary over the course of the day from relatively low levels below 50 Lux to very bright levels of 250 Lux or higher. A daytime room illuminance profile depends greatly upon the orientation of the windows in rooms where the televisions were located. The majority of homes (96%) can be categorized by one of three daytime illuminance profiles. These profiles describe the amount of light in the room where the television is located and not the light measured during actual television viewing. The background lighting levels during actual television viewing vary from home-to-home depending on the time of day at which the televisions are viewed. These profiles provide a representation of the type of lighting conditions in which televisions are typically viewed. Each profile is described below:

Profile 1: Early to mid-morning illuminance peaks

Room illuminance spikes in the morning then decreases until midday, and then the illuminance level stays relatively constant until sunset. This pattern can be explained by the presence of East or Southeast facing windows that allow the room to fill with light at sunrise and gradually

darken as the sun moves over the house and no longer shines directly through the windows. Twenty homes (37%) in the sample fit this profile. House 4 is typical of this profile (see Figure 8).

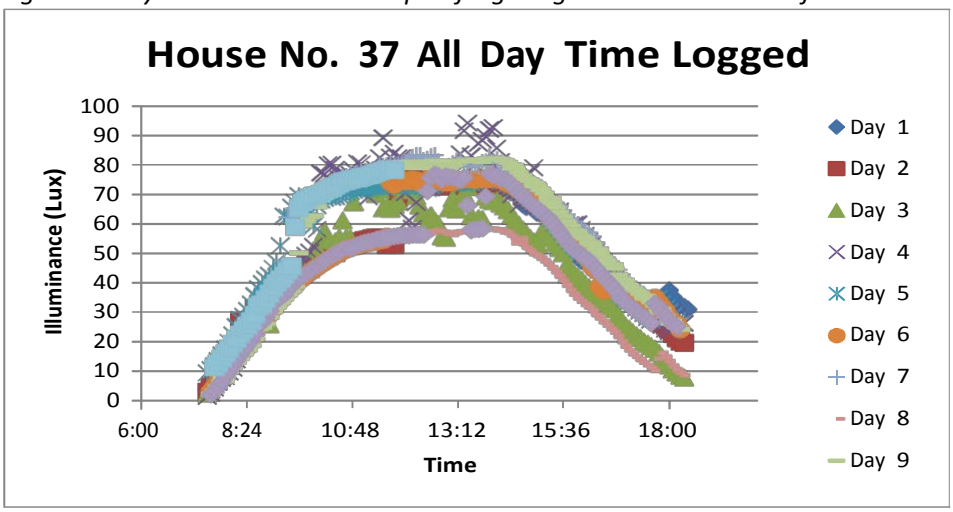
Figure 8: Daytime Illuminance Graph of Lighting Levels in the Room for House 4



Profile 2: Increasing brightness until the middle of the day followed by decreasing brightness into the afternoon

Room illuminance gradually increases until around midday, then the room gradually decreases in brightness. This pattern can be explained by the presence of a South facing window that allows the room to gradually fill with natural light as the sun rises and then darken as the sun sets. Twenty-two homes (41%) in the survey were characteristic of this profile. House 37 is typical of this profile (see Figure 9).

Figure 9: Daytime Illuminance Graph of Lighting Levels in the Room for House 37

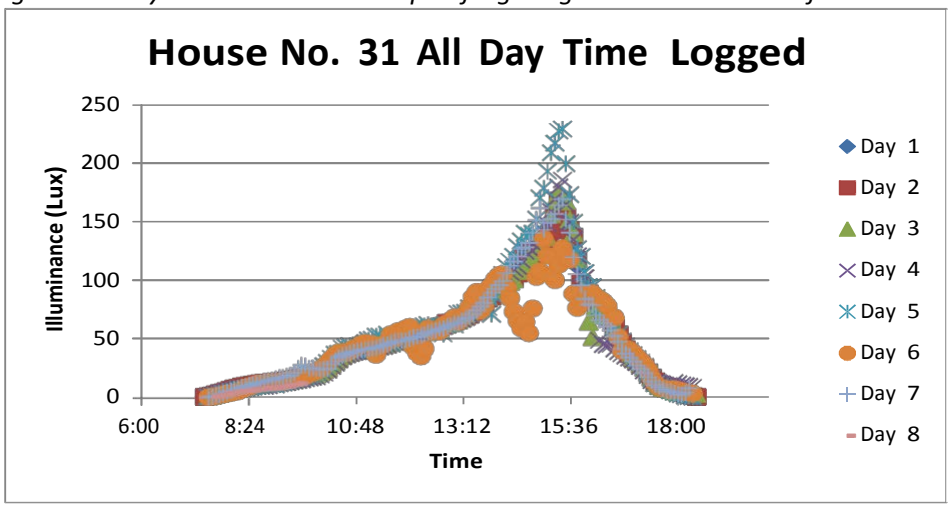


Profile 3: Lower light in the morning followed by an increase in brightness in the afternoon

Room illuminance is relatively low in the morning followed by an increase in brightness peaking in the afternoon and then decreasing until sunset. This pattern can be explained by the presence

of West or Southwest facing windows that allow the room to fill with natural light in the afternoon when the sun passes the window and then darken as the sun sets. Ten homes (19%) in the survey were characteristic of this profile. House 31 is typical of this profile (see Figure 10).

Figure 10: Daytime Illuminance Graph of Lighting Levels in the Room for House 31



A small number of houses in the sample did not fit any of the three profiles. Of the homes monitored, only two homes could not be categorized. They are homes 3 and 11.

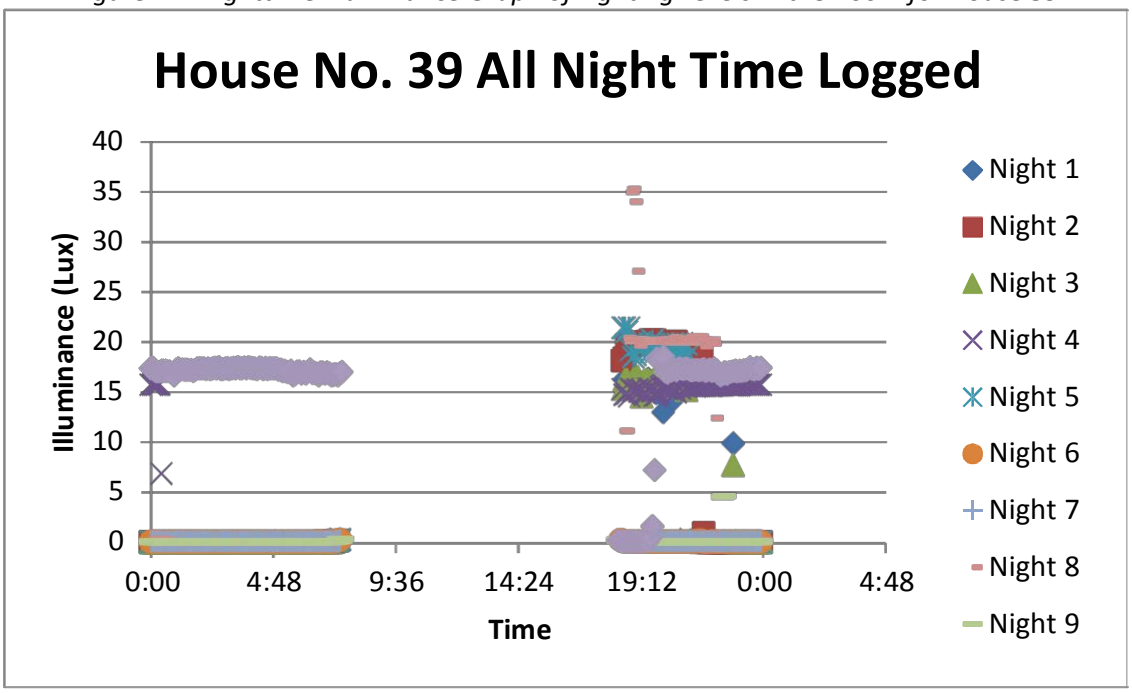
Nighttime Room Illuminance Profiles:

Room illuminance levels at night are lower than daytime room illuminance levels. Typical illuminance levels at night are 20 to 40 Lux. Unlike the daytime profiles, which are primarily dependent on natural light, nighttime profiles are dependent upon artificial lighting. As a result, illuminance levels do not decrease or increase over time but instead stay at consistent Lux levels for long intervals. 94% of homes monitored can be categorized by two room illuminance profiles. As explained before, these profiles describe the amount of light in the room where the television is located and not the light measured during actual television viewing. The background lighting levels during actual television viewing will vary from home-to-home. Both profiles are described below:

Profile 1: Consistent artificial light source

Room illuminance is recorded at only two levels. This pattern can be explained by either a single source of artificial light (e.g. one overhead light) or a consistent combination of sources (e.g. two overhead lights on the same light switch). When the artificial light source is turned on the room illuminance is at one consistent level and when the artificial light source is turned off the room illuminance is measured at another level, typically near 0 Lux. Eighteen homes (33%) in the sample were characterized by this profile. House 39 is typical of this profile (see Figure 11).

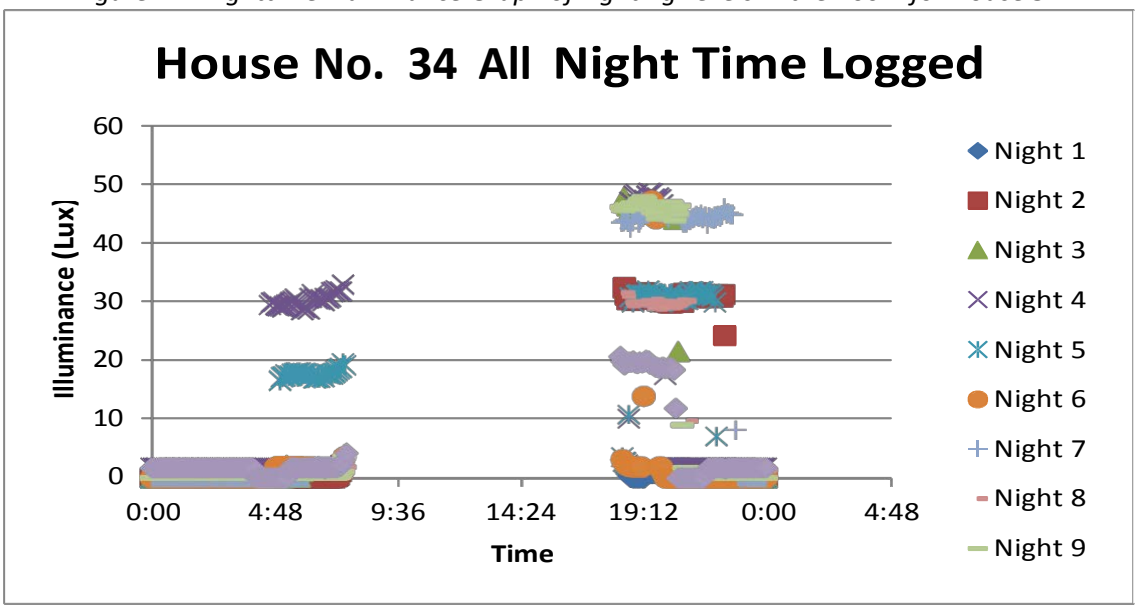
Figure 11: Nighttime Illuminance Graph of Lighting Levels in the Room for House 39



Profile 2: Variations in sources of artificial light

Room illuminance varies at multiple distinct levels for sustained periods of time. This pattern can be explained by the presence of multiple artificial light sources that are used intermittently during the course of the night. Thirty-three homes (61%) in the sample were characterized by this profile. House 34 is typical of this profile (see Figure 12).

Figure 12: Nighttime Illuminance Graph of Lighting Levels in the Room for House 34



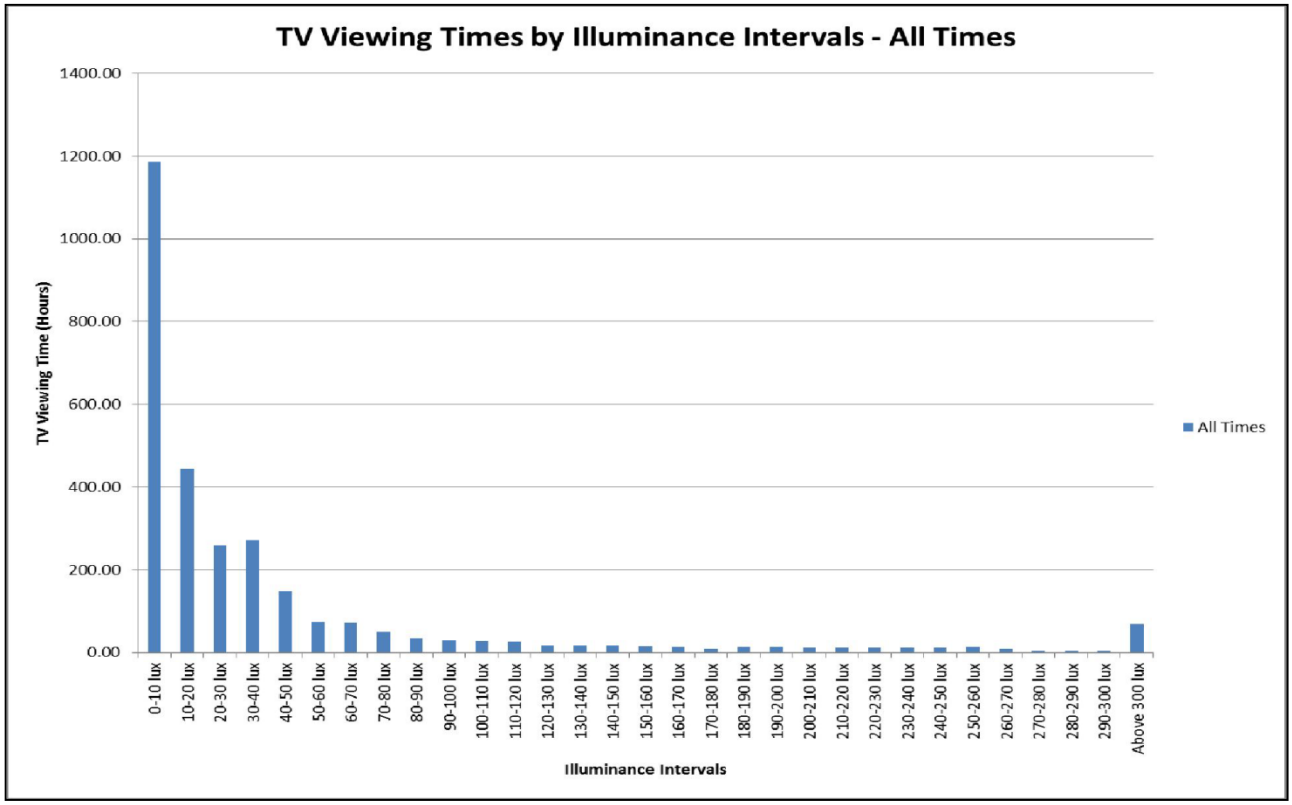
A small number of homes in the sample did not fit into either profile. Of the homes monitored, only three homes could not be categorized. They are homes 25, 27, and 29.

Background Illuminance During Television Viewing

Introduction:

To determine background lighting levels during television viewing, both background lighting levels and television energy consumption were monitored continuously at 5-minute intervals over a 7-day time period. Continuous measurement resulted in a more complete assessment of background lighting conditions during television viewing periods. Measuring devices were synced so that background lighting measurements could be matched with television viewing times. Analysis of the results indicated that daytime television viewing occurs at higher luminance levels than nighttime television viewing. Cumulatively (both daytime and nighttime), a majority of television viewing (89%) occurs between 0 Lux and 100 Lux (see Figure 13).

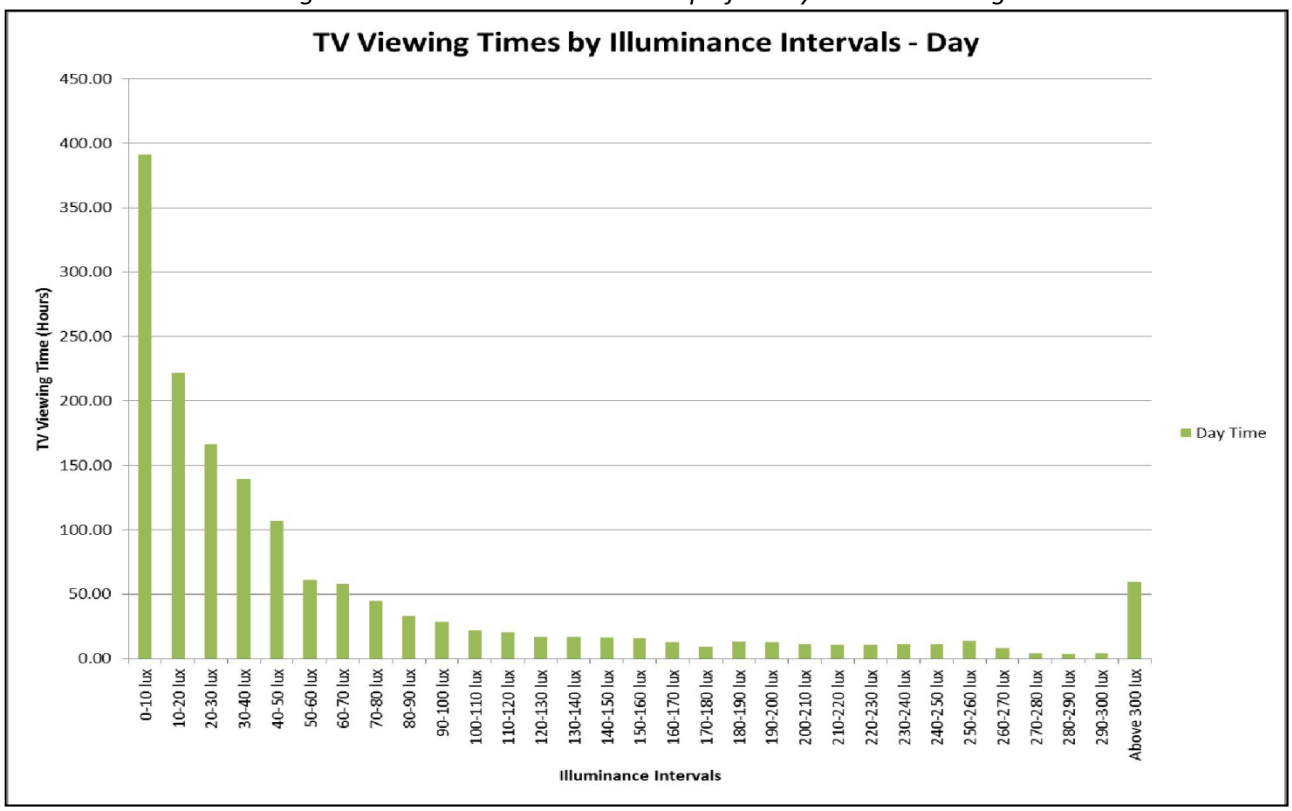
Figure 13: Illuminance Interval Graph for Daytime and Nighttime TV Viewing Combined



Daytime Television Viewing:

A majority (80%) of daytime television viewing occurred between 0 Lux and 100 Lux, with 20% of television viewing occurring above 100 Lux (see Figure 14). Half of television viewing occurred at illumination levels at or below 30 Lux.

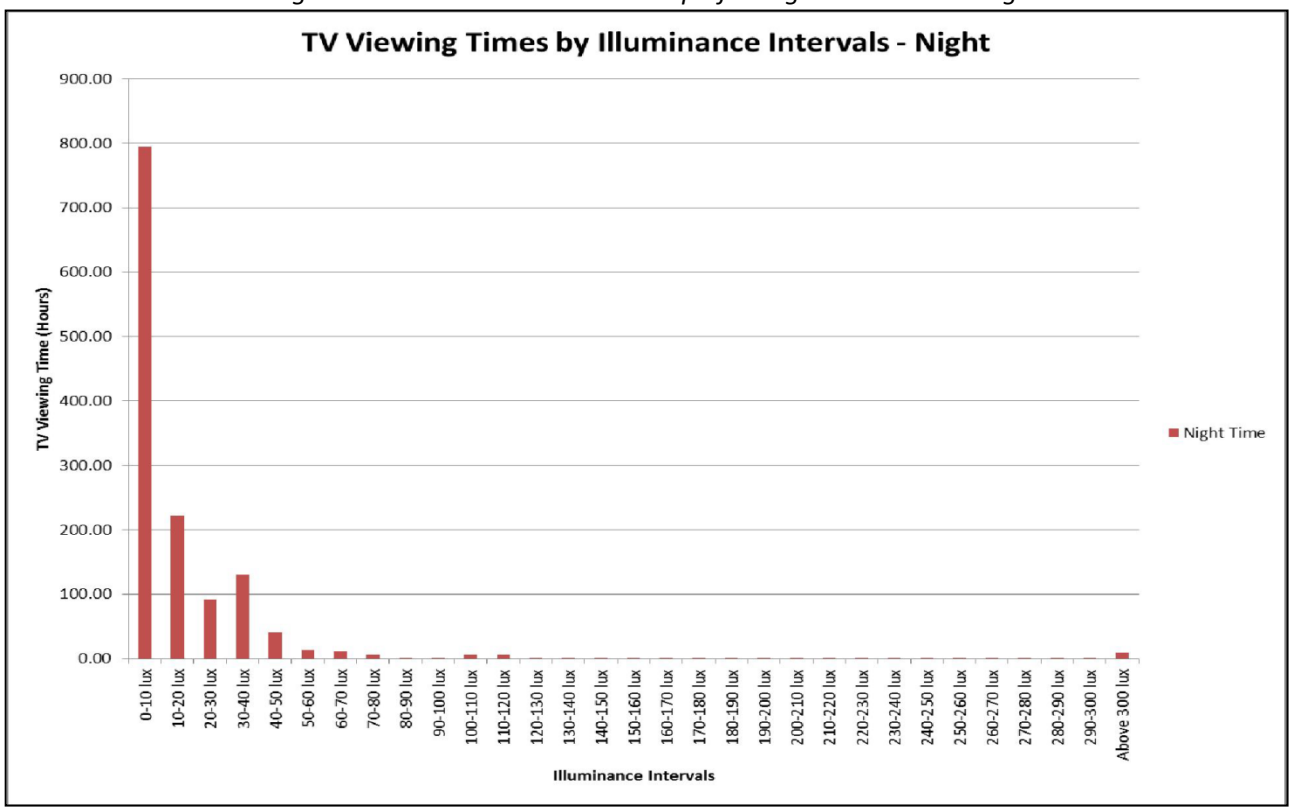
Figure 14: Illuminance Interval Graph for Daytime TV Viewing



Nighttime Television Viewing:

A majority (82%) of nighttime television viewing occurred between 0 Lux and 30 Lux, with some television viewing (13%) occurring between 30 and 50 Lux (see Figure 15). There is very little television viewing at background light levels above 50 Lux.

Figure 15: Illuminance Interval Graph for Nighttime TV Viewing



Assessment of ENERGY STAR Test Points:

The current ENERGY STAR test procedure for televisions specifies measurements of television energy consumption at 0 Lux and 300 Lux. An assessment of background lighting levels during daytime and nighttime television viewing indicates that there is an insignificant amount of television viewing at 0 Lux and at 300 Lux. Only a fraction of a percent of television viewing time occurs at 0 Lux and less than 4% occurs at 300 Lux or above (See Appendix C for a table of background lighting levels during daytime, nighttime, and cumulative television viewing.)

Daytime and Nighttime Television Viewing:

The study found that more television viewing occurred during the day than occurred at night; 54% of television viewing occurred during the day, while 46% of television viewing occurred at night (see Figure 16). Additional regional differences in daytime and nighttime television viewing were found; there was more television viewing in the Washington, D.C. metro area than the Sacramento, CA metro area. There was also more daytime viewing in the Washington D.C. metro area and nighttime viewing in the Sacramento, C.A. metro area.

Figure 16: Daytime and Nighttime Viewing Hours

City	Daytime Viewing Hours	Nighttime Viewing Hours
Washington	951	615
Sacramento	662	747
Total	1613	1362

Recommendations

Based on the analysis of background lighting levels during television viewing in sixty homes over a 7-day time period, CLASP makes the following recommendations:

1. **The 0 Lux and 300 Lux test points specified in the ENERGY STAR test procedure should not be used to measure television energy consumption with the ABC feature enabled because they do not represent actual background lighting levels during television viewing.**

   A majority of television viewing occurs at background illuminance levels between 0 Lux and 100 Lux. There are very few instances of television viewing at background lighting levels of 0 Lux and significant television viewing around the 10 Lux level. The data suggest that the ABC test procedure should be revised to more accurately represent background lighting levels at which televisions are viewed.

2. **Three new test points should be used to measure television energy consumption with the ABC feature enabled to ensure a more accurate measurement of the television's energy performance.**

   Previous testing indicated that some televisions with the ABC feature engaged consumed significant energy at a background lighting level of 50 Lux and above. These same televisions exhibited a sharp decreased in energy consumption at some point between 10 Lux and 50 Lux. The ABC feature is intended to dim the screen gradually to reduce energy consumption when the television is viewed in lower background illuminance conditions. In order to ensure that the ABC feature is managing television energy consumption in a way that meets expectations, an improved test method is needed. Measuring ABC effects at three test points will allow policy-makers to promote a gradual reduction in energy consumption and ensure a more accurate measurement of the television's energy performance.

3. **The three test points should be specified between the illuminance levels of 10 Lux and 100 Lux so that they represent actual background lighting levels during television viewing.**

   A majority of television viewing occurs at background lighting levels between 2.5 Lux and 100 Lux, with almost no television viewing at 0 Lux and significant viewing around 10 Lux. Specifying test points between 10 Lux and 100 Lux will capture the full range of background lighting levels at which televisions are viewed, while ensuring that each test point corresponds to typical viewing conditions.

4. **Further analysis is needed to determine if differences in the amount of time televisions are viewed during the daytime verses the nighttime has a material impact on television energy consumption with the ABC feature enabled.**

   Analysis of collected data shows a difference in the amount of time televisions are viewed during the daytime verses the nighttime; about 8% more television viewing occurs during the day than occurs at night. Further analysis is needed to determine if this difference has a material impact on television energy consumption and should be considered during a revision to the television test procedure.

5. **In order to further improve our understanding of background lighting levels, additional data collection is recommended including data collection in regions outside of the United States**

   Despite the sample size used for this study, the consistency between results for the majority of houses suggests that the results may be representative of houses in the Northeastern and Northwestern regions of the United States. Based on the data gathered and analyzed in this study, further generalization is difficult. To develop a better understanding of background lighting levels and to ascertain whether the consistency of results truly represents the typical house requires further data collection. Additionally, CLASP recommends that future data collection efforts include regions outside of the United States as a means of capturing regional differences in background lighting levels.

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