Development of an ENERGY STAR Program for Seasonal Light Strings: Stakeholder Meeting Summary Report

Prepared for:
Natural Resources Canada

Prepared by:
Navigant Consulting, Inc.

March 28, 2006

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1.0 Introduction

Natural Resources Canada (NRCan) is developing an ENERGY STAR test procedure and qualification criteria for 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.

NRCan convened a one-day stakeholder meeting to review the draft ENERGY STAR test procedure and qualification criteria in Toronto, Ontario, on Monday, March 6, 2006. Approximately 25 manufacturers, retailers, government, and non-profit representatives[1] attended and reviewed the draft ENERGY STAR qualification criteria and test procedure for seasonal and decorative light strings. This report presents an overview of the workshop presentations and discussions. The appendix contains a list of workshop attendees, the workshop agenda, copies of the workshop presentations, and copies of the draft ENERGY STAR documents (proposal, performance criteria, and test procedure).

[1] For a complete list of attendees, see Section 5.2.

2.0 Presentation Summaries

2.1. Seasonal and Decorative Holiday Lights Overview

Katherine Delves, Manager of Standards Development at NRCan's Office of Energy Efficiency (OEE), introduced the ENERGY STAR program and explained the purpose of the initiative in Canada. ENERGY STAR was introduced in Canada in 2001 based on an arrangement with the U.S. EPA and DOE to allow Canada to market and promote the ENERGY STAR symbol.

The OEE is the leading entity for ENERGY STAR in Canada, and plays a coordinating role with other Canadian organizations to promote the program. Canada promotes specific product categories where levels and criteria can be harmonized, but does not promote all of the products and promotional initiatives supported by U.S. ENERGY STAR program because of climatic, language or regulatory concerns. OEE supports over 35 ENERGY STAR qualified product categories, in the areas of home appliances, office equipment, consumer electronics, heating and cooling equipment, lighting and signage, and windows. And, over the last several years, consumer awareness of the ENERGY STAR symbol has grown steadily.

Pierrette LeBlanc, Senior Standards Engineer at NRCan's OEE, introduced the guiding principles for ENERGY STAR product labelling, and described how decorative lights meet each of these principles.

1. *Significant Energy Savings Can Be Realized on a National Basis:*
    - By converting only 20% of annual sales from incandescent to LED strings in Canada for a total of 10 million strings, this would amount to annual electricity savings of approximately 110 GWh.

2. *Product Performance Can be Maintained or Enhanced with Increased Energy Efficiency:*
    - Along with significant energy savings, the adoption of LED sources would be accompanied by other benefits, including a longer operating lifetime and a safer and more durable light strings.

3. *Purchasers Will Recover Their Investment in Increased Energy Efficiency Within a Reasonable Period of Time:*
    - The simple payback for replacing C7 incandescent strings with C7 LED light strings is approximately 2.3 years. The simple payback for replacing C7 incandescent strings with "mini" LED lights strings is approximately 2.1 years. [Note: See the calculations and assumptions in Section 5.4.1. The payback periods and the assumptions behind will be reviewed/updated following the workshop.]

4. *Energy-efficiency Can be Achieved With Several Technology Options, At Least One of Which is Non-proprietary:*

- LED technology is non-proprietary. LED illuminating devices are manufactured by several companies around the world.
- While seasonal lighting technology is still an emerging technology, there are a growing number of SLED strings available every year, with an expanding range of models and manufacturers.
- LED lights strings are currently available in strings from 25 to 150 lamps, and in a variety of colours including red, green, blue, white, yellow, and multicoloured. There are also a range of lamp shapes, including mini-lights, round lamps, C-6 and C-7.

5. *Product Energy Consumption and Performance Can be Measured and Verified With Testing:*
    - Powertech Labs in British Columbia has developed a preliminary LED Test Protocol that specifically targets SLED strings. This test method was the subject of discussion during the workshop.

6. *Labelling Would Effectively Differentiate Products and be Visible for Purchasers:*
    - The addition of an ENERGY STAR label will increase consumer awareness that these products are an energy-efficient alternative to conventional incandescent strings.

See Section 5.3.1 for the complete presentation by Katherine Delves and Pierrette LeBlanc.

2.2. Overview of Proposed ENERGY STAR Performance Criteria

Gary Hamer, Senior Energy Management Engineer at BC Hydro, presented an overview of the proposed ENERGY STAR Performance Criteria. Mr. Hamer began his presentation with an overview of BC Hydro’s Power Smart program for seasonal light strings.

The program was initiated in 2002, during which 20,000 seasonal LED strings were distributed to business improvement associations and select organizations in over 60 communities throughout BC Hydro’s service territory. The promotion campaign focused on the key attributes of LED strings, including: long lifetime, low energy use, durability, and safety. BC Hydro’s Power Smart representatives meet with seasonal lighting buyers for the major retail chains in Canada to enlist their support for the new product during the 2003 holiday season.

In 2003, several large retailers included seasonal LEDs in their 2003 seasonal lighting product lines. In addition, BC Hydro, Natural Resources Canada, and select LED manufacturers and distributors offered a $5 off mail-in coupon on the purchase of qualifying seasonal LEDs.

In 2004, customers were invited to trade-in energy inefficient seasonal lights at exchange events held at participating retail outlets in the Lower Mainland and Vancouver Island in return for a $5 off coupon for the purchase of seasonal LED lights which were then retailing for $14.90 or more per string.

BC Hydro estimates that 1.1 million strings of LED holiday lights, more than 50% of all holiday lights sold, were sold in the province in 2004. The number of brands found on store shelves increased from 1 in 2002 to 11 in 2004. The number of households purchasing LED decorative strings increased from 8% in 2003 to 18% in 2004. This resulted in an estimated energy savings of 13.86 GWh and peak demand savings of 81.7 MW.

Mr. Hamer also shared why he believed an ENERGY STAR program for decorative lights would be beneficial in Canada. He believes that awareness & availability of products in many other jurisdictions appears comparable to that which existed in BC prior to 2002, and could be increased to BC Hydro's 2004 levels. Lastly, 70% of LED decorative light purchasers polled in BC mentioned that saving electricity and reducing their energy bills were strong drivers behind consumer purchases, suggesting that the ENERGY STAR label would be very effective for this product.

Mr. Hamer presented an overview of the proposed ENERGY STAR Performance Criteria, including:

1. Definitions
2. Reference Standards
3. Qualifying Products
4. Energy-Efficiency Specifications for Qualifying Products
5. Product Approval
6. Warranty
7. Packaging
8. Testing Criteria
9. Recycling
10. Effective Date
11. Future Specification Revisions

See Section 5.4.1 for the complete ENERGY STAR performance criteria draft.

See Section 5.3.2 for the complete presentation by Gary Hamer.

2.3. Experience in Testing Seasonal LED Strings

Bruce Neilson, Supervisor & Specialist Engineer at Powertech Labs, presented an overview of the draft LED Test Protocol and shared the experiences of Powertech Labs in testing several different manufacturers' products.

Powertech Labs initially developed test protocol to support BC Hydro's Power Smart program for seasonal LED strings because initial tests completed in 2004 raised concerns with products sold 3-4 years ago. The 2005 test program was initiated to follow up on earlier testing and to ensure that concerns were addressed.

Mr. Neilson presented an overview of the proposed ENERGY STAR Test Protocol, including:

1. Initial Inspection
2. Light Output Test
3. Over Voltage Test
4. Temperature Cycling Test
5. Water Ingress Test
6. Corrosion Resistance Test
7. Lamp Lifetime Test
8. Cord Safety Test

He discussed each of these tests, his personal experiences with the tests and presented several photographs of the test setup at Powertech Labs. In summary, Mr. Neilson believed that the testing completed by Powertech Labs identified increased corrosion resistance between the 2004 and 2005 models (although the test method and model types tested did vary), and found that balanced waveform designs are desirable. Light output, accelerated lifetime, and corrosion tests should be research and discussed further.

See Section 5.3.3 for the complete presentation by Mr. Neilson.

2.4. Seasonal LED Strings: Lifetime Criteria and Testing

Conan O'Rourke, Director of the National Lighting Product Information Program (NLPIP) at the Lighting Research Center, presented an overview of issues to consider when developing lifetime and brightness criteria and testing for decorative light strings.

Mr. O'Rourke began his presentation with a brief overview of LED construction, the diode voltage – current relationship, and a history of materials used in solid-state lighting since the 1970's.

Mr. O'Rourke continued his presentation by describing how lamp life is defined and tested for conventional lighting products, and explained that these methods are not appropriate for LEDs because LEDs do not fail like other light sources. The LED industry has no standard, agreed-upon definition for LED life. This has resulted in unproven long-life claims from manufacturers, confusion among lighting professionals, and products with high lifetime variations. He explained that the Alliance for Solid-State Illumination Systems and Technologies (ASSIST), established by the Lighting Research Center in 2002, has proposed a standard definition and measurement methods for the life of LEDs used in general lighting applications. The ASSIST recommendations can be found at: http://www.lrc.rpi.edu/programs/solidstate/assist/recommends.asp.

The Lighting Research Center has been performing lifetime testing on coloured LEDs using an imaging system and individual life-test chambers which keep the ambient temperature constant and act as light-integrators. Through these experiments, the LRC has found that LEDs of different colours degrade differently under similar conditions. The LRC also studied how light output degradation varies with drive current.

The LRC has also studied how ambient temperature changes affect light output. The experiment found that the temperature change sensitivities are different for red, green, and blue LEDs.

Results of this research can be found at: http://www.lrc.rpi.edu/programs/solidstate/.

See Section 5.3.4 for the complete presentation, including images of the degradation curves for different colour LEDs under the different testing conditions.

3.0 Discussion Summary: Program Criteria

3.1. Definitions

The group began with a discussion of the appropriate scope for the ENERGY STAR criteria. It was decided to change "seasonal light strings" to "decorative light strings" because these products are used by some commercial sector customers and municipalities year round. The group also discussed adding the term "used temporarily," but later rejected the suggestion as these products are used year round, not just during the holiday season. For this same reason, the revised definition will not include a reference that the products should be used "during the holiday season" or even temporarily. In addition, group decided the definition should not differentiate between products that are DC or AC driven because the performance criteria would be the same.

The group also discussed, but eventually rejected, adding energy-efficient rope lights or other products (e.g., illuminated wire-frame lawn-ornamental holiday deer or snowmen) to the criteria to simplify the performance requirements and testing issues. There were also concerns about the quality, (failure rate up to 10%) and consumer acceptance of LED rope light products, along with an observed drop in demand for the product. (Note: For a point of comparison, one manufacturer reported that less than 0.5% of their LED decorative lights are returned. However, as noted later, some commercial installations of LED decorative strings have experienced significantly higher failure rates.).

The group agreed the definition should include a reference to the entire system, including transformers, adaptors, and not just the light string.

The group requested that "lumen maintenance" be changed to "maintained brightness," and that all the definitions containing the term "light output" be replaced with "brightness," as that is the performance metric that may possibly be tested. The group felt that "light output" was not a term that made sense in the context of holiday lights, since these sources are not serving an illuminating function.

The group agreed that brightness should be measured after a 100 hour seasoning, or "burn-in", period and that useful life should be defined as 50% of the 100 hour brightness for decorative products. Fifty-percent, as opposed to 70%, is appropriate because these light strings are indicator, not illuminating products.

The group also discussed safety issues, including reducing the required wire gauge, number of strings that could be attached end to end, and current CSA safety tests (e.g., stretch test). However, the group agreed that these issues would be more appropriately addressed by CSA, and the discussion returned to focusing on the ENERGY STAR criteria.

For input power definition, the group wanted to make it clear that it referred to system power and not just lamp power. The definition should be adjusted to include references to transformers and adaptors. The group also considered, but later rejected, defining input power in volt-amperes instead of watts.

The group also decided that it was necessary to add a definition for “watts per lamp,” as that is a performance criterion metric (in Table 1).

The group questioned what would occur in the case of a transformer that is meant to operate multiple strings, but is only packaged with one. Should it be measured against the ENERGY STAR performance criteria with its maximum number of strings, or as packaged with fewer than its maximum capacity? A final decision was not made on this issue. This is a potential follow-up question for manufacturers – are there commercially-available products that would otherwise not qualify under the proposed watt per lamp criteria using only the number of string(s) of lamps contained in a package? If so, would this same product qualify using the maximum number of strings?

The group also considered adding a definition for power factor, but decided not to, as the loads from decorative string are small and would have a minimal impact on overall power factor from a home or commercial building.

The group also considered adding colour definitions, and discussed whether this is necessary in the context of decorative lights. Some consumers are concerned about the quality and consistency of colours within strings and between strings, and this becomes even more important in large scale installations in the commercial sector. Or, on the consumer side, if a homeowner purchases five strings in 2005 for a tree in their front yard and needs an additional 2 strings in 2008 because the tree has grown, these new strings should closely match the colour and brightness of the strings that were previously purchased. However, setting colour definitions would be an arduous process, and may be “over the top” given that these are lights for the purpose of indication, not illumination. This issue was not resolved at this meeting, but will be an important topic to discuss again.

3.2. Reference Standards

One group member noted that the two of the reference standards, CSA and UL, were revised in 2004. The corrections are noted below:

<u>Canadian Standards Association (CSA)</u>
CSA-22.2 No.37-M1989 (R2004) Standard for Christmas Tree and Other Decorative Lighting Outfits

<u>Underwriters Laboratories Inc. (UL)</u>
UL 588-2004, Standard for Seasonal and Holiday Decorative Products
Powertech Labs Inc./BC Hydro

The group also considered adding IES reference standards for measuring brightness and IEC standards (2000 series) for measuring power quality of low power devices if these criteria are measured as part of the ENERGY STAR Program.

3.3. Qualifying Products

No comments. This section was approved by the group with no changes. However, the group agreed that this section could also be combined with Section 4 "Efficiency Specifications for Qualifying Products," although this would make the sections and section numbering for this product inconsistent with other ENERGY STAR products.

3.4. Energy-Efficiency Specifications for Qualifying Products

Power Consumption Characteristics (Old Energy Efficiency Characteristics)
A large portion of the afternoon discussion focused on the maximum watts/lamp criteria. The draft maximum watts/lamp was 0.08 watts/lamp, and the group agreed it was too low. Instead, a value of 0.10 watts/lamp was proposed, to make sure that all series-connected LED products currently on the market would meet this criterion. This essentially translates to a 25 lamp per string minimum. However, if manufacturers begin to market strings with 10 or 15 lamps per string, this limit would not cover all products. However, raising this value would still result in significant energy savings when compared to incandescent products (see table below). The group also discussed raising the criterion to 0.20 watts/lamp because the energy savings would still be significant (a 50% savings over the incandescent mini-lights, which are typically about 0.4 watts / lamp), and leave manufacturers the flexibility to manufacture higher brightness products or strings with fewer lamps. No group consensus was reached on this proposal.

Lamp Shape	Number of Lamps per Set	Incandescent Light Set Wattage	LED Light Set Wattage	Wattage per Lamp Incandescent	Wattage per Lamp LED
Mini	100	36-48W	3.6-4.8W	0.36-0.48W	.036-.048W
C-6	35	36W	1.8-2.4W	3.6W	1.8-2.4W
C-7	35			5W	

The group also discussed creating a criterion with different product classes (defined by lamp type), so that an "apple-to-apple" comparison could be made. For this same reason, several members of the group also advocated a criterion based on percent energy savings over an incandescent-equivalent lamp size / shape. However, a percentage could not be agreed upon. And, in order to leave discussion time for other topics, the group decided to leave the criteria at 0.10 watts/lamp, and revisit this decision at a later time. The group wanted to discuss other criteria that would improve the quality of the products for consumers. Participants pledged to follow-up with further thoughts and suggestions on this topic.

Electrical Characteristics
The group agreed that two of the proposed electrical characteristics (nominal operating voltage, voltage sag / surge) are correct. The nominal operating voltage and sag / surge are within the allowed operating range in North America for consumer voltage. The

group felt the current (20ma) criterion was redundant, and agreed to remove it from the table, even though one group member argued that it does serve as effective benchmark for manufacturers which would prevent products from being overdriven to improve initial brightness at the expense of longer-term lumen maintenance.

Physical Characteristics

The group agreed the proposed physical characteristics (polarized plug-ins, double strings opposite polarity) are correct.

Visibility Characteristics

The discussion in this section focused on brightness. The group agreed that they want to create pleasing products, but also identified that higher brightness products are higher priced products, so manufacturers regularly have to strike a balance between offering affordable products and acceptable brightness. Another challenge in measuring brightness is that different colour LEDs depreciate differently over time.

The group also discussed its concern about how to ensure compliance by manufacturers to the eventual ENERGY STAR criteria. As the decorative lighting industry is a low margin industry, the group explained one cannot expect high quality LED products. Some stakeholders indicated they are doubtful that the industry will police itself, and they suggested it would be necessary to test products coming off the line or on the shelves at random, as opposed to only testing those submitted by a manufacturer for certification.

One member of the group shared a story of a commercial installation in Ontario (by Niagara Electric) where one million LED lights were on display. One company’s green LED strings had a failure rate of 50%, and their colour-changing products had a failure rate of 80%+. Workshop participants speculated that this was most likely due to the fact that the power quality in that location was creating voltage surges and overdrive conditions that the strings were not designed to handle. However, this anecdotal story conveys possible problems with product quality and is something the ENERGY STAR program should be concerned about.

When questioned about acceptable brightness levels and energy savings criteria. Rachael Schmeltz from EPA responded that the purpose of the ENERGY STAR program is to achieve improved efficiency without sacrifice to other performance features. So, the products should have comparable quality and comparable brightness. And, additional requirements are acceptable as well. For compliance/false labelling issues, the ENERGY STAR program has historically relied on industry self-policing and random sampling, because of the level of concern over the cost/burden of compliance testing.

With respect to lifetime, 25,000 hours does not seem unrealistic for the LEDs in holiday lights (driven at 20ma). The real concern with this product is the lifetime of the wire, lamp sockets / housings and connections. Due to the lower voltage (higher currents) these connections are more susceptible to corrosion.

3.5. Product Approval

Not discussed, participants were asked to submit written comments and this issue would be addressed in the next workshop.

3.6. Warranty

Not discussed, participants were asked to submit written comments and this issue would be addressed in the next workshop.

3.7. Packaging

While the group did not discuss packaging, Gary Hamer of BC Hydro suggested several modifications to the draft ENERGY STAR Performance Criteria for packaging in his presentation. He suggested that the *packaging* containing the product should list:

- product's suitability for use indoor and/or outdoor,
- number of LED lamps,
- LED lamp spacing,
- total light string length in appropriate metric and SAE units, and
- wattage of light string.

He also suggested that the *light string* should be labelled with the following information:

- certification agency,
- rating for indoor or outdoor use, and
- maximum number of like strings that can be connected end to end.

These changes will be made to the next version of the criteria and discussed at the next workshop.

3.8. Testing Criteria

See Section 4.0.

3.9. Effective Date

Not discussed, participants were asked to submit written comments and this issue would be addressed in the next workshop.

3.10. Future Specification Revisions

Not discussed, participants were asked to submit written comments and this issue would be addressed in the next workshop.

4.0 Discussion Summary: Test Protocol

4.1. Initial Inspection

The group did not have any changes to the initial inspection list.

4.2. Light Output Test

Consumers, business improvement administrations (BIAs) and retailers all request brighter products from manufacturers. The major concerns relating to brightness testing include: maximum brightness, minimum brightness, brightness maintenance, and colour uniformity.

The discussion around light output/brightness testing centered on its appropriateness for the ENERGY STAR program. The group agreed that the simplest solution would be to eliminate brightness criteria/testing, and instead to provide a warranty, so that consumers had recourse for returning an unacceptable product. However, one group member reported that retailers do not keep backup stock, so most returns would result in a refund, and not an exchange.

CSA already performs maximum brightness criteria in *CSA-22.2 No.37-M1989 (R2004) Standard for Christmas Tree and Other Decorative Lighting Outfits* to ensure that the LEDs are verified in accordance with IEC 6082501 to be within Class 1 laser requirements. Therefore all products on the market in Canada already meet this safety standard and there is no need to include it in the ENERGY STAR criteria. A discussion of how the lamps should be tested also ensued, but this discussion pertained to CSA testing, and not to testing for the ENERGY STAR program. The maximum brightness test was removed from the next draft, as this is a safety, not reliability issue.

The workshop participants recognized that there is an inherent trade-off between LED brightness and cost. As the per unit price of LED devices gradually declines, manufacturers have a choice of either reducing the price or increasing the brightness. But, if they choose to increase brightness, then they cannot not decrease price, and may even increase it. The group wanted to know what would be considered an acceptable price/brightness combination for ENERGY STAR. This topic requires further discussion.

The group felt it is easier to measure white light than coloured light because it might be difficult to establish definitions for different colours (by nm range), and this level of precision may not be necessary for this product. This issue is closely tied to consumer acceptance. The participants suggested that perhaps ENERGY STAR should organize some focus groups to gauge consumer acceptance of brightness levels and colour definitions.

The need for a light output / brightness, testing remained unresolved.

4.3. Over Voltage Test

The group agreed this was acceptable.

4.4. Temperature Cycling Test

The group wanted the test protocol to explicitly state that the light strings are not to be energized during the temperature cycling test.

The group also stated that CSA performs a more difficult temperature cycling test, so this should be removed from the ENERGY STAR test protocol. However, this test was designed to be completed in conjunction with the water ingress test. A final decision was not made as to whether it should remain. Participants were asked to submit written comments and this issue would be discussed again in the next workshop.

4.5. Water Ingress/Corrosion Resistance Test

The water ingress and corrosion tests were designed to ensure the quality of products with removable sockets, due to concerns based on earlier testing results. However, several members of the group questioned the conclusions drawn from the corrosion test results because the tests were not completed uniformly each year, and unsealed products were excluded from testing in 2004.

Members of the group felt that the water ingress test should not be required because this was a safety test and CSA and UL do not require that products pass a water ingress test. However, others responded by stating that is actually a functional issue for LED products, and not a safety issue. Corrosion is a larger problem in LED products than in incandescent products because the lower operating current of LED products makes them more susceptible to corrosion. Furthermore, because the LED does not generate as much heat as an incandescent lamp, it is less able to ‘drive-off’ water attempting to enter the socket or housing around the lamp.

The group did agree that quality LED products should resist corrosion and this was a desirable feature for any ENERGY STAR product. It was suggested that a “rain test” or more effective/cheaper corrosion test would be more suitable. Alternatively, it could be required that manufacturers show that hermetically sealed products pass a water ingress test, and manufacturers of unsealed products show that their products pass an appropriate corrosion test.

A final decision was not made on this issue, but participants were asked to submit written comments and this issue would be addressed in the next workshop. Significant work is necessary on this portion of the test protocol and Natural Resources Canada is very interested in input from stakeholders.

4.6. Lamp Lifetime Test

Not discussed, participants were asked to submit written comments and this issue would be addressed in the next workshop.

4.7. Cord Safety Test

Not discussed, participants were asked to submit written comments and this issue would be addressed in the next workshop. This test was removed from the next draft, as this is a safety, not reliability issue.

5.0 Appendix

5.1. Final Agenda

ENERGY STAR Meeting on Seasonal LED Strings

March 6, 2006 MEETING
9:00 TO 16:00

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

8:30-9:00	Registration and Continental Breakfast
9:00-9:15	Opening Remarks and Introductions Michael Scholand – Navigant Consulting Inc.
9:15-9:30	Overview of ENERGY STAR Program and Requirements *Katherine Delves/Pierrette LeBlanc – NRCan*
9:30-10:00	Overview of Proposed ENERGY STAR Performance Criteria for Seasonal Light Emitting Diode Strings (SLEDs) *Gary Hamer – BC Hydro*
10:00-10:15	COFFEE BREAK
10:15-10:45	Overview of Proposed ENERGY STAR Test Protocol for SLEDs Developed by BC Hydro / Powertech Labs *Bruce Neilson – Powertech Labs*
10:45- 3:45	Group Discussion: “Proposed ENERGY STAR Performance Criteria” and “Proposed ENERGY STAR Test Protocol” Developed by BC Hydro / Powertech Labs *Facilitated by Navigant Consulting* Major Discussion Points: 1. Energy Consumption/Electrical Characteristics 2. Brightness Criteria and Testing *Presentation – Conan O’Rourke, Lighting Research Center* 3. Lifetime Criteria and Testing 4. Warrantee 5. Additional Test Criteria in “Proposed ENERGY STAR Test Protocol” (*e.g.,* water ingress, temperature cycling, corrosion)
12:00-1:00	LUNCH
2:00-2:15	COFFEE BREAK
3:45-4:00	Wrap-Up/Adjourn

5.2. List of Attendees

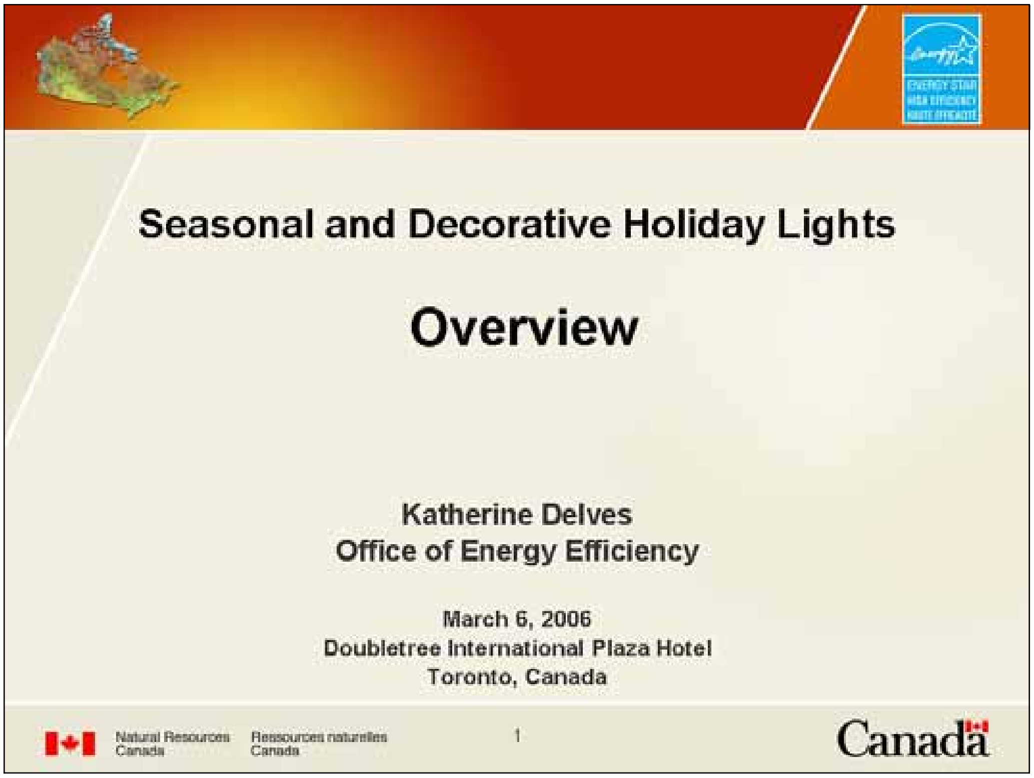
Table 5-1: List of Attendees at ENERGY STAR Stakeholder Meeting, March 6th

Name	Company
David Allen	Fiber Optic Designs, Inc.
Boon Chuah	Pharos Innovations
Louise Conroy	Navigant Consulting, Inc.
Katherine Delves	Natural Resources Canada
Dom Friio	Costco Canada
Bob Goldschleger	Universal Lites
Ed Grzesik	Ontario Ministry of Energy
Isabelle Guimont	Natural Resources Canada
Gary Hamer	BC Hydro
John Hayes	Holiday Creations
Janny Hogen Esh	Philips Lighting
Pierrette LeBlanc	Natural Resources Canada
Dejan Lenasi	CSA-International
Ted Marlow	Marlow & Associates
Jim Mc Crea	Conglom, Inc.
Bruce Neilson	Powertech Labs
Conan O'Rourke	The Lighting Research Center, RPI
Brian Owen	FIRSTeam - LEDesignWorks
Charles Parker	Carillon Decorative Products, Inc.
Rachel Schmeltz	U.S. EPA ENERGY STAR
Michael Scholand	Navigant Consulting, Inc.
Bob Storey	Canadian Standards Association
WayneTucker	Classic Displays
Sheila Waite-Chuah	Partner, Pharos Innovations
David Weiss	3H + Co.
Jerry Yu	LED up

5.3. Presentations

5.3.1. Seasonal and Decorative Holiday Lights

Presented by: Katherine Delves/Pierrette LeBlanc – Natural Resources Canada



The ENERGY STAR Solution

- Voluntary partnership with manufacturers
- Gives the purchaser an easy way to choose efficient products
- Makes link between energy consumption and environmental impact
- Facilitates collaboration among Government, manufacturers, retailers and utilities so as to increase sales of ENERGY STAR labelled products

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What is the Cdn ENERGY STAR initiative?

- Introduced in 2001, arrangement with US EPA and US DOE allows Canada to market and promote symbol.
- OEE is lead for ENERGY STAR and coordinates with Canadian organizations to promote the initiative.
- Canada promotes specific product categories where levels and criteria can be harmonized
- Canada does not promote all of the products and promotional initiatives supported by US ENERGY STAR. Some products not promoted because of climatic, language or regulatory concerns.

Natural Resources Canada Ressources naturelles Canada 3 Canada


35+ ENERGY STAR Qualified Product Categories
▪ Home Appliances: Refrigerators, freezers, clothes washers, dishwashers, dehumidifiers, water coolers
▪ Office equipment: Computers, monitors, printers, scanners, copiers, fax machines, multifunction devices, commercial refrigerators, vending machines
▪ Consumer electronics: TVs, VCRs, DVD players, audio equipment, cordless telephones, answering machines, external power supplies
▪ Heating and Cooling Equipment: Central AC and heat pumps, Room AC, furnaces, boilers, programmable thermostats, ventilation fans, ceiling fans
▪ Lighting and signage: CFLs, exit signs, traffic signals
▪ Windows, Doors and skylights
Natural Resources Canada
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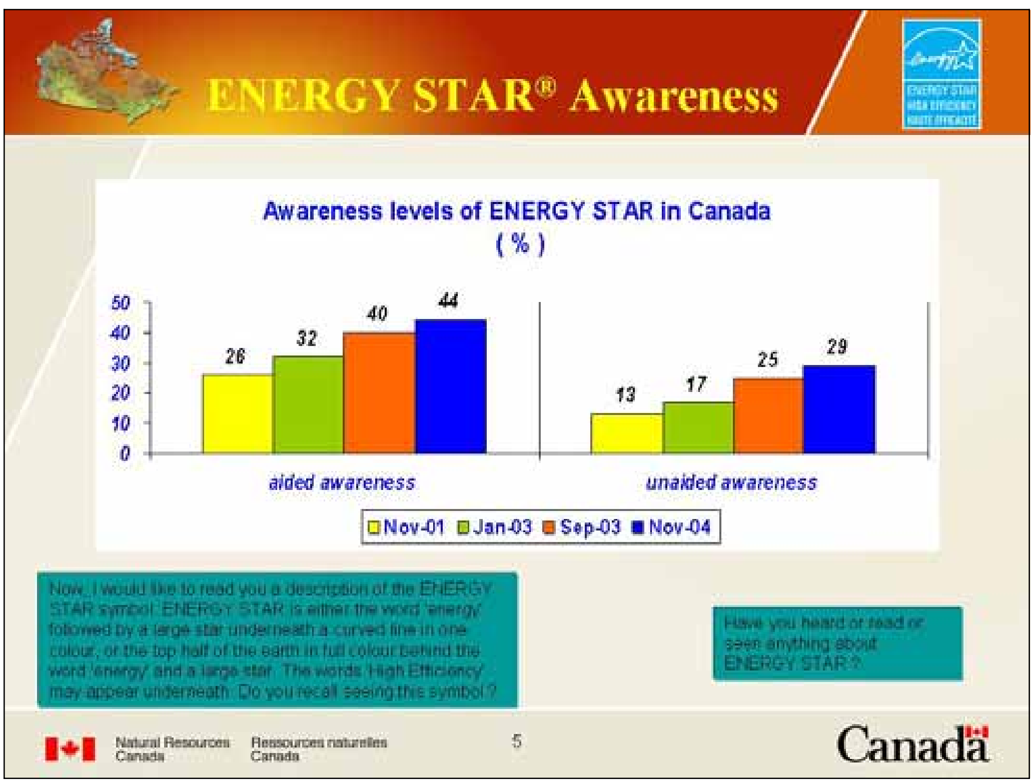
Canada


ENERGY STAR® Awareness
Awareness levels of ENERGY STAR in Canada
(%)
50
40
30
20
10
0
26
32
40
44
13
17
25
29
aided awareness
unaided awareness
Nov-01
Jan-03
Sep-03
Nov-04
Now, I would like to read you a description of the ENERGY STAR symbol. ENERGY STAR is either the word 'energy' followed by a large star underneath a curved line in one colour, or the top half of the earth in full colour behind the word 'energy' and a large star. The words 'High Efficiency' may appear underneath. Do you recall seeing this symbol?
Have you heard or read or seen anything about ENERGY STAR?
Natural Resources Canada
Ressources naturelles Canada
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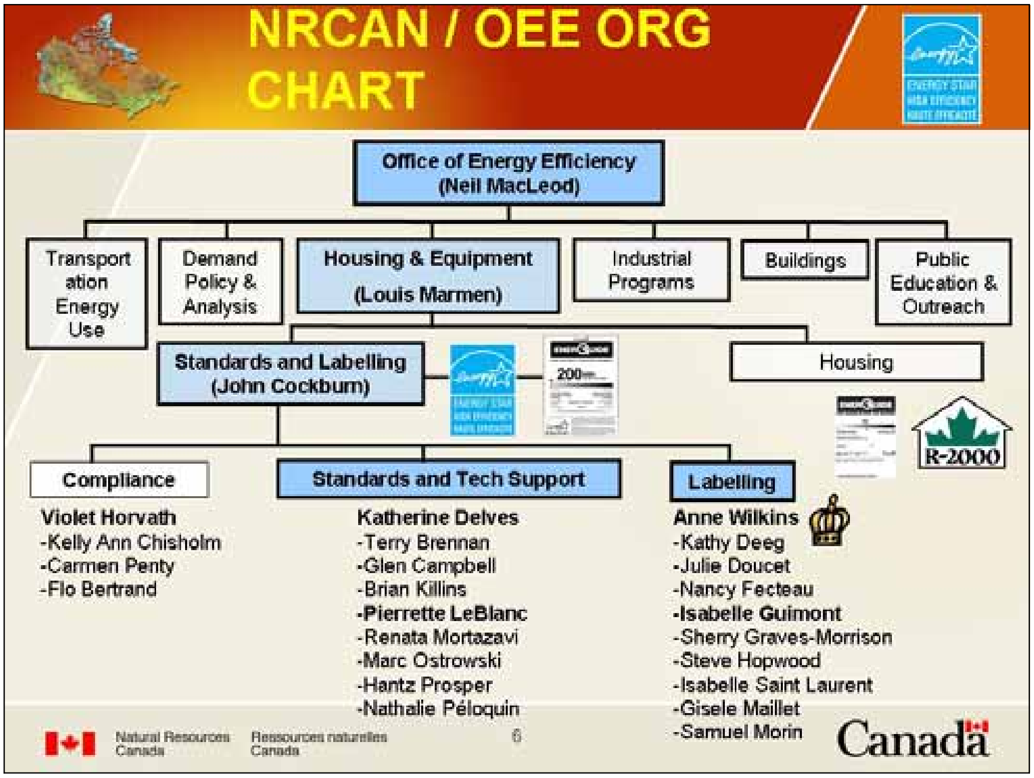
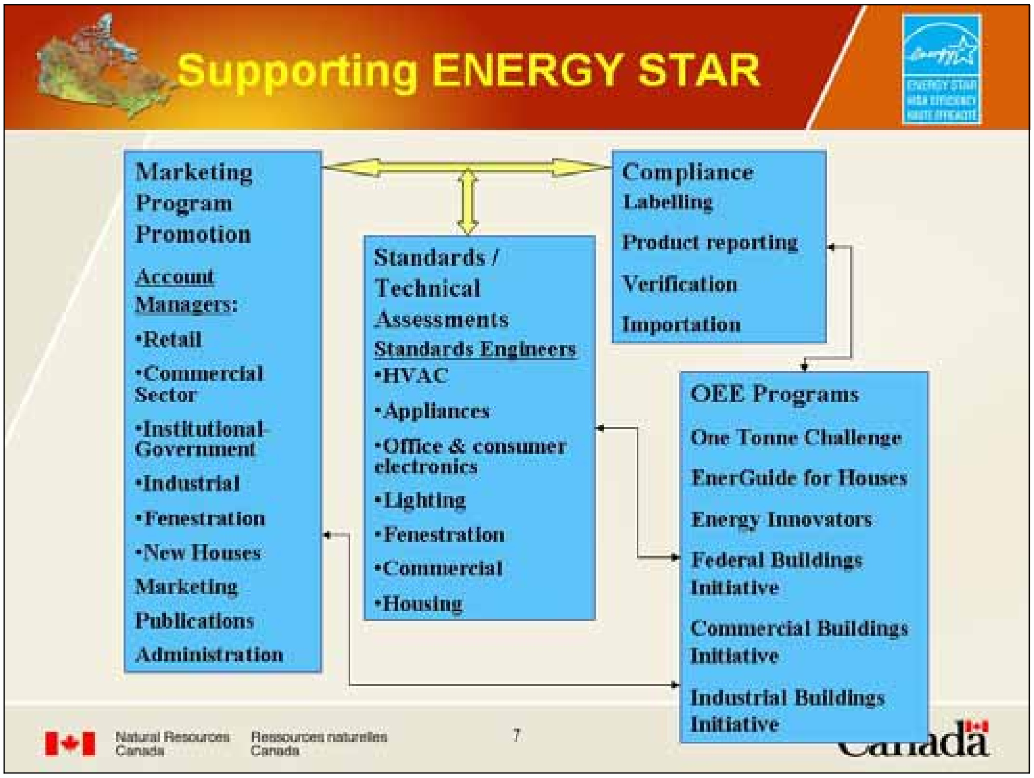
Canada


NRCAN / OEE ORG CHART
Office of Energy Efficiency (Neil MacLeod)
Transportation Energy Use
Demand Policy & Analysis
Housing & Equipment (Louis Marmen)
Industrial Programs
Buildings
Public Education & Outreach
Standards and Labelling (John Cockburn)
Housing
R-2000
Compliance
Standards and Tech Support
Labelling
Violet Horvath
-Kelly Ann Chisholm
-Carmen Penty
-Flo Bertrand
Katherine Delves
-Terry Brennan
-Glen Campbell
-Brian Killins
-Pierrette LeBlanc
-Renata Mortazavi
-Marc Ostrowski
-Hantz Prosper
-Nathalie Péloquin
Anne Wilkins
-Kathy Deeg
-Julie Doucet
-Nancy Fecteau
-Isabelle Guimont
-Sherry Graves-Morrison
-Steve Hopwood
-Isabelle Saint Laurent
-Gisele Maillet
-Samuel Morin
Natural Resources Canada
Ressources naturelles Canada
6
Canada


Supporting ENERGY STAR
Marketing
Program
Promotion
Account Managers:
•Retail
•Commercial Sector
•Institutional-Government
•Industrial
•Fenestration
•New Houses
Marketing
Publications
Administration
Standards / Technical Assessments
Standards Engineers
•HVAC
•Appliances
•Office & consumer electronics
•Lighting
•Fenestration
•Commercial
•Housing
Compliance
Labelling
Product reporting
Verification
Importation
OEE Programs
One Tonne Challenge
EnerGuide for Houses
Energy Innovators
Federal Buildings Initiative
Commercial Buildings Initiative
Industrial Buildings Initiative
Natural Resources Canada
Ressources naturelles Canada
7

Guiding Principles for ENERGY STAR Product Labelling

- **Significant energy savings can be realized on a national basis**
- **Product performance can be maintained or enhanced with increased energy efficiency**
- **Purchasers will recover their investment in increased energy efficiency within a reasonable time period**
- **Efficiency can be achieved with several technology options, at least one of which is non-proprietary**
- **Product energy consumption and performance can be measured and verified with testing**
- **Labelling would effectively differentiate products and be visible for purchasers**

Natural Resources Canada Ressources naturelles Canada 8 Canada

Why Seasonal Holiday Lights?

1. **Significant Energy Savings:**
   - By converting only **20%** of annual sales from incandescent to LED strings in Canada for a total of 10M strings, this would amount to annual energy savings of approximately **110 GWh.**

2. **Product Performance Can be Maintained or Enhanced with Increased Energy Efficiency**
   - Along with significant energy savings, the adoption of LED sources would be accompanied by other benefits, including a longer operating lifetime and a safer and more durable product.

3. **Purchasers Will Recover Their Investment in Increased Energy Efficiency Within a Reasonable Period of Time**
   - The simple payback for replacing C7 incandescent strings with C7 LED light strings is approximately 2.3 years. The simple payback for replacing C7 incandescent strings with "mini" LED lights strings is approximately 2.1 years.

Natural Resources Canada Ressources naturelles Canada 9 Canada

5.3.2. Overview of Proposed ENERGY STAR® Performance Criteria

Presented by: Gary Hamer- BC HydroBruce Neilson – Powertech Labs

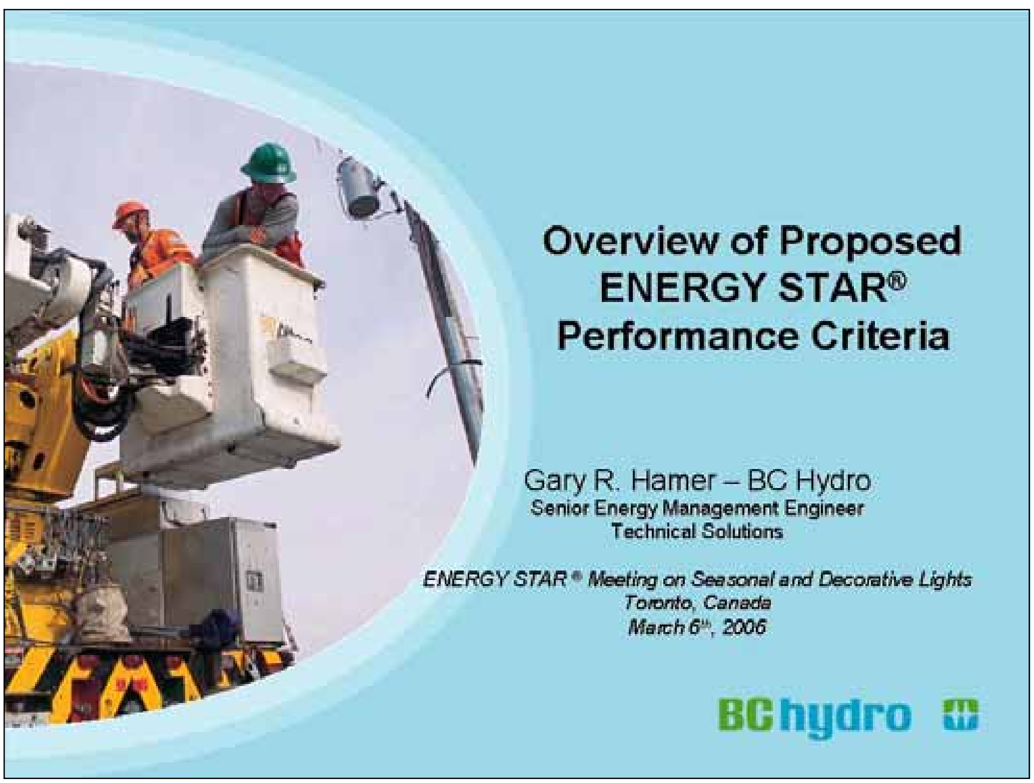


Table of Contents

BC Hydro Programming Highlights…

2002

- 20,000 seasonal LED strings to business improvement associations and select organizations in over 60 communities throughout BC Hydro's service territory.
- Promotion campaign focused on the key attributes including:
  - their longevity,
  - low energy use,
  - durability, and
  - safety.
- Power Smart representatives meet with seasonal lighting buyers for the major retail chains in Canada to enlist their support for the new product during the upcoming 2003 holiday season.

BC Hydro Programming Highlights…

2003

- Several large retailers include seasonal LEDs in their 2003 seasonal lighting product lines.
- BC Hydro, Natural Resources Canada, and select LED manufacturers and distributors offer a $5 off mail-in coupon on the purchase of qualifying seasonal LEDs.

2004

- Customers invited to trade-in energy inefficient seasonal lights at exchange events held at participating retail outlets in the Lower Mainland and Vancouver Island
  - in return for a $5 off coupon for the purchase of seasonal LED lights worth $14.90 or more. The maximum number of coupons per-household is set at three.
- BC Hydro customers in all regions are eligible to receive a $3 off mail-in rebate on purchases of seasonal LEDs worth $14.90 or more. A maximum of three coupons per-household is allowed.

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

Increase Sales…

BC Hydro Promotions…

Holiday Lighting Comparison

Application: 8' Christmas Tree:

Lighting Type	Power (Watts)	Energy Used (kWh/yr)	Energy Cost ($/yr)	Comments
Standard C-7, 5-watt	625	97	$6.00	5 strings, 125 lamps
Incandescent mini lights	150	23	$1.44	3 strings, 300 lamps
LED C-6 (strawberry)	14	2	$0.14	4 strings, 280 lamps

Application: 100' of Outdoor outlining (eaves/windows):

Lighting Type	Power (Watts)	Energy Used (kWh/yr)	Energy Cost ($/yr)	Comments
Standard C-7, 5-watt	500	78	$4.80	4 strings, 100 lamps, 25 ft/string
Incandescent mini lights	200	31	$1.92	4 strings, 400 lamps, 26 ft/string
LED C-6 (strawberry)	13	2	$0.12	4 strings, 280 lamps, 23 ft/string

Assumptions

- Seasonal lights are used for 31 days per year for 5 hours per day
- The cost of electricity is about 6 cents per kilowatt-hour (kWh) (the price paid by BC Hydro's residential customers)

Note: a kilowatt hour is equivalent to turning on ten, 100-watt light bulbs for one hour

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Savings from 2004 Initiative…

- **Market Effects**
  - Number of installed LED strings 803,855
  - Energy Savings = 13.86 GWh
  - Peak Demand Savings = 81.7 MW

Market Effects Algorithm

Market Effects = Total Sales of Seasonal LEDs in BC - Program Net Direct Impacts - LED Replacement Purchases - Baseline sales of Seasonal LEDs

Why Energy Star in Canada…

- Awareness & availability of product in many other jurisdictions appears comparable to that which existed in BC prior to 2002. Awareness & sales of product in the United States as "very low" to "virtually none".
- Overwhelmingly, saving energy / money most frequently mentioned reason for purchasing LED holiday lights in 2004 (70% of all purchasers). Appearance and being something new / different were the second and third most common reasons.
- **LED Replacement Purchases** – an estimated 19% of all seasonal LEDs purchased in 2004 by BC Hydro residential customers were acquired to replace existing LEDs.

Testing to ensure acceptance…

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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Table of Contents

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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ENERGY STAR® Criteria Outline

1. Definitions
2. Reference Standards
3. Qualifying Products
4. Energy-Efficiency Specifications for Qualifying Products
5. Product Approval
6. Warranty
7. Packaging
8. Testing Criteria
9. Recycling
10. Effective Date
11. Future Specification Revisions

1. Definitions

A. Seasonal Light Emitting Diode String - Decorative strings of lights employing light emitting diode (LED) technology that are used primarily during the holiday season. These strings use solid-state semi-conductor devices that convert electrical energy directly into light.

B. Series Block - A number of LED lamps connected in series, or utilizing a series connection. Additional series blocks can be added to the circuit (or light string) utilizing parallel connections. For example, a 70-lamp light string could have two 35-lamp series blocks connected in parallel.

C. Brightness - Luminous flux emitted from a surface per unit solid angle per unit of area, projected onto a plane normal to the direction of propagation (Iv). Also known as luminous sterance. LED intensity is specified in terms of millicandela (mcd).

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1. Definitions, cont'd

D. Lumen Maintenance - The light output of a lamp as a percentage of its initial light output after a 100-hour seasoning period.

E. Useful Life - The length of time an LED source takes, when operated at an ambient temperature of 35°C, to reach 50% (L50=) of its initial light output.

F. Viewing Angle – The spacial radiation pattern of the light emitted, indicating the degree of beam spread.

G. Input Power - The actual total power used by the seasonal LED string during operation, measured in watts (W).

2. Reference Standards

ENERGY STAR qualified seasonal LED strings shall comply with the applicable safety standards and relevant clauses from UL, CSA and other 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) Standard for Christmas Tree and Other Decorative Lighting Outfits

Underwriters Laboratories Inc. (UL)

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

Powertech Labs Inc./BC Hydro

LED Test Protocol developed by Powertech Labs for BC Hydro.

IES or Other Standard for light measurement (Apparent brightness or Luminous Flux

IEC Standards – to specify limits for harmonics and power quality measurements

3. Qualifying Products

In order to qualify for the ENERGY STAR label, any seasonal light strings must meet the definition in Section 1.A namely –

Seasonal Light Emitting Diode String - Decorative strings of lights employing light emitting diode (LED) technology that are used primarily during the holiday season. These strings use solid-state semi-conductor devices that convert electrical energy directly into light.

– and the specification requirements provided in Section 4.

Following is just a brief overview for afternoon's discussion.

4. Energy-Efficiency Specifications for Qualifying Products

Table 1: Product Characteristics and Specifications for Seasonal LED Strings	
Energy Efficiency Characteristics	**Specification**
Maximum watts per lamp	0.08 watts
Electrical Characteristics	
Nominal operating voltage	120 Volts
Voltage sag / surge	± 10%
Amperes	20 ma or less per series block
Physical Characteristics	
Plug / plug-ins	Polarized
Double strings	Two opposite polarity groups (balanced)
Visibility Characteristics	
Lifetime claim	25,000 hours (or 'long-lasting')
Brightness (depends on color)	Minimum: **TBD** I_v (mcd) Maximum: **TBD** I_v (mcd)
Minimum viewing angle, measured relative to mechanical centre	60°

5. Product Approval

In Canada, all light strings for use as portable seasonal holiday lighting must be CSA or UL approved with appropriate labelling on the string.

6. Warranty

All participating manufacturers must offer a minimum of a 3-year warranty against product defects.

7a. Packaging

The packaging containing the product shall list:

- product's suitability for use indoor and/or outdoor;
- number of LED lamps;
- LED lamp spacing;
- total light string length in appropriate metric and SAE units; and
- wattage of light string

7b. Labeling

The light string shall be labeled with the following information:

- certification agency;
- rating for indoor or outdoor use; and
- maximum number of like strings that can be connected end to end.

8. Testing Criteria

In order to qualify products for ENERGY STAR, manufacturers are required to certify their Seasonal LED Strings using test procedures referenced in this document (see Section 2). The criteria listed in Table 1 must be tested using "Powertech Labs / BC Hydro Seasonal LED String Test Protocol." These tests shall be conducted by a third-party laboratory accredited to ISO 17025 or NVLAP.

9. Recycling in 2004…

- 28,584 strings traded-in at BC Hydro in-store exchange events.
- 59% used 7 watt bulbs, 16% used 5 watt bulbs, and 25% used the 0.4 watt mini-light bulbs.
- Future – Involvement with Manufacturers, Distributors & Retailers

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10. Effective Date

The date that a manufacturer begins to qualify products as ENERGY STAR will be defined as the *effective date* of the agreement.

11. 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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5.3.3. Experience in Testing Seasonal LED Strings

Presented by: Bruce Neilson – Powertech Labs

POWERTECH

Background

- Developed test protocol to support BC Hydro power smart program for seasonal LED strings (SLEDS).
- Initial tests completed in 2004 raised concerns with products sold 3-4 years ago.
- The 2005 test program was initiated to follow up on earlier testing and ensure that concerns were addressed.
- Now being considered as the test protocol for the ENERGY STAR® seasonal and decorative lights program.

POWERTECH

Components of Test Protocol

1. Initial inspection
2. Light output test
3. Over voltage test
4. Temperature cycling test
5. Water ingress test
6. Corrosion resistance test
7. Lamp lifetime test
8. Cord safety test

POWERTECH

1. Initial Inspection

a. Inspect for safety or shock hazard concerns

b. Count bulbs per string and distance between bulbs

c. Check bulb type: sealed, polarized or unpolarized plug-in

d. Check that plug-in diodes or resistors cannot be incorrectly swapped with spare bulbs

e. Determine connection scheme (series, series/parallel, or other)

f. Measure power consumption and current

g. Measure current waveform and harmonic content

POWERTECH

Draft Initial Inspection Criteria

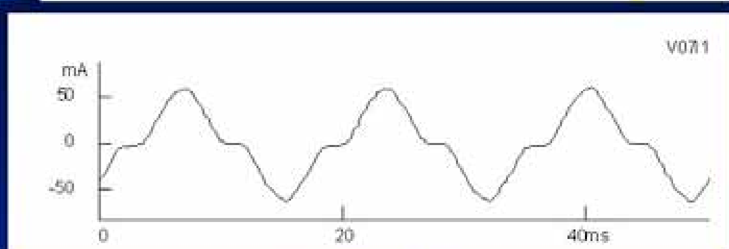
- There must be no obvious safety or shock hazards.
- If the string has plug-in bulbs, they must be polarized and keyed to prevent incorrect connection.
- If two strings are in parallel, they must have opposite polarity to minimize harmonic distortion.
- Single strings must be designed in balanced mode or so that polarity of multiple strings will balance.

POWERTECH

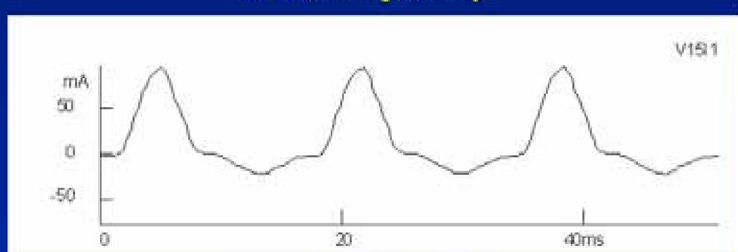
Unpolarized Sockets

POWERTECH

Waveform polarity



Balanced polarity



Unbalanced polarity

POWERTECH

2. Light Output Test

- A photometric system will be used to measure the luminous intensity of three individual bulbs from each test string (or one bulb of each colour in multicoloured strings).
- Each bulb will be mounted in turn, rotated to obtain maximum intensity, and the intensity (in candela) will be measured.
- The intensity will also be measured at two points each 30 degrees from the maximum intensity.
- If a diffuser can be removed without causing so much damage that the string or bulb is extinguished, test a will be repeated with a bulb with the diffuser removed.

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Draft Light Output Criteria

- These tests were not performed in the initial studies
- Two issues may need to be addressed:
  - Safety from eye damage
  - Apparent brightness of lights
- Do we need to address either of these issues?

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3. Over Voltage Test

- Strings will be energized at 132 V for 1 hour and examined for failure.

Draft acceptance criterion:

- Strings must survive without damage.

Results:

- All samples passed.

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4. Temperature Cycling Test

- Test strings will be subjected to 3 temperature cycles of cooling to –15°C (±5°C) for 8 hours and then warming to 20°C (±5°C) for 16 hours.
- This is also preparation for water ingress test.

Draft acceptance criterion:

- Strings must operate properly after cycling.

Results:

- All samples passed

POWERTECH

5. Water Ingress Test

- One sample of each type is tested after temperature cycling.
- The string is immersed in salt water at room temperature for 24 hours (except end fittings).
- The low voltage dc resistance is measured before and after

Draft acceptance criterion:

- The final resistance value is greater than 1 Megohm, indicating no water ingress has occurred.

Results:

- Some passed, some failed

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6. Corrosion Resistance Test

- After temperature cycling, two samples of each type are tested for corrosion resistance in alternating fog (1 hour) and dry heat (3 hours) at 30°C for 1000 hours.
- Strings are powered during the testing.
- The strings are checked every week (168 hours).

Draft acceptance criterion:

- Both samples must survive 1000 hours.

Results:

- All samples passed in 2005

POWERTECH

2004 Testing - UV Mist Chamber

POWERTECH

2004 Testing - UV Mist Chamber


POWERTECH
2004 Testing - UV Mist Chamber


POWERTECH
2005 Testing - Corrosion Chamber

POWERTECH

2005 Testing - Corrosion Chamber

POWERTECH

Corrosion Problems in 2004

POWERTECH

7. Lamp Lifetime Test

- Two samples of each type are mounted in an oven maintained at 50°C and energized for 1000 hours.
- The strings are examined every week.
- This test is intended as an accelerated aging test to identify substandard lamps. Higher temperatures might be used.

Draft acceptance criteria:

- Both strings survive 1,000 hours of testing.

Results:

- All samples passed in 2005

POWERTECH

8. Cord Safety Test

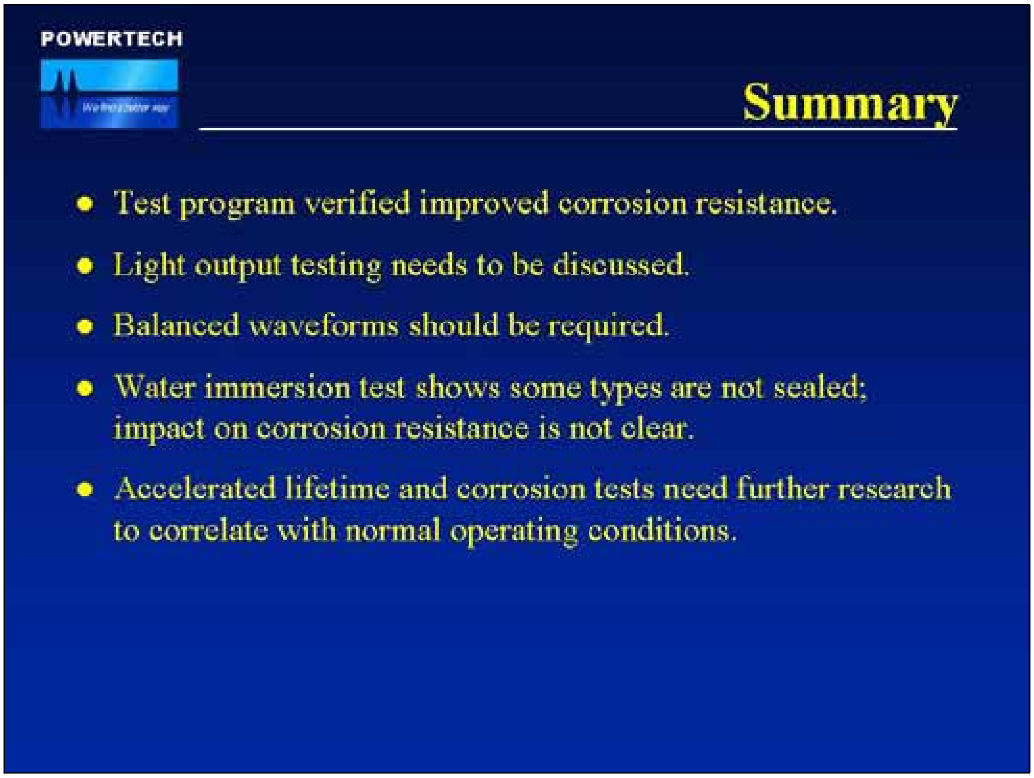
- Strings with extension outlets are tested for safety.
- A resistive current of 10 A (or rated current) is run through the cord for 24 hours.
- After 24 hours, the current is increased to 15 A for 1 hour.

Draft acceptance criteria:

- The string must survive the 24-hour test without damage.
- The string must not catch fire or create a safety hazard during the 15 A test.

Results:

- No failures or problems.

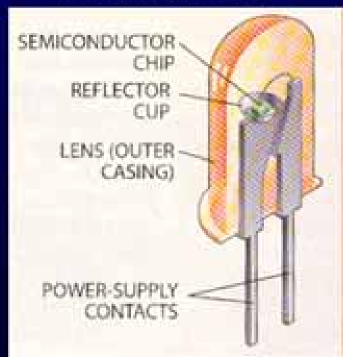


5.3.4. Seasonal LED Strings: Lifetime Criteria and Testing

Presented by: Conan O'Rourke – The Lighting Research Center

LED Construction

Indicator-type LED



The Anatomy of a Plastic T-1¾ TS

Reflector cup

- Improves light collection

Lens (epoxy dome)

- Improves light extraction
- Directs the light in a particular direction

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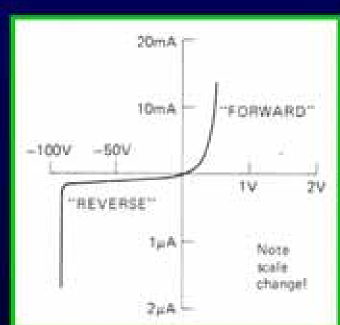
Diode Voltage – Current Relationship

- Very little current flows when reversed biased.
  - nanoAmperes (10^{-9})
- Current increases exponentially with voltage for forward bias.
- Exact current for a given voltage is highly unpredictable. Must control or limit current when forward biased.



Diode V-I Curve

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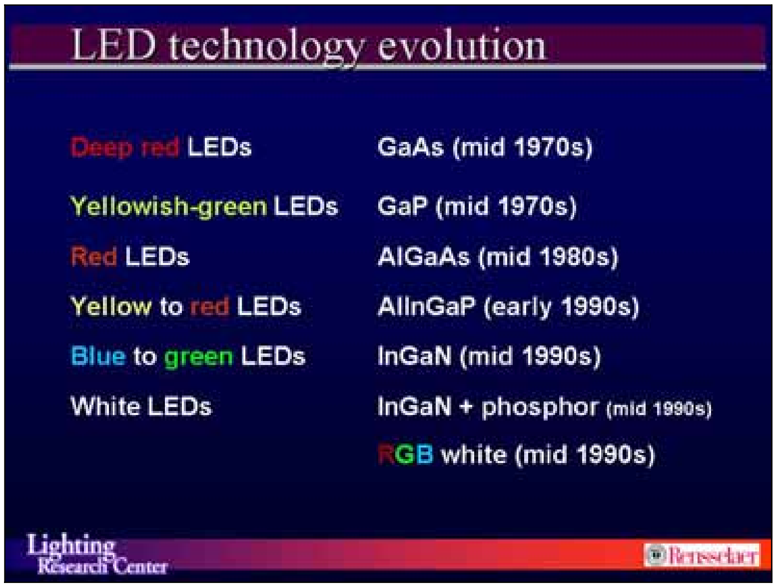
LED technology evolution
Deep red LEDs
GaAs (mid 1970s)
Yellowish-green LEDs
GaP (mid 1970s)
Red LEDs
AlGaAs (mid 1980s)
Yellow to red LEDs
AlInGaP (early 1990s)
Blue to green LEDs
InGaN (mid 1990s)
White LEDs
InGaN + phosphor (mid 1990s)
RGB white (mid 1990s)
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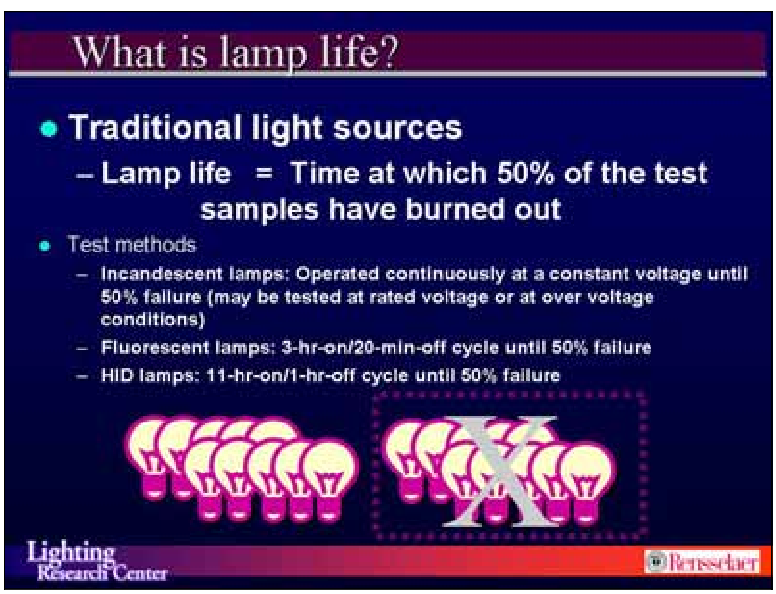
What is lamp life?
• Traditional light sources
– Lamp life = Time at which 50% of the test samples have burned out
• Test methods
– Incandescent lamps: Operated continuously at a constant voltage until 50% failure (may be tested at rated voltage or at over voltage conditions)
– Fluorescent lamps: 3-hr-on/20-min-off cycle until 50% failure
– HID lamps: 11-hr-on/1-hr-off cycle until 50% failure
X
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Life definition for LEDs?
No standard, agreed-upon definition is available for LED life.
This has led to:
– Confusion among lighting professionals
LEDs do not fail like other light sources
– Long-life claims from manufacturers without proof
No measured life data provided to purchasers
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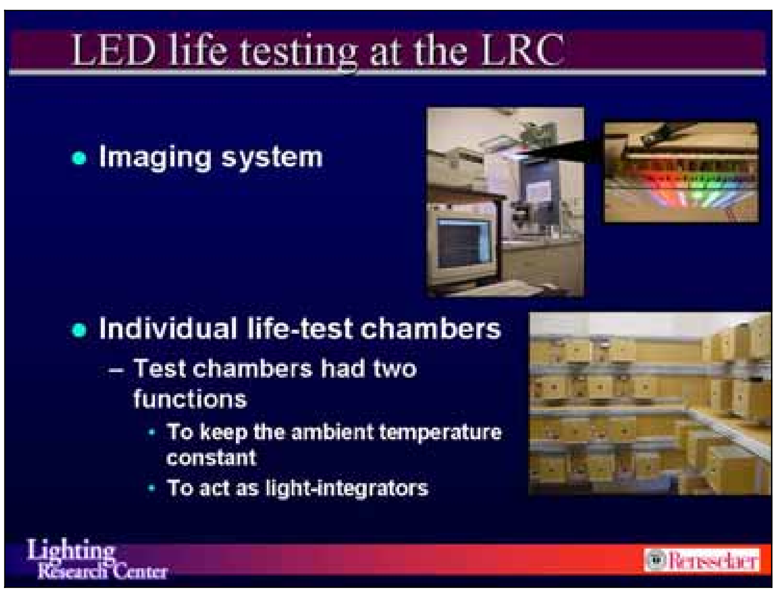
LED life testing at the LRC
Imaging system
Individual life-test chambers
– Test chambers had two functions
To keep the ambient temperature constant
To act as light-integrators
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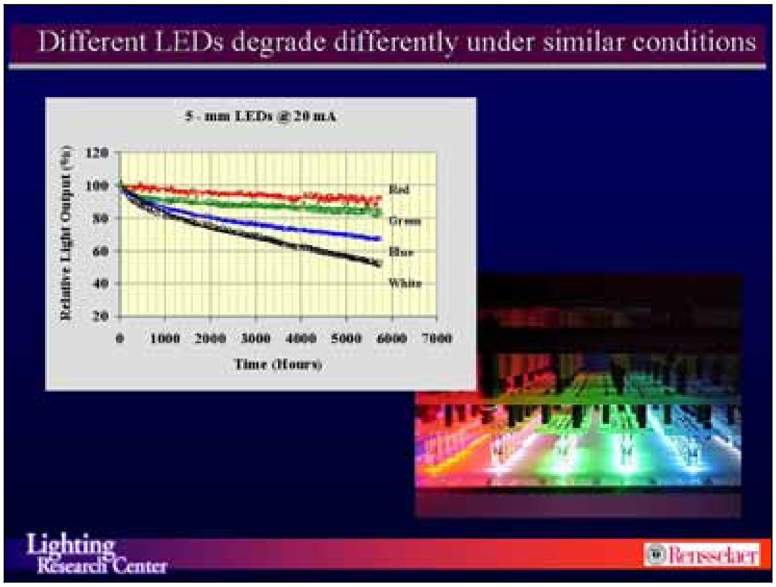
Different LEDs degrade differently under similar conditions
5 - mm LEDs @ 20 mA
Relative Light Output (%)
120
100
80
60
40
20
0
1000
2000
3000
4000
5000
6000
7000
Time (Hours)
Red
Green
Blue
White
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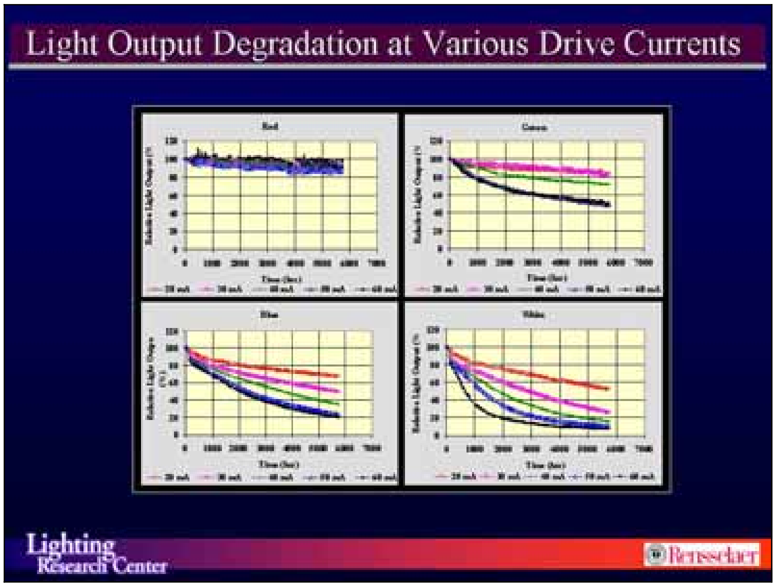
Light Output Degradation at Various Drive Currents
Red
Green
Blue
White
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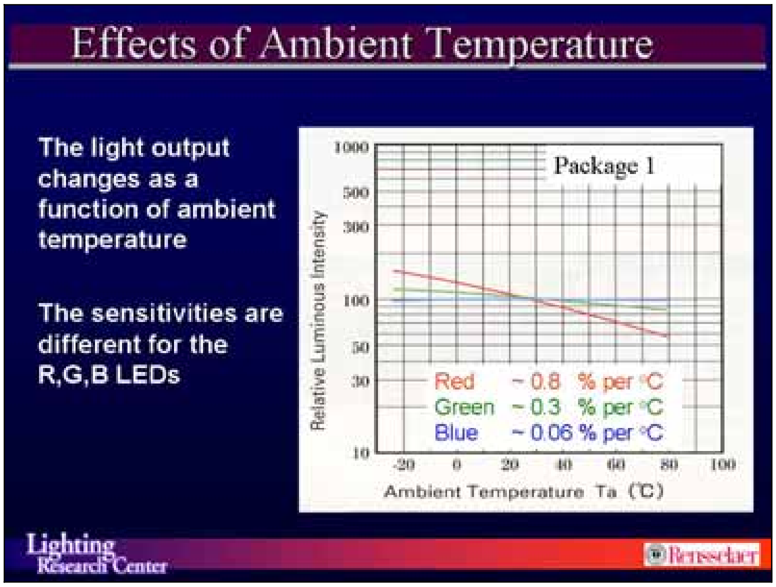
Effects of Ambient Temperature
The light output changes as a function of ambient temperature
The sensitivities are different for the R,G,B LEDs
Package 1
Relative Luminous Intensity
Red ~ 0.8 % per °C
Green ~ 0.3 % per °C
Blue ~ 0.06 % per °C
Ambient Temperature Ta (℃)
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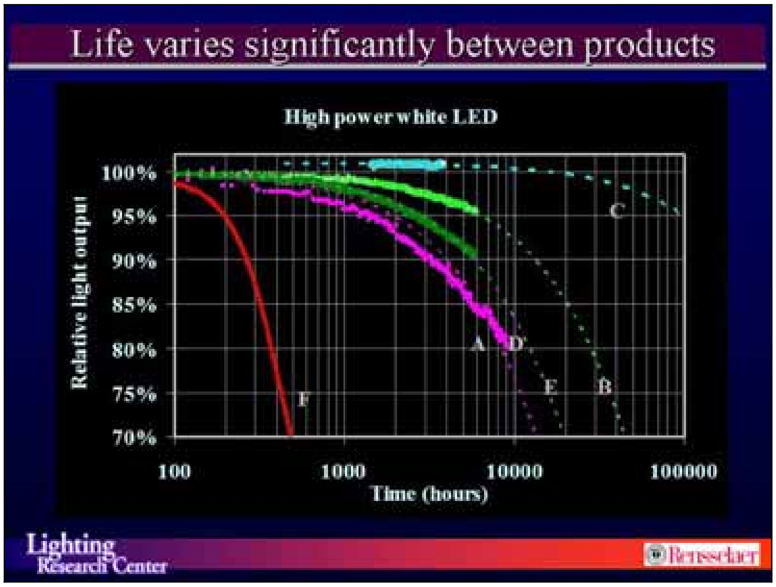
Life varies significantly between products
High power white LED
Relative light output
Time (hours)
A
B
C
D
E
F
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LED life: ASSIST Recommends
The Alliance for Solid-State Illumination Systems and Technologies (ASSIST) has proposed a standard definition and measurement methods for the life of LEDs used in general lighting applications.
ASSIST program
Lighting Research Center
Rensselaer


ASSIST Recommends
ASSIST recommends is free to download:
http://www.lrc.rpi.edu/programs/solidstate/assist/recommends.asp
ASSIST sponsors:
– Boeing
– GELcore
– New York State Energy Research and Development Authority
– Nichia
– Seoul Semiconductor
– OSRAM SYLVANIA
– Philips
– U.S. Environmental Protection Agency (EPA)
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So what should be done?

- How should the life of Seasonal LED strings be evaluated?
- Is a measure of maintained light output needed?
- If so, what method should be used?

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LED Luminous intensity

Near field photometry issues

- Intensity is used to describe point sources – LEDs are not ideal point sources leading to errors when using 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.

Lighting Research Center

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5.4. Seed Documents for the Workshop

5.4.1. Proposal for Seasonal and Decorative Lights

Proposal for Seasonal Holiday Lights for Inclusion as Part of the ENERGY STAR Program

Prepared for:

United States Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, D.C., 20460

Prepared by:

Office of Energy Efficiency
Natural Resources Canada

and

Navigant Consulting, Inc.

February 2006

I. Introduction

Even though the holiday season last only a few weeks of the year, the conversion of holiday lights from incandescent to more efficient light sources would generate considerable energy savings. One of the latest technology developments for this application is the light emitting diode (LED) technology that has only become available to Canadian consumers in the last few years. This energy efficient product, which uses up to 90% less energy than its incandescent counterpart, would have a considerable impact during critical heating season months, reducing demand during peak periods.

Due to recent technology developments and the potential for energy savings, the Office of Energy Efficiency (OEE) of Natural Resources Canada (NRCan) is proposing that this product be considered as a candidate for the ENERGY STAR Program. To determine the feasibility for any new ENERGY STAR product category and the corresponding performance-based specifications, EPA and DOE follow a set of six key principles (EPA & DOE, 2003).

1. Significant energy savings can be realized on a national basis
2. Product performance can be maintained or enhanced with increased energy efficiency
3. Purchasers will recover their investment in increased energy efficiency within a reasonable period of time
4. Energy-efficiency can be achieved with several technology options, at least one of which is non-proprietary
5. Product energy consumption and performance can be measured and verified with testing
6. Labeling would effectively differentiate products and be visible for purchasers

The purpose of this document is to show that creating an ENERGY STAR program for seasonal light strings is in line with these six key principles. This document provides preliminary market and testing information, focused primarily on the benefits of seasonal LED strings. A draft ENERGY STAR eligibility criteria document (Attachment 1) and test procedure (Attachment 2) for light strings are also included with this proposal.

II. Energy Savings (Guiding Principle #1)

Even though the holiday season is just a few weeks of the year, the conversion of holiday lights from incandescent to more energy efficient sources, such as LEDs, would generate considerable energy savings.

In Canada

A study conducted in British Columbia (BC) on consumption for residential holiday lighting in 2002, shows the electrical consumption attributable to holiday lighting was **73.1** gigawatt-hours (GWh). Extrapolating this figure by population for total seasonal energy consumption, the national consumption is approximately **584.8 GWh** per year.

The potential annual energy savings of a complete market shift to seasonal light-emitting diode (SLED) strings would be approximately **555 GWh**. Converting only **20%** of the 10 million strings sold in Canada from incandescent to LED in Canada would result in annual energy savings of approximately **110 GWh.**

In 2003, approximately 470,000 sets of SLED stings were sold in the province of British Columbia. It is estimated that the province of BC saved approximately **4 GWh** in 2003 (based on an annual savings estimate of 8.5 kWh per string).

In the United States

Holiday lights in the U.S. can be found donning the thirty-four million holiday trees sold annually in the U.S., as well as decorating the exteriors of residential and commercial buildings. A 2003 study estimates the annual energy consumption of *miniature* holiday lights based on the product of the installed base of lights in the U.S., the annual operating hours, and the wattage of each lamp. Consuming 0.4 watts each, the installed base of 37.1 billion miniature incandescent lamps operating for 150 hours per year consumes approximately **2220 GWh** of electricity (NCI, 2003).

An LED miniature holiday light consumes only 0.04W, or 90% less than its incandescent counterpart. The potential annual energy savings from just a 20% market shift to LED holiday lights is approximately **400 GWh** (NCI, 2003). If this estimate included light strings other than miniature lamps, such as C-7 or C-9 lamps, the potential savings would be even greater.

III. Product Performance (Guiding Principle #2)

Along with significant energy savings, the adoption of LED sources would be accompanied by other benefits, including a longer operating lifetime and a safer and more durable product. Each year, the performance of products released into the market improves. For instance, several years ago, LED products appeared dim when compared with incandescent products. However, products introduced in 2004 and 2005 were significantly brighter, almost on par with incandescent strings.

Not only do LEDs have significantly longer operational life characteristics than incandescent lamps, but they also produce little heat and remain cool to the touch, making them safer around combustible materials. SLED lamps are also encapsulated in an epoxy plastic resin, making them more resistant to shattering or impact damage during installation or disassembly.

Because LED chips generate little heat and do not rely on deteriorating materials to generate light, LEDs are proven to have a long operating life. That said, this statement does not take into consideration the fact that the light output of LED lamps (LED chips mounted in an encapsulant) does decrease slowly over time, and at present, there is no industry-accepted test standard to measure operating lifetime of these devices. Manufacturers offer up to a 5 year limited warranty on LED seasonal lights, but claim product lifetimes up to 200,000 hours (more than 20 years of continuous operation). This claim would have to be considered in the context of the life of the product envelope. The issue of warranty, stated operating life, and appropriate test procedures for determining operating life will be discussed during the development of the ENERGY STAR criteria for this product.

Being a relatively new product on the market, there are some instances of SLED strings having had a high failure rate. Study of these failures was found to be related not to the LED source itself, but rather poor manufacturing quality. Through the introduction of an ENERGY STAR program for seasonal light strings, higher quality products can be more readily identified and consumer confidence in this technology can be constructed. This program would be an important strategic move for ENERGY STAR, particularly in regard to the emergence of white-light LEDs in general illumination applications around the world.

The specification document (Attachment 1) provides a list of proposed product characteristics and performance specifications for seasonal light strings. A test protocol (Attachment 2) was developed by Powertech Labs for BC Hydro to further qualify this product for quality purposes. Related test standards are also listed in the specification document.

Although the technology has been proven to be energy-efficient and long lasting, there are still several quality issues that must be addressed. A series of tests on **outdoor** SLED strings were conducted in 2004 by Powertech Labs in British Columbia to determine the durability of this product compared to the existing incandescent light bulbs in varying weather conditions. The test cycles included periods of rain and periods of intense heat. It is estimated that this test procedure simulates approximately 10,000 hours or about 14 months of actual outdoor exposure. The study pointed out specific problems with the SLED stings, where corrosion became a problem in some models when they were exposed to high humidity levels. This issue will be discussed during the development of the criteria for this product, as the problem is not related to the LED lamp itself, but rather the packaging and product envelope. As manufacturers improve product design and packaging, this issue is being addressed.

IV. Payback on Investment (Guiding Principle #3)

A simple economic and energy consumption analysis of seasonal light strings shows that C7 LED and miniature LED lamps are cost effective replacements for C7 incandescent seasonal light strings, which are often used in outdoor applications. This analysis is based on decorating one 8-foot tree for ten holiday seasons. In this example, five C7 incandescent strings (25 lamps/string), are replaced with two alternative energy-efficient options: (1) five C7 SLED strings (25 lamps/string), or (2) four “miniature” SLED strings (70 lamps/string).

The assumptions for the analysis are outlined below:

- Hours of operation: 5 hrs/day for 30 days (150 hrs/year)

- Price of electricity (national average): CAD$0.08 per kWh.
- Estimated life span for incandescent light string: 2.5 years
- Estimated useful life span for SLED string: 12 years
- Average cost of C7 SLED string: $14.25
- Average cost of "mini" SLED string: $18.90
- Average cost of incandescent C7 string: $12.60

Based on data from BC Hydro and holiday light manufacturers, the following table outlines the cost, monetary savings, energy savings, life-cycle cost, and payback of LED holiday lights compared to C7 incandescent seasonal light strings. The simple payback for C7 LED light strings is approximately 1.5 years. The simple payback for "mini" LED lights strings is approximately 2.2 years.

Table 1: Economic Analysis of Replacing Incandescent Light Strings with LED Strings

	C7 Incandescent Tree (5X25-lamp strings)	**C7 LED Tree (5X25-lamp strings)**	**"Mini" LED lights (4X70-lamp strings)**
Wattage	500 watts	50 watts	11.2 watts
Initial Cost	$63	$71	$76
Replacement Strings	1	0	0
Hours of Operation	150 hours	150 hours	150 hours
Annual Electricity Cost ($CAD)	$6.00	$0.60	$0.13
Total Life-Cycle Cost (including Replacements)	$156	$74	$76
Simple Payback		1.5 years	2.2 years
Energy Consumed per Year	75 kWh/year	7.5 kWh/year	1.68 kWh/year
Energy Saved		67.5 kWh/year	73.3 kWh/year

Sources: BC Hydro Website, 2005; WSU & NEEA, 2005; NCI, 2003.

If a homeowner replaced the seasonal lights on only his tree, he would save over $5 each year on energy costs, and between 68 and 73 kWh of energy would be saved. If that same homeowner were to replace all the lights used for decoration outdoors, these savings would increase several fold. And, if this number is extrapolated over the population of Canada and the U.S., significant energy savings would accrue.

V. Technology Options and Product Availability (Guiding Principle #4)

The province of British Columbia has witnessed consumer acceptance following the promotional activities held there in the past few years. The success of the promotional campaigns influenced retailers to sell this product nationally, with some exclusively carrying the LED products as seasonal light strings. Another retailer has decided that 50% of its light strings would be SLEDs. Consumers across Canada have reacted positively to adopting this new product when decorating their homes for the holiday season.

Distributors of SLED strings in Canada offer a whole range of products characterized by the string's length and the color and size of the lamps. While seasonal lighting technology is still in its infancy, there are a growing number and selection of SLED strings available every year. LED lights strings are currently available in strings from 25 to 150 lamps, in a variety of colors including red, green, blue, white, yellow, and multi-colored. These lamps are also offered in several styles including: miniature, ball-shaped (raspberry), C-7, C-9, candle shaped, and icicle-style lamps. In 2005, several new products entered the market, including rope lights, strings with lamps that can change colors, and strings with commercial-grade plugs that allow more than 100 strings to be connected end-to-end (NEEA & WSU, 2005).

Each holiday season, as manufacturers improve on the existing delivery envelope of this technology, consumers have witnessed continual improvements in the quality and reliability of these products.

VI. Performance Testing (Guiding Principle #5)

Powertech Labs in British Columbia has developed a preliminary seasonal light test procedure specifically for SLED strings (see Attachment 2) (PowerTech Labs, 2005). This test procedure, "Powertech Labs / BC Hydro Seasonal Light String Test Protocol" was originally developed to test products for a BC Hydro rebate program. NRCan would like to continue the development of this protocol, so that it can serve as the test procedure for an ENERGY STAR program for this product.

There are also two safety standards available for seasonal lighting:

- CSA-22.2 No.37-M1989 (R1999) *Christmas Tree and Other Decorative Lighting Outfits*
- UL 588-2000 *Standard for Seasonal and Holiday Decorative Products*

VII. Product Visibility (Guiding Principle #6)

BC Hydro has introduced this product into the Canadian marketplace by promoting SLEDs strings starting in 2002. In 2003, based on the huge success of the 2002 campaign, the province contacted Canadian retailers to bring SLED lights into the province on a trial basis. In order to raise awareness about the technology, BC Hydro and the Office of Energy Efficiency, Natural Resources Canada, held a highly successful product promotion in the autumn of 2003. Through the BC Hydro program in 2005, over 46,000 in-store coupons were distributed, over 18,000 mail-in coupons have been redeemed, and nearly 57,000 incandescent strings were collected.

Since SLEDs are a fairly new technology for seasonal lighting strings, the SLED product is not yet easily recognized by the consumer as an superior, energy-efficient product compared the incandescent strings. Distributors will also likely be marketing the SLED strings as an "energy-efficient" lighting product to attracting customers. The addition of an ENERGY STAR label will increase the perception that these products are an energy-efficient, quality alternative to conventional incandescent strings.

VIII. Conclusion

With new technology offering the possibility of energy savings, lower consumer consumption during peak hours, longer operating life, higher operating efficiency, high durability, and a good payback on the initial investment, NRCan's Office of Energy Efficiency strongly supports the initiation of discussions with stakeholders in time to enable the ENERGY STAR label to be available for the 2006 holiday season. To this end, NRCan is convening a one-day stakeholder meeting to review the draft ENERGY STAR test procedure and qualification criteria in Toronto, Ontario, on Monday, March 6, 2006.

IX. References:

ASSIST, 2005. *Recommends...LED Life for General Lighting – Definition of Life*. Vol. 1, No.1 February 2005. Alliance for Solid-State Illumination Systems and Technologies Program. Accessed on February 7th, 2006 at: http://www.lrc.rpi.edu/programs/solidstate/assist/pdf/ASSIST-LEDLifeforGeneralLighting.pdf

BC Hydro, 2004. *Seasonal LED (Light Emitting Diode) Program Winter 2003 Program* Prepared by Alicia Forrester. BC Hydro. March 2004.

EPA & DOE, 2003. *The ENERGY STAR® Label: A Summary of Product Labeling Objectives and Guiding Principles*. Andrew Fanara. US EPA. May, 2003. Accessed on February 7, 2006 at: http://energystar.gov/ia/partners/prod_development/downloads/guiding_princip.doc

E-Source, 2001**.** *LEDs in Exterior Applications: An Emerging Market*. Esource ER-01-17 November 2001.

NCI, 2005. Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications, November 2003. Prepared by Navigant Consulting Inc. for the U.S. Department of Energy.

NEEA & WSU, 2005. *Energy Efficiency Fact Sheet. Holiday Lights: LED and Fiber Optics*. Energy Ideas Clearinghouse. Washington State University with support from the Northwest Energy Efficiency Alliance. October 2005.

PowerTech Labs, 2005. *Seasonal LED String Testing*. Powertech Labs Inc.

Sampson Research, 2003. *Holiday Lighting Market Assessment Phase III Report*

Adjusted Baseline Estimates. Sampson Research. Prepared by Sampson Reserach for Power Smart Quality and Assurance, BC Hydro. August 15, 2003.

USITC, 2003. USITC Interactive Tariff and Trade DataWeb. Data available online: http://dataweb.usitc.gov/scripts/user_set.asp

5.4.2. Eligibility Criteria for Seasonal and Decorative Lights

ENERGY STAR® Program Requirements for Seasonal Light Strings

Eligibility Criteria
Draft Version 1.0

Table of Contents

ENERGY STAR® Program Requirements for Seasonal Light Strings

Eligibility Criteria
Draft Version 1.0

Below is the product specification (Draft Version 1.0) for ENERGY STAR qualified seasonal 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 Canada in this product category is to reduce seasonal peak electricity consumption by encouraging Canadian consumers to use energy-efficient decorative seasonal strings.

1) Definitions:

A. Seasonal Light String - Decorative strings of lights that are used primarily during the holiday season.

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. For example, a 50-lamp light string could have two 25-lamp series blocks connected in parallel.

C. Brightness - Luminous flux emitted from a surface per unit solid angle per unit of area, projected onto a plane normal to the direction of propagation (I_v). Also known as luminous sterance. Intensity is specified in terms of millicandela (mcd).

D. Lumen Maintenance - The light output of a lamp as a percentage of its initial light output after a 100-hour seasoning period.

E. Useful Life - The length of time a light source takes, when operated at an ambient temperature of 35ºC, to reach 50% ($L_{50=}$) of its initial light output.

F. Viewing Angle – The spacial radiation pattern of the light emitted, indicating the degree of beam spread.

G. Input Power - The total power used by the seasonal string during operation, measured in watts (W).

2) Reference Standards: ENERGY STAR qualified seasonal holiday strings shall comply with the applicable safety standards and relevant clauses from

UL, CSA and other 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 (R1999) *Christmas Tree and Other Decorative Lighting Outfits*

Underwriters Laboratories Inc. (UL)

UL 588-2000, *Standard for Seasonal and Holiday Decorative Products*

Powertech Labs Inc. / BC Hydro

Powertech Labs / BC Hydro Seasonal Light String Test Protocol Draft Version 1.0. developed by Powertech Labs for BC Hydro. ***(See Note 1).***

> *Note 1: Please see attached document ("Powertech Labs / BC Hydro Seasonal Light String Test Protocol Draft Version 1.0") to comment on the Seasonal Light String Test Protocol developed by Powertech Labs.*

3) **Qualifying Products:** In order to qualify for the ENERGY STAR label, any seasonal light strings 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.

Table 1: Product Characteristics and Specifications for Seasonal Light Strings	
Energy Efficiency Characteristics	**Specification**
Maximum watts per lamp	0.08 watts ***(See Note 2)***
Electrical Characteristics	
Nominal operating voltage	120 Volts
Voltage sag / surge	± 10%
Amperes	20 ma or less per series block
Physical Characteristics	
Plug / plug-ins	Polarized ***(See Note 3)***
Double strings	Two opposite polarity groups (balanced)
Visibility Characteristics	
Lifetime claim	25,000 hours (or 'long-lasting') ***(See Note 4)***
Brightness (depends on color)	Minimum: **TBD** I_v (mcd) Maximum: **TBD** I_v (mcd) ***(See Note 5)***
Minimum viewing angle, measured relative to mechanical centre	60º ***(See Note 5)***

All performance measurements, except for lifetime, must be conducted according to the "*Powertech Labs / BC Hydro Seasonal Light String Test Protocol Draft Version 1.0*", cited in Section 2.

Note 2: This maximum wattage criterion is intended to be inclusive of all Seasonal LED String light products on the market. Product research shows that most LED lamps (including the "mini-light", C-7, and C-9) are 0.04W, however some LED products do consume up to 0.08W. While this is twice the typical value, the difference is negligible, when compared with incandescent light strings, where a "mini-light" uses 0.5W and a C-7 or C-9 can consume 6 to 8W per lamp. Please comment on the selected threshold maximum value of 0.08W.

Note 3: Please comment on whether an explicit criterion requiring polarized plugs for seasonal light strings is necessary.

Note 4: There are two lifetimes of concern with respect to seasonal light strings – 1) the operating life of the LED lamp and 2) the lifetime of the string itself, including the sockets, housing and wires. With respect to the LED lamp lifetime, there is no industry accepted definition of or test method for this measurement. Methods for characterizing LED lifetime, particularly as changes in materials or processes are introduced, require accelerated aging tests, which are under development. There are concerns that some Seasonal LED Strings on the market which made claims of 200,000 hours of life are excessive. The second lifetime, that of the string itself, is also of concern. The ENERGY STAR program also recognizes the lifetime of the packaging (e.g., wire, housing), and to this end, manufacturer warranties can be an indicator. Some manufacturers warranty their products for 3 and 5 years - indeed, a much shorter timeframe. To maintain the integrity of the ENERGY STAR label, NRCan is seeking comment on two options – either 1) making no lifetime claim, and instead stating only that the string is "long-lasting" or 2) establish a maximum lifetime claim of 25,000 hours. Alternative proposals are also welcome.

The ASSIST program at the Lighting Research Center has outlined a method for measuring useful life of LED components (L_{50} and L_{70}). It does seem, however, that requiring this method to be used would be excessively burdensome for this product at this time.

Note 5: Stakeholders are invited to comment on whether minimum brightness specifications are necessary given the recent rapid development of products with increased brightness. If this requirement is omitted, is there a risk that manufacturers would market "dim" products that meet ENERGY STAR specifications? Or, would a lack of consumer demand (and returned products to retail outlets) send a sufficient message to manufacturers that certain brightness levels are expected in order to be commercially viable? If this requirement is included, how can brightness of these products measured in a cost-effective manner and what should the levels be for the various colors?

Related to this issue, are maximum brightness / minimum viewing angle specifications necessary for safety reasons? Should bare LEDs be tested or should the seasonal light string be tested as it would be used in the field (with diffuser / shaped lens)?

5) **Product Approval:** In Canada, strings for exterior use as portable seasonal lighting must be CSA or UL approved.

6) **Warranty:** All participating manufacturers must offer a minimum of a 3-year warranty against product defects. **(See Note 6)**

Note 6: Stakeholders are invited to comment on what should be considered a reasonable minimum warranty period. Today's products currently offer warranties in the range of 1-5 years. ENERGY STAR is considering setting a three-year minimum warranty promise for eligible products.

7) **Packaging:** The packaging containing the product shall specify the number of lamps, the lamp spacing and the total light string length in appropriate metric and SAE units.

8) **Testing Criteria:** In order to qualify their products for ENERGY STAR, manufacturers are required to certify their seasonal light strings using test procedures referenced in this document (see Section 2). The criteria listed in Table 1 must be tested using "*Powertech Labs / BC Hydro Seasonal Light String Test Protocol Draft Version 1.0*." These test results shall be conducted by a third-party laboratory approved by 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.

References:

ASSIST, 2005. *Recommends...LED Life for General Lighting – Definition of Life*. Vol. 1, No.1 February 2005. Alliance for Solid-State Illumination Systems and Technologies Program. Accessed on February 7th, 2006 at: http://www.lrc.rpi.edu/programs/solidstate/assist/pdf/ASSIST-LEDLifeforGeneralLighting.pdf

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PowerTech Labs, 2005. *Seasonal LED String Testing*. Powertech Labs Inc.

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USITC, 2003. USITC Interactive Tariff and Trade DataWeb. Data available online: http://dataweb.usitc.gov/scripts/user_set.asp

5.4.3. Powertech Labs / BC Hydro Seasonal Light String Test Protocol

Powertech Labs / BC Hydro Seasonal Light String Test Protocol Draft
Draft Version 1.0

I. Objective

This test protocol is intended to define a test procedure that will be applied to seasonal light strings as part of the evaluation process to determine eligibility for the ENERGY STAR Program. Tentative acceptance criteria follow in Section IV.

II. Performance Issues

The following issues have been recognized as critical to customer safety, ENERGY STAR needs, or long term customer acceptance.

- Existence of shock hazards
- Existence of fire hazards
- Excessive brightness leading to potential eye hazard
- Power consumption
- Current harmonic content
- Apparent brightness and viewing angle
- Lifetime and reliability

Other issues may be added, as they arise.

III. Tests Performed

The following tests may be performed on seasonal light strings submitted for evaluation:

1. **Initial inspection**
   a. Inspect for safety or shock hazard concerns
   b. Count bulbs per string and separation
   c. Check bulb type: sealed, polarized plug-in, or unpolarized plug-in
   d. Check that plug-in diodes, resistors, etc. cannot be incorrectly swapped with spare bulbs
   e. Determine electrical connection scheme (series, series/parallel, etc)
   f. Measure power consumption and current
   g. Measure current waveform and harmonic content
2. **Light output test**

> *Note: During the stakeholder meeting on March 6th, it is planned that the group will spend time discussing the need for a light output test. If it is deemed necessary, the group will discuss the most effective method to test light output. This section has been inserted as a placeholder until that decision is made (See Attachment 1).*

A photometric system (described in the appendix) will be used to measure the luminous intensity of three individual bulbs from each test string (or one bulb of each colour in multicoloured strings).

   a. Each bulb will be mounted in turn, rotated to obtain maximum intensity, and the intensity (in candela) will be measured.
   b. The intensity will also be measured at two points each 30 degrees from the maximum intensity.

c. If a diffuser can be removed without causing so much damage that the string or bulb is extinguished, test a will be repeated with a bulb with the diffuser removed.

3. **Overvoltage test**
Strings will be energized at 132 V for 1 hour and examined for failure.

4. **Temperature cycling test**
Test strings will be subjected to 3 temperature cycles of cooling to –15°C (±5°C) for 8 hours and then warming to 20°C (±5°C) for 16 hours.

5. **Water ingress test**

After completing temperature cycling, one sample of each type was tested for water ingress. The low voltage dc resistance was measured at the plug. The string was then immersed in a salt-water solution at room temperature for 24 hours (the end fittings were kept out of the solution). At the end of the immersion period, the low voltage dc resistance was measured again to check for water ingress.

6. **Corrosion resistance test**
After completing test 4, two samples of each type will be tested for corrosion resistance. The samples will be mounted in a test chamber and subjected to a cycle of cold water spray alternating with dry heat for 1000 hours. Power to the strings will be cycled on and off during the testing. The strings will be examined every week (168 hours) to see if they are still illuminated. The exact conditions of the corrosion cycle are still under consideration. Note that this test is not a simulation of actual operation, but an accelerated aging test to try to identify strings susceptible to corrosion in service.

7. **Lamp lifetime test**

One sample of each type will be mounted in an oven maintained at 50°C and energized for 1000 hours. The strings will be examined every week (168 hours) to see if they are still illuminated. Note that this test is not a simulation of actual operation, but an accelerated aging test to try to identify substandard diodes. Note: Please comment on the appropriateness of the 50°C oven temperature.

8. **Cord safety test**
Strings equipped with extension outlets will be tested for safety.

a. A resistive load of 10 A will be powered through the cord for 24 hours. If a warning label specifies a smaller maximum current rating, the reduced current will be used.
b. After 24 hours, the current will be increased to 15 A for 1 hour or until failure occurs.

IV. Tentative Acceptance Criteria
The following criteria are under consideration. The criteria will change as new information becomes available, including test results from current seasonal light products. Until firm criteria are adopted, product support will depend on an engineering analysis of each product based on the test results and manufacturer's information provided.

1. **Initial inspection**
    a. There must be no obvious safety or shock hazards.
    b. If the string has plug-in bulbs, they must be polarized and keyed so that incompatible components cannot be exchanged and diodes cannot be reverse biased.
    c. If two series strings are in parallel, they must have opposite polarity to minimize harmonic distortion.
    d. Single strings must be designed so that if multiple strings are connected, approximately half will be of each polarity.
2. **Light output test**

> *Note: During the stakeholder meeting on March 6th, it is planned that the group will spend time discussing the need for a light output test. If it is deemed necessary, the group will discuss the most effective method to test light output. This section has been inserted as a placeholder until that decision is made (See Attachment 1).*

a. The maximum intensity (with or without diffusers) will not exceed a safety threshold (to be determined).

> *Note: Would a maximum brightness level equal to IEC Class I Laser brightness levels (depending on color) be appropriate?*

b. In future, the maximum and 30° intensity may be used for acceptance or ranking criteria.

3. **Overvoltage test**
Strings will survive without damage.
4. **Temperature cycling test**
Strings will survive without damage.
5. **Water ingress test**
The final resistance value will be greater than a threshold (to be determined), indicating no water ingress has occurred.
6. **Corrosion resistance test**

> *Note: Requirements are to be determined. Ideally, both strings survive 1000 hours of testing.*

7. **Lamp lifetime test**

> *Note: Requirements are to be determined. Ideally, both strings survive 1000 hours of testing.*

8. **Cord safety test**
    a. The string must survive the 24-hour test without damage.
    b. The string may fail during the 15 A test, but must not create a fire or safety hazard.

Appendix: Photometric system specifications

The photometric system is intended to provide reasonably accurate measurements (±5%) of luminous intensity with sufficient angular resolution to identify potentially hazardous bright spots, at a reasonable cost.

The test chamber will include a mounting head with provision for holding individual bulbs of various designs firmly in position while still connected to the remainder of the light string. The mounting head will have fine adjustments with approximately 0.5 degree resolution in azimuth and elevation angle so that the bulb can be aligned for maximum intensity. The head will also have a coarse adjustment so that it can be rotated in 30 degree steps for the off-axis measurements.

The head will be mounted in a non-reflective, baffled measurement chamber with a calibrated illuminance meter fixed in direct line of sight, 50±1 cm from the bulb base. The aperture of the illuminance meter will be approximately 1 cm, providing a resolution of approximately 1 degree. At 0.5 m distance, the bulb output in candela at any given angle will be ¼ of the illuminance meter reading in lux.

The illuminance meter will have an accuracy of 5% or better, and will be calibrated for the standard CIE photopic response curve. Background and reflected light levels will be kept to less than 5% of the normal measurement level through the use of suitable baffles and non-reflective coatings. The centre of rotation for the coarse angle adjustment will be aligned with the base of the bulb. The coarse angle adjustment will be checked geometrically, and the steps will be 30±1 degrees.

Note: During the stakeholder meeting on March 6th, it is planned that the group will spend time discussing the need for a light output test. If it is deemed necessary, the group will discuss the most effective method to test light output. This section has been inserted as a placeholder until that decision is made (See Attachment 1).