Latest LED-Projects in Germany

Energy Saving Potential, Lighting Quality and Evaluation of 10 state-aided interior and street lighting LED-projects

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FACHGEBIET LICHTTECHNIK

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1. Motivation and Background of the Project(s)
2. Overview: 10 LED projects
3. Method: Evaluation and Documentation
4. Selected Results (two indoor projects)

1. Motivation and Background

Barriers for use of LED-Technologie

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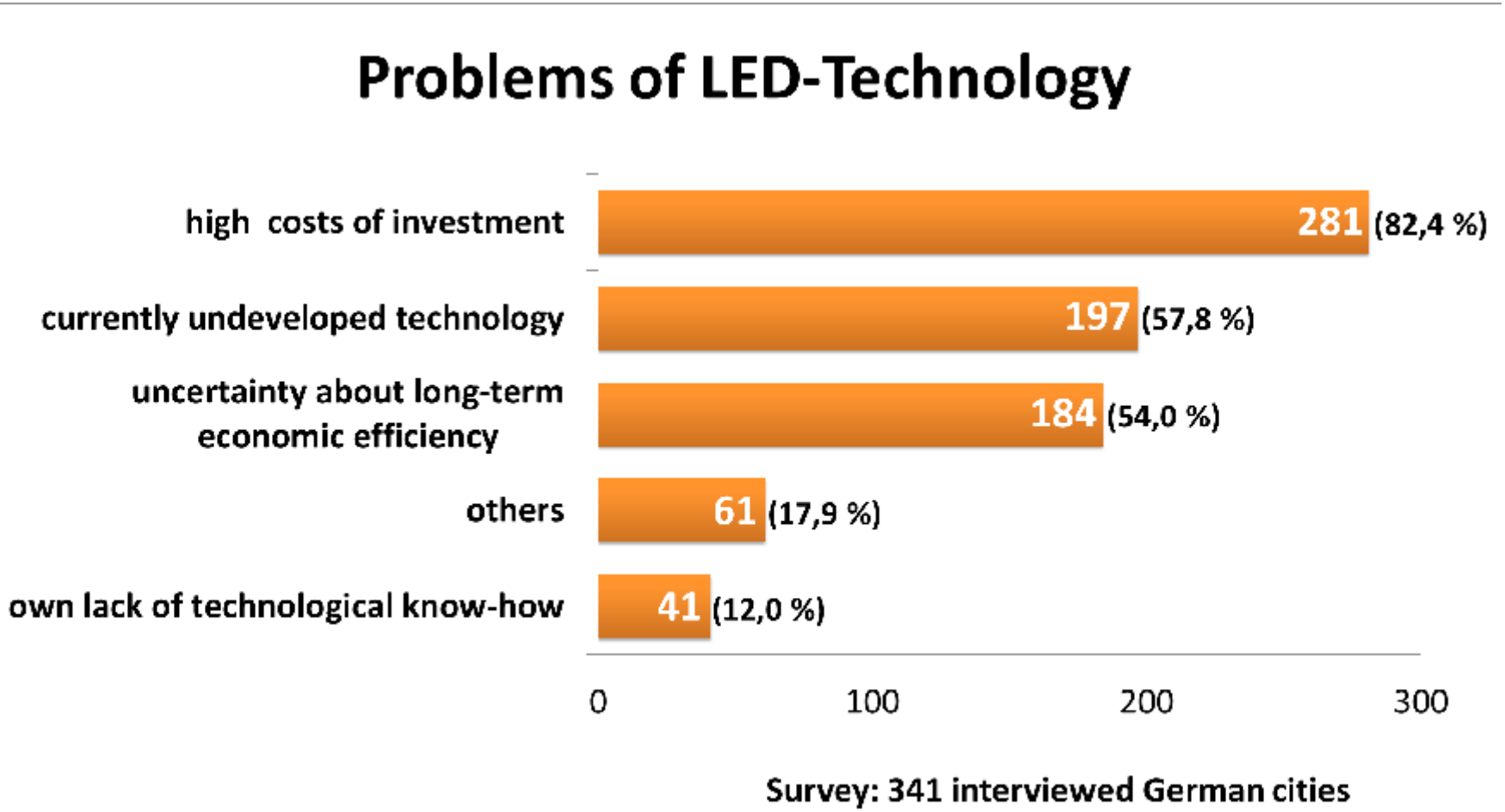

PricewaterhouseCoopers AG (PwC), March 2011

1. Motivation and Background

Aims of Competition „Cities in a new Light“

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- „Cities in a new Light“ – competition-based sponsoring for 10 cities:

  →LEDs for all applications in general lighting

  - Quick transfer of latest LED research to general lighting
  - Experience in real life: Setup of reference projects in local authority areas
  - Break down of market barriers and speed up of market launch of LED products

- Evaluation of all 10 projects (TU Darmstadt) from 10.2010- 9.2013

Definition of required data and consulting

 Consistent acquisition of data across all 10 projects

- Selection of evaluation criteria

  electrical, visual, lighting, economic, project specific and target achievement parameters

  - Documentation

2. Overview: 10 LED Projects

Status quo

Announcement of the 10 „winner cities“ from 141 candidates:
Light and Building Fair, April 2010, Frankfurt

Start of Project:			Measurement					Questionnaire						
			Interior Lighting	Street Lighting	Cyle- / footway	Architectural Lighting	Tunnel Lighting	Interor Lighting	School Illumination	Street Lighting	Architectural Lighting	Tunnel Lighting	Light Control	Solar Lights
June 2011	1	Erfurt		X		X				X	X		X	
February 2011	2	Görlitz	X	X	X	X		X		X	X			
February 2011	3	Königsfeld (Schwarzwald)	X	X		X			X	X	X		X	X
June 2011	4	Wuppertal			X	X	X			X		X		
December 2010	5	Trier	X						X					
June 2011	6	Norden		X	X					X			X	
June 2011	7	Munich	X					X					X	
November 2010	8	Paderborn		X						X			X	
April 2011	9	Freiburg		X	X	X				X	X		X	X
April 2011	10	Rietberg		X	X	X				X	X		X	

Some examples in some winner cities

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ktmasterformate durch Klicken bearbeiten
weite Ebene
Dritte Ebene
- Vierte Ebene
  - Fünfte Ebene

Facade lighting in Erfurt or Rietberg

Tunnel lighting in Wuppertal

Street lighting in Paderborn

3. Method: Evaluation and Documentation

Cooperation- clear tasks for the partners

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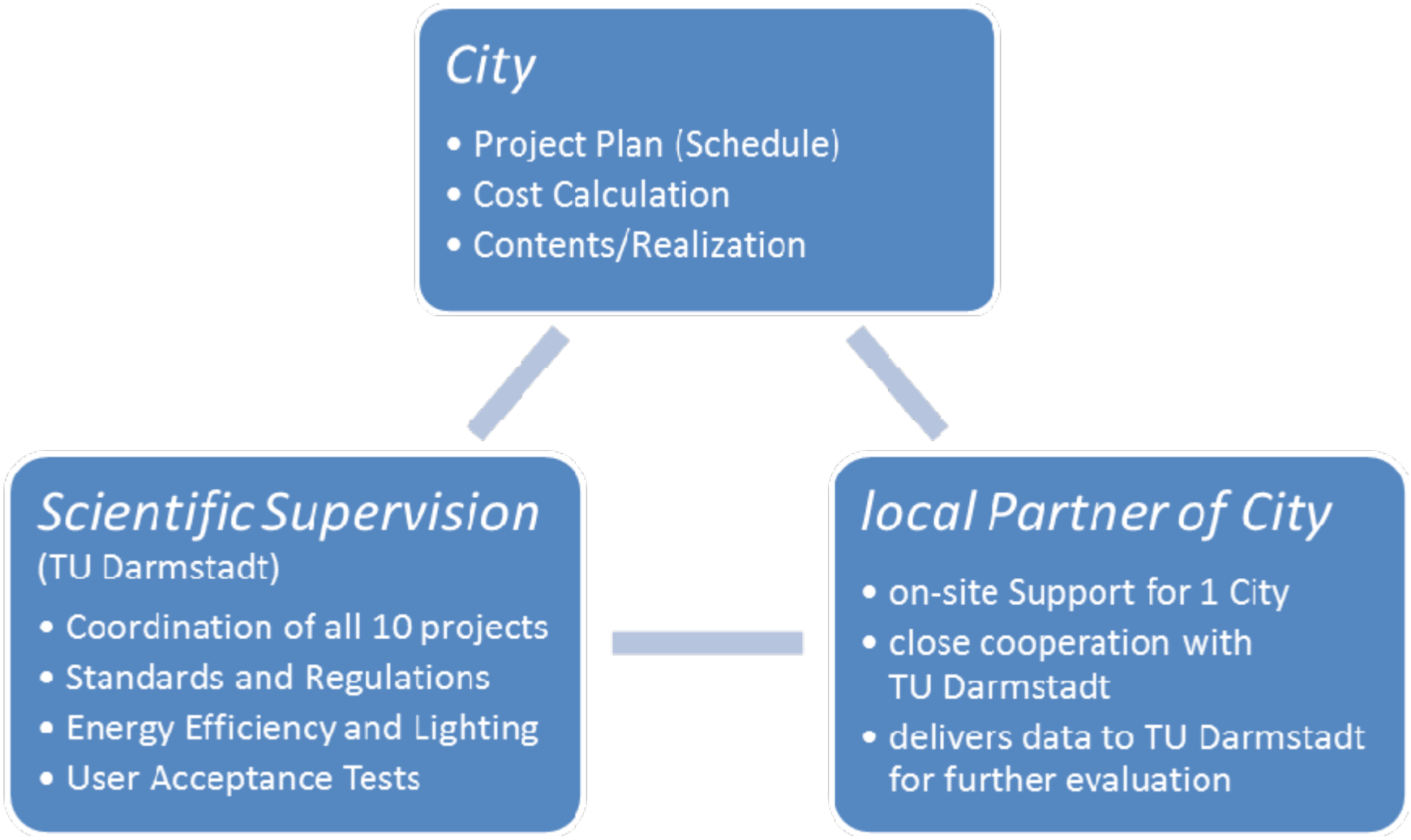

3. Method: Evaluation and Documentation

Project Steps for each of the 10 cities

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Step 1: Coordination

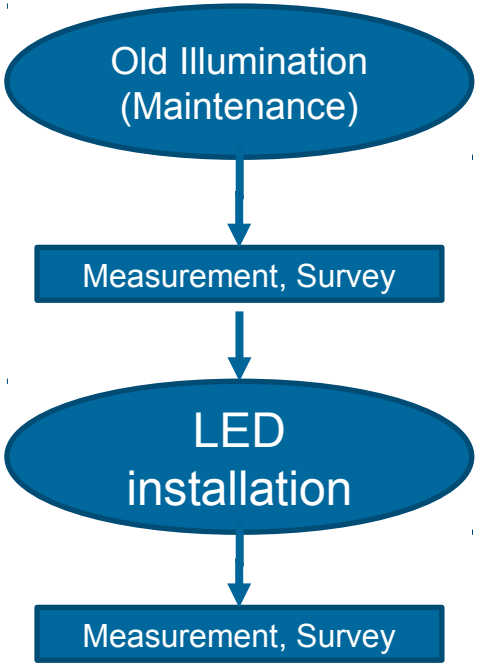
- Schedule, Method, Actual state, …

Step 2: Old Illumination (if available)

- After maintainance, cleaning the old luminare and burn-in (minimum 100 h)

Step 3: LED lighting

- simulation with Dialux software, lab measurement
- New LED luminaires after burn-in (min. 100 h until 500 h)



Step 4: Documentation

- Website (latest results), Publication, Presentation, Handbook

3. Method: Evaluation and Documentation

Acquisition of Data

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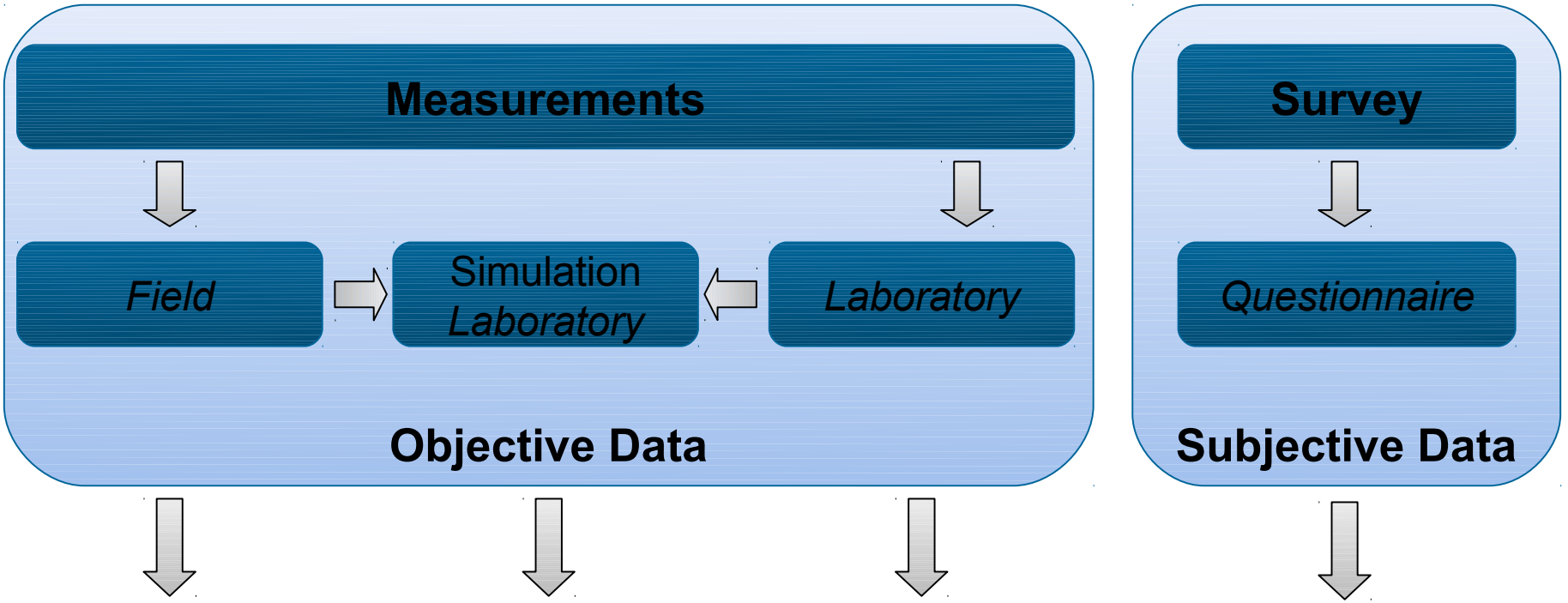

Database for Evaluation and Documentation

Conventional versus LED

- **Energy Efficiency**
- **Energy Saving Potential**
- **Lighting Quality**
- **Costs (Maintenance, luminaires, installation, …)**
- **Lifetime of Luminaires (e.g. failure rate)**
- **User Acceptance and target achievement**

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Measurement and Simulation

Laboratory – Luminous flux and luminous intensity distribution

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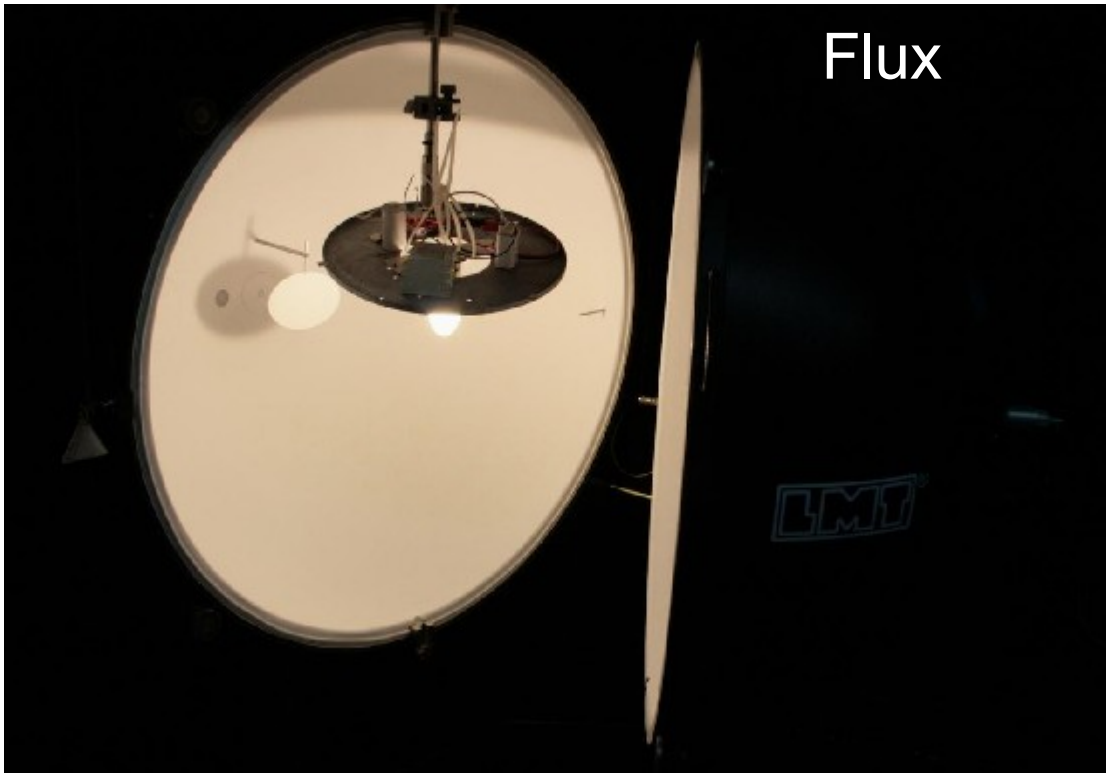
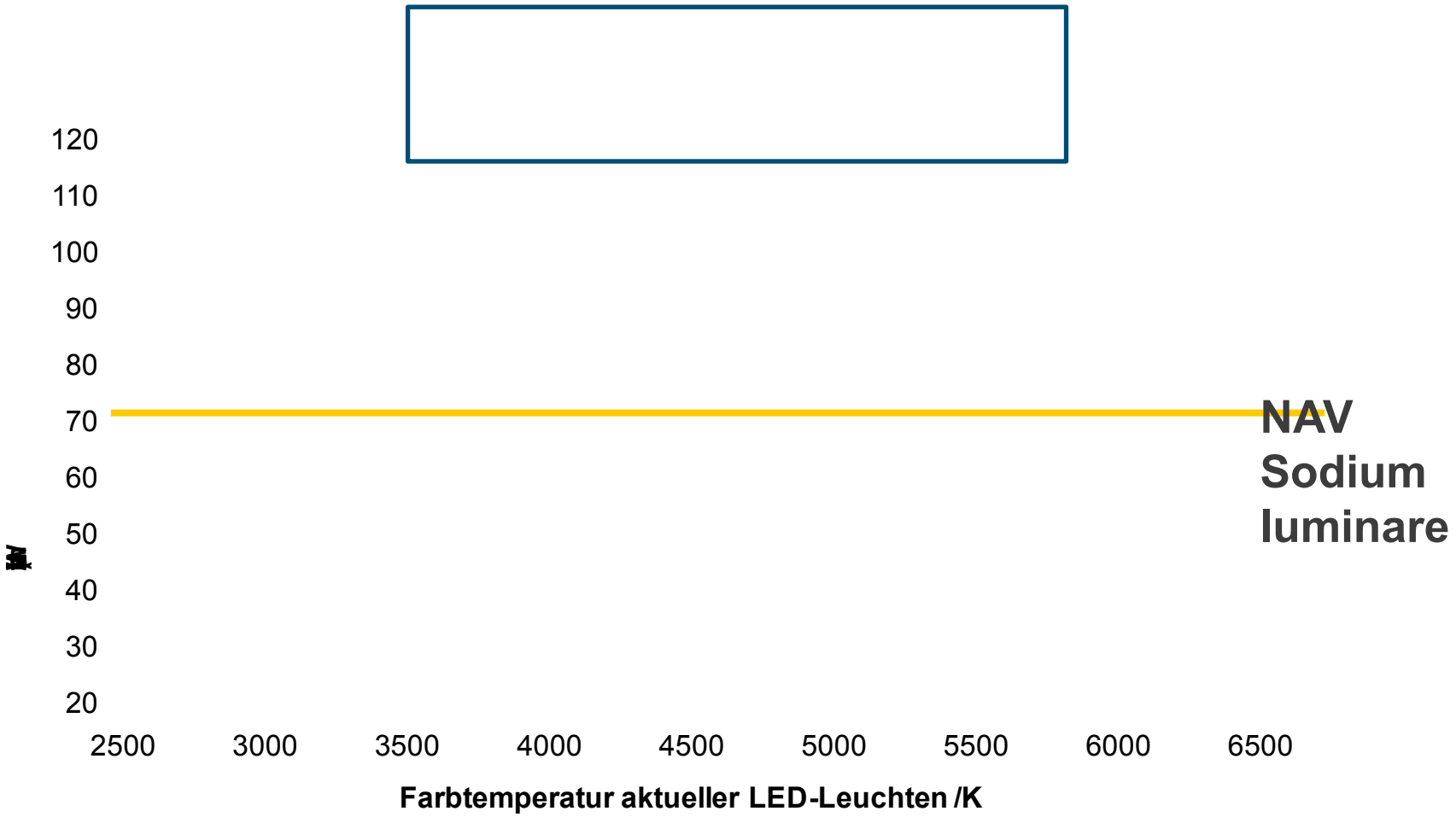


Ulbricht-sphere: Luminous flux

Goniophotometer:Luminous flux

Luminous efficacy of 33 LED-street luminares on the facility in Kaarst /Germany (stand: summer 2011)



Source: RWE Leuchtenpark (KAARST-DRIESCH)

Laboratory-measurement - Simulation

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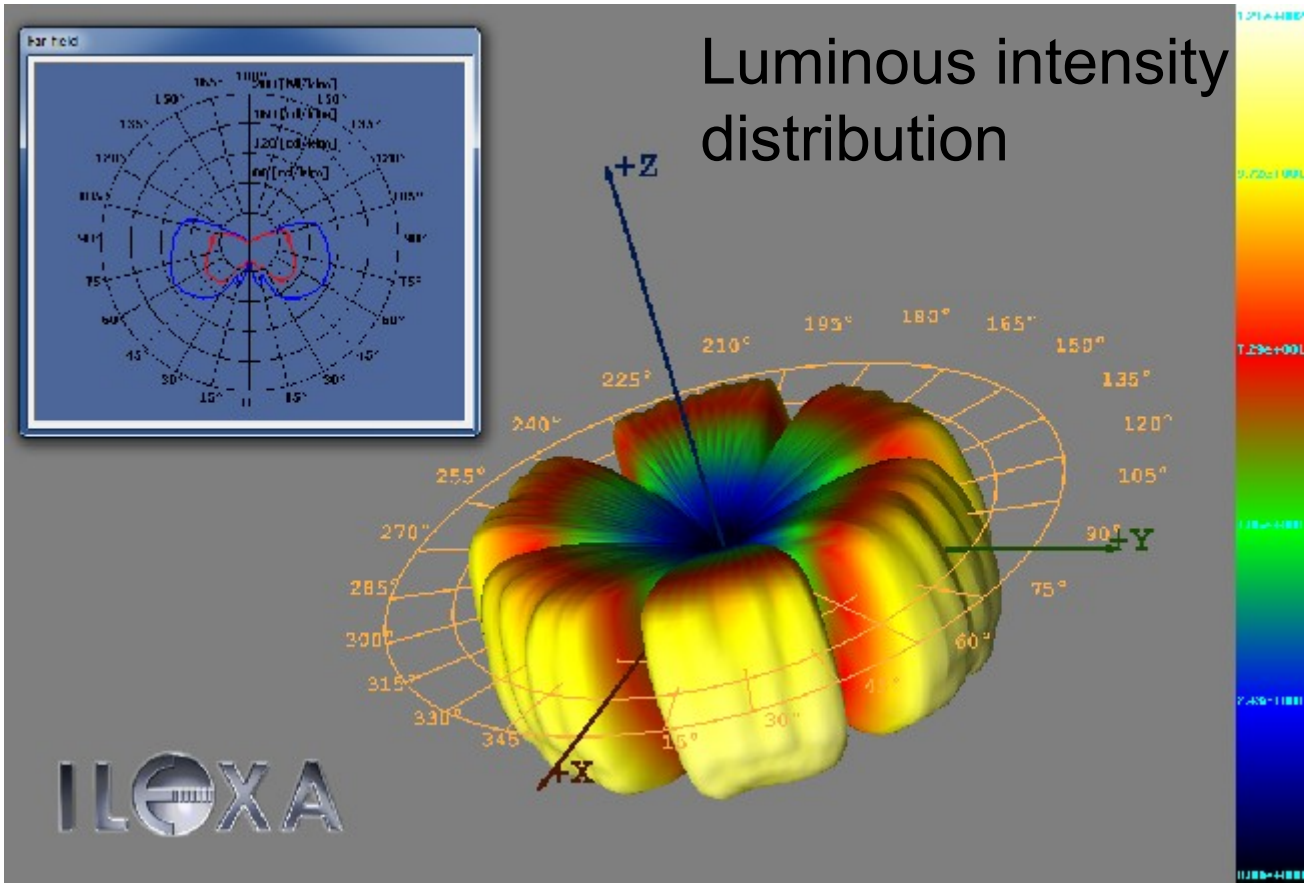

Calculation of the illumination level

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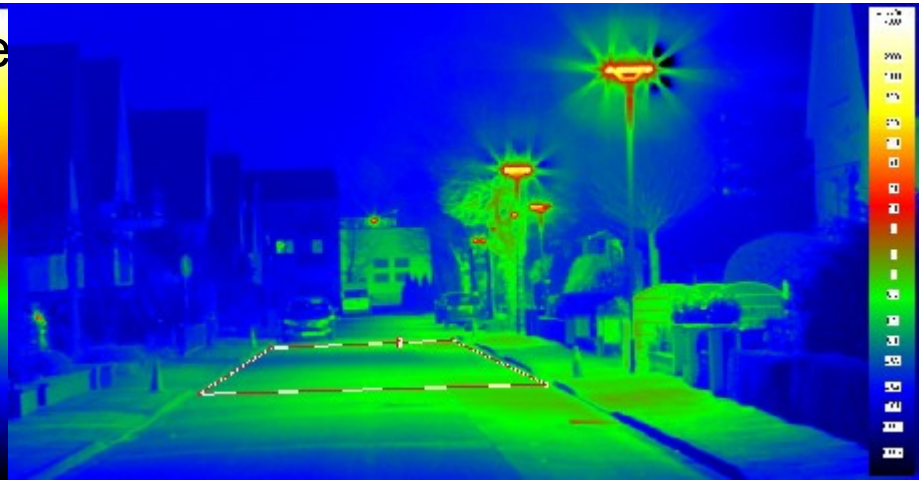
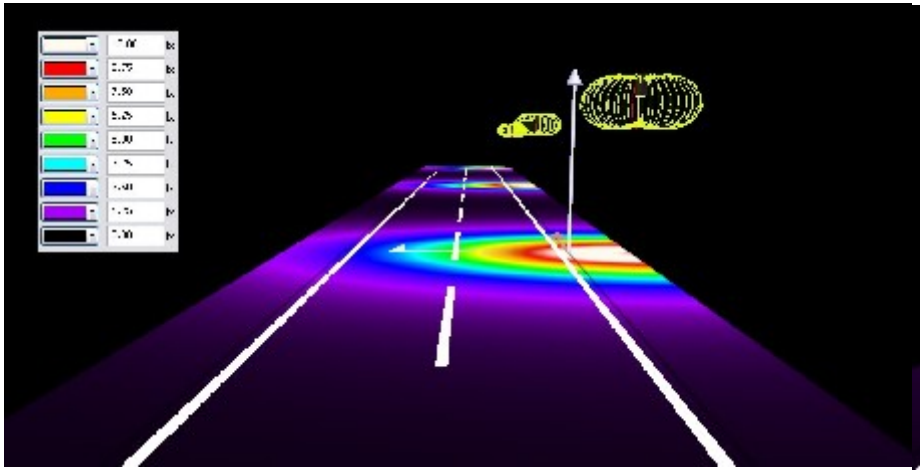
Measurement **Before** **After: with LED-luminare**

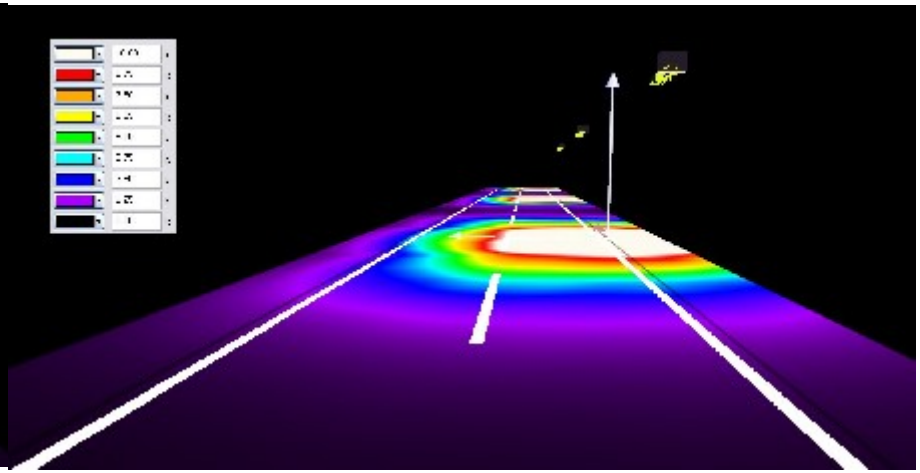


Textmasterformate durch Klicken bearbe

- Zweite Ebene
  - Dritte Ebene
    - Vierte Ebene
      - Fünfte Ebene

Simulation





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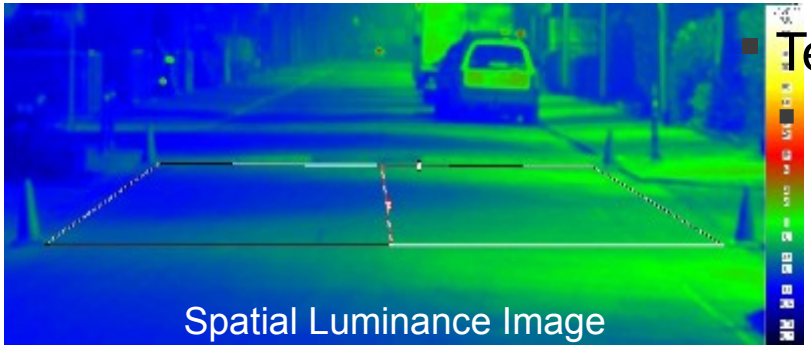
3. Method: Evaluation and Documentation

Example – Street Lighting: Objective Data



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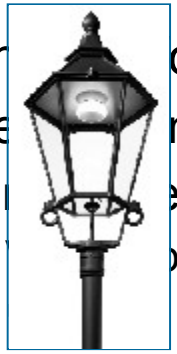
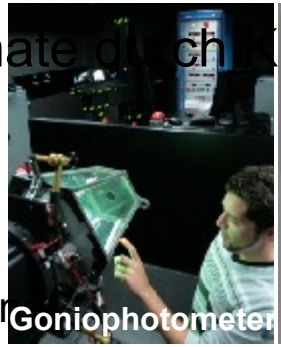
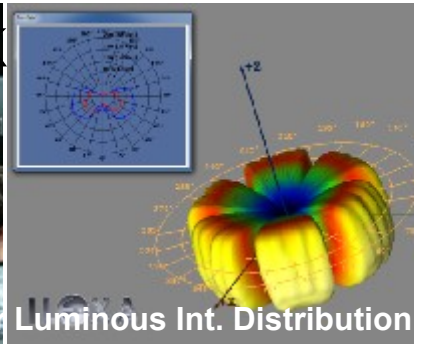






Field

- Geometries
- Lighting Quality
- Electr. Param.

DIN EN 13201

Lighting Class (S or ME):

P, | Em, Emin, Lm, U0, Ul, | TI, SR

Laboratory

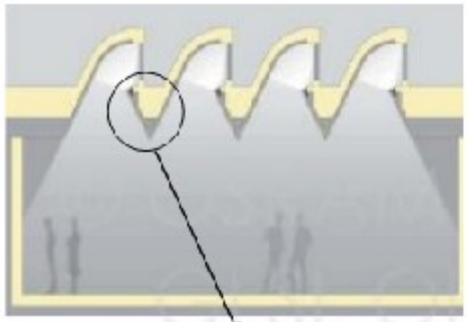
- LI-Distribution
- P
- CCT
- SPD
- CRI

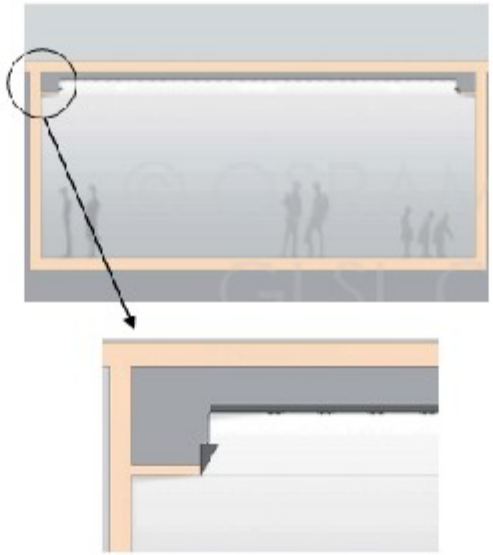
Measurement

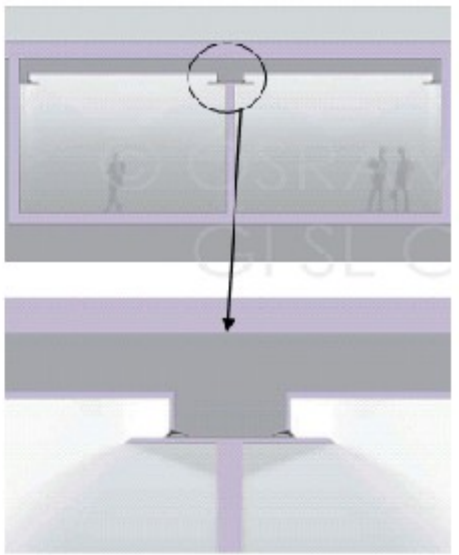
Simulation

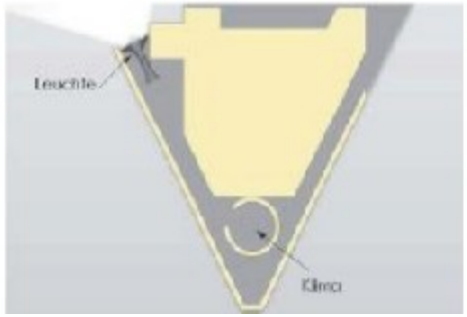
4. Selected Results
Munich Lenbachhaus (Museum)

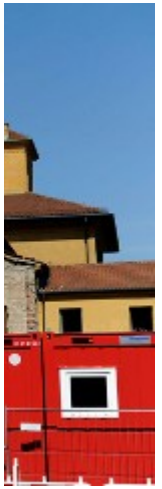
- General reconstruction of the museum Lenbachhaus (60 millions Euro)
- LED-illumination with three different luminare systems (2 millions Euro)









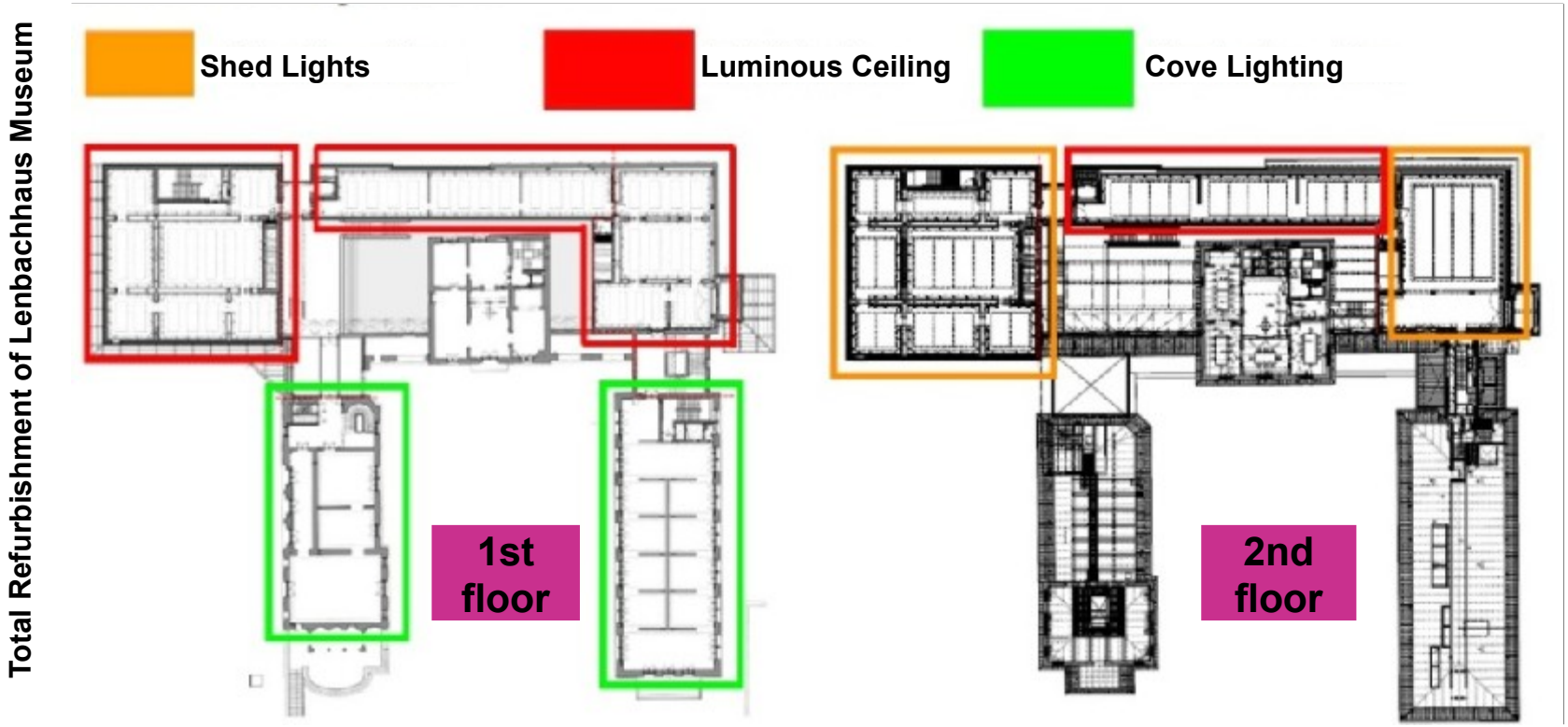


4. Selected Results

Munich Lenbachhaus (Museum) - Requirements

- Variation of Colour Temperature
- Variation of illuminance for constant CCT
- High CRI (> 90)

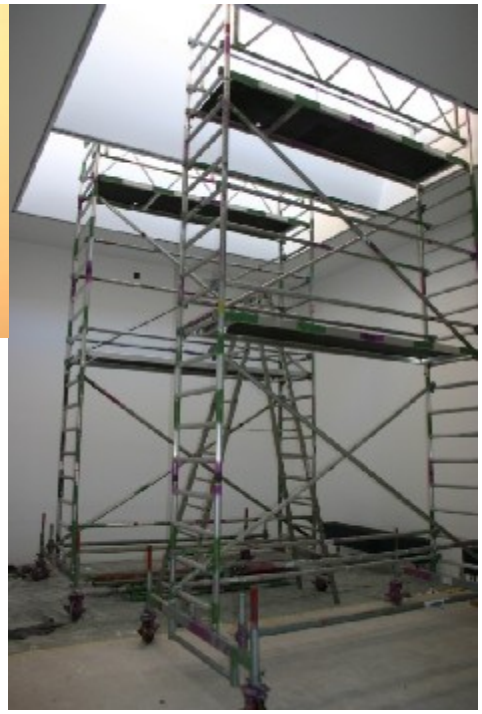
- No damage of artwork by illumination
- Homogeneous illumination
- 3 different types of illumination



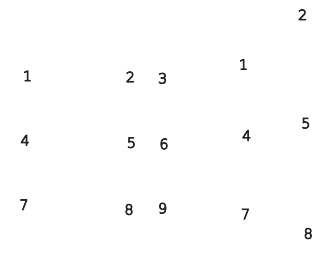
Current stand January 2012

- Currently- three rooms are installed with the LED-luminares

- Measurement of these three rooms (by TU Darmstadt)



- Due to the very good color and light quality- decision of the museum management to install the lights into whole museum



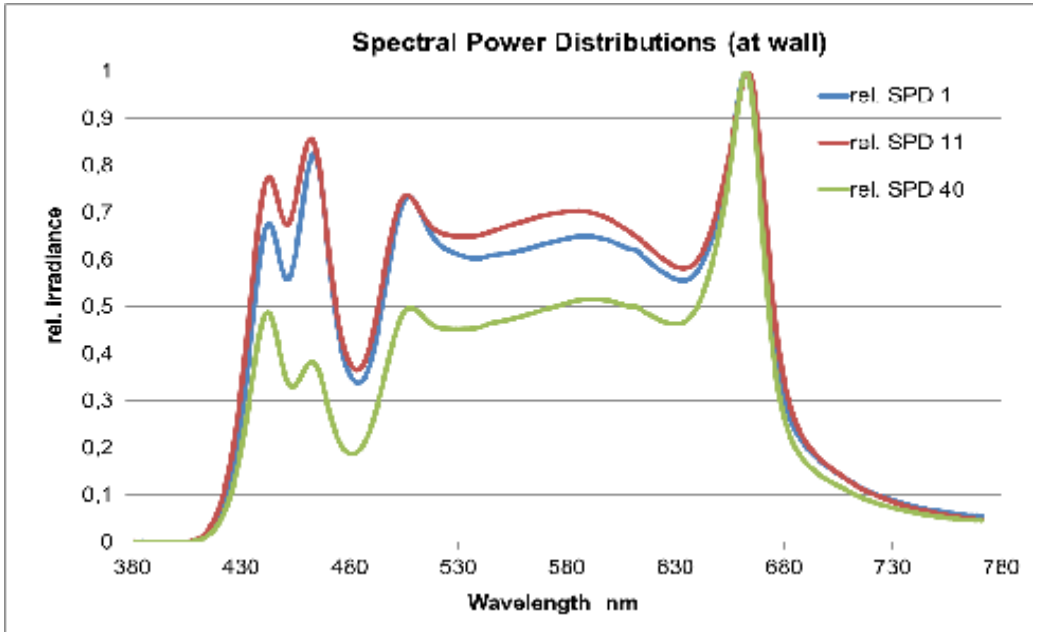
4. Selected Results

Munich Lenbachhaus (Museum) – Luminous Ceiling

Sample Room with Luminous Ceiling

LED-Modules with 12 LEDs:

- RGBW solution
- about 100 lighting scenarios (steps)
- 13 different CCTs for 100% luminous flux
- Steps between: dimming



4. Selected Results

Munich Lenbachhaus (Museum) – Luminous Ceiling

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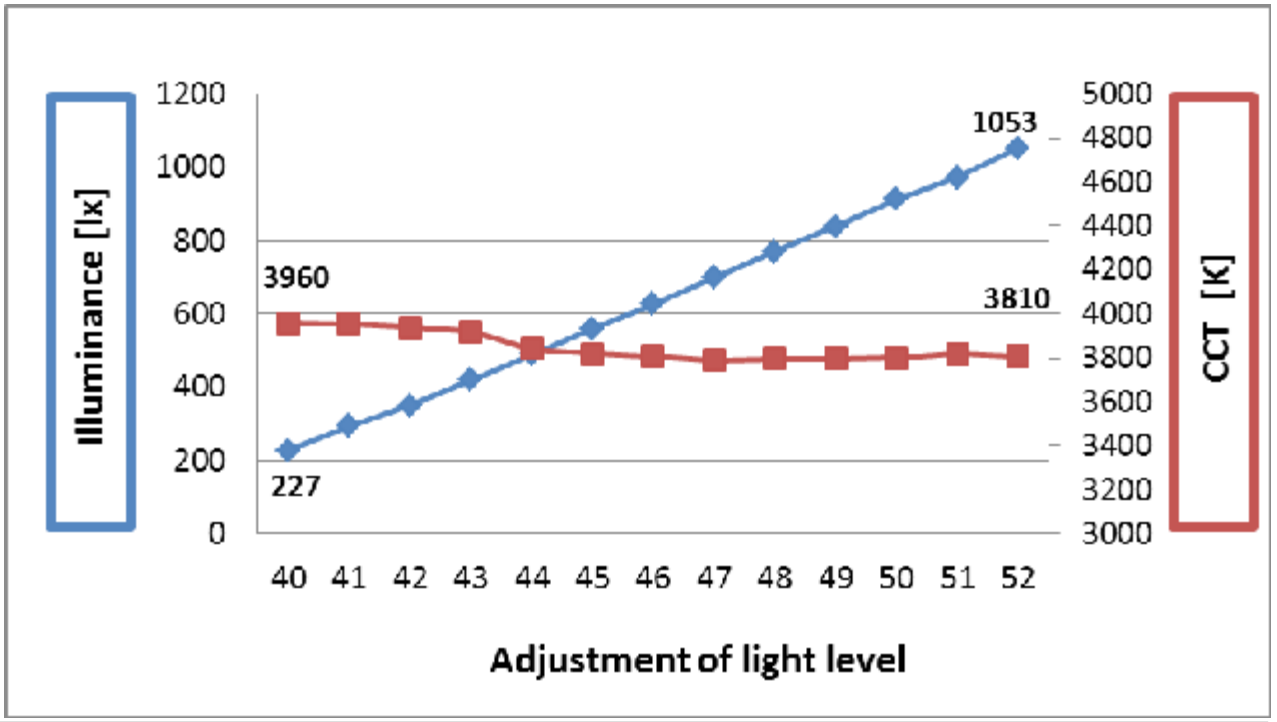
Measurements in a Sample Room:

- CRI:
  93.8 – 97.8
  (Average: 95.8)

- Adjustable
  Colour Temperature:
  3022 K - 4800 K

	E(2 m above floor)	Em	g1=Emin/Em
Wall 1	795 lx	763 lx	0.9
Wall 2	875 lx	767 lx	0.8
Requirement	min. 350 lx @ 3000 K 2m above floor		



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Trier – school illumination with LED

masterformate durch Klicken bearbeiten
eite Ebene
itte Ebene
ierte Ebene
Fünfte Ebene

School center Mäusheckerweg

School illumination according the standard EN 12464

Replacement of the luminares with tubular fluorescent lamps by LED-luminares

- **First step**: Experiments in some class rooms in order to select the best concept and LED-luminare

School illumination in Trier – Selection and qualification of the LED- indoor luminares

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Type/company	luminous efficacy [lm/W]	colour temperature [K]	Color rendering index Ra-value
company P1-Type 1	64.4	3930	75
company P1/Type 2	55.7	3930	78
company P1/Type 3	79.9	4023	82
company N2	42.1	ca. 3200	78-80
company SL3-Type 1	54.0	7629	75
company SL3-Type 2	50.1	3250	64
company T4	about 48.0 .	6600	68
Best conventional luminare T5-lamp	**about 80**	**4000**	**>80**

For EN 12464 for indoor lighting: CRI ≥ 80

Trier – Stand of the current work

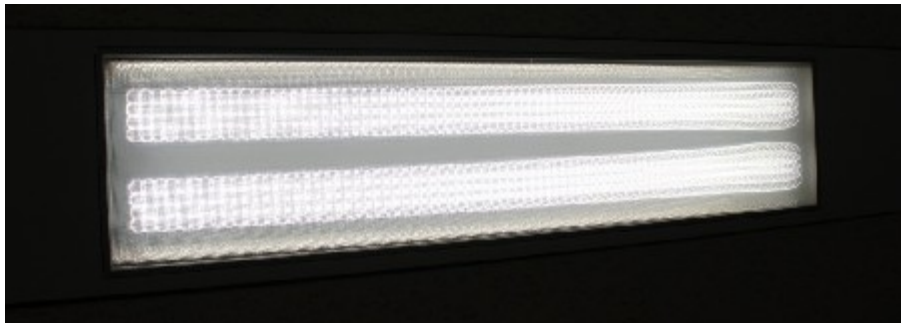
Finished now

- Measurement of the conventional and LED illumination in the test rooms
- Interviews and question round with the teachers and school children (10th class)
- Selection of the best LED-luminare 79.9 lm/W
- Illumination design (Dialux) for the whole school

Textmasterformate durch Klicken bea
Zweite Ebene
Dritte Ebene
Vierte Ebene
Fünfte Ebene

- **In work**: replace[illegible] LED-luminares

- **In plan**: final int[illegible] LED-luminares



4. Selected Results

Trier – School Illumination

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Dimensions of sample room:

64 m2

LED-Luminaires compared with FTL-Luminaires:

Requirements according DIN EN 12464-1:

Em: ≥ 300

Maintenancefactor: 0,8

g1: ≥ 0,6

CRI: ≥ 80

UGR: ≤ 19

Measurement 21.01.2011 (not maintained)

Luminaire	Fluorescent Tube Lamps	Fluorescent Tube Lamps
Average Illuminance E_m (lx)	✓ 377,75	
Uniformity $g_1 = E_{min}/E_m$	✗ 0,20	
Uniformity $g_2 = E_{min}/E_{max}$	0,13	
CCT (K)	3783,00	
CRI	✗ 70,00	
Glare UGR	---	
el. Power (W)	1280,00	
Specific Value (W/(m²*100lx))	5,29	

Measurement 15.04.2011 (LED-Luminaires und FTL after Maintenance)

Luminaire	LED Luminaires	Fluorescent Tube Lamps
Average Illuminance E_m (lx)	738,00	858,28
--- minus Maintenance Factor	✓ 553,50	✓ 686,62
Uniformity $g_1 = E_{min}/E_m$	✓ 0,67	✓ 0,72
Uniformity $g_2 = E_{min}/E_{max}$	0,55	0,56
CCT (K)	3703,00	3556,00
CRI	✗ 77,43	✓ 81,39
Glare UGR	✓ 15,86	✓ 17,22
el. Power (W)	825,00	1900,00
Specific Value (W/(m²*100lx))	1,75	3,46

Trier – Stand

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Evaluation of the „winner“-luminare

1: very good, 2: good, 3: acceptable, 4: not acceptable, 5: very bad

	Conventional light	After the LED installation
HS Raum 22	2,8 **T8-Lamp**	1,3 **LED**
RS Raum 30 **Control room**	3,1 **T8-Lamp**	2,6 **T8-Lamp**

Thank you very much for your attention!

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