LED Lamps and Luminaires at End-of-Life

Lessons from the past and present.
Solutions for the future.

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Who am I?

I am an observer of history and a thinker

- Over 40 years in the lighting industry.
- Worked as consultant to the US EPA helping to develop standards for ENERGY STAR products.
- Managed energy-efficiency programs for both NY State and Energy Trust of Oregon.
- I am not a scientist or an environmentalist, but I had help from a scientist and an environmentalist in creating this presentation.

Credits

- Thanks to David Shiller from LightNOW for the many articles he shared with me that contributed to this presentation.
- Thanks to Professor Jesse Schwartz, PhD. Washington University who provided environmental and technical data.

Sustainability

The Many Stages of Sustainability

- Mining chemicals
- Processing chemicals
- Manufacturing components
- Assembling components to make a product
- Packaging the product
- Shipping the product
- Selling the product
- Second shipping to the home or place of business
- Using the product

End-of-Life

- We are making great strides in many areas of sustainability.
- Many presentations here have focused on these areas.
- This presentation will focus on the final area of sustainability.
- End-of-Life

Acknowledging the Problem

First you must recognize the problem

- In developing my course on the history of lighting, I observed a problem which followed the lighting community throughout the development of new technologies. That problem continues today.
- I am as guilty as anyone else in the lighting industry.
- Simply put, we jump on new technologies without end-of-life solutions.

The Lighting Industry is Not Alone

- Other industries face the same problem.
- They offer convenience or energy savings without regard to end-of-life.
- The Lighting Industry should be a leader, not a follower.

Household Batteries

- Batteries with mercury: 50 years of mass production with mercury, with no recycling.

Automobiles

- Junk yards filled with decaying cars. Gasoline leaking into the ground.
- Current efforts to recycle metals.

Electric Vehicle Batteries

- It takes an enormous amount of energy to make these and that produces large amounts of CO2.
- What are the plans for end-of-life?
- At last year's international EV Conference

Agreed to spend large amount to resolve

The problem

Cordless Battery-Operated Tools

- Great innovation. But what happens at end-of-life.
- I already have hand tools with integrated rechargeable batteries that failed. Electric lawnmower. Battery life is only 3 to 5 years.

Computers

- Anyone remember early computers? Sent to third world countries for recycling.
- What about current computers? Where will they end up?

Appliances

- Some can be recycled.
- Some metals can be extracted.
- Most end up in junk piles.

The problem continues

New Technologies

- If I told you today that there was a product that saved 50% of the energy used by LED lamps, probably the last question most of us would ask would be:
  - Are there any harmful components and what do we do with them at the end-of-life?

Current Solutions

Where do our new technologies go at end-of-life?

Current Solutions

Third World Countries

- Shipping products to third world countries where the children and poor scavenge for precious components, risking their health and lives.

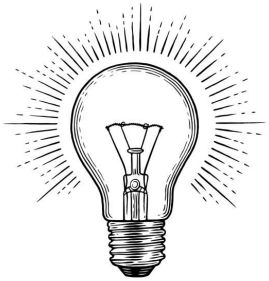
Let’s take a look at lighting

Lead, Mercury, and now LEDs

- The lighting industry jumps on innovations without thinking through end-of-life.
- Convenience and energy savings lead the way without thought to long-term environmental concerns.
- These “new” technologies are often promoted by voluntary organizations and/or governmental agencies.

Incandescent

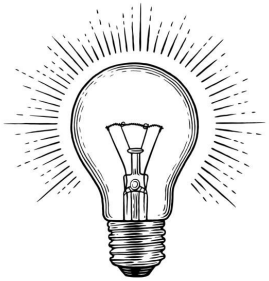
Harmful LEAD



- Large scale use of incandescent lamps started around 1882. For over 140 years there has been no strong voluntary or government effort to recycle the glass, or to keep the harmful lead out of landfills. What are the effects of lead on soil?

Incandescent

Harmful Lead



- Elevated blood lead levels (BLLs) of children living near landfills were related to increased soil lead levels. Toxic effects of lead included adverse outcomes such as encephalopathy or death for children. Different approaches to decrease lead level include environmental surveillance, BLL screening, and soil abatement which are costly.* But recycling is almost never offered as part of the solution!

Mercury Vapor and Metal Halide

Mercury Vapor – Oh Boy

- By the early 1900s we developed Mercury Vapor lamps. By the 1930s they became a popular light source, and we spent the next 50 years or more throwing used lamps in our landfills.
- We followed the same pattern with Metal Halide lamps.
- Both lamp types contained high levels of mercury.
- Eventually we started recycling these lamps.

Broken Mercury Vapor Lamps

What Happens?

- When the lamps are put in a landfill the glass breaks and the mercury is released. The mercury usually becomes part of leachate, the liquid that washes out of the bottom of the landfill. Modern landfills are designed with leachate collection systems. However, these systems can fail and the mercury containing leachate can leak into our groundwater. Also, the way some leachate collection systems work, the leachate is pumped to a sewerage treatment plant. Unfortunately, these plants cannot remove mercury and it gets released into our waterways.

Fluorescent

What is the problem?

- In the 1930s the fluorescent lamp had emerged as a practical source for commercial lighting. Again, nobody was thinking about toxicity or the potential dangers of mercury.
- Add to this the problems of PCB containing ballasts!
- For the advantage of “better” lighting and energy savings we plowed ahead without any thought to end-of-life problems.*

Mercury Levels

- Some studies suggest that children of mothers with blood mercury levels as low as 30 to 40 ng/ml may exhibit delayed development and subtle nervous system effects during early childhood.
- Blood mercury levels above 100 ng/mL have been reported to be associated with clear signs of mercury poisoning in some individuals (e.g., poor muscle coordination, tingling and numbness in fingers and toes).
- Lamps made up to the 1940s used toxic beryllium compounds, which were implicated in the deaths of factory workers.

Fluorescent Continued

Manufacturing

- Fluorescent lamps produced in China contained relatively large amounts of mercury (up to 40 mg per lamp) due to the prevalence of liquid mercury dosing, which also released significant amounts of mercury to the environment.
- In some areas the land around the plants are now totally contaminated. Nothing will grow.
- Manufacturing processes have been improved to reduce the handling of liquid mercury during manufacture and improve accuracy of mercury dosing.

Fluorescent Solutions

What to do with fluorescent at end of life.

- Europe was way ahead of us in reduction of mercury in fluorescent lamps and recycling mandates.
- About 40 years ago we started recycling fluorescent on a regular basis, mandated in many areas.
- This is a great solution making use of the glass, end caps, phosphors, and recapturing the mercury for reuse keeping it out of the landfills.

Fluorescent and HID Solutions

What to do with fluorescent at end-of-life.

Fluorescent Solution Exsists

The Problem

- We have the long-term solution for fluorescents, but new DOE Standards will eliminate fluorescent lamps and tubes before we have a solution for LEDs.
- DOE prohibits “manufacturing and imports.”
- Seven states so far, and more to come, are banning the sale. Oregon has passed legislation.
  - Starting January 1, 2024, ***the sale, offer, or distribution*** of new screw- or bayonet-base type compact fluorescent lamps will be prohibited.
  - A year later, from January 1, 2025, similar restrictions will be imposed on pin-base type compact fluorescent lamps and linear fluorescent lamps.

LEDs

The Beginning

- The first practical visible-spectrum light-emitting diode was developed in 1962, leading the way to LED exit signs and traffic signals.

LEDs

Once again, no thought to end-of-life

- End-of-life solutions? Who cared. This was a way to save an enormous amount of energy and redesign every home and building in the world.
- Both energy savings and potential sales and profits were enormous.

LEDs

Ingredients

- Reading the ingredients on an LED chip is like reading the label on a box of children's cereal. Most of the ingredients I can't even pronounce.
- LEDs and circuit boards contain arsenic, gallium, indium, cerium, europium, gadolinium, and yttrium. ARSENIC!! You need to know this is not good. What about the other elements' long-term effects to our drinking water?

ARSENIC in Drinking-Water

What is the problem?

- In drinking-water supplies arsenic poses a problem because it is toxic at low levels and is a known carcinogen.

My Confession

LED Exit Signs

- I assisted on working on the specifications for the first, and the last, ENERGY STAR Exit Signs, complying with UL specifications for brightness.
  - When I started selling LED exit signs in the late 1980s people asked how long they would last, and I would tell customers not to worry about that because “we will all be retired by that time.”
  - Well, I am semi-retired, and the time has come to replace early versions.

Exit Signs Continued

A pressing question for Exit Signs End of Life

- The US EPA estimates that there are over 100 million exit signs in the U.S., and they contain batteries and circuit boards that are now recognized as hazardous universal wastes. Nobody is even talking about the harmful LEDs. The early LED signs (yes, the ones I sold) have either burned out by now or the components have died out or they simply do not meet UL requirements for brightness. Even allowing 25 to 30 years per new exit signs, where are the plans for end-of-life?
- Are we simply going to throw 100 million exit signs into the landfills with their harmful batteries, circuit boards, and LEDs?
- Once again, encouraged by the DOE we leaped forward without fully developed plans for end-of- life.

Why worry about LEDs

- Arsenic is one of the critical elements used in the manufacturing of silicon-based semiconductors. Arsenic is the fundamental physical building block for all semiconductor devices.
- There are risks related to the critical nature of arsenic used to make high-speed computer chips that contain gallium arsenide.
- There are municipalities looking at replacing tens of thousands of first-generation LED streetlamps. That is a lot of arsenic and other chemicals.

LEDs in Europe

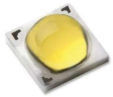
European Semiconductor Industry Association (EESIA)

- Arsenic is rigorously managed in the semiconductor **manufacturing environment** and there is no consumer exposure. The end-of-life phase of electronic products are covered by the EU WEEE (waste electrical and electronic equipment) directive and therefore potential exposure is minimized. Environmental exposure is minimized.
- Treated as hazardous waste.

Current Problem

End of Fluorescent?

- When we move to LED, what is our plan for recycling?
- Can individual chips really be recycled? Or just other components?



LEDs – Current Solutions?

How to deal with LED lamps right now

- When my LED MR16 burned out I called around to find out how to deal with the lamp. All my local authorities told me there was no mercury, so just threw it in the regular garbage.
- A highly respected colleague in Vermont (one of the states banning fluorescent) was told the same thing.
- It should be noted that some big box stores are accepting them, but info on what happens to them seems to be non-existent.

LEDs in Landfills

Arsenic Limits

- TCLP leachate concentrations of arsenic greater than 5 mg/L require disposal in a hazardous waste landfill. When the leachate arsenic concentration is below 5 mg/L, the waste is classified as nonhazardous and suitable for disposal in a municipal solid waste landfill.
  - Arsenic contamination of ground water may persist for many years after closure of a landfill because of the high organic carbon content of contamination according to the United State Geological Survey.

LEDs – Current Solutions?

How to deal with LED lamps right now

- People and companies are not being encouraged to recycle LEDs.
- How much is really being recycled?
- Should we really be banning fluorescent before we have a viable solution for LED end-of-life.
- Are landfills the right solution?

The Big Question

What about luminaires



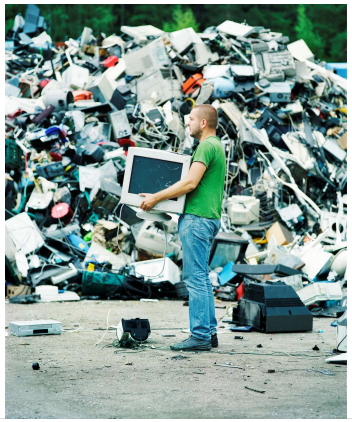





Solutions

Sustainability

- Sustainability has become a big and important issue in the lighting community, and that is a good thing.
- Thinking about component replacement will help in the long term. Think about fluorescent luminaires that went from first generation T12 all the way to T8 fluorescent to LED.
- Shouldn’t we make it that simple for LEDs with a viable end-of-life solution?



Solutions

Other Sustainability Solutions for Lighting

- Material Homogeneity: ex: water soluble adhesives.
- Sequencing Disassembly: identification of materials.
- Effect of Fasteners: easy to use.
- Reduce Time/Cost: technologies that minimize numbers and variety of materials used.
- Replaceable parts.
- Packaging: reduce by designing fixtures to fit into smaller packaging including pallets.
- Material Health: avoid use of environmentally hazardous materials.
- NEW: we must address end-of-life plan other than just throwing away LEDs. If that requires mandates, so be it.

Solutions

Other Sustainability Solutions for Lighting

- In full disclosure I am a past member and EPA liaison to The National Association of Innovative Lighting Solutions (NALID)
- NAILD's Sustainability Committee's White Paper supports the practice of recyclable and/or reusable components. An example would be using recyclable lamps vs. integral LEDs which will be hard to extract from luminaires.
- Use simple, replaceable, component parts.

Solutions

Other Sustainability Solutions for Lighting

- Ontario Canada: January 1, 2023, lamp/bulb manufacturers have new “extended producer responsibility” requirements in Ontario, Canada, for end-of-life management of “lighting” under Ontario Regulation 522/20: Electrical and Electronic Equipment. This includes both residential and commercial lamps sold in Ontario. But not LUMINAIRES.
- Should LED products contain end-of-life messaging on packaging?
- Create LED Manufacturer Alliance to provide a one-stop resource for recycling information

Solutions

Other Sustainability Solutions for Lighting

- Examples of materials like wood in luminaires.
- Aluminum that can be recycled (using recycled aluminum to start with).
- Packaging?
- Material components?
- Easy removal of toxic components?
- Handle as electronics and harmful waste like Europe?
- Other ideas?

Conculsion

Next Urgent Steps

- We need a plan for LED end-of-life now. Not 20 years from now.
- Do current recycling options really fill our needs?
- How do we ensure that LED lamps **and luminaires** will be kept out of landfills?
- Will it take legislation at local, state, or federal levels to help protect our environment?

Sustainability

Various Sustainability Organization Are Happening

- Are they including end-of-life options? If not, is that full responsibility for sustainability?

The Future

Next energy-efficient technology

- How are we going to deal with quantum dots, blue laser, and other new technologies?
- How do we focus on more than just lumen packages and energy efficiency.
- We must address end-of-life before we leap into future technologies.
- AND THAT TIME IS NOW.

Thanks

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