Sustainability as a Foundation for Collaboration between Science and Design

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Sustainability

Economy

Equity

Ecology

From *Cradle to Cradle* by William McDonough & Michael Braungart. 2002.
Sustainability is a framework to gain competitive advantage and increase profitability through strategic planning and long-term decisions.
Is lighting profitable?

- What is the price of light?
- What is the price of lighting?
Price of light

\[
\left( \frac{\text{lamp price}}{\text{wattage} \times \text{efficacy} \times \text{life}} \right) + \frac{\text{electricity rate}}{\text{efficacy} \times 1000}
\]

\times \text{recommended illuminance}

= \text{dollars per square meter-hour}

Lamp price adjusted to constant dollars
Efficacy in lumens/watt
Lamp life in hours
Electricity cost adjusted to constant dollars
Recommended illuminance in lux per IESNA

$1.00 \ (1967) = $6.21 \ (2008)$
Price of light: Lamps (for prevailing technology)

![Chart showing the price of light lamps over time, with marked data points for 1913 (~300 lm) and 2008 (~3000 lm).]
Price of light: Lamp life

- LEDs (50,000 hrs)

Graph showing the lifespan of incandescent and fluorescent lamps over the years, with LEDs reaching 50,000 hours.
Price of light: Lamp efficacy

Adapted from: http://americanhistory.si.edu/lighting.tech/chart.htm
Price of light: Electricity

Adapted from: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_38.pdf
Price of light (for prevailing technology)
Price of light: Recommended illuminances

Recommended Illuminances for Office Lighting, 1947-present
(regular office tasks)

Source: IESNA Lighting Handbook, 1st-9th eds.
Price of light (for prevailing technology)

- Incandescent technology introduced
- Fluorescent technology introduced
- Increased light levels
- Three reduced light levels
- Peak electricity cost

Lamp replacement: incandescent technology
LED replacement: LEDs + energy

1967 dollars per square meter • hour


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Sustainability is a framework to preserve the environment through ecologically intelligent design and rational use of resources.
What is the real cost of light?

- Air pollution
- Global warming

—probably impossible to measure precisely

—but not necessarily impossible to tax
Environmental pollution: Acid rain
Global warming
Price of light: Electricity

“Real” cost of electricity

Adapted from: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_38.pdf
Price of light (for prevailing technology)

- 1967 dollars per square meter • hour
- Year range: 1910 to 2010

Graph showing the price of light from 1910 to 2010, with three lines representing different costs:
- Lamps + energy
- Lamps + energy x 2

The graph illustrates the upward trend in cost from 1910 to 1970, with a peak in the 1970s, and then a decline towards 2010.
Price of lighting

\[
\left( \frac{\text{lamp price}}{\text{wattage} \times \text{efficacy} \times \text{life}} \right) + \text{electricity rate} \times 1000 \times \text{recommended illuminance} + \text{luminaires}
\]

= dollars per square meter-hour
Price of lighting (for prevailing technology)

1967 dollars per square meter • hour

+ installation
+ luminaires
lamp replacement lamps + energy
Price of lighting

\[
\text{Price of lighting} = \left( \frac{\text{lamp price}}{\text{wattage} \times \text{efficacy} \times \text{life}} + \frac{\text{electricity rate}}{\text{efficacy} \times 1000} \right) \\
\times \text{recommended illuminance} + \text{luminaires} + \text{design} \\
= \text{dollars per square meter-hour}
\]
Price of lighting (for prevailing technology)

1967 dollars per square meter • hour

$2.50/m²* = 2.6% of the cost of ownership

* in 2008 dollars

+ design
+ installation
+ luminaires
lamp replacement
lamps + energy
Price of lighting, percentages

- Lamps/energy: 41.4%
- Lamp replacement labor: 2.6%
- Luminaires: 25.6%
- Luminaire installation labor: 4.9%
- Lighting design: 25.6%
Price of light: Lamps (for prevailing technology)

As a commodity, lamp price drops by 2/3
Design becomes a commodity?

- $2.50/m^2 \rightarrow $0.80/m^2?
Equity

- Sustainability is a framework to add social value, and a foundation for maintaining the value of design.
Equity = People

- More than just lumens
Equity = People

- More than just lumens
- More than just aesthetics
Equity = People

- More than just lumens
- More than just aesthetics
- Includes safety
Equity = People

- More than just lumens
- More than just aesthetics
- Includes safety
- Includes security
**Equity = People**

- More than just lumens
- More than just aesthetics
- Includes safety
- Includes security
- Includes health

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**Night shift workers**

**Jet lag**

**Adolescents’ sleep patterns**

**Sports performance**

**Neonatal intensive care units**

**Breast cancer**

**Seasonal affective disorder**

**Space travel**

**Older adults’ sleep patterns**

**Sleep disorders**

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New paradigm: Partnership between design and science

- Performance
- Well-being
- Satisfaction
- Comfort

Intensity
Spectrum
Distribution
Timing
Duration

Appearance
Visual System

Visual Performance

Performance, Well-being, Satisfaction, and Comfort
Luminous efficiency functions

**Relative Value vs. Wavelength (nm)**

- **Photopic**
- **Scotopic**
- **Mesopic**
- **Brightness (on-axis)**
- **Brightness (off-axis)**
- **Glare**
New paradigm: Partnership between design and science

Appearance

Visual System

Visual Performance

Performance, Well-being, Satisfaction, and Comfort

Alerting Effects

Circadian System

Phase Shift

Intensity
Spectrum
Distribution
Timing
Duration
Luminous efficiency functions

![Graph showing luminous efficiency functions for various conditions such as photopic, scotopic, mesopic, brightness on-axis, brightness off-axis, glare, and circadian. The graph plots relative value against wavelength (nm) ranging from 400 to 700 nm.](image-url)
New paradigm: Partnership between design and science

- Appearance
- Visual System
- Performance, Well-being, Satisfaction, and Comfort
- Circadian System
- Alerting Effects
- Visual Performance
- Culture, Experience, Expectations
- Phase Shift

Factors:
- Intensity
- Spectrum
- Distribution
- Timing
- Duration
Visual pleasure pathways

Biederman, I. and Vessel, E. A. 2006. Perceptual Pleasure and the Brain. *American Scientist*. May-June. Fig. 2.
Opportunities

- U.S. EPA: National Center for Environmental Research
- U.S. Department of Health & Human Services: Agency for Healthcare Research and Quality
- AIA Upjohn Research Initiative
- NIH Office of Dietary Supplements
- American Federation for Aging Research (AFAR) Research Grants/New Investigator Awards in Alzheimer’s Disease
- Wisconsin Energy Conservation Corporation
- City of Welland, Ontario, Canada
- Nuckolls Fund for Lighting Education Inc.
Sustainable lighting is...

- **Economy**
  - Lighting for profit: More than price

- **Equity**
  - Lighting for people: More than lumens

- **Ecology**
  - Lighting for energy/environment: More than the price of electricity
Thank you.

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