Cost models and evidence data for innovation
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Quality – Costs - Energy efficiency – Versatility - Miniaturization

« Solid State Lighting (LEDs) is a disruptive technology which is changing the whole way we will design, install, maintain and finance lighting installations. »

Will bring some facts

Will show examples of our contribution
New LED based luminaires have an **efficiency 2 to 3 times of** the ones they replace.

Cost evolution will reduce **Total Cost of Ownership** by 2 to 5 by 2020...
Efficiency/Cost

WHITE LED TECHNOLOGY AND COST
AVERAGE 1 WATT COOL WHITE LED PACKAGE

Average Lumens per 1W package

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

$/klm

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October 4, 2011
Some trends:

Standards are missing but clusters of companies begin to agree on standard approaches Connected Lighting Alliance, Zhaga...

Some players propose long term supply of lighting (manufacturers, facility managers, utilities, etc.)

Value of general lighting may go down

Value moves to visual effects, entertainment, displays, and maintenance contracts.

Unit: €/Mlm.hr of useful light
Looking for «low hanging fruits» and best solutions

<table>
<thead>
<tr>
<th></th>
<th>Industrial building</th>
<th>Office building</th>
<th>School</th>
<th>Store</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference installation (15 – 30 yrs)</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
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</tbody>
</table>

| New generation (2014-2015) | ![Image](image5.png) | ![Image](image6.png) | ![Image](image7.png) | ![Image](image8.png) |
IEA SHC Task 50: Advanced Lighting Solutions for Retrofitting Buildings

**Office building**

**LCC, Fluorescent T8 and LED**

Relative distribution of costs within LCC

**Fluorescent T8**

- **Electricity**
- **Component**
- **Work time**
- **Cleaning**

**LED**

- **Electricity**
- **Component**
- **Work time**
- **Cleaning**
Wholesale Retail  Usage hours: 4801 h/year

<table>
<thead>
<tr>
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<th>Cost</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref, T8</td>
<td>10.35 €/m²</td>
<td></td>
</tr>
<tr>
<td>New, LED</td>
<td>4.31 €/m²</td>
<td>58%</td>
</tr>
<tr>
<td>New, LED + CTRL</td>
<td>3.65 €/m²</td>
<td>65%</td>
</tr>
</tbody>
</table>

Electricity price 13c/kWh  Increase rate + 1,75 %

Cumulated cost [€/m²]

Year

Change of luminaire  (€/m²)  Ref  New, LED  New, LED + CTRL

Electricity consumption (€/m²) WATTAGE  10.35 €/m²  4.31 €/m²  3.65 €/m²

Usage hours (h/year)  4801 h/year  4801 h/year  4069 h/year
Classroom  Usage hours: 932 h/year

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<tr>
<td>Ref, T8</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>New, LED</td>
<td>0.42</td>
<td>68%</td>
</tr>
<tr>
<td>New, LED + CTRL</td>
<td>0.28</td>
<td>78%</td>
</tr>
</tbody>
</table>

Electricity price 13c/kWh
Increase rate +1.75 %

Cumulated cost [€/m²]

- 3.5 W/m²
- 3.5 W/m²
- 11 W/m²

Luminaire
Change

Year

Change of luminaire (€/m2)

- Ref
- New, LED
- New, LED + CTRL

Electricity consumption (€/m2) WATTAGE

- 1.33 €/m²
- 0.42 €/m²
- 0.28 €/m²

Usage hours (h/year)

- 932 h/year
- 932 h/year
- 620 h/year

SBi - AAU (2015)
Wholesale Retail  
Usage hours: 4801 h/year

Influence of Existing Installed Power

Year

Luminaire Change

New, LED

New, LED + CTRL

Ref

+25%

+50%

-25%

-50%

Payback time

SBI - AAU (2011)
Open Space Office Usage hours: 2148 h/year

Cost of Equipment

Luminaire Change

Payback time

New, LED Ref New, 75% of price New, 50% of price

Marc Fontoynont 2016, IEA 50
Open Space Office
Usage hours: 2148 h/year

Influence of Electricity Cost

Cumulated cost [€/m²]

Year

2015
2020
2025
2030
2035

Luminaire Change

Payback time

Luminaire Change

SBi - AAU (2015)

New, LED

New, LED + CTRL

Ref, 0.130 €/kWh

Bulgaria

France

Belgium

United Kingdom

0.075 €/kWh

0.110 €/kWh

0.168 €/kWh

0.192 €/kWh

Marc Fontoynont 2016, IEA 50
Quality vs Energy Efficiency:
Searching for the Holly Graal
Perceived quality vs electric power of lighting at work places

Quality: workplane, glare control, global luminous environment

Source: ADEME PUCA, ENTPE, Ingelux, SONEPAR, 2005 ->

Fontoynont Marc 2016
SBI-1. Comparison of calibrated photorealistic images by pairs

Principle: present calibrated photorealistic images of selected scenes (5 to 15) by pairs, randomly, and ask a question (criterion)
For instance, which one of the two lighting scheme is...
• More suitable to a given use of the space: work, circulation, orientation?
• More comfortable (low glare)?
• More agreeable, elegant???
• ... and many other possible attributes
For all processes, multi step calibration procedure by SBI-AAU

Step 1: Light sources: lamps and luminaires, sky conditions (daylighting)
Step 2: Surfaces and glazing photometry
Step 3: Calculation algorithms / convergence / sampling.
Step 4: Verifications Flux / Illuminance/ Luminances / Colour coordinates
Step 5: Calibration of display (screen, video projection, Head Mounted Display)

Accuracy issue is linked to operator more than the software!
Which football team is the best in Germany?

Lest them play all against each other and the one with the highest number of victory wins

( which is adjusted with draws)
Preference in lighting for office environment
Obtained from comparison of 150 pairs judged by 25 assessors

Electric power density for lighting (W/m²)

Normalized working environment preference score
(Number of preferred votes in comparison by pair)
Point of view 1: from lying patient
Point of view 2: from standing visitor

Figure 32 Hospital room, visitor POV scheme 1
Figure 33 Hospital room, visitor POV scheme 2
Figure 34 Hospital room, visitor POV scheme 3
Figure 35 Hospital room, visitor POV scheme 4
Figure 36 Hospital room, visitor POV scheme 5
Figure 37 Hospital room, visitor POV scheme 6
Figure 38 Hospital room, visitor POV scheme 7
Figure 39 Hospital room, visitor POV scheme 8
Preference of lighting visibility from a visitor's PoV

Obtained from comparison of 36 pairs judged by 14 assessors

- **Possibility for design optimizations**
  - 1: Ref
  - 2: Ref + WW
  - 3: WW + reading + pozzo
  - 4: WW + BeachPanel
  - 5: WW + reading + spotClothes + pozzo

- **Optimal solutions**
  - 6: WW + spotClothes + BeachPanel + AJ

- **Inappropriate solutions**
  - 7: Custom Lamp

- **Possibility for energy optimizations**
  - 8: WW + spotClothes + BeachPanel

- Electric power density for lighting (W/m²)
  - 0 to 8

- Efficiency
  - 0 to 16

- Normalized environment preference score
  - (Number of preferred votes in comparison by pair)
  - 0 to 10
Preference of lighting visibility from a patient's PoV

Obtained from comparison of 36 pairs judged by 14 assessors

- Possibility for design optimizations
  - 1: Ref
  - 2: Ref + WW
  - 3: WW + reading + pozzo
  - 4: WW + BeachPanel

- Optimal solutions
  - 5: WW + reading + spotsClothes + spotVisitor + pozzo
  - 8 W/m²

- Inappropriate solutions
  - 6: WW + spotClothes + BeachPanel...
  - 7: WW + SpotsClothes + Uplight

- Possibility for energy optimizations

Efficiency vs. Electric power density for lighting (W/m²) vs. Normalized environment preference score
(Number of preferred votes in comparison by pair)
Results (1):

Added value of a task lamp above a work place, or pendants above a meeting room

Added value of thin wall washers, or lines created by cove lighting, or accentuation of architectural features, to increase the perception of space (make it more interesting, more spacious)

Role of illuminance of faces of occupants, suggesting that sufficient light is provided on face, and that contrast is obtained with a darker background

The importance of deliberate lighting was stressed, with light focussing on specific functions (reading, vision of people, circulation, etc.)
Results (2)

Added value of a task lamp above a work place, or pendants above a meeting room

Added value of thin wall washers, or lines created by cove lighting, or accentuation of architectural features, to increase the perception of space (make it more interesting, more spacious)

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Some examples of results: luminaires to design.
Ceiling integrated LEDs

Indoor luminaires for large volumes, inspired by outdoor luminaires.
Specifications for AAU processes:

• Present luminous schemes (stimuli) to individuals or groups of observers, rate lighting schemes with respect to a criterion ...

• Imaging systems **appropriate** to the proposed test.

• **Portable**, to be easily used by groups of stakeholders.

Screen

Low Power video

High Power video

Head mounted display
Conclusion

Solving problem **together**: Client/manager/architect/engineer/Lighting professional

**Collective** exploration, collection validation.

**Long term** approach (costs, operation, etc.)

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