Development of an ENERGY STAR Program for Seasonal Decorative Light Strings

Second Stakeholder Meeting Summary Report Toronto, Ontario; June 27, 2006

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Natural Resources Canada

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1.0 Introduction

Natural Resources Canada (NRCan) continues its work to develop an ENERGY STAR test procedure and qualification criteria for seasonal decorative light strings. Compared to incandescent decorative light strings, other technologies, such as light emitting diodes (LED), offer energy savings, lower energy consumption during peak hours, longer operating life, high durability, and reasonable payback on the initial investment.

Building on the progress from a one-day stakeholder meeting on this same subject in March 2006, NRCan convened a series of technical committee conference calls to discuss critical issues raised at the March workshop, and revise the draft test procedure and qualification criteria. This second meeting re-convened the stakeholders from the March 2006 workshop to review the revised document and discuss next steps. Approximately twenty-five manufacturers, retailers, and government and utility representatives attended and participated in the review of the draft ENERGY STAR qualification criteria and test procedure. The list of workshop attendees below includes both people who participated in person in Toronto and who phoned-in.

Steven Altamura, Seasonal Specialties LLC
Jenny Flores, Pacific Gas and Electric Company
Bob Goldschleger, Universal Lites
Isabelle Guimont, Energy Star/NRCan
Nina Gupta, GREENLITE Lighting Corporation
Gary Hamer, BC Hydro
Ryan Hannink, Navigant Consulting, Inc.
John Hayes, Holiday Creations
Jose Luis Hernandez, Canadian Standards Association
Kerry House, Home Hardware
John Kiru, TABIA
Pierrette LeBlanc, NRCan
Joe Lincoln, Everstar Merchandise
Ted Marlow, Marlow & Associates
Conan O'Rourke, LRC
Brian Owen, FIRSTeam - LEDesignWorks
Charles Parker, Carillon Decorative Products Inc
Jim Ruxton, Pharos Innovations
Rachel Schmeltz, EPA Energy Star
Michael Scholand, Navigant Consulting, Inc.
Anthony Tassone, Underwriters Laboratories
Wayne Tucker, Classic Displays
Michael Vladimer, Navigant Consulting, Inc.
Jerry Yu, LEDUP

This report summarizes the workshop, providing copies of the workshop presentations, the draft documents reviewed and a summary of the discussions.

2.0 Workshop Materials

The purpose of this meeting was to reconvene the stakeholders from the March 2006 workshop to discuss and review the draft revised test procedure and qualification criteria that the technical committee had been developing. The workshop agenda was designed around a careful review of language in each of the critical sections of the two documents, to enable discussion on the draft proposal.

2.1. Workshop Agenda

ENERGY STAR® Program Requirements for
Decorative Light Strings

Second Plenary Meeting
Doubletree International Plaza Hotel
655 Dixon Rd, Toronto, M9W 1J3

June 27, 2006

8:30-9:00	Registration
9:00-9:15	Welcome and Overview of Progress to Date Pierrette LeBlanc – Natural Resources Canada
9:15-9:30	Introductions and Opening Statements Michael Scholand – Navigant Consulting, Inc.
9:30-10:00	Overview of Seasonal Decorative Light String Market Michael Vladimer – Navigant Consulting, Inc.
10:00-10:15	COFFEE BREAK
10:15-11:00	Test Procedure and Eligibility Criteria: Overview, Inspection and Power Test, Over-Voltage Test Michael Scholand – Navigant Consulting, Inc.
11:00-11:20	Test Procedure and Eligibility Criteria: Lifetime Test Conan O'Rourke – Lighting Research Center Michael Scholand – Navigant Consulting, Inc.
11:20-12:00	Test Procedure and Eligibility Criteria: Lamp Intensity Test Conan O'Rourke – Lighting Research Center Michael Scholand – Navigant Consulting, Inc.

12:00-1:00 LUNCH

1:00-1:45 Test Procedure and Eligibility Criteria: Accelerated Weathering Test
Gary Hamer – British Columbia Hydro
Michael Scholand – Navigant Consulting, Inc.

1:45-2:30 Test Procedure and Eligibility Criteria: Review of Documents
Michael Scholand – Navigant Consulting, Inc.

2:30-2:45 COFFEE BREAK

2:45-4:00 Final Discussion Points and Next Steps

4:00 ADJOURN

2.2. Documents Distributed at the Workshop

This workshop was convened to discuss a draft test procedure and qualification criteria (version 1.1.1 of both documents). Following on from a decision at the March 2006 workshop, a technical subcommittee was formed (all participants were volunteers) to discuss the test procedure and qualification criteria in a series of weekly conference calls. The output from this process was to be revised versions of both documents, which would then be reviewed by the second plenary meeting of all the participating stakeholders.

Due to vacation schedules and other conflicts, not all members of the technical committee were able to participate in every call over the intervening period between the March and June workshops. Therefore, the draft documents presented in the appendix to this report should not be seen as consensus products from the technical committee. Rather, they are drafts that were developed in a tight timeframe to enable discussion and evolution of the concepts. The sections of the draft documents that are highlighted in yellow indicate those parts of the documents that may be considered particularly controversial and subject to review.

In the appendix to this report, all the hand-outs provided at the workshop are included:

A. ENERGY STAR® Program Requirements for Decorative Light Strings Test Procedure, Draft Version 1.1.1
B. ENERGY STAR® Program Requirements for Decorative Light Strings Eligibility Criteria, Draft Version 1.1.1
C. ENERGY STAR® Program Requirements for Decorative Light Strings Master Presentation from the Workshop
D. BC Hydro Proposed ENERGY STAR® Testing Criteria Workshop Presentation

One of the critical outcomes from this workshop was a decision to conduct testing of samples of decorative light strings to determine if the tests being considered are appropriate, and if the

durations / requirements of those tests need to be modified. In response to this request, NRCan worked with the technical committee in the weeks following the workshop to both revise the ENERGY STAR® Program Requirements for Decorative Light Strings (creating version 1.2) and develop a test protocol which would provide data from which to make decisions on the test procedure and program requirements.

3.0 Workshop Discussion and Decisions

This section of the report summarizes the workshop discussion and identifies the main issues that were raised and discussed at the workshop. As stated earlier in this report, the workshop was primarily structured around a review of the draft test procedure and qualification criteria for ENERGY STAR. The workshop did however include a discussion on patent issues as they relate to the ENERGY STAR program and a brief market assessment presentation.

3.1. Patent Issues

A stakeholder expressed concern to NRCan about the requirements contained in draft version 1.1 of the qualification criteria for ENERGY STAR. Some of the requirements in the previous draft were patented or had patents pending. NRCan spent some time at the start of the workshop to assure stakeholders that ENERGY STAR does not knowingly set requirements for qualification that are patented or have patents pending. When this issue was brought to NRCan's attention, immediate action was taken - the criteria in question were discussed on the next technical committee conference call and NRCan issued a letter which clearly stated the objectives of this initiative and that no qualification criteria would knowingly be included that involved patented technology. A copy of the letter appears below.

TO: Members of the Committee for the Development of ENERGY STAR Criteria for Decorative Light Strings
DATE: June 19, 2006

Dear Members:

In recent days, there has been communications amongst members regarding patent and intellectual property issues on decorative light string products sold in Canada. Clearly, this is a concern for some of you and Natural Resources Canada (NRCan) would like to respond.

As stated in the workshop meeting held in March 2006, the ENERGY STAR program is based on certain principals (Environmental Protection Agency's (EPA) website at: http://www.energystar.gov/index.cfm?c=prod_development.prod_development_index)
In order to qualify a product category to the ENERGY STAR program, we need to establish that:

> *"Energy efficiency can be achieved with several technology options, at least one of which is non-proprietary"*

This being said, there cannot be a "proprietary" hold on product categories within an ENERGY STAR program that would give a manufacturer sole access to qualify to the criteria established by the committee.

The criteria and performance specifications for a category of product is developed through the consensus process and it is expected that participants will take these issues seriously and collaborate with program requirements voluntarily if required. If the process we are currently undergoing does not satisfy the principal of non-proprietary technology, **the program for**

decorative light strings would be suspended and reviewed. This would be a very unfortunate outcome that we want to avoid, and I am sure you do too.

At the present time NRCan and EPA are looking into this matter carefully. In the meantime, we'll continue business as usual.

Sincerely,
Pierrette LeBlanc
Standards Engineer
Natural Resources Canada

3.2. Market Assessment

Navigant Consulting gave an overview presentation on some initial findings from a Market Assessment in Canada on seasonal decorative light strings. The slides from this briefing presentation can be found in the Appendix of this report. The presentation had four sections – 1) Market Overview, 2) Value Proposition for Consumers, 3) Product Quality Issues and 4) Product Lifetime.

3.2.1. Market Overview

While the market assessment is not yet complete, eleven manufacturers of seasonal decorative light strings that incorporate light emitting diode (LED) technology were mentioned in the overview: 3H & Co.; AVH Supply, Inc.; Blachere Illumination; Bortex Industry Company, Ltd.; Congolm, Inc.; Holiday Creations; LEDUp; LUXLITE; Mobiltech; NOMA and Pharos Innovations, Inc. The market assessment, which included interviews with representatives from many of these companies, found that decorative LED light strings are distributed through three main channels – retail chains, on-line sales, and electrical wholesalers (primarily for the commercial sector).

During the interviews, manufacturers identified the broad range of products that are commercially available today that incorporate energy-efficient LED lamp technology. Figure 1 below shows many of these shapes, and they are manufactured in a variety of colours. Some of the colours offered include: purple, blue, green yellow, gold, orange, red, white and multi-coloured strings. This matrix of lamp shapes and colours leads to a very large number of catalogue models that would otherwise need to be qualified for ENERGY STAR. This issue – the burden of manufacturers – was raised at the workshop later in the day as well, and is the subject of on-going study.

Figure 1. Decorative LED light strings come in a wide variety of shapes and colours.

3.2.2. Value Proposition for Customers

A cursory review of retail prices found that LED light string prices vary with colour, but generally, LED light strings are approximately 2 to 8 times more expensive than mini-incandescent light strings. This price premium was identified by those interviewed as the primary barrier to more broad market adoption of this technology.

To overcome the affordability barrier, electric utilities in Canada and the United States have sponsored two different types of market transformation programs – exchanges/rebates and large pilot projects. Several utilities were identified that do exchanges, whereby customers who bring in a string of incandescent lights are given a string of LED lights. Additionally, there is one utility which provides a $4 instant rebate coupon towards the purchase of a seasonal LED light string. Concerning the large-scale pilot projects, one utility was identified which was working with their local municipality to cover half the cost of those holiday displays that incorporated LED lights. Other utilities were identified which donated LED light strings for large lighting projects.

A review of the industry literature was conducted, and the major points highlighted as the unique selling points or value proposition for decorative LED strings were identified as follows:

- Brighter colour, will not fade
- Energy saving – up to 90%
- Indoor/Outdoor use
- Rugged, no glass to break
- Cool to the touch
- Lower risk of fire or shock
- Stackable or end-to-end
- Easy and flexible installation
- 200,000 hour lamps

- Guaranteed, UL listed
- Advanced technology

In conducting the market assessment, stakeholders were asked about typical residential sector applications. The main applications identified relate to the holiday season (December / January), and center around the decoration of trees, houses and entryways. Lights are typically operated 30 to 45 days per year for 6 to 8 hours per day. A secondary application was identified as ambiance decoration of patios and decks during the summer months, where lights would typically operate 45 to 90 days per year for 4 to 5 hours per day.

In the commercial sector, the primary applications are related to holiday displays at commercial establishments (which includes retail and office establishments). Concentrated in the December / January time-frame, decorative strings of LED lamps are typically operated 45 to 60 days per year for 6 to 12 hours per day. Secondary applications relate to non-seasonal decorative lighting (e.g., white mini-lights in ficus trees in shopping malls). These installations typically operate year-round (365 days per year) for the duration the establishment is open (12 hours per day).

The experts interviewed indicated that when making a purchasing decision about decorative light strings, the primary considerations are generally purchase price (dominant consideration, particularly for residential sector), energy-efficiency (particularly in Canada), product durability and long operating lifetime, and technological edge (new product designs / fads). Another, lesser consideration mentioned by the experts, was brightness of the lamps themselves.

3.2.3. Product Quality Issues

Decorative LED light stings, like decorative incandescent light strings, are subject to the same safety requirements of CSA / UL. These requirements are: Canadian Standards Association CSA-22.2 No.37-M1989 (R2004) Christmas Tree and Other Decorative Lighting Outfits and Underwriters Laboratories UL 588-2004, Standard for Seasonal and Holiday Decorative Products.

LED light strings have been questioned in the past whether they are sufficiently bright for decorative purposes. Those experts interviewed felt that LEDs are sufficiently bright for the applications where they are used, even though some lamp shapes have lower light emission than incandescent lights. The majority of consumers use light strings for decoration only and are generally satisfied with brightness.

With respect to colour, LED lights have stronger colours than incandescent lights. White LEDs can have a blue tint (high CCT), which can draw some complaints, as consumers are used to incandescent white (“warm white”, CCT ~2800 K). Colour consistency has improved in recent years, with better colour binning techniques (sorting lamps into groups of similar light colour).

The issue of patented technology was raised here as well, as certain aspects of LED technology in decorative light strings are patented, and therefore could not be a criterion for ENERGY STAR program qualification. Patents were identified for “keyed” lamp-holders to prevent installing lamps backward, polarized plugs and end-connectors and AC-powered LED light strings without a transformer. Pending patents were identified for strings with one or more series

blocks must be connected in opposite polarity to reduce THD and a lamp-holder that is moulded to the LED lamp / decorative cover. These are all issues that must be kept in mind when establishing the ENERGY STAR qualification criteria.

3.2.4. Product Lifetime

All stakeholders at the workshop, and those interviewed for the market assessment, agreed that the LED lights in decorative light strings will have a much longer lifetime than the lifetime of the light string as a whole. For the market assessment, a calculation was performed which found that at the end of the typical useful life of an LED light string (3 to 7 years), the LED lamps themselves have only utilized 5% of their estimated life. This estimate was based on an assumption that the LED string is used 45 days per year and 8 hours per day, where LED light lifetime in decorative light strings range from around 20,000 to 50,000 hours – 20 times longer. The wiring harness is was frequently cited as the factor most likely to cause failure of the string, particularly with aging and environmental exposure.

Case studies found that the product lifetime of LED light strings compares favourably to incandescent light strings. Return rates for LED light strings are at or below those for incandescent light strings - generally less than a 2% return rate for LED light strings (compared to a 3% return rate for incandescent light strings), as cited by manufacturers, distributors, and retailers. For utilities interviewed, there was less than a 0.1% return rate reported by utilities / municipalities that conduct light string exchanges (11 sets returned out of 21,100 sets distributed for three different utilities / municipalities).

There was, however, a large recall of a certain type of decorative LED light string in 2005 increased the overall return rates involving the recalled product. The strings were recalled because the product posed a shock and fire hazard due to a manufacturing defect that could lead to overheating and melting. A second highly visible problem with lifetime occurred at a recent Niagara Falls Winter Festival of Lights installation. At this project, the municipality experienced significantly higher failure rates than other installations. The problems at the Winter Festival were attributed to water mist from the falls and power spikes.

3.3. Overview, Inspection and Power Test, Over-Voltage Test

The slides accompanying this presentation / discussion can be found in the appendix of this report. This section focused on two tests that were in the Test Procedure – the Inspection and Power Test and the Over-Voltage Test.

This section started by reviewing four definitions that were pertinent to these two tests – Decorative Light String, Series Block, Input Power and Maximum Watts per Lamp. The workshop participants reviewed the definition for a *decorative light string,* and had no modifications at this time, so the definition was not changed. The workshop participants felt that the *series block* definition numbers in example statement “a 50-lamp light string could have two 25-lamp series blocks connected in parallel” should be changed from 50 and 25 to 70 and 35, as that was felt to be more common for these light strings. All other parts of the definition were unchanged. The participants felt that the definition of *input power* needed clarification only for powe adaptors that can accommodate multiple strings of lamps. Thus, a sentence was appended

to the end of the definition that reads: "For power adaptors that can accommodate multiple strings, the input power shall be measured with the rated maximum number of strings attached." Finally, for the term maximum watts per lamp, the stakeholders had two modifications. First, they did not believe the word 'maximum' was necessary, as the procedure will calculate the actual watts per lamp, irrespective of whether it's a maximum or not. Second, the participants wanted clarification on how watts per lamp might apply to adaptors that could accommodate multiple strings. Therefore, a parenthetical statement was added to the definition that reads; "(or strings, in the case of power adaptors that can accommodate multiple strings). The final versions of the definitions for these terms can be found in version 1.2 of the draft test procedure and eligibility criteria, published after the workshop.

The technical references in both the test procedure and eligibility criteria were reviewed and approved by the group. In addition to these, two other reference documents were identified and have now been added to draft version 1.2. These two references are:

- Commission Internationale de l'Eclairage CIE 127-1997, Measurement of LEDs

- Illuminating Engineering Society of North America IESNA TM-16-05, IESNA Technical Memorandum on Light Emitting Diode (LED) Sources and Systems

For the Inspection and Power Test, the following changes were made to the requirements:

- Modify 'count lamps per string' to 'count lamps per string and ensure this is consistent with the packaging label'.

- Merge the requirements to 'check lamps type: sealed or plug-in. If plug-in, the socket/lamp must have a marking or polarizing socket to enable correct insertion of replacement lamps' with 'check that plug-in diodes, resistors, etc. cannot be incorrectly swapped with spare lamps.' Modify language to remove 'polarizing socket', as polarized refers to plugs intended for a wall socket, not the small socket in which a decorative lamp is inserted.

- Modify the power measurement test to clarify what's being measured and account for power adaptors that can accommodate multiple light strings. Previously, the document simply said "Measure power and current at 120 volts ±2% RMS AC. Calculate the power per lamp." In the revised draft, the paragraph reads: "Measure input power and current at 120 volts ± 2% RMS AC. For systems with power adaptors that can accommodate multiple light strings, the input power should be measured with the rated maximum number of strings attached. Calculate the input power consumed per lamp operated. The input power consumption per lamp should not exceed 0.1 watts." This final requirement – not to exceed 0.1 watts – is subject to change, but is used in version 1.2 as a placeholder.

- Add a requirement that if lamp lifetime is stated on the packaging, the claim should be 25,000 hours or more.

- Add a requirement that before any testing begins, the decorative light string is operated for a 24 hour "seasoning" period. The duration of the seasoning period is subject to change, based on the findings of the tests being conducted at the Lighting Research Center on actual samples of decorative light strings.

An issue was also raised with respect to how to define a light set or a lamp as inoperative. In the draft version 1.1.1 of the test procedure, inoperative was defined as "…a voltage drop of >60 volts or < 0.5 volts RMS AC across any one lamp." This issue was discussed in the plenary session, and then it was decided that this issue would be better decided by the technical committee with a proposal brought back to the plenary session at the next meeting.

3.4. Lifetime Test

The slides accompanying this presentation / discussion can be found in the appendix of this report. Conan O'Rourke of the Lighting Research Center initiated discussion of this session, by reviewing a proposal of a possible lifetime test for decorative light strings. This test involves assembling the string into a testing bundle, conducting an initial light measurement in an integrating sphere, operating the lamps for 1000 hours and conducting a second light output measurement. This proposal was generally well received by the participants, who rightly noted that 1000 hours of operation represents approximately four holiday seasons of regular usage by consumers (residential sector). Thus, sustaining good light output over this time period is important.

The group briefly discussed what the maximum acceptable percentage degradation in light output and number of failed lamps should be in order to qualify for ENERGY STAR, but then decided this issue would be better to discuss once an initial round of testing was completed on samples of decorative light strings. Therefore, the placeholder values were removed with the understanding that the plenary group will decide these levels at the next plenary meeting, when test data is available for review.

3.5. Lamp Intensity Test

The slides accompanying this presentation / discussion can be found in the appendix of this report. This section was also initiated by Conan O'Rourke of the Lighting Research Center, as he presented an overview of light and light intensity measurements. The language in the draft test procedure document version 1.1.1 which is shown in the slides was not reviewed by all members of the technical committee. Due to travel schedules and conflicts, not all participants were available for the final conference call when much of the approach for the lamp intensity test was developed. For this reason, all the text associated with the intensity test was highlighted in yellow, to signify that this test might be controversial and did not reflect a consensus view point of the technical committee.

A discussion ensued on the value of lamp intensity, and how the measurement of specific points of light emission may not be appropriate for all lamp shapes, particularly festive new shapes such as pumpkins, snowmen and so-on. Concern was expressed about the cost of these measurements, both in labour and equipment cost. Concern was also expressed in the level of

rigor being assigned to measuring light intensity of a product that is not related to safety and has no safety applications or requirements. Discussion around what should be the appropriate level of intensity, given that the viewing angle for a consumer can vary substantially in the diversity of field applications.

Ultimately, through the discussion, the group reached a consensus that this test was not a critical test to conduct at this time, and the issue of lamp intensity was one that would be left to the discretionary eye of the end-user. Manufacturers firmly believe that if consumers to not find the decorative light strings to be sufficiently bright, they will be returned.

3.6. Accelerated Weathering Test

The slides accompanying this presentation / discussion can be found in the appendix of this report. This section was initiated by Gary Hamer of BC Hydro, who developed the test procedure for the BC Hydro market transformation program for decorative seasonal light strings. Gary's presentation centered on discussion of the accelerated weathering test, which is conducted with the assistance of an ASTM G154-05 testing chamber. His presentation contained photos and he gave a detailed explanation of the process and what they had done a few years ago when testing products for his program.

The group agreed that the accelerated weathering test was pertinent, and should remain in the test procedure and qualification criteria documents. A change was noted that the document should only require this test for decorative strings that are labelled for outdoor use only. In other words, those strings labelled for indoor use could qualify for ENERGY STAR without having to be subjected to the accelerated weathering test.

There existed uncertainty around how many cycles of the ASTM accelerated weathering test (Cycle 7 of Table X2.1 in ASTM G154-05) the strings should be subjected to, and what amount of accelerated weathering that would represent in the real world. It was decided by the group that there should be some testing of actual product, initially for 10 consecutive iterations and then a review of the impact both on light output and failed lamps should be made. This testing is now being conducted by BC Hydro, and the results will be presented at the next meeting.

3.7. Review of Documents

This final session of the workshop provided an opportunity for stakeholders to review other sections of the test procedure and eligibility criteria documents. These sections did not relate to a test or particular eligibility criteria, but included discussion on the inclusion of an acknowledgements section, an overview / purpose statement at the start of the document, and requirements for safety, warranty, packaging, testing requirements, effective date and the possibility of revising the procedure in the future. In general, there were not many significant changes to these sections, as most of them were based on boilerplate language from other ENERGY STAR documents. A decision was made, however, to remove the acknowledgements section of the document, as when adopted, the document is meant to represent broad consensus support for the ENERGY STAR program established.

3.8. Remaining Issues / Next Steps

The following is a list of some of the issues and unresolved items that were raised by the workshop participants and will continue to be studied in the coming months.

1. Ensure that all requirements are not patented or subject to any patent pending. All participants working on the development of the test procedure and qualification criteria will strive to ensure that none of the eligibility requirements are patented or have a patent pending.

2. The technical committee will continue to work on the definition of a failed LED lamp. This issue, while seemingly simple, actually requires careful development of a clear method by which technicians who are conducting the test can determine whether an LED lamp or series block has failed.

3. Conduct testing – inspection and power test, over-voltage test, lifetime test and accelerated weathering test – on actual decorative seasonal light strings. These actual tests will assist both in refining the test procedure requirements for these four tests, and in developing appropriate qualification criteria for participation in the ENERGY STAR program.

4. Following testing and a careful review of the test data, establish an acceptable percentage light degradation and number of failed lamps after 1000 hours of operation.

5. Following testing and a careful review of the test data, establish an acceptable percentage light degradation and number of failed lamps after 10 cycles of ASTM G154-05.

6. NRCan will continue to study the issue of testing burden, as this could prove a significant barrier to program participation for some manufacturers. At the workshop, questions were raised such as: how many samples should be tested? Can one fitting/diffuser/lens represent many Stock Keeping Unit (SKU) numbers? Is there a way to limit the number of needed tests? Can a baseline unit be used? How representative of the population are the tests conducted?

7. The issue of the wattage limit per lamp may need refinement. Workshop participants identified the fact that some LED-based holiday light strings have lamps that contain more than one LED die. In larger form factors (e.g., C-9), several die may be necessary to achieve the appropriate level of brightness or to add a functionality such as changing light color. With a maximum of 0.1 watts per lamp, some designs that contain multiple dies per lamp may be prevented from qualifying (even though they consume significantly less energy than their incandescent counterparts). The group may need to consider different lamp wattages for different shapes (C7, C9). The group may also need to consider defining the term lamp or perhaps light sources to

allow for multiple LED die per lamp.

8. In addition to the request for conducting testing of actual lamps, there was a group consensus view that NRCan should conduct some focus groups to evaluate the decorative LED light strings and provide input both on how to improve the product and what criteria the ENERGY STAR program should emphasize with respect to how consumers will use the product. NRCan agreed to look into this issue.

9. The group is considering holding its next meeting in Toronto in November 2006, when the rush for the 2006 holiday season has passed, and thus the plenary meeting will have a higher level of participation.

4.0 Workshop Materials Appendix

4.1. ENERGY STAR® Program Requirements for Decorative Light Strings Test Procedure, Draft Version 1.1.1

ENERGY STAR® Program Requirements for Decorative Light Strings

Test Procedure

Draft Version 1.1.1

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ENERGY STAR® Program Requirements for Decorative Light Strings

Test Procedure

Draft Version 1.1.1

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1. **Scope:** This document describes the test procedure that a candidate decorative light string shall undergo to determine eligibility for ENERGY STAR® certification, as specified in ENERGY STAR® *Program Requirements for Decorative Light Strings Eligibility Criteria Draft Version 1.1.1*. This procedure includes tests that assess both the energy-efficiency and quality of decorative light strings, and is comprised of the following:

    - Inspection and Power Test,
    - Over-Voltage Test,
    - Lifetime Test,
    - Lamp Intensity Test, and
    - Accelerated Weathering Test.

2. **References:** The following list includes documents used and/or referenced in the development of this draft test specification.

    I. ENERGY STAR® Program Requirements for Decorative Light Strings Eligibility Criteria Draft Version 1.1.1, June 2006. Natural Resources Canada, Ottawa, Canada.

    II. ASTM G 154 – 05, Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials. ASTM International, West Conshohocken, PA, USA.

    III. CIE Publication 84-1989, The Measurement of Luminous Flux. Commission Internationale de l'Eclairage (CIE). Bureau Central de la CIE, Vienna, Austria.

3. Tests Performed: The following tests shall be performed on decorative light strings to determine eligibility for participation in the ENERGY STAR® program. All strings tested must undergo the inspection and power consumption test, however different sets of strings may be used for the remaining tests. Record all measured and calculated values in the test report.

3.1. Inspection and Power Test

The steps in this test shall be conducted for all strings tested by this test procedure.

3.1.1. Count lamps per string.

3.1.2. Check lamps type: sealed or plug-in. If plug-in, the socket / lamp must have a marking or polarized socket to enable correct insertion of replacement lamps.

3.1.3. Check that plug-in diodes, resistors, etc. cannot be incorrectly swapped with spare lamps.

3.1.4. Measure power and current at 120 volts ± 2% RMS AC. Calculate the power per lamp.

3.2. Over-Voltage Test

Strings will be energized at 132 volts RMS AC for one hour and examined for failure (i.e., light sets become inoperative, defined as a voltage drop of > 60 volts or < 0.5 volts RMS AC across any one lamp). Count the number of failed lamps and calculate the failed lamps as a percentage of total lamps on the string.

3.3. Lifetime Test

A decorative light string shall be tested for maintaining light output as described below. In summary, light strings will be prepared for testing, mounted in an integrating sphere and measured for light output. The assembly shall then be operated for 1000 hours and a second measurement of light output recorded. The 1000 hours of operation does not have to be performed inside the integrating sphere; the only requirement is that the lamps in the testing assembly remain in the same orientation to each other, such that any self-adsorption or interference losses in the initial light output measurement will also be present in the second measurement. The steps to follow for conducting this test are outlined below.

3.3.1. Assemble the decorative light string into a configuration for testing. The strings shall be bundled together so that all lamps are directed

Figure 1. Sample Test Setup

outward. The assembly shall be made as compact as possible and shall be taped together to maintain the relative positioning of the lamps throughout the test. Figure 1 shows a possible test set-up to conduct a maintained light output test.

3.3.2. Operate the assembly in this configuration for a 24 hour (± 1 %) "seasoning" period.

3.3.3. Insert the assembly into an integrating sphere and measure the light output following the guidelines for conducting measurement of light output in an integrating sphere contained in CIE Publication 84-1989, *The Measurement of Luminous Flux.*

3.3.4. Keeping the testing assembly intact (i.e., do not remove the tape, or move any of the lamps), operate the assembly for 1000 hours (± 1 %) continuously. This period of operation (41 days, 16 hours) may be conducted using a test bench facility (i.e., not inside the integrating sphere), provided that none of the lamps in the assembly have been moved relative to each other.

3.3.5. Conduct a second measurement of the light output in an integrating sphere, following the same procedure in step 3.3.3 above.

3.3.6. Count the number of failed lamps (as per section 3.2) and record the failed lamps as a percentage of total lamps on the string.

3.3.7. Calculate the percentage reduction in light output of the second measurement relative to the first measurement.

3.4. Light Intensity Test

On a string of decorative lamps that has been seasoned (per step 3.3.2), select three non-consecutive lamps on the string and record the position of the lamp on the string relative to the input plug (e.g., lamp #5, #20, #32). Lamps selected shall all be of the same colour and shall be tested with diffusers installed. Light intensity measurements shall be taken on each of these lamps at either a 30°, 60°, or 90°,viewing angle, ±2° of mechanical center as shown in Figure 2A. Measurements shall be taken at the selected viewing angle at 0°, 90°, 180°, and 270° (±2°) around the circumference of the lamp, and averaged together for the measured lamp as shown in Figure 2B. The three lamps shall then be averaged together to determine the average initial light intensity for the tested string.

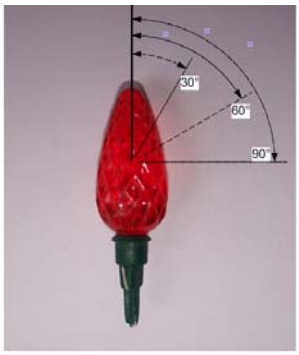

Figure 2A. Side view

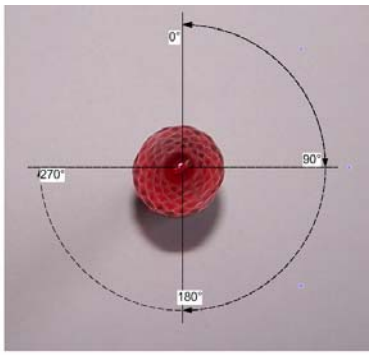

Figure 2B. Top view

3.5. Accelerated Weathering Test

This test is intended to assess degradation of the wire insulation, lamp mounting sockets with lamps and/or lamp diffusers. This test may be conducted on the same lamp strings that were tested in section 3.4. In summary, this test involves taking an initial light intensity measurement (section 3.4). The string is then subjected to ASTM G154-05 accelerated life testing which involves UV light exposure, water spray and condensation. Next, the string and lamps are inspected for failure and a subsequent light intensity measurement is taken and compared to the initial measurement. The steps to follow for this test are outlined below.

3.5.1. Determine the average intensity of lamps on a string of decorative lights per the procedure outlined in section 3.4. Alternatively, manufacturers can simply use the same strings of lamps that were tested in section 3.4 for the Accelerated Weathering Test.

3.5.2. The string of lights shall be subjected to the exposure conditions contained in Cycle 7 of Table X2.1 of ASTM G154-05, which includes 8 hours of UV light (340 nm at 1.55 W/m²/nm) at 60°C, 0.25 hours of water spray, and 3.75 hours of condensation at 50°C. The strings shall be mounted in the chamber so that the lamps and/or diffusers are exposed to the UV light, and the wire and lamp couplings are exposed to the UV light and the water spray and condensation as much as possible. The lamp strings shall be operated for the duration of this test. The number of cycles of this test have yet to be determined, but for this draft test procedure, ten consecutive iterations of Cycle 7 are required.

3.5.3. The light string shall then be removed from the ASTM G154-05 testing chamber and inspected for any cracking or breakage in wire insulation. The number of failed lamps (as per section 3.2) shall be counted and recorded as a percentage of total lamps on the

string.

3.5.4. If the string is operable, a second lamp intensity measurement shall be taken on the same three lamps using all the same angles that were used by the technician in step 3.5.1.

3.5.5. Calculate the percentage reduction in light intensity of the second measurement relative to the first measurement.

4. Acknowledgements

Special thanks to members of industry, government, and research laboratories for volunteering their time to develop this Test Procedure:

Organization	Name
3H and Company Ltd.	David Weiss
British Columbia Hydro	Gary Hamer
Canadian Standards Association International	Dejan Lenasi
Fiber Optic Design	David Allen
LEDUp Enterprises, Inc.	Jerry Yu
Lighting Research Center	Conan O'Rourke
Powertech Labs	Bruce Neilson

4.2. ENERGY STAR® Program Requirements for Decorative Light Strings Eligibility Criteria, Draft Version 1.1.1

ENERGY STAR® Program Requirements for Decorative Light Strings

Eligibility Criteria

Draft Version 1.1.1

Table of Contents

ENERGY STAR® Program Requirements for Decorative Light Strings

Eligibility Criteria

Draft Version 1.1.1

Below is the product specification (Draft Version 1.1.1) for ENERGY STAR® qualified decorative light strings. A product must meet all of the identified criteria if it is to be labelled as ENERGY STAR® by its manufacturer.

The intent of the ENERGY STAR® initiative in this product category is to reduce seasonal peak electricity consumption by encouraging consumers to use quality, energy-efficient decorative strings of lights.

1) Definitions:

A. Decorative Light String - String of lamps used for a decorative purpose. The lamps may be replaceable or sealed into the lampholder.

B. Series Block - A number of lamps connected in series, or utilizing a series connection. Additional series blocks can be added to the circuit (or light string) utilizing parallel connections (e.g., a 50-lamp light string could have two 25-lamp series blocks connected in parallel).

C. Intensity - A photometric measurement of light output at defined viewing angles and spatial coordinates, specified in terms of millicandela (mcd).

D. Maintained Light Output - The light output of a lamp as a percentage of its initial light output after a 1000-hour testing period.

E. Viewing Angle – The angle at which photometric light intensity is measured, at a defined number of degrees from mechanical center, ±2 degrees.

F. Input Power - The total, or system, power used by the decorative string during operation, measured in watts, including transformers, adaptors, etc.

G. Maximum Watts per Lamp – The input power divided by the number of lamps on the decorative

light string.

2) **Reference Standards:** ENERGY STAR® qualified decorative holiday strings must comply with the applicable safety standards and relevant clauses from the Canadian Standards Association, Underwriters Laboratories and any other applicable global standards organizations, unless the requirements of the ENERGY STAR® specification are more restrictive. Relevant standards include, but are not limited to:

Canadian Standards Association (CSA)

CSA-22.2 No.37-M1989 (R2004) *Christmas Tree and Other Decorative Lighting Outfits*

Underwriters Laboratories Inc. (UL)

UL 588-2004, *Standard for Seasonal and Holiday Decorative Products*

3) **Qualifying Products:** In order to qualify for the ENERGY STAR® label, a decorative light string must meet the definition in Section 1.A and the specification requirements provided in Section 4, below.

4) **Energy-Efficiency Specifications for Qualifying Products:** Only those products that comply with the requirements of Section 2 and meet the following criteria in Table 1 may qualify for ENERGY STAR®. All measurements must be conducted according to the "*ENERGY STAR® Program Requirements for Decorative Light Strings, Test Procedure, Draft Version 1.1.1.*"

Table 1: Product Characteristics and Specifications for Decorative Light Strings	
Test	**Requirement**
Inspection and Power Test For removable / plug-in lamp type strings Lifetime claim Maximum watts per lamp	 Lamps must be marked or keyed. 25,000 hours (or 'long-lasting'). 0.1 watts.
Over-Voltage Test	<5% of lamps failed.
Lifetime Test	Light output from string should not have degraded by more than 30% and <5% of lamps failed.
Light Intensity Test Average light intensity of lamps tested (including diffusers) at viewing angle of 30°, 60°, or 90° ± 2° of mechanical center. Intensity must meet or exceed the threshold values for the colour emitted.	Violet < 420 nm 200 mcd Indigo 421-460 nm 250 mcd Blue 461-495 nm 300 mcd Green 496-540 nm 350 mcd Yellow 541-580 nm 300 mcd Orange 581-630 nm 300 mcd Red > 631 nm 300 mcd White n/a 500 mcd
Accelerated Weathering Test	Average light intensity from three lamps tested should not have degraded by more than 15% and <5% of lamps failed.

5) **Product Approval:** Strings labelled for exterior use as portable decorative lighting shall be CSA or UL approved for exterior use.

6) **Warranty:** All decorative light strings shall be offered with a minimum 3-year warranty against all product defects.

7) **Packaging:** The packaging containing the product shall specify:

- Product's suitability for use indoor and/or outdoor,
- Number of LED lamps,
- Total lighted length of string in appropriate metric and SAE units, and
- Wattage of light string.

The light string should be labelled with the following information:

- Certification agency,
- Rating for indoor or outdoor use, and
- Maximum number of light strings that can be connected end to end.

8) **Testing Criteria:** In order to qualify their products for ENERGY STAR®, manufacturers are required to test their decorative light strings using the "*ENERGY STAR® Program Requirements for Decorative Light Strings, Test Procedure, Draft Version 1.1.1*." These tests must be conducted by a third-party laboratory approved by Natural Resources Canada. Manufacturers are invited to submit names and qualification criteria of candidate testing laboratories to Natural Resources Canada.

9) **Effective Date:** The date that a manufacturer begins to qualify products as ENERGY STAR® will be defined as the *effective date* of the agreement.

10) **Future Specification Revisions:** ENERGY STAR® reserves the right to change the specification should technological and/or market changes affect its usefulness to consumers, industry, or the environment. In keeping with current policy, revisions to the specification will be arrived at through stakeholder discussion and consultation.

4.3. ENERGY STAR® Program Requirements for Decorative Light Strings Main Presentation from the Workshop

ENERGY STAR®
Program Requirements for Decorative Light Strings

Second Plenary Meeting
Hosted by Natural Resources Canada

Doubletree International Plaza Hotel
Toronto, Ontario
June 27, 2006

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Today's Agenda

8:30-9:00	Registration
9:00-9:15	Welcome and Overview of Progress to Date Pierrette LeBlanc – Natural Resources Canada
9:15-9:30	Introductions and Opening Statements Michael Scholand – Navigant Consulting, Inc.
9:30-10:00	Overview of Seasonal Decorative Light String Market Michael Vladimer – Navigant Consulting, Inc.
10:00-10:15	COFFEE BREAK

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Today's Agenda

10:15-11:00	Test Procedure and Eligibility Criteria: Overview, Inspection and Power Test, Over-Voltage Test Michael Scholand – Navigant Consulting, Inc.
11:00-11:20	Test Procedure and Eligibility Criteria: Lifetime Test Conan O'Rourke – Lighting Research Center Michael Scholand – Navigant Consulting, Inc.
11:20-12:00	Test Procedure and Eligibility Criteria: Lamp Intensity Test Conan O'Rourke – Lighting Research Center Michael Scholand – Navigant Consulting, Inc.
12:00-1:00	LUNCH

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Today's Agenda

1:00-1:45	Test Procedure and Eligibility Criteria: Accelerated Weathering Test Gary Hamer – British Columbia Hydro Michael Scholand – Navigant Consulting, Inc.
1:45-2:30	Test Procedure and Eligibility Criteria: Review of Documents Michael Scholand – Navigant Consulting, Inc.
2:30-2:45	COFFEE BREAK
2:45-4:00	Final Discussion Points and Next Steps
4:00	ADJOURN

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Chronology of Events

Date	Event
~2003	BC Hydro launches a provincial incentive program to promote Decorative Light Strings
~2005	NRCan and U.S. EPA initiate work evaluating Energy Star requirements for Decorative Light Strings
March 6, 2006	Meeting in Toronto to review draft test protocol (BC Hydro/Power Tech) and eligibility criteria (v. 1.0)
April – June, 2006	Weekly conference calls with technical experts reviewing test protocol issues
June 27, 2006	NRCan convenes second meeting in Toronto to review revised draft test protocol and eligibility criteria (v. 1.1.1)

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Technical Committee

Company	Technical Expert
3H and Company Ltd.	David Weiss
British Columbia Hydro	Gary Hamer
Canadian Standards Association International	Dejan Lenasi
Fiber Optic Design	David Allen
LEDUp Enterprises, Inc.	Jerry Yu
Lighting Research Center	Conan O'Rourke
Powertech Labs	Bruce Neilson

- Held five Technical Committee conference calls
- Typically discussed one test method issue per call
- Participation was good, but not all members were able to participate in every call
- Due to tight timeframe, final product does not represent consensus view of the Committee

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ENERGY STAR® Requirements for Decorative Light Strings

Overview of Seasonal Decorative Light String Market

Michael Vladimer
Navigant Consulting, Inc.

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Preliminary Market Assessment for Decorative Light Strings

Office of Energy Efficiency
Natural Resources Canada

June 27, 2006
Doubletree International Plaza Hotel
Toronto, Canada

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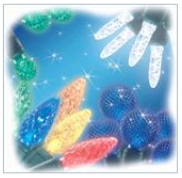
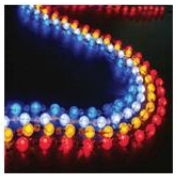

Navigant Consulting, Inc.
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Washington D.C. 20006

www.navigantconsulting.com

Caveats

There are two important issues to mention up-front.

1. Several commercially available products are shown or may be mentioned in this presentation. These are for discussion and illustrative purposes only, and should not be viewed as an endorsement by NRCan or Navigant Consulting.

2. The material presented in these slides is a work in progress. These slides represent an interim deliverable, and NCI is continuing to work on this assessment. Any comments, corrections or guidance you can offer are very welcome.

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Market Assessment *Objectives*

The objectives of this work are centered around understanding the market for decorative light strings.

1. Prepare a product database of decorative LED light strings currently offered in North America
   - Identify manufacturers and importers
2. Interview manufacturers, retailers, and distributors about the quality of the products on the market
   - Brightness, lifetime, colour and colour consistency
3. Identify the qualities of decorative LED light string products that consumers consider important
   - Also, look at common applications, usage patterns, and general price information

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Market Overview *Manufacturers*

Eleven manufacturers identified so far, with one identified as having the majority of the market share.

- Manufacturers identified include:

3H & Co.	LEDUp
AVH Supply, Inc.	LUXLITE
Blachere Illumination	Mobiltech
Bortex Industry Company, Ltd.	NOMA
Congolm, Inc.	Pharos Innovations, Inc.
Holiday Creations	

- Holiday Creations is the manufacturer with the majority of the market share in the decorative LED light string market in Canada and the United States

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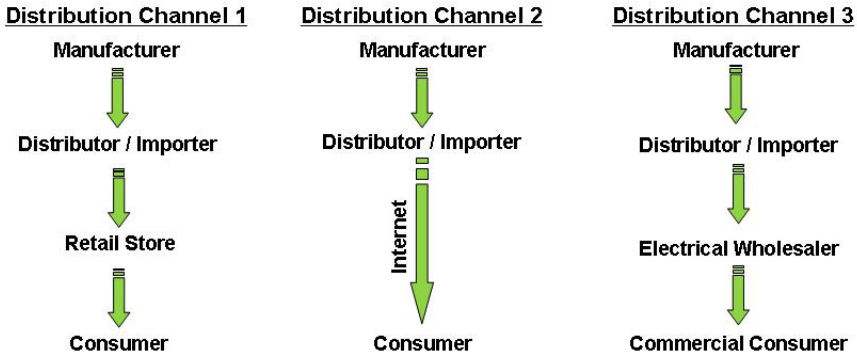
Market Overview *Distribution channels*

Decorative LED light strings are distributed through three main channels – retail chains, on-line sales, and electrical wholesalers (commercial).

- **Most Common Distribution Channels for Decorative LED Light Strings**



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Market Overview *Lamp shapes*

Decorative LED light strings come in a wide variety of lamp shapes.

C6 ("Strawberry"), C7, and C9

M5 ("Mini-lamps")

Icicle Lights

G12 ("Raspberry")

Novelty: Trees, stars, etc.

Rope Lights

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Market Overview *Colours*

Decorative LED light strings come in a wide variety of colours, comparable to the colours of incandescent light strings.

- LED lamps come in a wide variety of colours
  - Purple
  - Blue
  - Green
  - Yellow
  - Gold
  - Orange
  - Red
  - White
  - Multi-coloured strings

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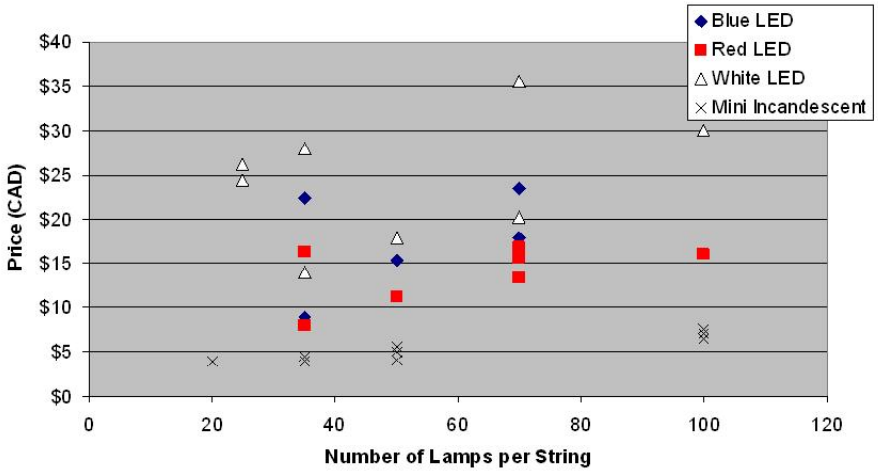
Market Overview *Price*

The price of LED light strings varies with colour, but all LED light strings are 2 to 8 times more expensive than mini-incandescent light strings.



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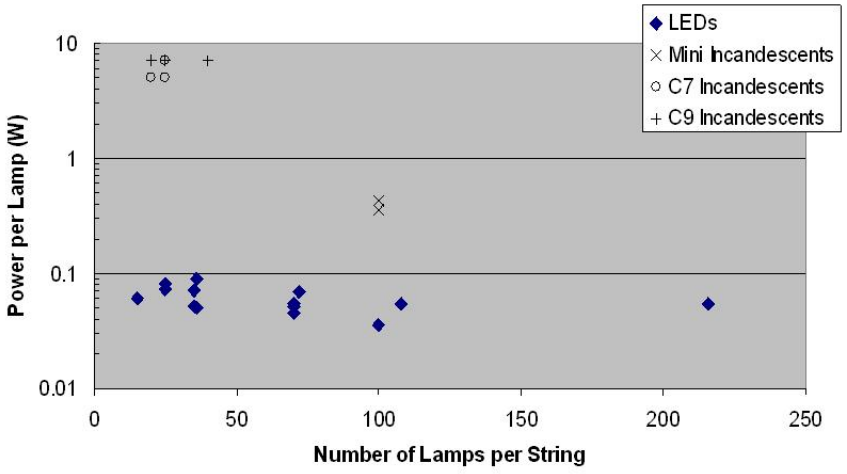
Market Overview *Energy usage*

LED light strings use less energy than comparable incandescent light strings. On a power per lamp basis, LEDs consume less than 0.1 watts.



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Market Overview *Market transformation programs*

Utilities in Canada and the United States have sponsored two different types of market transformation programs.

- Incandescent for LED light string exchanges
  - 1 incandescent light string for 1 LED light string
    - Hydro Mississauga
  - 2 incandescent light strings for 1 LED light string
    - Toronto Hydro, Hydro One, Pacific Gas & Electric, Niagara Falls Hydro
  - An incandescent light string for a $4 instant rebate coupon towards the purchase of a seasonal LED light string
    - BC Hydro
- Large-scale lighting projects
  - Paid half the cost of municipal holiday displays using LED lights
    - Nova Scotia Department of Energy
  - Donation of LED light strings for large lighting projects
    - Hydro One, Toronto Hydro, Niagara Falls Hydro, Pacific Gas & Electric, Sacramento Municipal Utility District

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Value Proposition *Overview*

Key points often highlighted when selling strings of LED holiday lights.

- Brighter colour, will not fade
- Energy saving – up to 90%
- Indoor/Outdoor use
- Rugged, no glass to break
- Cool to the touch
- Lower risk of fire or shock
- Stackable or end-to-end
- Easy and flexible installation
- 200,000 hour lamps
- Guaranteed, UL listed
- Advanced technology

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Value Proposition *Residential applications and usage patterns*

Decorative light strings are generally used in the <u>residential</u> sector for holiday decoration.

- Residential sector applications
  - Main applications are related to the holiday season (December / January)
    - Decoration of trees, indoors and outdoors
    - Decoration of house eaves and entryways
    - Lights are typically operated 30 to 45 days per year for 6 to 8 hours per day
  - Secondary application is for ambiance decoration of patios and decks during the summer months
    - Lights typically operate 45 to 90 days per year for 4 to 5 hours per day

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Value Proposition *Commercial applications and usage patterns*

Decorative light strings in the commercial sector are primarily used for holiday displays to attract customers.

- Commercial sector applications
  - The main applications are related to holiday displays at commercial establishments (which includes retail and office establishments)
    - Concentrated in the December / January time-frame, typically operating 45 to 60 days per year for 6 to 12 hours per day
  - Secondary applications are related to non-seasonal decorative lighting (e.g., white mini-lights in ficus trees in shopping malls)
    - These installations typically operate year-round (365 days per year) for the duration the establishment is open (12 hours per day)

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Value Proposition *Consumer considerations*

Experts interviewed indicated the primary considerations that consumers look for in decorative light strings are purchase price, energy-efficiency, durability/lifetime, and technological edge.

- Primary considerations
  - Purchase price (dominant consideration, particularly for residential sector)
  - Energy-efficiency (particularly in Canada)
  - Product durability and long operating lifetime
  - Technological edge (new product designs / fads)
- Minor considerations
  - Brightness

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Quality *Safety standards*

Decorative LED light stings, like decorative incandescent light strings, are subject to the same safety requirements of CSA / UL.

- Canadian Standards Association (CSA)
  - CSA-22.2 No.37-M1989 (R2004) *Christmas Tree and Other Decorative Lighting Outfits*
- Underwriters Laboratories (UL)
  - UL 588-2004, *Standard for Seasonal and Holiday Decorative Products*

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Quality *Brightness*

LED lights are considered sufficiently bright for decorative purposes, even though some lamp shapes have lower light emission than incandescent lights.

- The majority of consumers use light strings for decoration only and are satisfied with brightness
  - Feedback from consumers in response to utility exchange programs and retail store research indicates consumers are satisfied with the brightness of LED light strings
- Some consumers use a mix of LED and incandescent mini-lights for colour effects
- A few consumers attempt to use decorative light strings for general illumination applications and are not satisfied with the brightness

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Quality *Colour and colour consistency*

The range of LED colours is very good and the colour consistency of LED light strings has been improving.

- Colour
  - LED lights have stronger colours than incandescent lights
    - White LEDs can have a blue tint (high CCT), which can draw some complaints, as consumers are used to incandescent white ("warm white", CCT ~2800 K)
- Colour Consistency
  - By binning different colours together, colour consistency problems within strings are rare
  - Problems with colour consistency between strings can be more of a problem (even with light strings from the same company)

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Quality *Intellectual property / legal issues*

Certain aspects of using LED technology in decorative light string applications are patented, and therefore cannot be a criterion for Energy Star qualification.

- Patents that we are aware of exist for:
  - "Keyed" lampholders to prevent installing lamps backward
    - "Keyed" lampholders are not required by UL 588
    - Polarity can be indicated using alternate means
  - Polarized plugs and end-connectors
  - AC-powered LED light strings without a transformer
- Pending patents that we are aware of exist for:
  - Strings with one or more series blocks must be connected in opposite polarity to reduce THD
  - A lampholder that is molded to the LED lamp / decorative cover

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Product Lifetime *True lifetime versus LED lifetime*

The LED lights in decorative light strings will have a much longer lifetime than the lifetime of the light string as a whole, with the LED lights using only 5% of their useful life by the end of the life of the light string.

- Estimates of the true lifetime of a LED light string range from 3 to 7 years (highly dependent on usage pattern and environmental conditions)
  - Assuming usage of 45 days per year and 8 hours per day, the total lifetime ranges from 1000 to 2500 hours of use
- Estimates of the LED light lifetime in decorative light strings range from around 20,000 to 50,000 hours – 20 times longer
  - Assuming usage of 45 days per year and 8 hours per day, **LED lights will have used only 5% of their useful life** by the end of the true life
- The wiring harness is often cited as the factor most likely to cause failure with aging and environmental exposure

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Product Lifetime *Rough payback calculation (versus mini)*

Simple payback for a string of LED lamps versus a mini incandescent string becomes more attractive as annual operating hours increase.

Cost assumptions:
LED string (2 Watts) = C$15
Mini incandescent string (20 Watts) = C$5
Electricity = C$0.10/kWh

Days per Year	Hours (hr/day)	Savings (kWh/yr)	kWh Savings ($CAD/yr)	Payback (Years)
30	6	3.2	$0.32	30.9
45	6	4.9	$0.49	20.6
45	8	6.5	$0.65	15.4
60	12	13.0	$1.30	7.7
365	12	78.8	$7.88	1.3

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Product Lifetime *Rough payback calculation (versus C7)*

The simple payback for a string of LED lamps versus a C7 incandescent is much shorter.

Cost assumptions:
LED string (2 Watts) = C$15
C7 incandescent string (125 Watts) = C$10
Electricity = C$0.10/kWh

Days per Year	Hours (hr/day)	Savings (kWh/yr)	kWh Savings ($CAD/yr)	Payback (Years)
30	6	22.1	$2.21	2.3
45	6	33.2	$3.32	1.5
45	8	44.3	$4.43	1.1
60	12	88.6	$8.86	0.6
365	12	538.7	$53.87	0.1

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Product Lifetime *Case studies 1 of 2 (general conclusions)*

Case studies reveal that the product lifetime of LED light strings compares favorably to incandescent light strings.

- Return rates for LED light strings are at or below those for incandescent light strings
  - Generally less than a 2% return rate for LED light strings (compared to a 3% return rate for incandescent light strings), as cited by manufacturers, distributors, and retailers
- Less than a 0.1% return rate reported by utilities / municipalities that conduct light string exchanges (11 sets returned out of 21,100 sets distributed for three different utilities / municipalities)

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Product Lifetime *Case studies 2 of 2 (exceptions)*

Case studies also revealed some problematic installations.

- A large recall of a certain type of decorative LED light string in 2005 increased the overall return rates involving the recalled product
  - Failures of recalled product were frequent and often spectacular
  - Recalled product posed a shock and fire hazard
  - Manufacturing defect led to overheating and melting
- Failure rates are highly dependent on the usage pattern and environment
  - Niagara Falls Winter Festival of Lights installation experienced significantly higher failure rates than other installations
    - Mist and power spikes cited as contributors to the high failure rates

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Comments and Feedback

Please provide further comment and input for this Market Assessment directly to Navigant Consulting.

- Thank you for your time and attention this morning.
- Please be reminded, this presentation is a work in progress.
- More information about the market and the value proposition for consumers is requested by July 10th.
- Contact directly:

Michael Vladimer, Navigant Consulting, Inc.

Tel: (202) 481-7323

Fax: (202) 973-2401

Email: MVladimer@navigantconsulting.com

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ENERGY STAR® Requirements for Decorative Light Strings

Test Procedure and Eligibility Criteria: Overview, Inspection and Power Test, Over-Voltage Test

Michael Scholand
Navigant Consulting, Inc.

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Test Procedure – Scope of Coverage

1. **Scope:** This document describes the test procedure that a candidate decorative light string shall undergo to determine eligibility for ENERGY STAR® certification, as specified in ENERGY STAR® *Program Requirements for Decorative Light Strings Eligibility Criteria Draft Version 1.1.1.* This procedure includes tests that assess both the energy-efficiency and quality of decorative light strings, and is comprised of the following:

    - Inspection and Power Test,
    - Over-Voltage Test,
    - Lifetime Test,
    - Lamp Intensity Test, and
    - Accelerated Weathering Test.

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Qualification Criteria – Select Definitions

1) **Definitions:**

A. Decorative Light String - String of lamps used for a decorative purpose. The lamps may be replaceable or sealed into the lampholder.

B. Series Block - A number of lamps connected in series, or utilizing a series connection. Additional series blocks can be added to the circuit (or light string) utilizing parallel connections (e.g., a 50-lamp light string could have two 25-lamp series blocks connected in parallel).

F. Input Power - The total, or system, power used by the decorative string during operation, measured in watts, including transformers, adaptors, etc.

G. Maximum Watts per Lamp – The input power divided by the number of lamps on the decorative light string.

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Test Procedure – References

2. **References:** The following list includes documents used and/or referenced in the development of this draft test specification.

I. ENERGY STAR® Program Requirements for Decorative Light Strings Eligibility Criteria Draft Version 1.1.1, June 2006. Natural Resources Canada, Ottawa, Canada.

II. ASTM G 154 – 05, Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials. ASTM International, West Conshohocken, PA, USA.

III. CIE Publication 84-1989, The Measurement of Luminous Flux. Commission Internationale de l'Eclairage (CIE). Bureau Central de la CIE, Vienna, Austria.

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Qualification Criteria – References

2) **Reference Standards:** ENERGY STAR® qualified decorative holiday strings must comply with the applicable safety standards and relevant clauses from the Canadian Standards Association, Underwriters Laboratories and any other applicable global standards organizations, unless the requirements of the ENERGY STAR® specification are more restrictive. Relevant standards include, but are not limited to:

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CSA-22.2 No.37-M1989 (R2004) *Christmas Tree and Other Decorative Lighting Outfits*

Underwriters Laboratories Inc. (UL)
UL 588-2004, *Standard for Seasonal and Holiday Decorative Products*

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Qualification Criteria – Requirements

3) **Qualifying Products:** In order to qualify for the ENERGY STAR® label, a decorative light string must meet the definition in Section 1.A and the specification requirements provided in Section 4, below.

4) **Energy-Efficiency Specifications for Qualifying Products:** Only those products that comply with the requirements of Section 2 and meet the following criteria in Table 1 may qualify for ENERGY STAR®. All measurements must be conducted according to the "*ENERGY STAR® Program Requirements for Decorative Light Strings, Test Procedure, Draft Version 1.1.1.*"

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Test Procedure – Inspection and Power Test

3. **Tests Performed:** The following tests shall be performed on decorative light strings to determine eligibility for participation in the ENERGY STAR® program. All strings tested must undergo the inspection and power consumption test, however different sets of strings may be used for the remaining tests. Record all measured and calculated values in the test report.

3.1. Inspection and Power Test

The steps in this test shall be conducted for all strings tested by this test procedure.

3.1.1. Count lamps per string.

3.1.2. Check lamps type: sealed or plug-in. If plug-in, the socket / lamp must have a marking or polarized socket to enable correct insertion of replacement lamps.

3.1.3. Check that plug-in diodes, resistors, etc. cannot be incorrectly swapped with spare lamps.

3.1.4. Measure power and current at 120 volts ± 2% RMS AC. Calculate the power per lamp.

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Qualification Criteria – Inspection and Power Test Requirements

Table 1: Product Characteristics and Specifications for Decorative Light Strings	
Test	**Requirement**
Inspection and Power Test	
For removable / plug-in lamp type strings	Lamps must be marked or keyed.
Lifetime claim	25,000 hours (or 'long-lasting').
Maximum watts per lamp	0.1 watts.

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Test Procedure – Over-Voltage Test

3.2. Over-Voltage Test

Strings will be energized at 132 volts RMS AC for one hour and examined for failure (i.e., light sets become inoperative, defined as a voltage drop of > 60 volts or < 0.5 volts RMS AC across any one lamp). Count the number of failed lamps and calculate the failed lamps as a percentage of total lamps on the string.

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Qualification Criteria – Over-Voltage Test Requirements

Table 1: Product Characteristics and Specifications for Decorative Light Strings	
Test	**Requirement**
Over-Voltage Test	<5% of lamps failed.

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ENERGY STAR® Requirements for Decorative Light Strings

Test Procedure and Eligibility Criteria: Lifetime Test

Conan O'Rourke
Lighting Research Center, RPI

Michael Scholand
Navigant Consulting, Inc.

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Lifetime (Reduction in Light)

- LEDs tend to reduce light output over time
- Evaluate light output overtime
- Look for large effect
  - Protect against some SLED strings that may be overdriven or the use low quality LEDs
- Suggest evaluating what is currently on the market prior to adding to the spec

Lifetime (Reduction in Light)

- Depreciation test procedure
  - Use existing lighting standards as a guide
    - IES LM-45, LM-66 or CIE 84-1989
  - Seasoning - need to determine how much is needed
    - suggest 12 hours
  - Measured initially (after seasoning) and at 1000 hours
  - Use an integrating sphere with a spectroradiometer
  - Evaluate using radiometric/photometric results
  - Determine criteria for passing
    - suggest 50% of initial output

Lifetime (Reduction in Light)

- Suggest evaluating whole SLED string
  - Simplifies measurement
  - Repeatable positioning for initial and 1000-hr measurements could lead to large differences for individual LEDs
  - If there are broad depreciation issues we look at the next step

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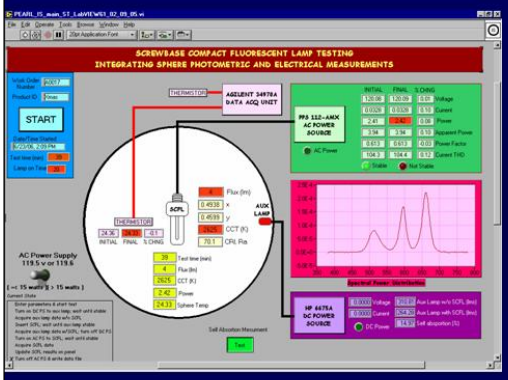

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Test Procedure – Lifetime Test

3.3. Lifetime Test

A decorative light string shall be tested for maintaining light output as described below. In summary, light strings will be prepared for testing, mounted in an integrating sphere and measured for light output. The assembly shall then be operated for 1000 hours and a second measurement of light output recorded. The 1000 hours of operation does not have to be performed inside the integrating sphere; the only requirement is that the lamps in the testing assembly remain in the same orientation to each other, such that any self-adsorption or interference losses in the initial light output measurement will also be present in the second measurement. The steps to follow for conducting this test are outlined below.

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Test Procedure – Lifetime Test

3.3.1. Assemble the decorative light string into a configuration for testing. The strings shall be bundled together so that all lamps are directed outward. The assembly shall be made as compact as possible and shall be taped together to maintain the relative positioning of the lamps throughout the test. Figure 1 shows a possible test set-up to conduct a maintained light output test.

Figure 1. Sample Test Setup

3.3.2. Operate the assembly in this configuration for a 24 hour (± 1 %) "seasoning" period.

3.3.3. Insert the assembly into an integrating sphere and measure the light output following the guidelines for conducting measurement of light output in an integrating sphere contained in CIE Publication 84-1989, *The Measurement of Luminous Flux*.

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Test Procedure – Lifetime Test

3.3.4. Keeping the testing assembly intact (i.e., do not remove the tape, or move any of the lamps), operate the assembly for 1000 hours (± 1 %) continuously. This period of operation (41 days, 16 hours) may be conducted using a test bench facility (i.e., not inside the integrating sphere), provided that none of the lamps in the assembly have been moved relative to each other.

3.3.5. Conduct a second measurement of the light output in an integrating sphere, following the same procedure in step 3.3.3 above.

3.3.6. Count the number of failed lamps (as per section 3.2) and record the failed lamps as a percentage of total lamps on the string.

3.3.7. Calculate the percentage reduction in light output of the second measurement relative to the first measurement.

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Qualification Criteria – Lifetime Test Requirements

D. Maintained Light Output - The light output of a lamp as a percentage of its initial light output after a 1000-hour testing period.

Table 1: Product Characteristics and Specifications for Decorative Light Strings	
Test	**Requirement**
Lifetime Test	Light output from string should not have degraded by more than 30% and <5% of lamps failed.

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ENERGY STAR® Requirements for Decorative Light Strings

Test Procedure and Eligibility Criteria: Lamp Intensity Test

Conan O'Rourke
Lighting Research Center, RPI

Michael Scholand
Navigant Consulting, Inc.

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Brightness Test

- There may be a need to ensure that there is a minimum amount of light from the SLEDs
- Still need to determine appropriate method to evaluate
- Current thinking
  - Test individual LEDs
  - Use an integrating sphere
  - Use existing lighting standards as a guide
    - IES LM-45 and LM-66

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Brightness

- The subjective attribute of any light sensation giving rise to the perception of luminous magnitude, including the whole scale quantities of being bright, light, brilliant, dim, or dark.
(IESNA Lighting Handbook)

- One of the basic psychological dimensions of light. It varies primarily with physical intensity.
(Sensation and Perception Schiffman)

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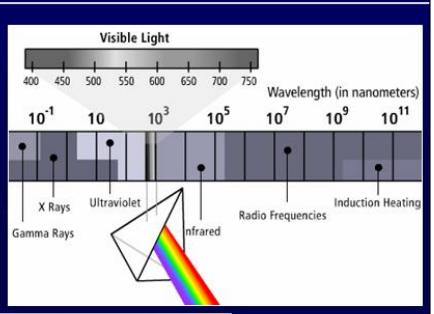
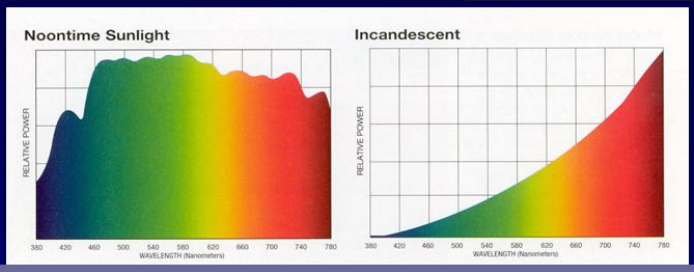
Spectrum

- The electromagnetic spectrum can be divided into smaller and smaller bands, or expressed as a continuous function of wavelength (or frequency)
- Units: W/nm

$$P_{total} = \int_0^\infty P(\lambda)d\lambda \quad = \text{area under curve}$$





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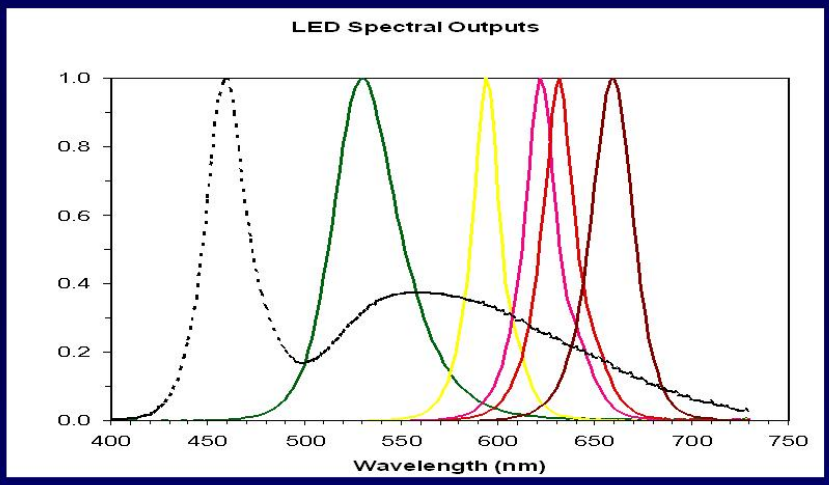
Some LED Spectra



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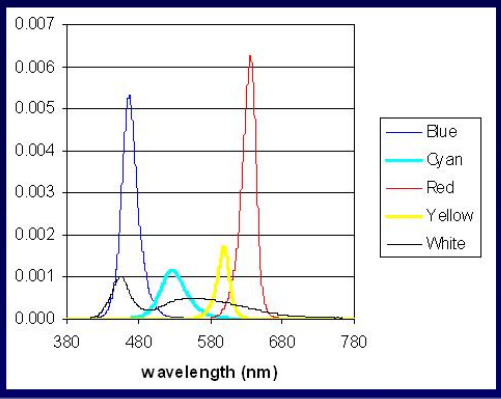
Some LED Spectra

	LED Current (mA)	LED Voltage (V)	LED Power (W)	Luminous Flux (lm)	Efficacy (lm/W)	Radiant Energy (W)	Peak Wavelength (nm)	x	y
Blue	350	3.2083	1.12	11.1	9.9	0.154	466.37	0.130	0.071
Cyan	350	3.2254	1.13	29.4	26.1	0.054	526.72	0.214	0.706
Red	350	2.1665	0.76	27.8	36.6	0.156	635.68	0.699	0.301
Yellow	350	2.8148	0.99	18.1	18.3	0.038	599.14	0.602	0.397
White 350mA	350	3.3824	1.18	31.0	26.2	0.102	455.09	0.303	0.306



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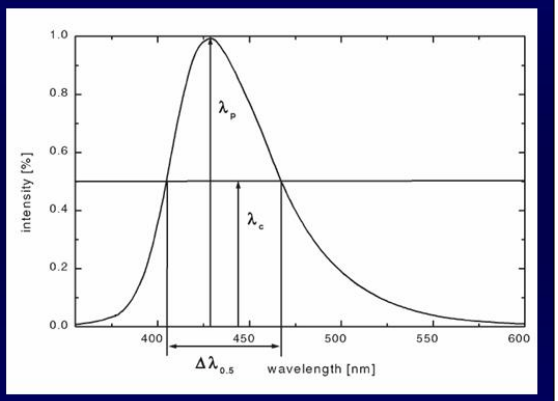
Physical Measures of LED Color

- Peak wavelength
- Full width half max (FWHM)
- Center wavelength
- Centroid wavelength
- Dominant wavelength
- Color purity



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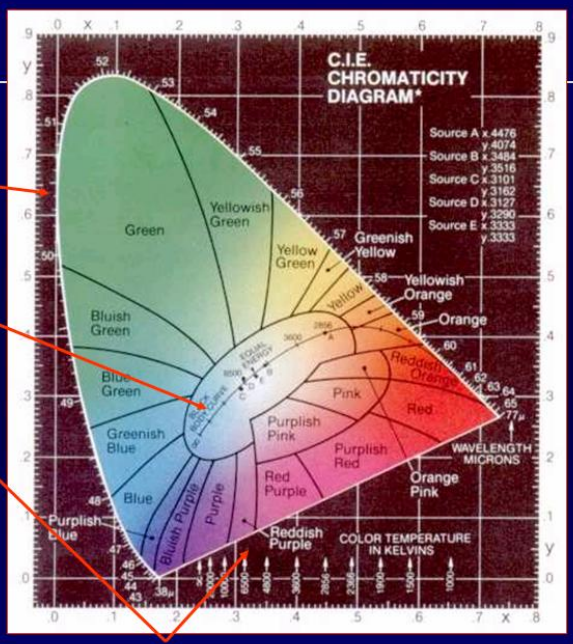
Spectrum Locus

Blackbody Locus

Purple Boundary

CIE 1931 Chromaticity Space



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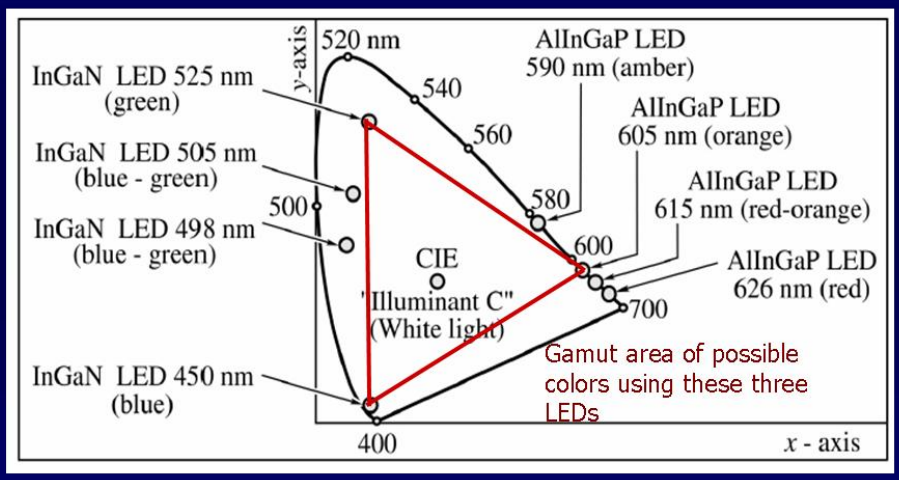
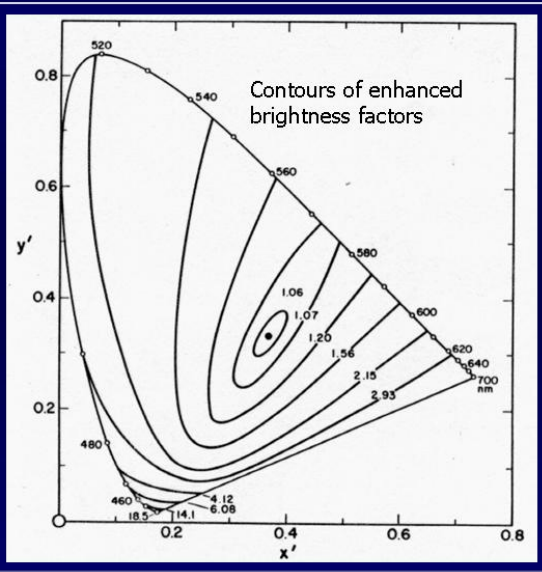
Properties of the Chromaticity Diagram

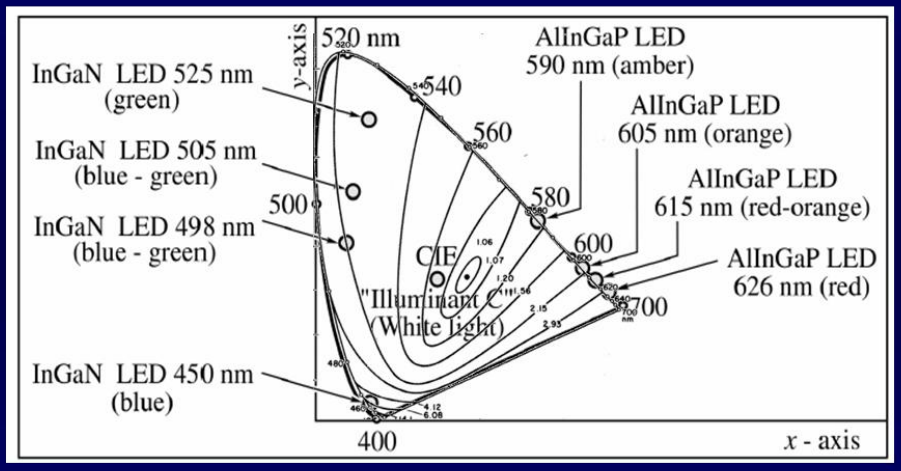


Brightness of Saturated Colors

Saturated colors, especially deep reds and blues, appear brighter than photometric measurements imply



Brightness of Saturated Colors



Luminous intensity

- Near field photometry issues
  - Intensity is used to describe point sources – LEDs are not point sources – no inverse square law
  - Mechanical axis ≠ optical axis
  - Difficult to locate the position of the light source
- CIE recommended the following geometry

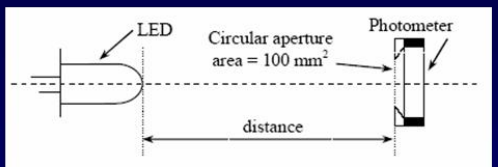
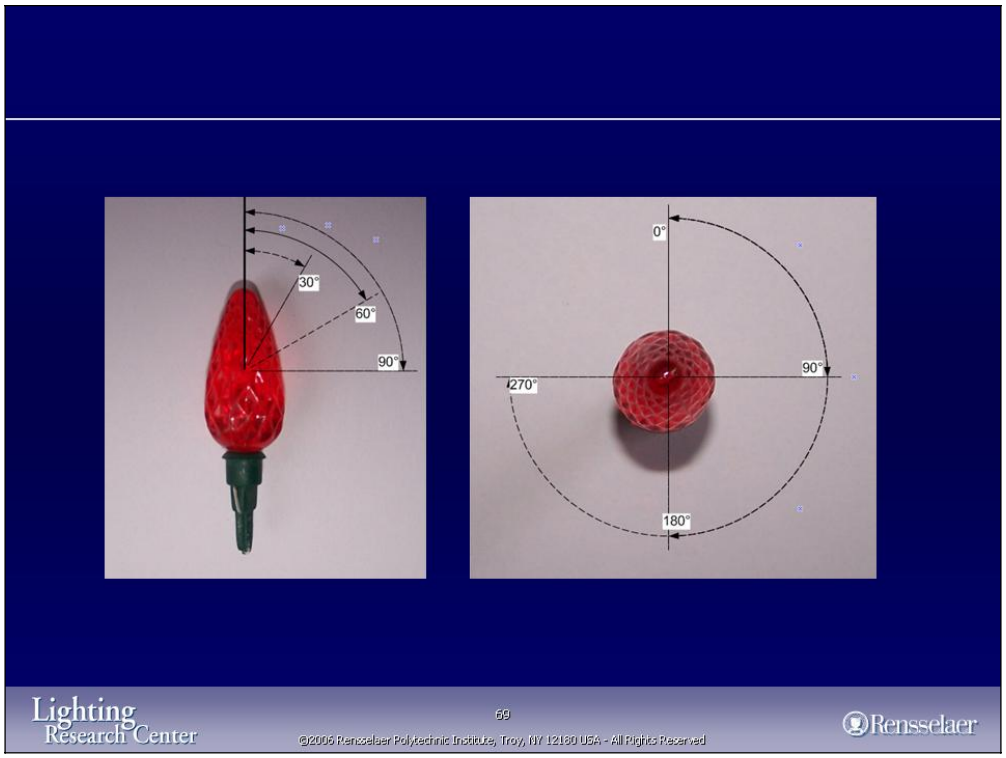


Figure 1 – Schematic diagram of CIE Standard Conditions for the measurements of Averaged LED intensity.

d= 100 mm
316 mm

Result is called Average LED Intensity


30°
60°
90°
0°
90°
270°
180°
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Measuring LED Intensity
Small devices may allow short test distances, but watch out for optics!
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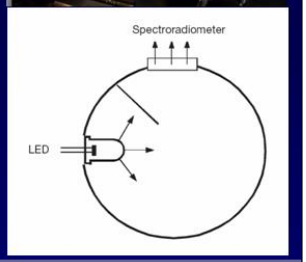
Integrating Sphere Measurements

- Real spheres are not perfect
  - Reflectance is not spectrally flat
  - Baffles and light source degrade uniform sphere wall illuminance
    - Limits the size of test sources
- Substitution method is used
  - LED reading is calibrated by reading of known standard lamp
- Corrections for self absorption necessary for accuracy
  - Self absorption factor = $\Phi_{LED} / \Phi_{empty}$



Test Procedure – Lamp Intensity Test

3.4. Light Intensity Test

On a string of decorative lamps that has been seasoned (per step 3.3.2), select three non-consecutive lamps on the string and record the position of the lamp on the string relative to the input plug (e.g., lamp #5, #20, #32). Lamps selected shall all be of the same colour and shall be tested with diffusers installed. Light intensity measurements shall be taken on each of these lamps at either a 30°, 60°, or 90°,viewing angle, ±2° of mechanical center as shown in Figure 2A. Measurements shall be taken at the selected viewing angle at 0°, 90°, 180°, and 270° (±2°) around the circumference of the lamp, and averaged together for the measured lamp as shown in Figure 2B. The three lamps shall then be averaged together to determine the average initial light intensity for the tested string.

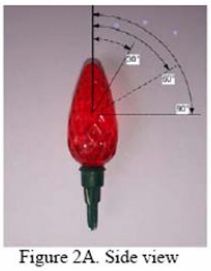


Figure 2A. Side view

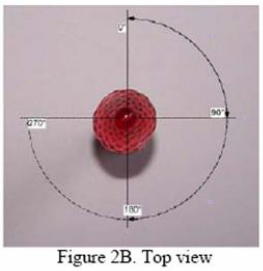


Figure 2B. Top view

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Qualification Criteria – Lamp Intensity Test

C. Intensity - A photometric measurement of light output at defined viewing angles and spatial coordinates, specified in terms of millicandela (mcd).

E. Viewing Angle – The angle at which photometric light intensity is measured, at a defined number of degrees from mechanical center, ±2 degrees.

Table 1: Product Characteristics and Specifications for Decorative Light Strings

Test	Requirement		
Light Intensity Test Average light intensity of lamps tested (including diffusers) at viewing angle of 30°, 60°, or 90° ± 2° of mechanical center. Intensity must meet or exceed the threshold values for the colour emitted.	Violet	< 420 nm	200 mcd
	Indigo	421-460 nm	250 mcd
	Blue	461-495 nm	300 mcd
	Green	496-540 nm	350 mcd
	Yellow	541-580 nm	300 mcd
	Orange	581-630 nm	300 mcd
	Red	> 631 nm	300 mcd
	White	n/a	500 mcd

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ENERGY STAR® Requirements for Decorative Light Strings

Test Procedure and Eligibility Criteria: Accelerated Weathering Test

Gary Hamer
British Columbia Hydro

Michael Scholand
Navigant Consulting, Inc.

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Test Procedure – Accelerated Weathering Test

3.5. Accelerated Weathering Test

This test is intended to assess degradation of the wire insulation, lamp mounting sockets with lamps and/or lamp diffusers. This test may be conducted on the same lamp strings that were tested in section 3.4. In summary, this test involves taking an initial light intensity measurement (section 3.4). The string is then subjected to ASTM G154-05 accelerated life testing which involves UV light exposure, water spray and condensation. Next, the string and lamps are inspected for failure and a subsequent light intensity measurement is taken and compared to the initial measurement. The steps to follow for this test are outlined below.

3.5.1. Determine the average intensity of lamps on a string of decorative lights per the procedure outlined in section 3.4. Alternatively, manufacturers can simply use the same strings of lamps that were tested in section 3.4 for the Accelerated Weathering Test.

3.5.2. The string of lights shall be subjected to the exposure conditions contained in Cycle 7 of Table X2.1 of ASTM G154-05, which includes 8 hours of UV light (340 nm at 1.55 W/m²/nm) at 60°C, 0.25 hours of water spray, and 3.75 hours of condensation at 50°C. The strings shall be mounted in the chamber so that the

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Test Procedure – Accelerated Weathering Test

lamps and/or diffusers are exposed to the UV light, and the wire and lamp couplings are exposed to the UV light and the water spray and condensation as much as possible. The lamp strings shall be operated for the duration of this test. The number of cycles of this test have yet to be determined, but for this draft test procedure, ten consecutive iterations of Cycle 7 are required.

3.5.3. The light string shall then be removed from the ASTM G154-05 testing chamber and inspected for any cracking or breakage in wire insulation. The number of failed lamps (as per section 3.2) shall be counted and recorded as a percentage of total lamps on the string.

3.5.4. If the string is operable, a second lamp intensity measurement shall be taken on the same three lamps using all the same angles that were used by the technician in step 3.5.1.

3.5.5. Calculate the percentage reduction in light intensity of the second measurement relative to the first measurement.

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Qualification Criteria – Accelerated Weathering Test

Table 1: Product Characteristics and Specifications for Decorative Light Strings	
Test	**Requirement**
Accelerated Weathering Test	Average light intensity from three lamps tested should not have degraded by more than 15% and <5% of lamps failed.

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ENERGY STAR® Requirements for Decorative Light Strings

Test Procedure and Eligibility Criteria: Review of Documents

Michael Scholand
Navigant Consulting, Inc.

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Test Procedure – Other Language in the Document

4. **Acknowledgements**

Special thanks to members of industry, government, and research laboratories for volunteering their time to develop this Test Procedure:

Organization	Name
3H and Company Ltd.	David Weiss
British Columbia Hydro	Gary Hamer
Canadian Standards Association International	Dejan Lenasi
Fiber Optic Design	David Allen
LEDUp Enterprises, Inc.	Jerry Yu
Lighting Research Center	Conan O'Rourke
Powertech Labs	Bruce Neilson

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Qualification Criteria – Other Language in the Document

Below is the product specification (Draft Version 1.1.1) for ENERGY STAR® qualified decorative light strings. A product must meet all of the identified criteria if it is to be labelled as ENERGY STAR® by its manufacturer.

The intent of the ENERGY STAR® initiative in this product category is to reduce seasonal peak electricity consumption by encouraging consumers to use quality, energy-efficient decorative strings of lights.

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Qualification Criteria – Other Language in the Document

5) **Product Approval:** Strings labelled for exterior use as portable decorative lighting shall be CSA or UL approved for exterior use.

6) **Warranty:** All decorative light strings shall be offered with a minimum 3-year warranty against all product defects.

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Qualification Criteria – Other Language in the Document

7) **Packaging:** The packaging containing the product shall specify:

- Product's suitability for use indoor and/or outdoor,
- Number of LED lamps,
- Total lighted length of string in appropriate metric and SAE units, and
- Wattage of light string.

The light string should be labelled with the following information:

- Certification agency,
- Rating for indoor or outdoor use, and
- Maximum number of light strings that can be connected end to end.

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Qualification Criteria – Other Language in the Document

8) **Testing Criteria:** In order to qualify their products for ENERGY STAR®, manufacturers are required to test their decorative light strings using the "*ENERGY STAR® Program Requirements for Decorative Light Strings, Test Procedure, Draft Version 1.1.1.*" These tests must be conducted by a third-party laboratory approved by Natural Resources Canada. Manufacturers are invited to submit names and qualification criteria of candidate testing laboratories to Natural Resources Canada.

9) **Effective Date:** The date that a manufacturer begins to qualify products as ENERGY STAR® will be defined as the *effective date* of the agreement.

10) **Future Specification Revisions:** ENERGY STAR® reserves the right to change the specification should technological and/or market changes affect its usefulness to consumers, industry, or the environment. In keeping with current policy, revisions to the specification will be arrived at through stakeholder discussion and consultation.

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4.4. BC Hydro Proposed ENERGY STAR® Testing Criteria Workshop Presentation

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BC hydro
POWER SMART

Testing to ensure acceptance…

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BC hydro
POWER SMART

Increases since 2002…

- Linear shelf space – 13% in 2004; 4% in 2003; 0.2% in 2002.
- Number of brands found on store shelves – 11 in 2004; 6 in 2003; 1 in 2002
- BC Hydro households making purchases – 18% of in 2004; 8% in 2003
- Percentage of all seasonal lighting purchases – 54% in 2004; 28% in 2003.
- Estimated purchases in 2004 – 1.1 million LED strings

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Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations.
BC hydro
POWER SMART

Agreement of Test Cycle & a 'few other items'…

1. Test Cycle 7 – recommended
2. Duration of Test – 1000 hrs, maybe less for cost reasons
3. Number of strings to test – 1 multicoloured string of each type or 1 string of each colour? (Multiple strings would improve the statistics, but cost more.)
4. Allowed failures: 5% of individual lights? What if whole strings fail?
5. Allowed light reduction after aging: 10%?
6. Deterioration of cords: Already covered by CSA testing?
7. Power on or off during testing: On/off cycling would be good – or continuous on)

ASTM Corrosion Standard

Designation: G 154 – 05

Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials[1]

This standard is issued under the fixed designation G 154; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

Cycle 7: Table X2.1, page 9

G 154 – 05

TABLE X2.1 Common Exposure Conditions

Cycle	Lamp	Typical Irradiance	Approximate Wavelength	Exposure Cycle
7	UVA-340	1.55 W/m²/nm	340 nm	8 h UV at 60 (± 3) °C Black Panel Temperature; 0.25 h water spray (no light), temperature not controlled; 3.75 h condensation at 50 (± 3) °C Black Panel Temperature

8 h UV at 60 (± 3) °C Black Panel Temperature;
0.25 h water spray (no light), temperature not controlled;
3.75 h condensation at 50 (± 3) °C Black Panel Temperature

Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations.

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POWER SMART

Corrosion examples from 2004 Tests…

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2004 Test Chamber…

Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations.

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Inside the Test Chamber…

Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations.

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Setting test racks into place…

Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations.

BC hydro
POWER SMART

Setting test racks into place…

Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations.

BC hydro
POWER SMART

Ready to test…

Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations.

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POWER SMART

Lights with power after testing…

Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations.

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Note yellowed lenses…

Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations. Reliable power, at low cost, for generations.

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POWER SMART

Agreement of Test Cycle & a 'few other items'…

1. Test Cycle 7 – recommended
2. Duration of Test – 1000 hrs, maybe less for cost reasons
3. Number of strings to test – 1 multicoloured string of each type or 1 string of each colour? (Multiple strings would improve the statistics, but cost more.)
4. Allowed failures: 5% of individual lights? What if whole strings fail?
5. Allowed light reduction after aging: 10%?
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7. Power on or off during testing: On/off cycling would be good – or continuous on)

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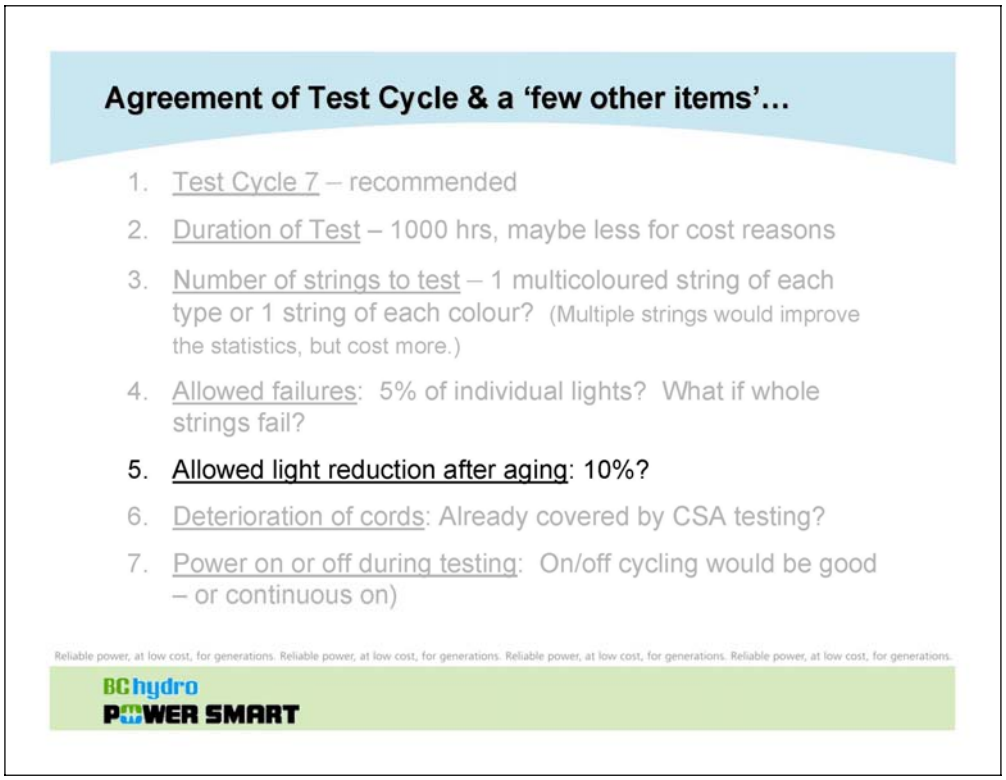
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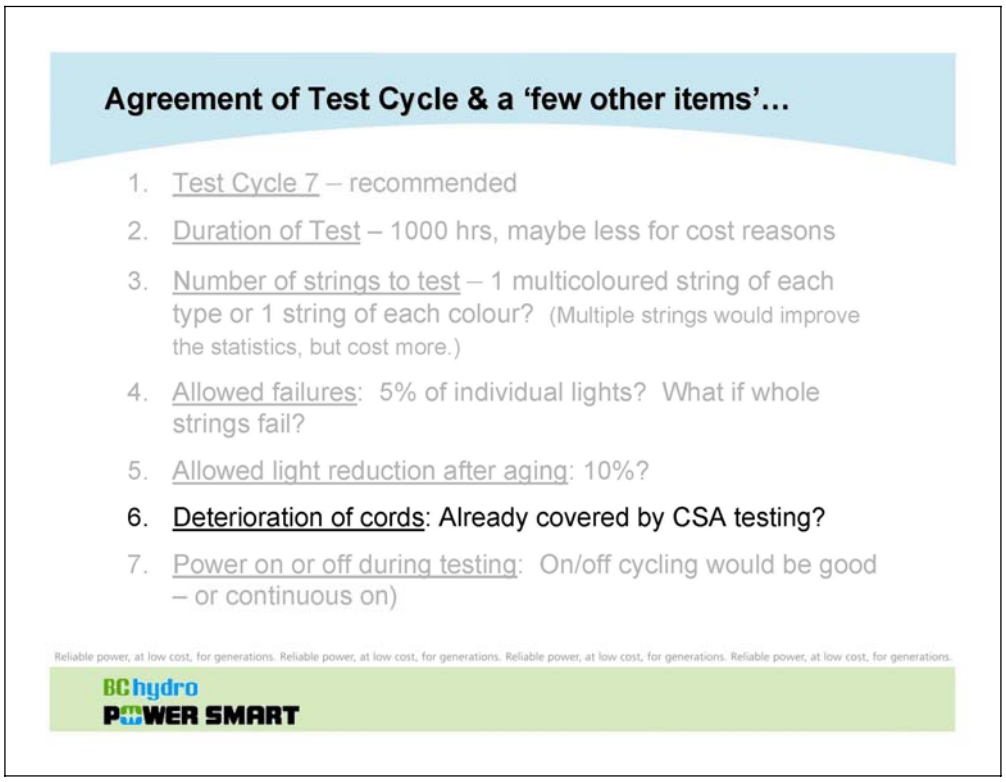
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Thanks…

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