Achieving Sustainable LED Lighting: A Product Design Guide

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ilumisys
Solid State Lighting Products

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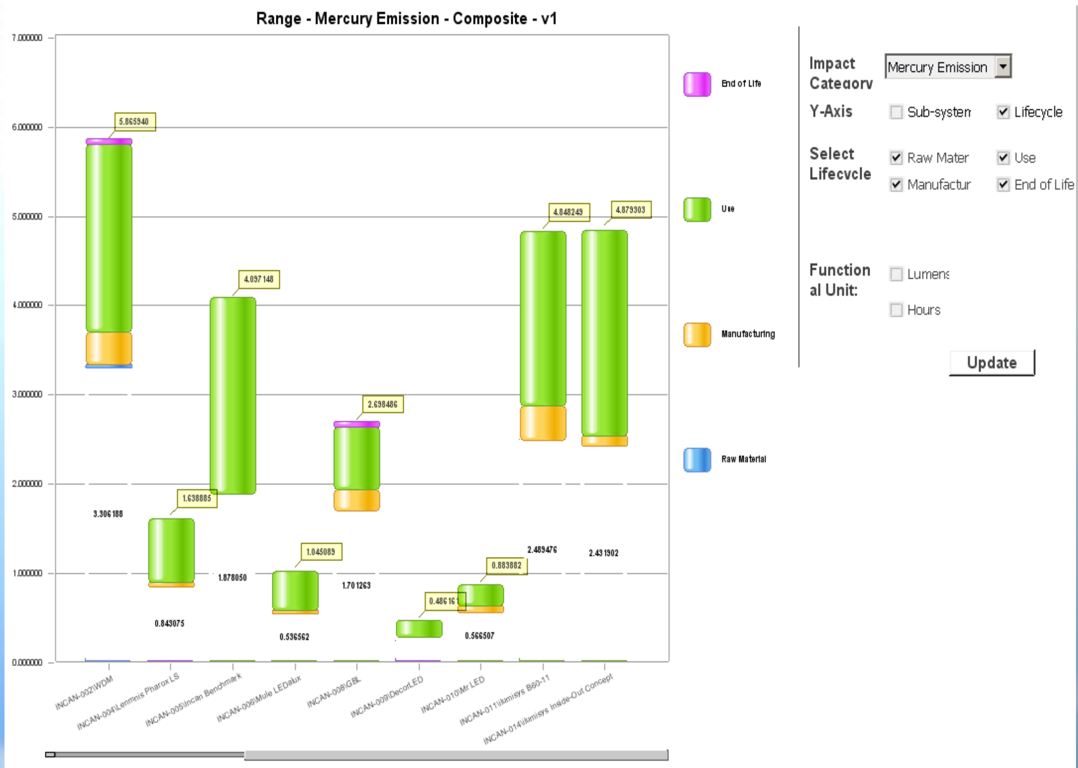
Sustainable Lighting Product Development

ilumisys is a Troy, Michigan-based company focused on next-generation solid-state lighting technology. The company was formed in 2007 as a spinoff venture and wholly owned subsidiary of Altair Engineering, Inc. with initial products based on Altair's intellectual property for the direct replacement of fluorescent light tubes with light-emitting diode (LED) lamps.

NCMS is a not-for-profit organization, based in Ann Arbor, MI, and a premier provider of collaborative research, information, knowledge and expertise to the North American manufacturing and defense community. Backed by over 350 corporate members, NCMS has spearheaded numerous advancements – in advanced materials, alternative energy, electronics, high performance computing, rapid prototyping/ manufacturing, enterprise integration and sustainability – all focused on enhancing the nation's manufacturing competitiveness in the global economy

Sustainable Lighting Design



U.S. Department of Energy sustainability of LED lighting products project

The U.S. Department of Energy (DOE) has contracted ilumisys and the National Center for Manufacturing Science (NCMS) to evaluate the sustainability of LED lighting products. ilumisys is conducting durability and output testing of numerous LED lighting products to define a an evaluation process (including LCA).

The study findings will generate a best practices guide to allow LED product designers to make sustainable design decisions.

Phase 1: As-Is Analysis

Select Products for Analysis

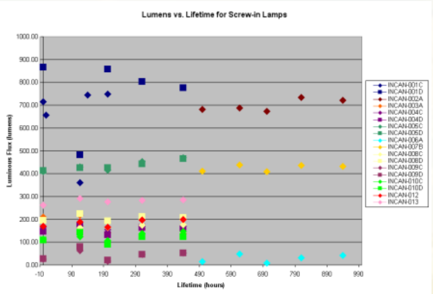
Several commercially-available LED lighting products were selected from two categories: screw-in incandescent replacement lamps and linear fluorescent replacement lamps.

Life Cycle Analysis

INCAN-001 CFL Benchmark	Lamp Type:	Incandescent Replacement								
Component/ Process	Description	Assembly Level	Material Class	Material	Process	Quantity	Life Cycle Phase	Process Measurable	Weight Each (kg)	Weight Total (kg)
INCAN-001	CFL Benchmark	1	NA	NA	NA	1	NA	NA	[illegible]	[illegible]
Power Consumption	Lifetime energy use	2	NA	NA	NA	1	NA	NA		0
Energy Use	12.1W for 8000 hours	3	Energy	Energy Use	US Grid Mix	1	Use	Energy		0
Electronics Subsystem	Power and lighting electronics	2	NA	NA	NA	1	NA	NA		0
Bare Wire RM	Bare Wire Raw Material	3	Ferro	Steel	Raw Material	1	Raw Material	Weight	[illegible]	[illegible]
Bare Wire Prod	Bare Wire Production	3	Ferro	Steel	Wire Drawing	1	Manufacturing	Weight	[illegible]	[illegible]
Bare Wire EOL	Bare Wire Disposal	3	Ferro	Steel	Unspecified Disposal	1	End of Life	Weight	[illegible]	[illegible]
Standoffs RM	Standoff Raw Material	3	Ferro	Steel	Raw Material	4	Raw Material	Weight	[illegible]	[illegible]
Standoffs Prod	Standoff Production	3	Ferro	Steel	Wire Drawing	4	Manufacturing	Weight	[illegible]	[illegible]
Standoffs EOL	Standoff Disposal	3	Ferro	Steel	Unspecified Disposal	4	End of Life	Weight	[illegible]	[illegible]
Wires	Edison Base Wire Production	3	Other	PVC Insulated Wire	Processing	1	Manufacturing	Weight	[illegible]	[illegible]
Wires EOL	Edison Base Wire Disposal	3	Other	PVC Insulated Wire	Unspecified Disposal	1	End of Life	Weight	[illegible]	[illegible]
PCB	PCB Production	3	Electronics	FR4 PCB through hole	Processing	1	Manufacturing	Weight	[illegible]	[illegible]
PCB EOL	PCB Disposal	3	Electronics	FR4 PCB through hole	Unspecified Disposal	1	End of Life	Weight	[illegible]	[illegible]
Bulb Body Subsystem	Heat sink and other bulb structural components	2	NA	NA	NA	1	NA	NA		0
Glue	Glue production	3	Adhesives	Thermal Adhesive	Processing	1	Manufacturing	Weight	[illegible]	[illegible]
Glue EOL	Glue Disposal	3	Adhesives	Thermal Adhesive	Unspecified Disposal	1	End of Life	Weight	[illegible]	[illegible]

Products were disassembled and bills-of-material were generated, including all production-related processes. Life cycle analyses were performed for three impact categories.

Product Testing



Light output and useful lifetime testing were performed on each product to support the LCA results and to define the functional units used to compare products.

Products Selected for Evaluation – Screw-In Replacements

GE 13W Spiral CFL (benchmark)

SLI 60W Incandescent (benchmark)

GBL 9W 150 LED

WDM 15W LED

Sylvania 8W LED

EvoLux S 13W LED

MR LED 2.3W

Luxterra 5W LED

Mule LEDalux 1W LED

Lemnis Pharox 4W LED

Products Selected for Evaluation – Fluorescent Replacements

Philips F40T12 Alto 40W

& Philips F32T8 Alto 32W

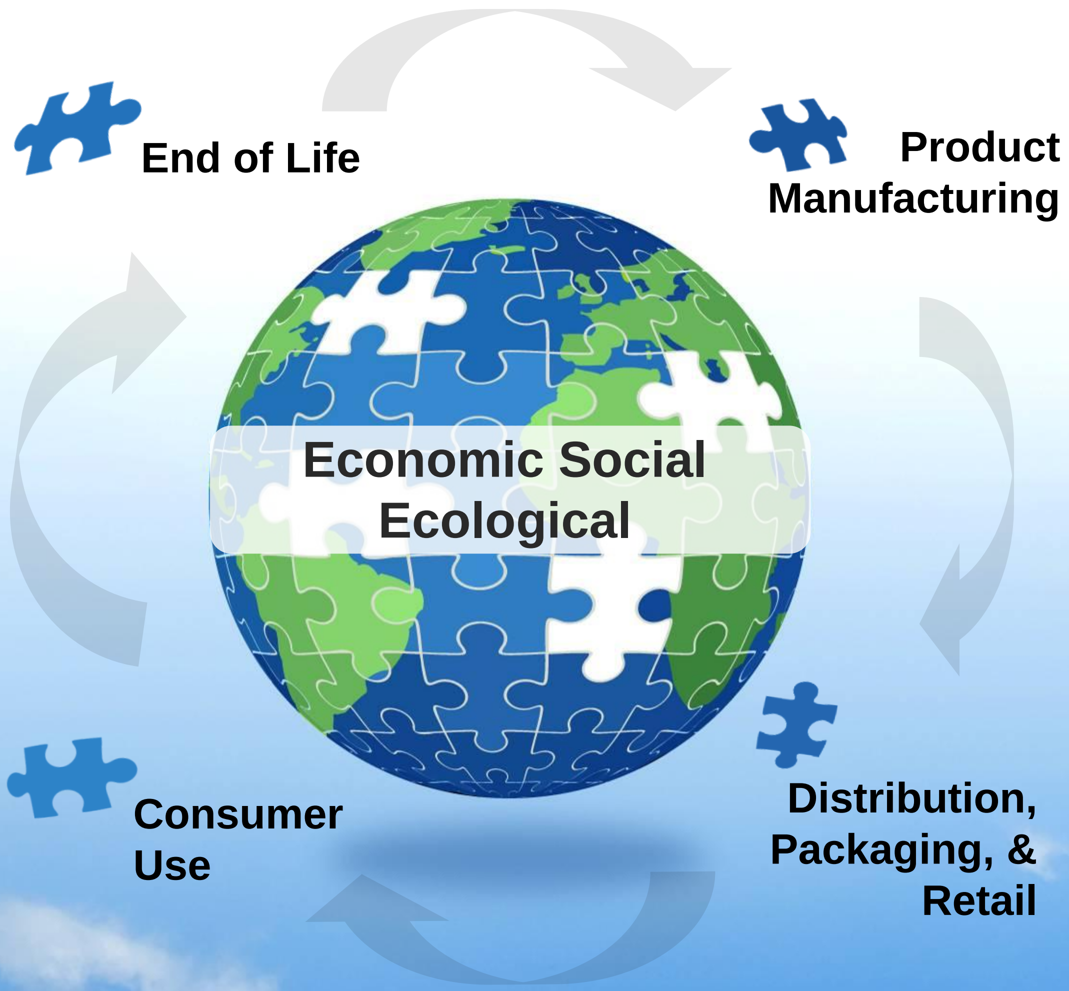
(Benchmarks)

ilumisys Mk1 28W LED & ilumisys Mk2 22W LED

SeeSmart 15W LED

Clean Light Green Light 17W LED

What is Life Cycle Assessment?



Life Cycle Assessment or Analysis (LCA) is the evaluation of the environmental, economic, and/or social impacts of a product or process throughout its life.

The lifecycle phases considered in this program were:

- Raw Material Extraction/Manufacturing
- Use
- End of Life

Transportation was not considered due to lack of information on the products we are considering. An extension of this program may allow for the consideration of transportation within the LCA.

The program focus will be on select environmental impacts.

LCA Impact Category Selection

Energy Consumption

Energy consumption was chosen as a general impact category to consider because many other impacts are driven by the energy required for each of the life cycle phases.

Greenhouse Gas Emission

With climate change at the forefront of the environmental discussion, greenhouse gas emissions (measured in kg CO_2 equivalence) was a clear choice for evaluation.

Mercury Emission

Because a frequent benefit cited for LEDs over fluorescent lighting is the lack of mercury, mercury released to the environment over the lifecycle was evaluated.
Note that while incandescent and LED lamps contain no mercury, mercury is released in their use due to its emission in coal-fired power plants.

Assumptions in the LCA Study

- **Populated circuit boards were considered by weight as a unit rather than as each of the constituent components. This is driving higher-than-realistic impacts for the electronics package. We are developing our own metric from the LCA software tools and measurements on actual lamp circuits to replace these values. This high impact per mass is due to the LCA inventories using telecom circuits and PC motherboards as their standard.**

- **"Unspecified" categories were established for use of primary, secondary, and production mix metals. Worst case of these defines the value for the unspecified condition.**

- **Default assumption for metals was production mix, as discussions with metals industry experts indicated that there is very little primary metal used except in very specific applications. The same is true of 100% secondary materials.**

- **Waste in any forming process was left to the defaults in the LCA software tools. Not enough information was available to identify waste, therefore only the mass of the finished part was used for impact calculations.**

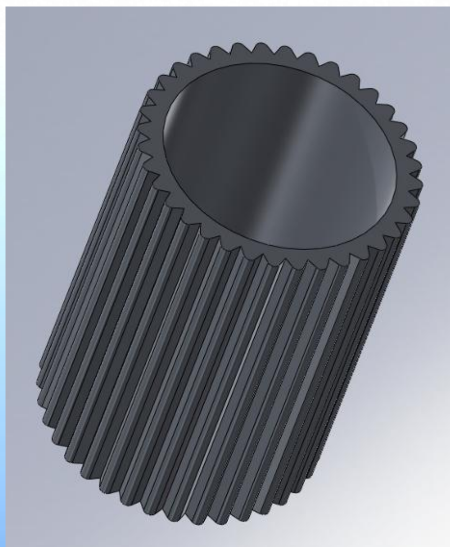
- **Lamps that required a standard external electronic ballast (fluorescent tubes and the ilumisys Mk1 tubes) had the ballast impacts included in their LCA. The contribution of the ballast was based on a rated life of 50,000 hours and the assumption that a ballast runs two lamps, so if a ballast runs lamps that have a life of 25,000 hours, ¼ of the ballast impacts are included for a single lamp.**

- **Initially, useful life of the lamps, used in defining functional units, will be based on manufacturer claims. Lab testing will measure real life numbers and these will replace the other values as they become available.**

Product BOM Creation

Turning a bill-of-materials into a bill-of-processes…

No longer only a 65-gram heat sink, now it is…



GHG Emissions from production and end-of-life phases: ~1.12 kg CO_2 eq.

Extruding
~.06 kg CO_2 eq.

Raw Material Extraction
~.78 kg CO_2 eq.

Anodizing
~.27 kg CO_2 eq.

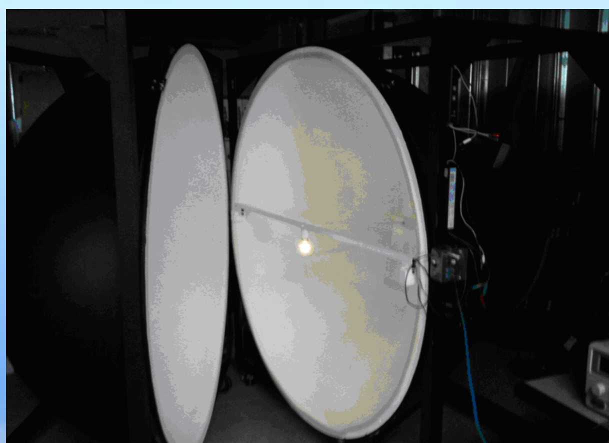
Machining
~.005 kg CO_2 eq.

Landfill
~.001 kg CO_2 eq.

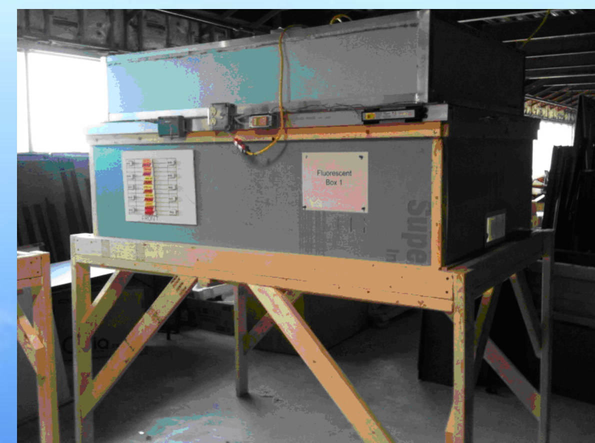
Product Testing

What is being tested, and why?

- **Power consumption and useful life are needed to quantify the use phase in the life cycles of the lamps.**
- **Light output and useful life contribute to the functional unit against which products can be compared.**
- **Testing conditions are guided by best practices taken from Energy Star and IES LM-79 and LM-80 standards.**
- **Color temperature and color rendering index are also being measured.**

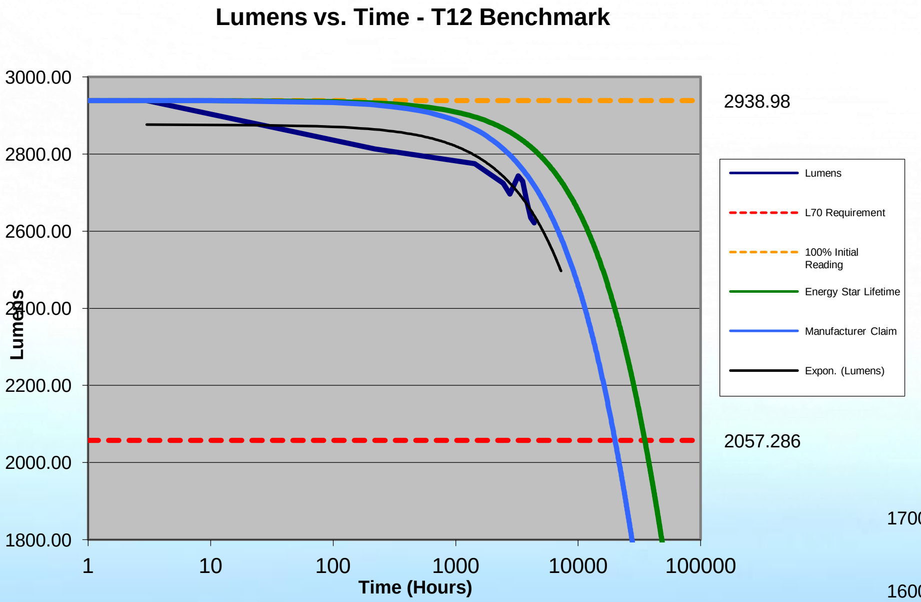


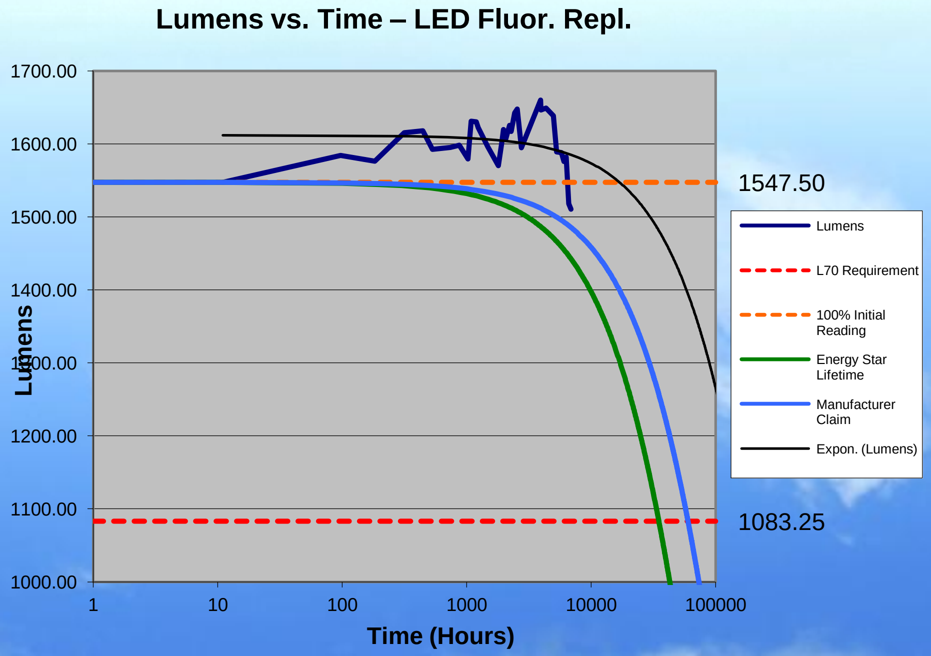
62” integrating sphere for photometric testing



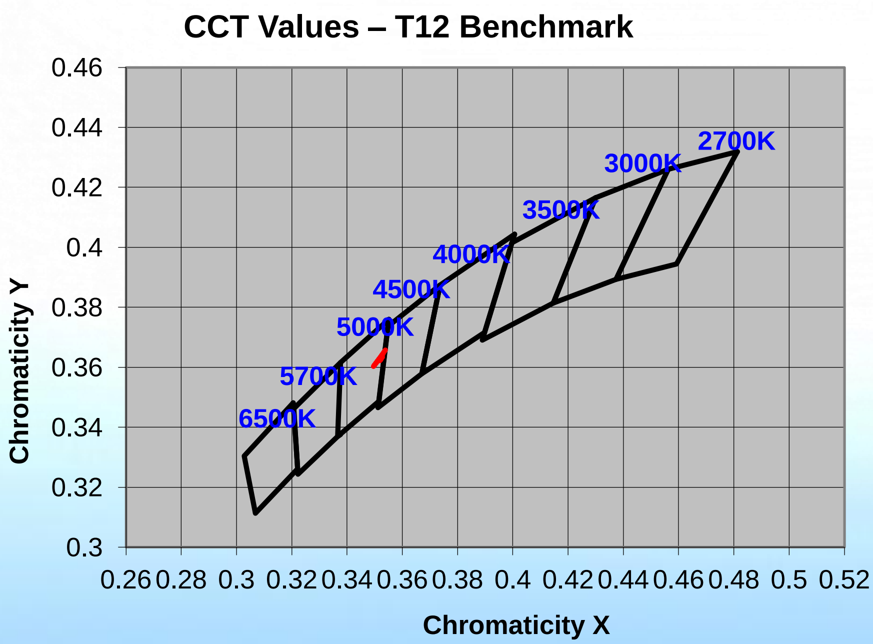
Lamps run continuously on a 3-hour on, 20-minute off cycle at 45˚C inside of temperature control chambers

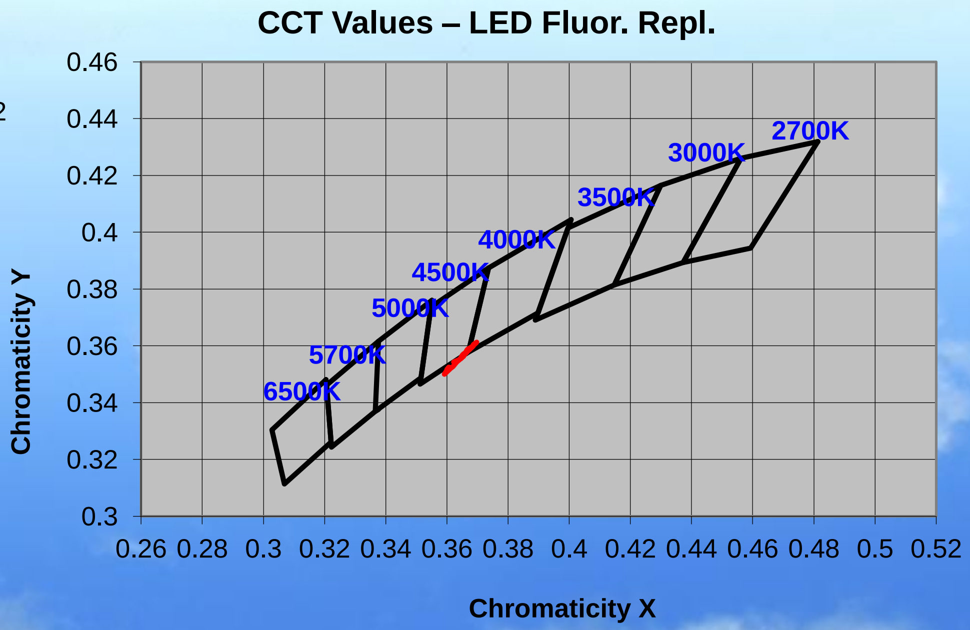
Some Preliminary Test Results – Lumens vs Time





Some Preliminary Test Results – CCT Over Time

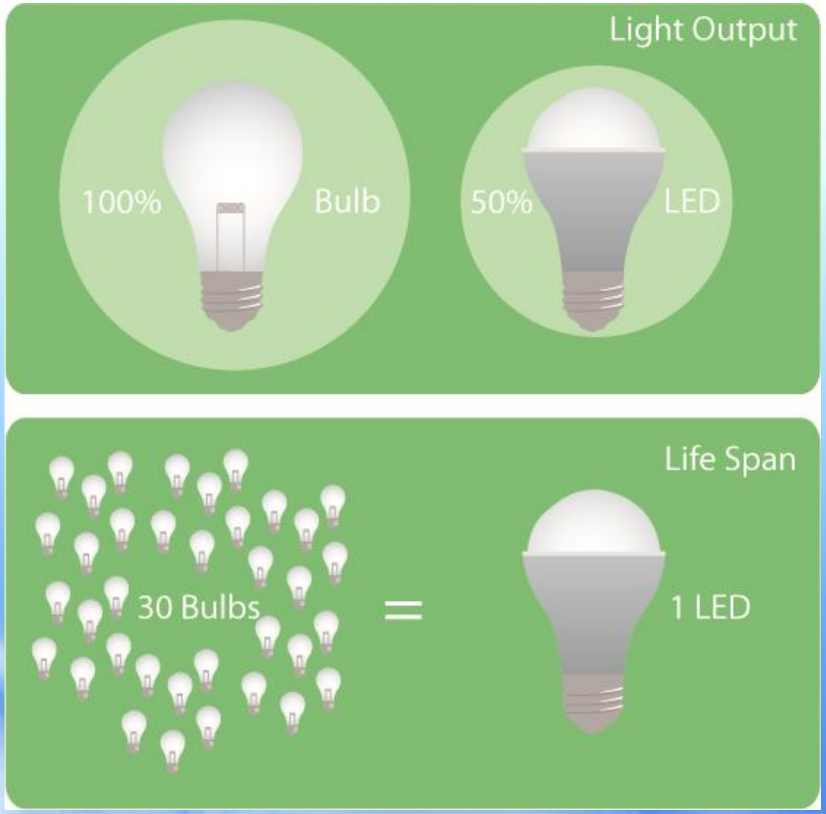




Functional Units in LCA

Why are functional units important?

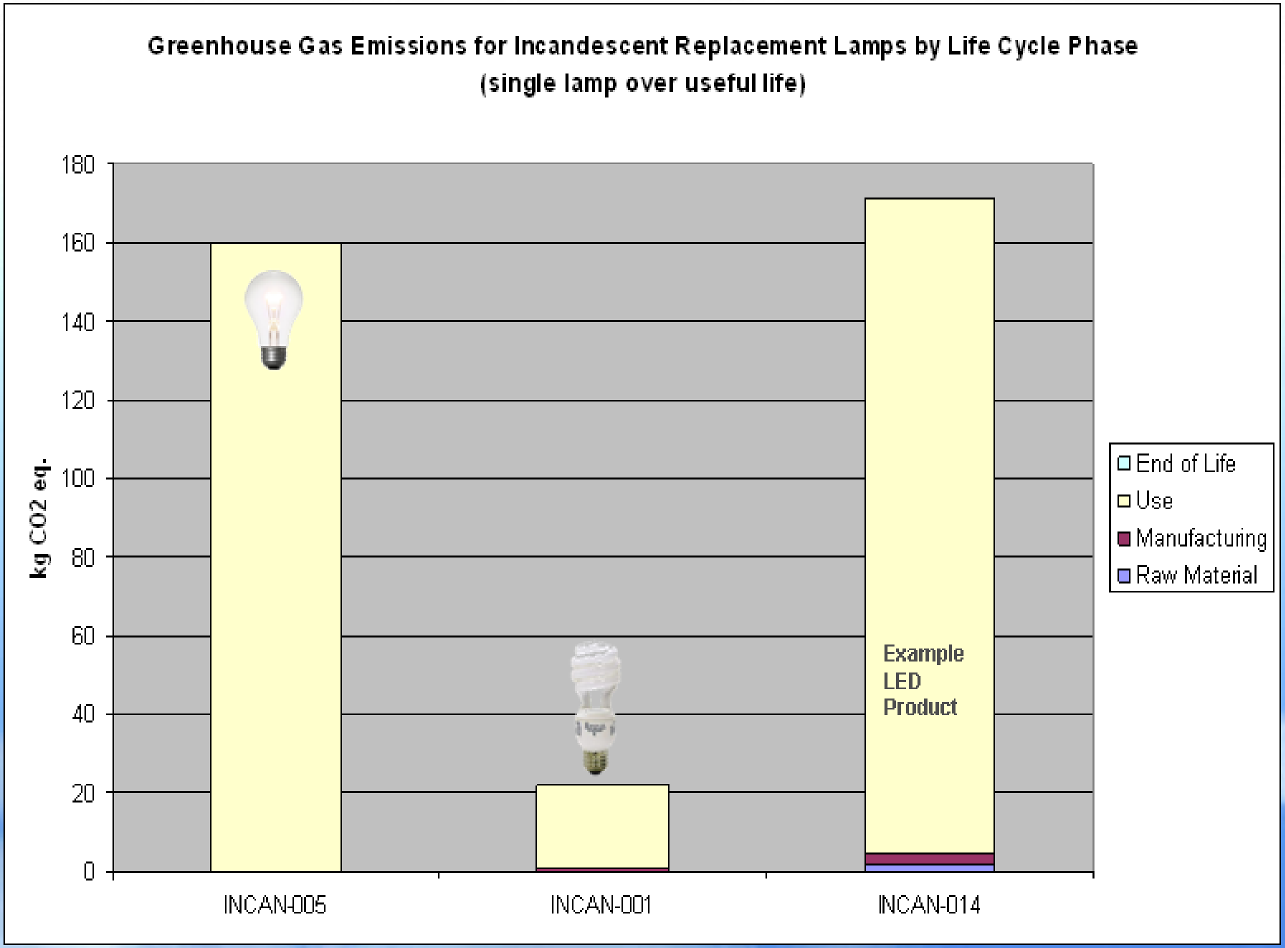
Allow comparisons of products with different levels of performance without penalizing better performing products that have higher impacts



As an example, to get the same amount of light over the same period of use, it might require 15 incandescent lamps to equate to the performance over time of one LED lamp. Thus, in comparison, 15-times the impacts of the incandescent lamp are considered against a single LED lamp.

Functional Units in LCA

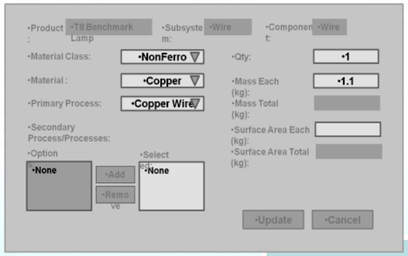
When looking at single lamps, the LED lamps have very high impacts due to their complexity…



…but when compared against a functional unit, equivalent light output over a longer life reduces the impacts in achieving that quantity of light over time.

Creating a Best Practice Guide for Sustainable LED Lighting Products

The design guide, when complete will be available via the sustainability portal on the NCMS website. The frame work of the tool will be as follows:



- Populate the Bill-of-Material Subsystems
- Input power consumption and light output

Select a component to advance to the process input screen

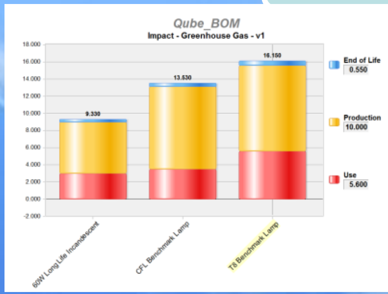
Product Name	Qty	Mass Each(kg)	Mass Total(kg)	Material	Processes	GHG	ME	EU
T8 Benchmark Lamp	1	Total mass of subsystems	Mass Each * Qty	(leave it blank)	(leave it blank)	Total of subsystems	Total of subsystems	Total of subsystems
Electronics Subsystem	1	Total mass of components in this subsystem	Mass Each * Qty	(leave it blank)	(leave it blank)	Total of components in this subsystem	Total of components in this subsystem	Total of components in this subsystem
Wire	1	0.000248	0.000248	Copper	Copper wire	0.00131907606263	0.0248414138321417	3.445685612450642e-4
....								

Return to BOM page to apply impacts to the component

- Assign a material to the component
- Assign secondary processes
- Indicate component mass

- Compare the impacts of your design concept against other concepts
- Create what-if studies

View and print reports



Questions