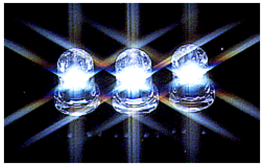
Transforming the Lighting Sector With Semiconductor Lighting Technologies



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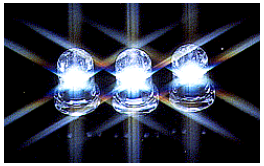

USAEE/IAEE Annual Meetings

Philadelphia, PA

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Overview

- Introduction
- U.S. Lighting Demand
- Evolution of LEDs
- The LED Simulation Model (LEDSim)
- Results

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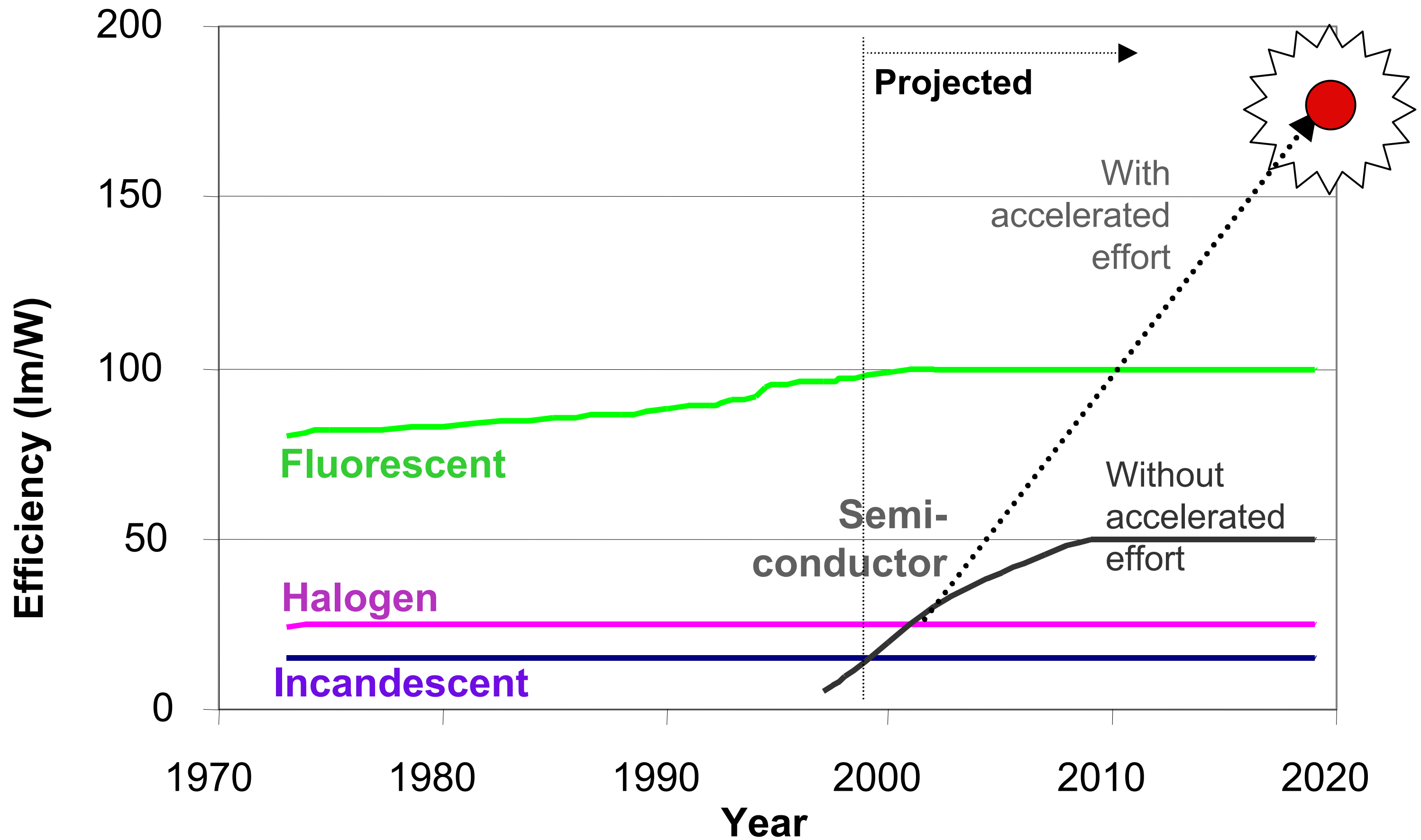
Introduction



U.S. Lighting Demand, 1995

	Total Electricity Demand (Quads)	Lighting (Quads)	Lighting % of Total	Annual Growth (%)
Residential	11.4	1.3	11.4%	1.5%
Commercial	10.5	3.0	28.6%	0.1%
Industrial	11.1	0.7	6.3%	0.9%

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Characteristics of Existing Lights

Lamp Type	Power (Watts)	Efficiency (lm/W)	Lifetime (hrs)
Standard Incandescent	15-250	8-19	750-2,500
Long Life Incandescent	135	12	5,000
Halogen	42-150	14-20	2,000-3,500
Compact Fluorescent	5-55	50-70	10,000
Standard Fluorescent	30-40	70-80	20,000
Mercury Vapor	40-1,000	50	29,000
Metal Halide	32-1,500	46-100	5,000-20,000
High Pressure Sodium	35-1,000	50-124	29,000

Estimated % of Lumens from High Efficient Light Sources

Sector	% of Lumens from High Efficient Light
Residential	13.0%
Commercial	94.8%
Industrial	94.8%

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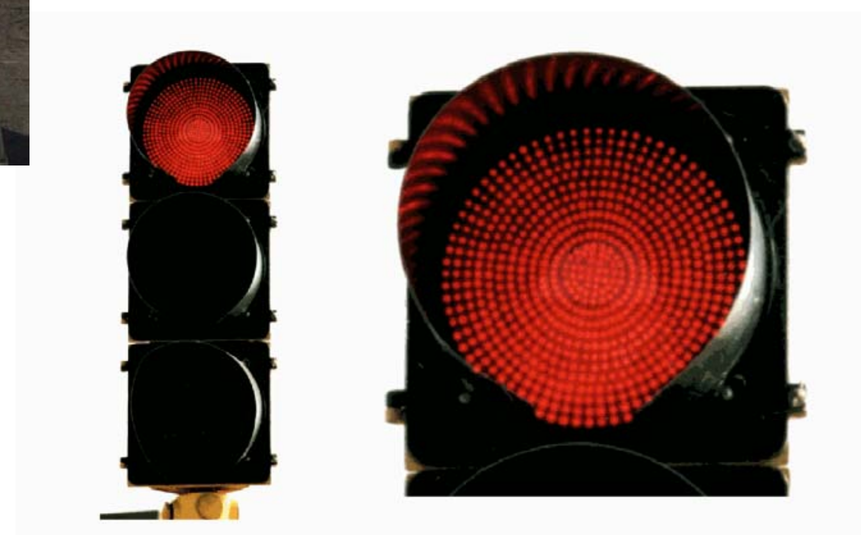
LED Evolution

- **First LED demonstrated by GE in 1962**
- **Monochrome applications**
  - **Automobile center-high mount brake lights on cars**
    - » **Durability & size key attributes**
  - **Exit signs**
  - **Traffic lights**
    - » **Directionality, durability, and power consumption key attributes**
  - **Outdoor display screens**
    - » **Durability and brightness key attributes**

Monochrome Applications



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Monochrome Applications (continued)

The Instant Replay Screen at Liberty Bowl Stadium in Memphis, Tennessee

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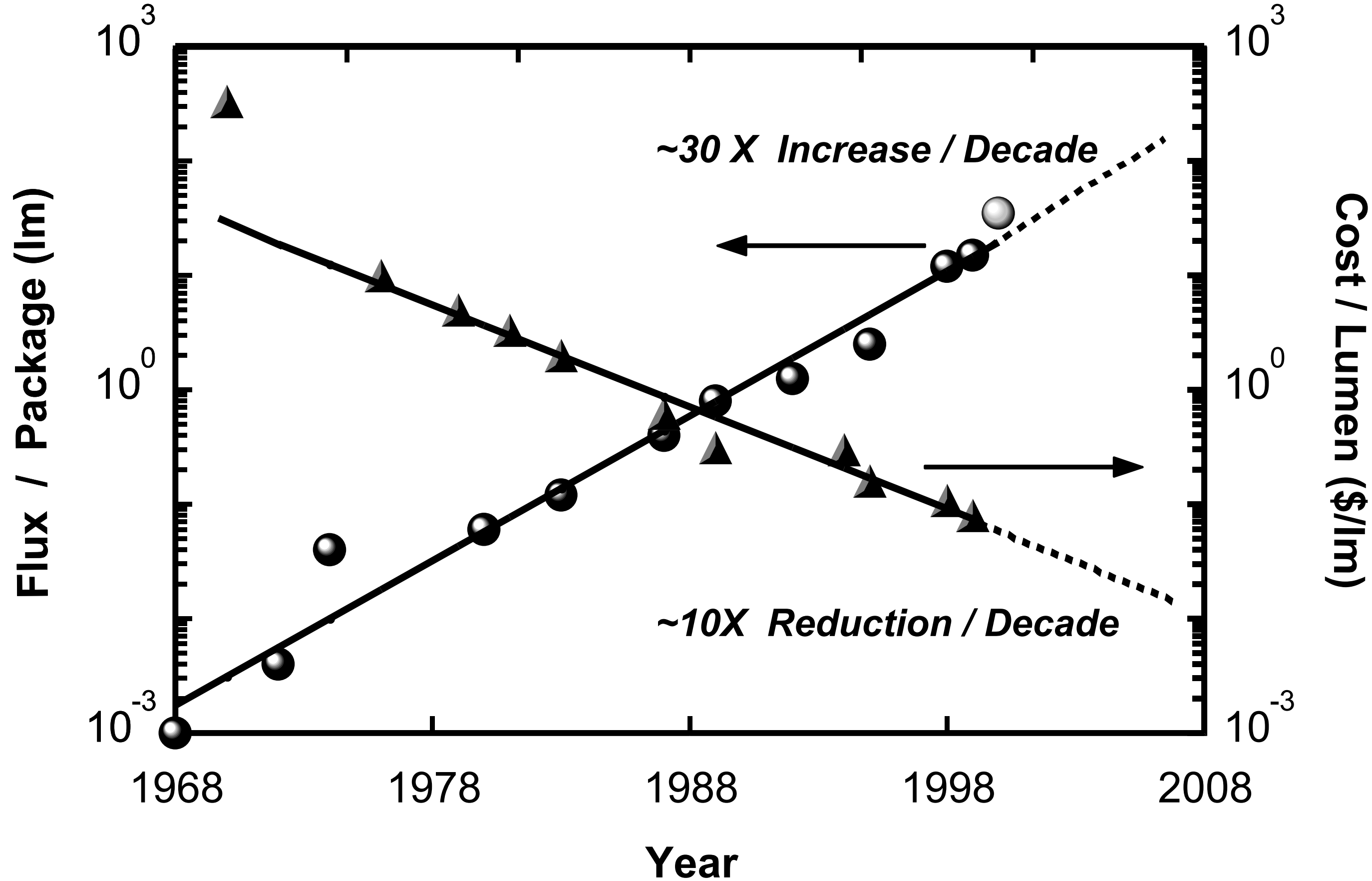
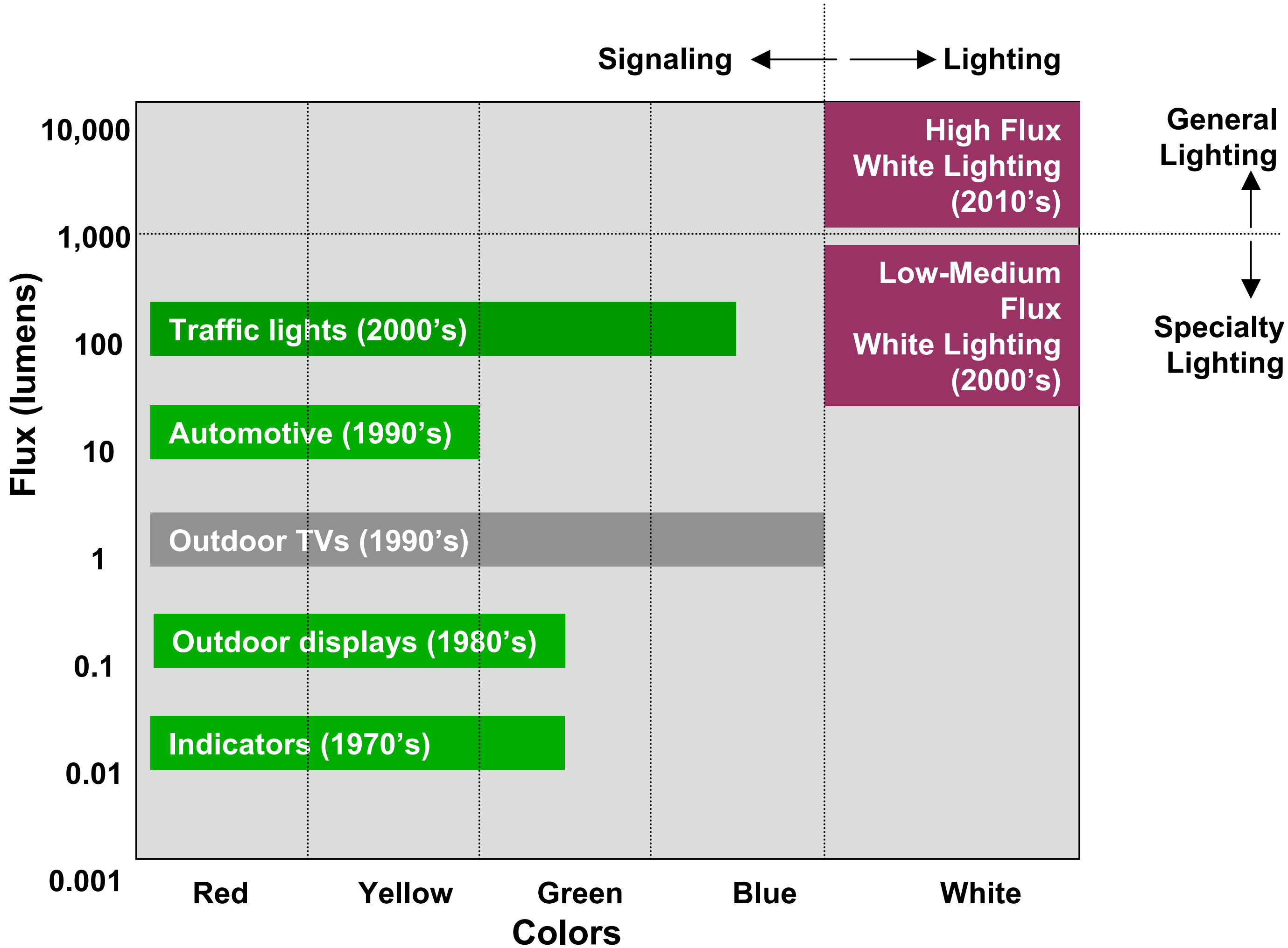
Evolution of Performance and Cost of Red LEDs



Evolution of LEDs: the Future



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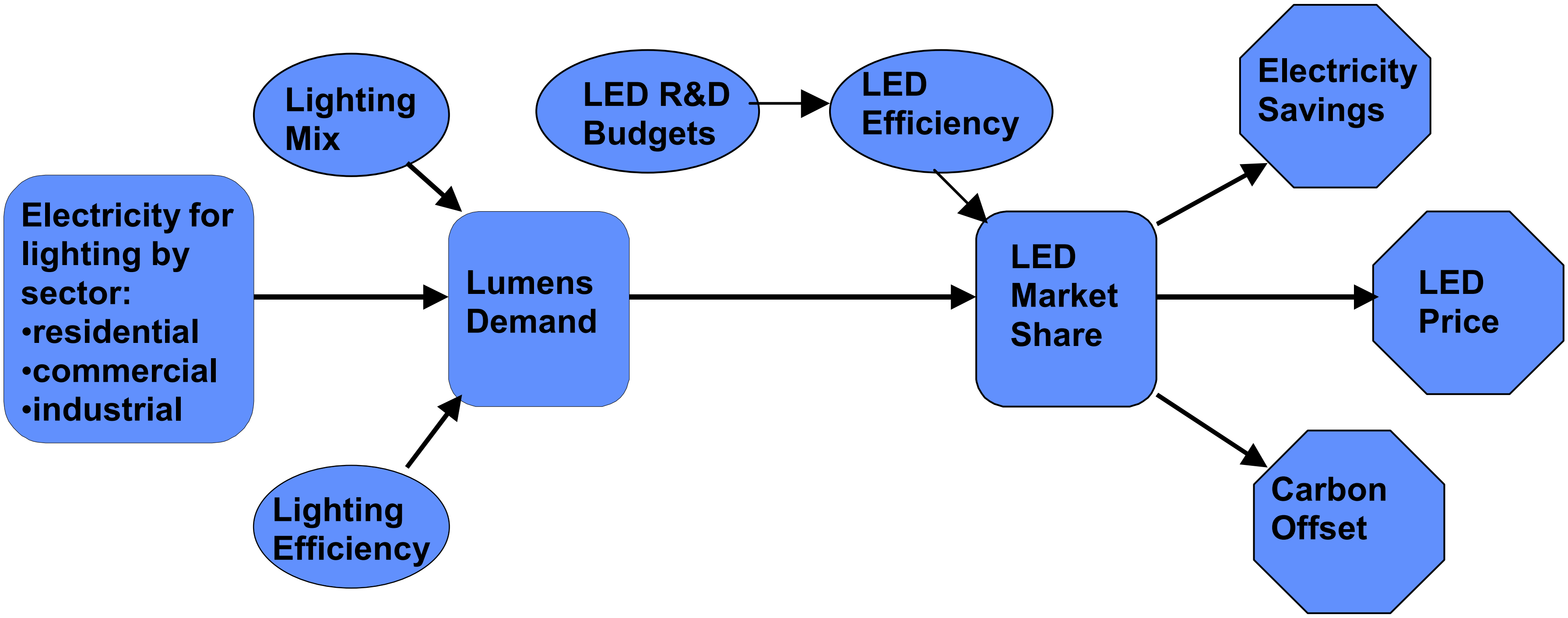
The LED Simulation Model

- Dynamic simulation model written in Powersim
- Market diffusion using S-shaped diffusion methodology
  - Separate markets for low efficiency (incandescents, halogens) and high efficiency (fluorescents, HIDs)
  - LED efficiency a function of research investment
- Two main scenarios
  - Low investment: industry sponsored effort, driven initially by monochrome market
  - High investment: government partners with industry to create national initiative

The LED Simulation Model Structure



Market Diffusion Component

$$MP_i = \frac{k_i}{1 + \exp(-\ln 81 * (t - t_i) / \Delta t)}$$

Where:

- **MP_i = market diffusion for lighting type i in year t (low or high efficient)**
- **k_i = maximum market diffusion for lighting type i (assumed to be 50% for each type)**
- **t_i = year get 50% market share (tied to cumulative investment)**
- **delta t = time to go from 10% to 90% of maximum allowed saturation, k_i**

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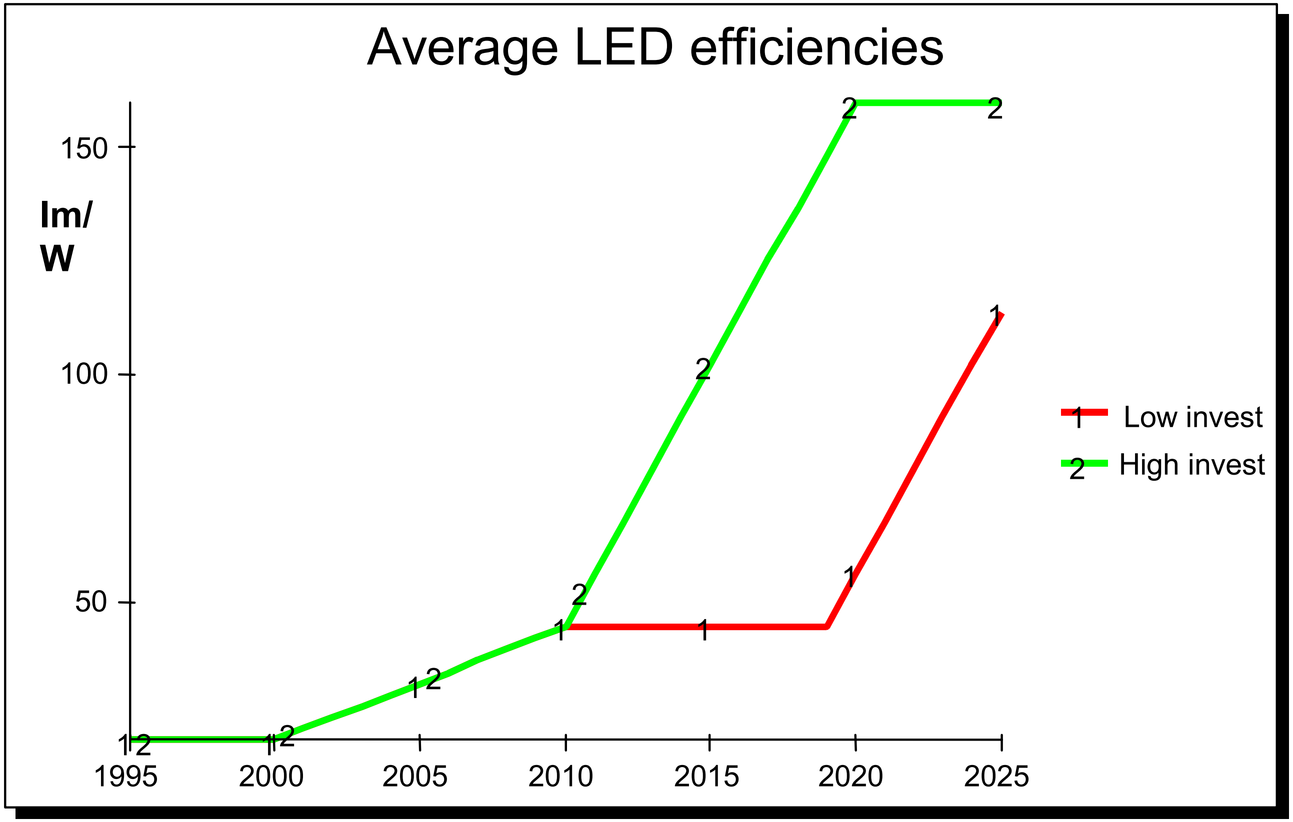
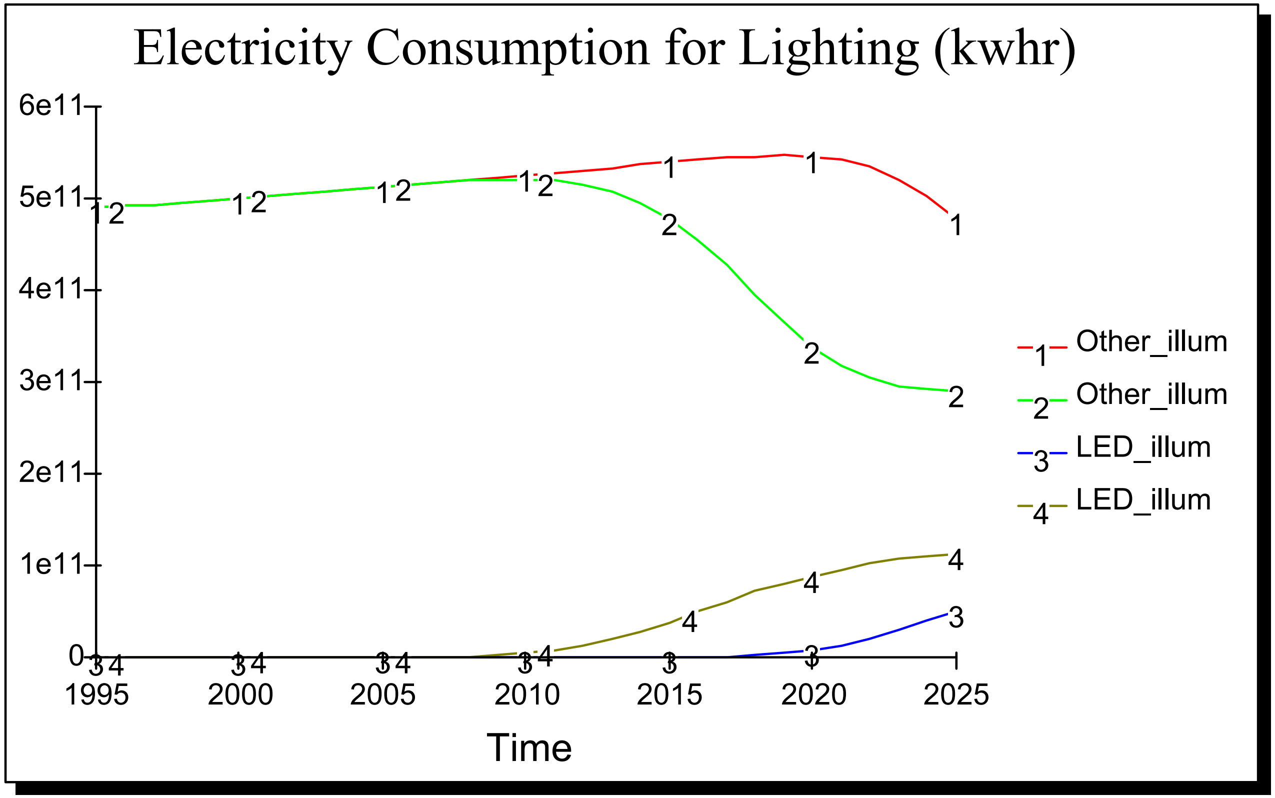
Projected LED Efficiencies



Results, 2025

	Low Investment	High Investment
Electricity (billion kwhr)	531	404
Annual Savings	40	167
Cumulative Savings	82	1233
LED Market Share (% of delivered lumens)	16	49
Avoided Electrical Capacity (MW)	4,107	17,671
Electricity Savings (billion $)		
Annual Savings	3	12
Cumulative Savings	6	87
Carbon Emissions (MtC)		
Annual Savings	10	41
Cumulative Savings	20	313

Results (continued)



1 = Non LED lighting, low investment case
2 = Non LED lighting, high investment case
3 = LED lighting, low investment case
4 = LED lighting, high investment case

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Projected LED Prices

Bulb Type	Purchase Cost (cents/klmhrs)	Operating Costs (cents/klmhrs)	Total Cost (cents/klmhrs)
Incandescent	0.07	0.47	**0.54**
CFL	0.11	0.12	0.23
Fluorescent	0.01	0.09	0.10
LED 2000	0.12	0.35	**0.47**
LED 2010 (low invest)	0.05	0.16	0.20
LED 2020 (low invest)	0.01	0.13	0.14
LED 2010 (high invest)	0.03	0.16	0.19
LED 2020 (high invest)	0.01	0.04	**0.06**

klmhrs = kilolumen hours

Conclusions

- **White LEDs soon will be a viable substitute for white illumination**
- **LED market penetration initially will be limited to low flux lighting (accent lights) followed by incandescents and eventually fluorescents**
- **Degree of LED penetration will be dependent on LED efficiency and price**

Conclusions (continued)

- **Key attributes of LEDs include:**
  - durability
  - directionality
  - color control
  - small size
- **In high investment case, LEDs capture 49% market share by 2025**
  - 17.2 GW of installed electrical capacity
  - $11.8 billion annual electrical savings
  - 41 million tons annual carbon avoided

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