

Efficient lighting in hospitals to minimize cooling

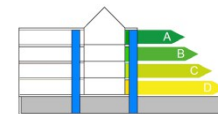
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Oslo University College of Applied Sciences

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**23rd Congress of the
International Federation of Hospital Engineering (IFHE)**

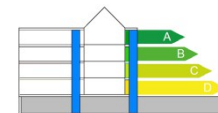
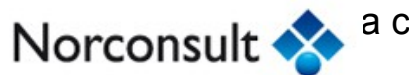




Low Energy Hospitals

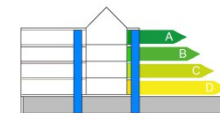
- **Low Energy Hospitals** is an innovation project whose goal is to find and promote feasible design measures which can halve the energy consumption in new hospitals built in Norway
- Led by **Norconsult AS**, Norway's largest multi-disciplinary consulting engineering company, supported by the Norwegian Research Council and matching funds from private sector partners:

- **Helse Sør-Øst** - Norway's largest regional health authority
- **Nordic Office of Architecture** - a leading architecture firm in Norway
- **GK-Norway** - a large supplier of HVAC equipment and services in Scandinavia
- **SAAS** - designs and delivers complete building automation systems
- **Siemens Healthcare** - global supplier of medical equipment
- **Norconsult Information Systems** - IT solutions for hospitals or in Scandinavia



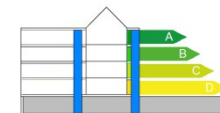
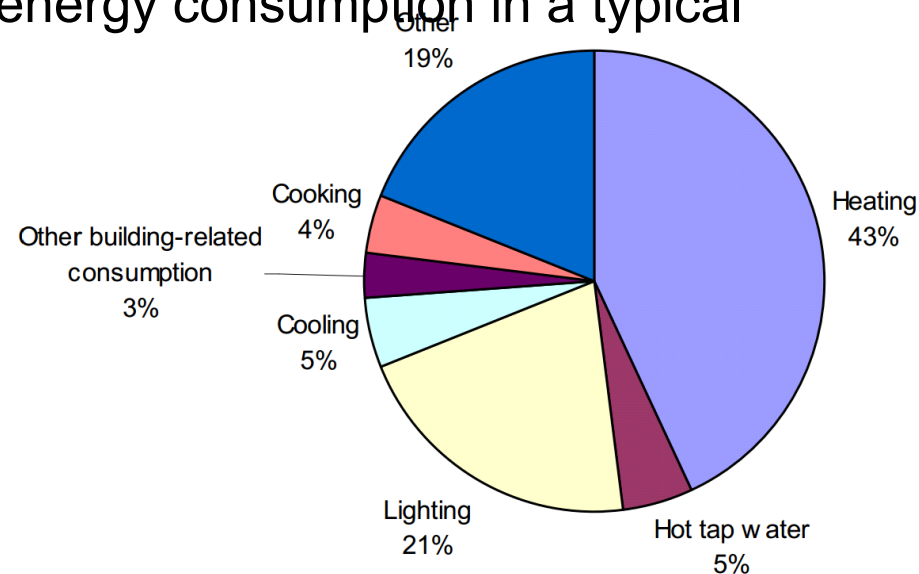
Objectives

- Energy consumption in hospitals in focus
 - Reducing energy consumption with 50% (in total) without compromising health, comfort and staff efficiency
- Energy-efficient lighting in hospitals
 - Examples from different room types and typical areas
- Conclusion - strict control and light where needed
 - new technology, innovative lighting, detectors, impact on cooling 4



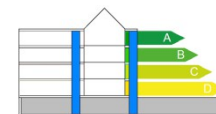
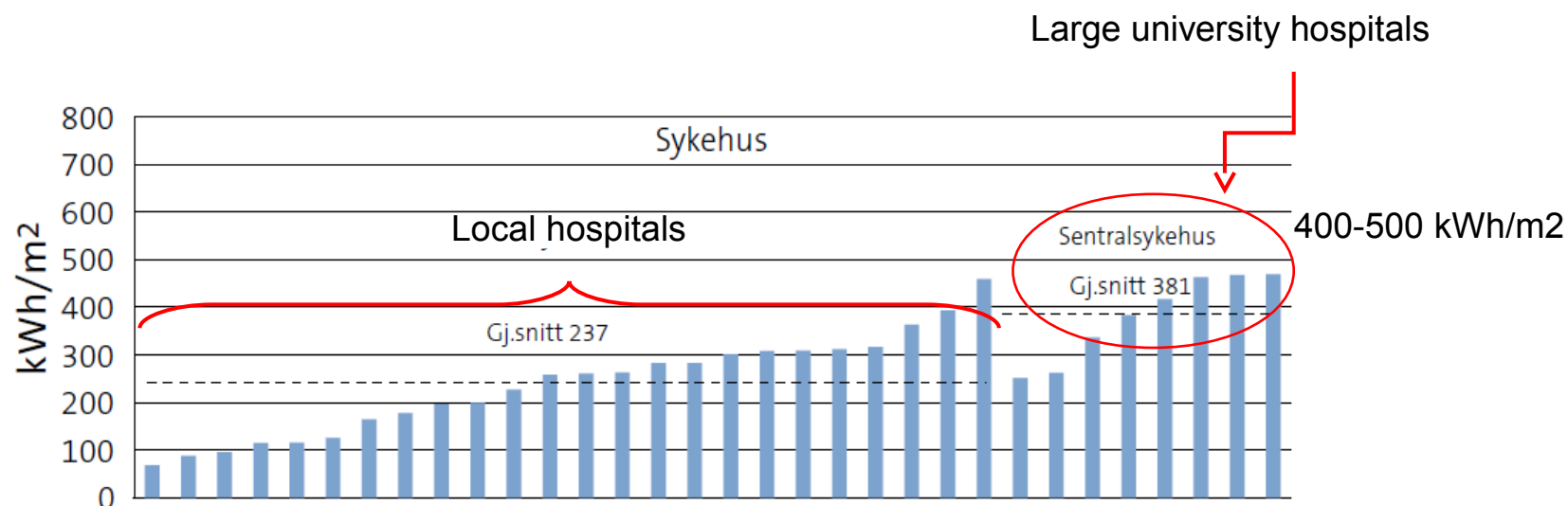
Focus on Hospital Energy Consumption

- Healthcare buildings represents 10% of the total heated area of commercial buildings in Norway
- Hospitals are the building category with the highest specific energy consumption
- The figure shows a breakdown of energy consumption in a typical large hospital
- Lighting represents 21% of the energy flow



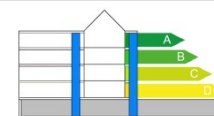
Focus on Hospital Energy Consumption

- Specific energy consumption for hospitals pr year

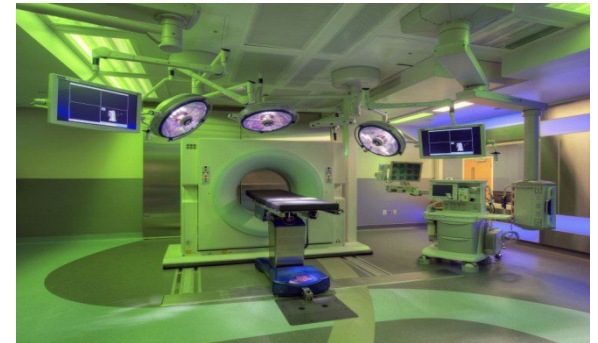
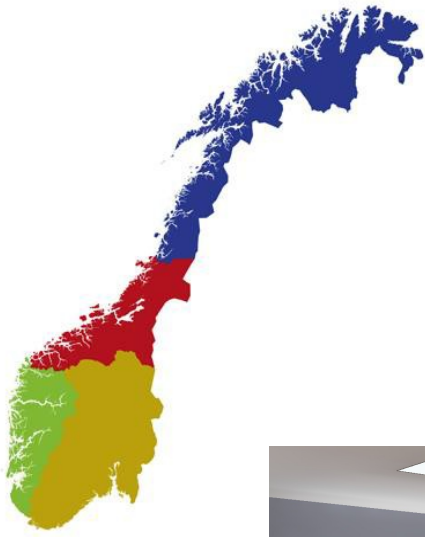


Requirement of technical regulations and energy label

Building Category	Total net energy - maximum values (kWh/m2 heated BRA per year)					
	TEK-10	TEK-07	Diff Tek10- Tek07	Energy label A	Energy label B	Energy label C
Small Houses, holiday homes of 150 m ²	120+1600m ² oppv.BRA	125+1600m ² oppv.BRA	-5	79	118	158
Apartment building	115	120	-5	67	100	134
Children's garden	140	150	-10	90	135	180
Office building	150	165	-15	84	126	168
school building	120	135	-15	79	118	158
University / College	160	180	-20	95	143	191
Hospital	300(335)	325	-25	179	268	358
Nursing homes	215(250)	235	-20	136	203	271
Hotels	220	240	-20	135	202	269
Sports building	170	185	-15	109	164	218
Business Buildings	210	235	-25	129	194	258
Culture Building	165	180	-15	105	158	210
Light industrial / garage	175(190)	185	-10	106	159	212
						tilsv. TEK07?



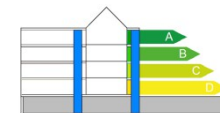
The Research project



Healthcare - energy consumption

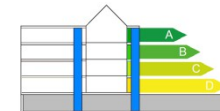
- Hospital building category with the largest specific energy consumption
- The energy consumption is spread on the following categories

		kWh/year	kWh/m2	%
Electrical power	Ventilation Fans	632 667	40	9,6 %
	Light	1 470 095	92	22,3 %
	Equipment	1 483 725	93	22,5 %
Thermal cooling	Ventilation cooling	167 453	10	2,5 %
	Room cooling	566 822	35	8,6 %
Thermal heating	Ventilation heating	1 828 830	114	27,7 %
	Room heating	443 297	28	6,7 %
	Sum	6 592 889	412	100,0 %



Planning the light

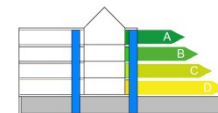
- Needs and demands
- Identify the function in different areas
- Identify the behavior from the employees and staff
- Identify the different operations
- Areas for patients, and which patients
- Areas for visitors
- Areas for examination



Lighting systems

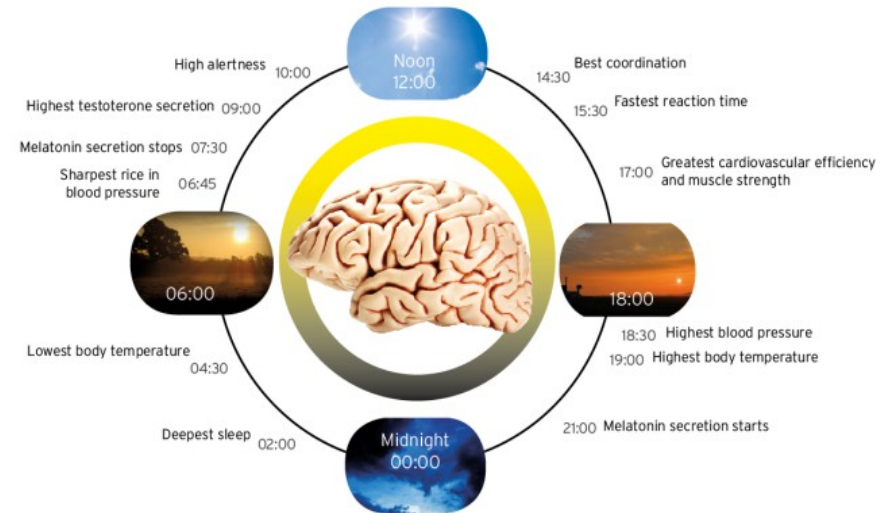
In this project we describe lighting systems for the following hospital areas/rooms:

- Patient room
- Operation room
- Corridor
- Examination room
- Laboratory
- Wardrobe
- Toilets/bathrooms



Planning criterias

- Quality parameters
- Energy efficient technologies
- Daylight
- Control
- LCC



Life cycles calculations - LCC

Luminaire solution cost comparison

General information

Existing solution (reference solution for pay-off calculation)

Number of luminaire types

Luminaire types

Total number of luminaires

Total number of light sources

Investment cost

Total luminaire cost (incl. light source)

Total light source cost

Total installation cost

Total material and labour cost

Total investment cost

Energy cost

Total installed wattage

Average usage factor

Total usage wattage

Average operating hours

Total energy consumption (excl. parasitic power)/year

Total parasitic wattage

Average time for parasitic power

Parasitic energy consumption

Total luminaire energy consumption

Cooling system usage factor

Cooling efficiency

Cooling energy consumption

Total energy consumption/year

Energy price

Total energy cost/year

Total present energy cost

Light source cost

Total number of light sources

Total light source replacement cost

Total present light source cost

Maintenance cost

Total maintenance cost

Total present maintenance cost

**Total luminaire solution cost
LENI**

Traditional lighting

No solution is existing

2

1 - M T5

1 - Pendel T5

2

6

400 EUR

0 EUR

0 EUR

0 EUR

400 EUR

136 W

80,0 %

108,8 W

5 824 h/year

633,6512 kWh/year

11,0 W

2 936 h/year

32,3 kWh/year

665,9472 kWh/year

50,0 %

2,5

133,189 kWh

799,1 kWh

0,1 EUR/kWh

80 EUR

1 228 EUR

6

180 EUR

783 EUR

0 EUR

0 EUR

2 411 EUR

~55,1 kWh/m², year

Innovative lighting

2

1 - L Pendel LED

1 - M LED

2

2

700 EUR

0 EUR

0 EUR

0 EUR

700 EUR

107 W

45,0 %

48,2 W

5 824 h/year

280,4256 kWh/year

1,0 W

2 936 h/year

2,9 kWh/year

283,3616 kWh/year

56,672 kWh

340,0 kWh

34 EUR

522 EUR

2

0 EUR

0 EUR

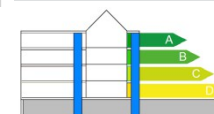
0 EUR

0 EUR

1 222 EUR

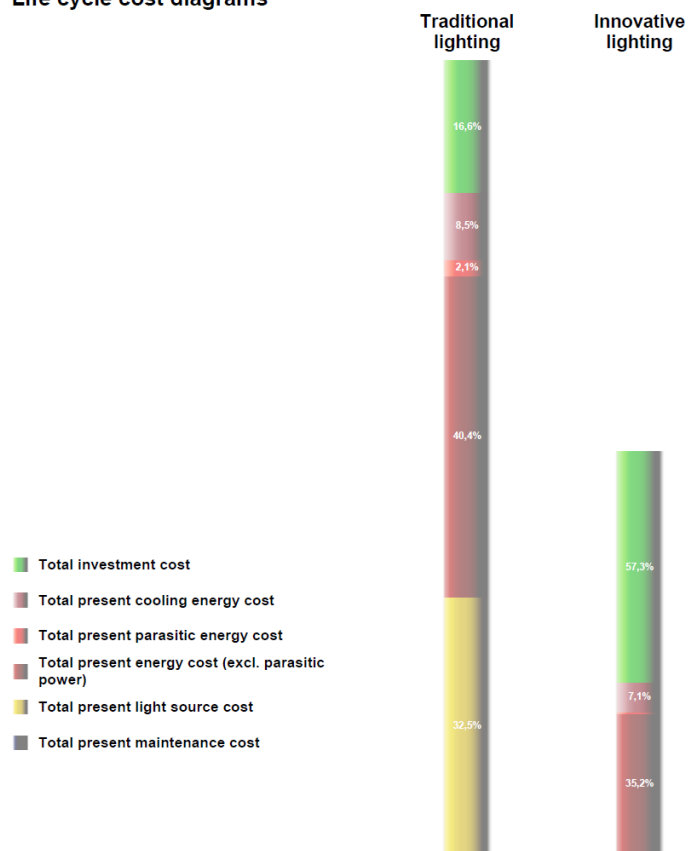
~23,4 kWh/m², year

Example from typical
examination room

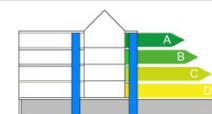
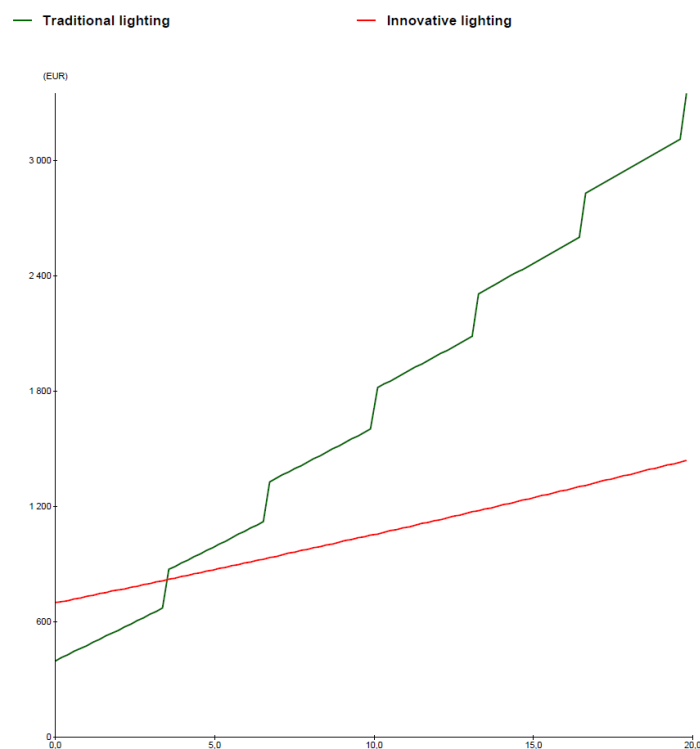


Livssyklusberegninger - LCC

Life cycle cost diagrams



Cost growth comparison



Recommendations and guidelines

- The lighting requirements in the different areas/rooms will depend of the function and operation in the room
- Install dimmers and achieve different sequences of the light
- A best practise design methodology is:
think of where exactly the light is needed, when it is needed,
and try to exploit daylighting where possible.

Solutions and results from different areas

- By using new technology for lighting systems, and thinking of new solutions as only plan and install lighting where and when needed regarding to operation, we are able to reduce the cooling energy as well.
- It is important that when planning the technical solutions, both for lighting and others, to take the human factors in considerations, and making good installations without making effort to comfort, health and well-being.



The dynamic "Light Wheel"

Patient room

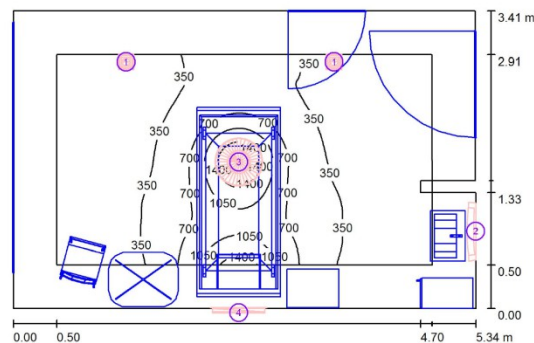
- patient room in a bed ward
 - avoid glare from light fixtures
 - different needs during the day
 - examining requires 1000 lx
 - dynamic illumination
 - color temperature, control
 - different lighting scenes



Patient room

Traditional lighting

Sengerom LED / Sammenfatning



Takhøyde: 2.700 m, Vedlikeholdsfaktor: 0.80

Verdier i Lux, Målestokk 1:44

Flate	ρ [%]	E_m [lx]	E_{min} [lx]	E_{max} [lx]	E_{min} / E_m
Arbeidsplan	/	443	127	1698	0.287
Gulv	20	183	22	469	0.121
Tak	70	123	54	1277	0.444
Vegger (5)	50	134	12	5007	/

Arbeidsplan:

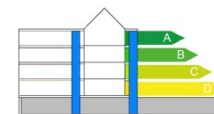
Høyde: 0.850 m
Målepunkter: 128 x 128 Punkter
Yttergrense: 0.500 m

Lysstyrkeforhold (etter LG7): Vegger / arbeidsplan: -, Tak / arbeidsplan: -.

Armatur-stykkliste

Nr.	Antall	Betegnelse (Korreksjonsfaktor)	Φ (Armatur) [lm]	Φ (Lamper) [lm]	P [W]
1	2	ERCO 36800000 Quintessence Lens wallwasher 1xLED 22W red green blue warm white (1.000)	862	1430	26.0
2	1	FAGERHULT 17882 Aqua 1xT16 14 W (1.000)	760	1200	16.0
3	1	FAGERHULT 56781-402 Eira 550 3000K 1xLED 56781 69 W (1.000)	5515	5520	69.0
4	1	FAGERHULT 74602-402 Aluflex 600 integrert 4K 1xLED 74602 40 W (1.000)	2701	2700	40.0
Samlet:			10700	12280	177.0

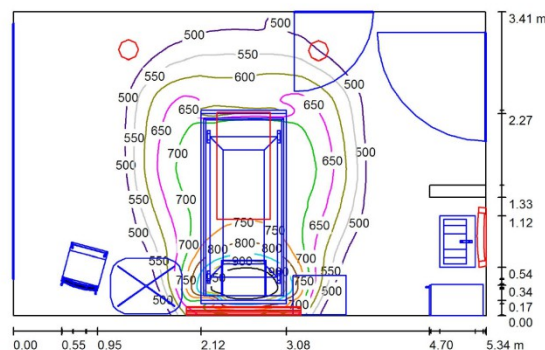
Spesifikk tilkoblet effekt: $9.73 \text{ W/m}^2 = 2.20 \text{ W/m}^2 / 100 \text{ lx}$ (Grunnflate: 18.19 m^2)



Patient room

Innovative lighting

Sengerom Tradisjonel / Sammenfatning



Takhøyde: 2.700 m, Vedlikeholdsfaktor: 0.80

Verdier i Lux, Målestokk 1:44

Flate	ρ [%]	E_m [lx]	E_{min} [lx]	E_{max} [lx]	E_{min} / E_m
Arbeidsplan	/	444	66	1046	0.149
Gulv	20	263	30	465	0.116
Tak	70	148	65	604	0.439
Vegger (5)	50	168	16	1081	/

Arbeidsplan:

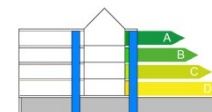
Høyde: 0.750 m
Målepunkter: 128 x 128 Punkter
Ytergrense: 0.000 m

Lysstyrkeforhold (etter LG7): Vegger / arbeidsplan: -, Tak / arbeidsplan: -.

Armatur-stykkliste

Nr.	Antall	Betegnelse (Korreksjonsfaktor)	Φ (Armatur) [lm]	Φ (Lamper) [lm]	P [W]
1	1	FAGERHULT 17882 Aqua 1xT16 14 W (1.000)	760	1200	16.0
2	1	Fagerhult 24907+Ipri Indigo Combo Beta 2-celle 2xT5 54 W (1.000)	7236	8900	114.0
3	2	FAGERHULT 26838 Notor G2 Tak Opal 1xT16 28 W (1.000)	1714	2600	30.0
4	2	FAGERHULT 77546 Pleiad Compact Wallwasher G2 205 1xTC-DEL 26 W (1.000)	1145	1800	27.0
Samlet:			13714	18900	244.0

Spesifikk tilkoblet effekt: $13.41 \text{ W/m}^2 = 3.02 \text{ W/m}^2/100 \text{ lx}$ (Grunnflate: 18.19 m^2)



Patient room

Luminaire solution cost comparison

General information

Existing solution (reference solution for pay-off calculation)

Number of luminaire types

Luminaire types

Total number of luminaires

Total number of light sources

Investment cost

Total luminaire cost (incl. light source)

Total light source cost

Total installation cost

Total material and labour cost

Total investment cost

Energy cost

Total installed wattage

Average usage factor

Total usage wattage

Average operating hours

Total energy consumption (excl. parasitic power)/year

Total parasitic wattage

Average time for parasitic power

Parasitic energy consumption

Total luminaire energy consumption

Cooling system usage factor

Cooling efficiency

Cooling energy consumption

Total energy consumption/year

Energy price

Total energy cost/year

Total present energy cost

Light source cost

Total number of light sources

Total light source replacement cost

Total present light source cost

Maintenance cost

Total maintenance cost

Total present maintenance cost

Total luminaire solution cost

LENI

Traditional lighting

No solution is existing

4

1 - M

2 - N

2 - P

1 - Aq

6

7

1 300 EUR

0 EUR

0 EUR

0 EUR

1 300 EUR

244 W

90,0 %

219,6 W

5 824 h/year

1,2789504 MWh/year

13,0 W

2 936 h/year

38,2 kWh/year

1,3171184 MWh/year

50,0 %

2,5

263,424 kWh

1,6 MWh

0,1 EUR/kWh

158 EUR

2 428 EUR

7

210 EUR

1 015 EUR

0 EUR

0 EUR

4 743 EUR

~72,4 kWh/m², year

Innovative lighting

No solution is existing

4

1 - E

1 - A

2 - Q

1 - Aq

5

5

2 400 EUR

0 EUR

0 EUR

0 EUR

2 400 EUR

177 W

60,0 %

106,2 W

5 824 h/year

618,5088 kWh/year

4,0 W

2 936 h/year

11,7 kWh/year

630,2528 kWh/year

50,0 %

2,5

126,051 kWh

756,3 kWh

0,1 EUR/kWh

76 EUR

1 162 EUR

5

40 EUR

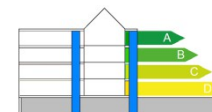
174 EUR

0 EUR

0 EUR

3 736 EUR

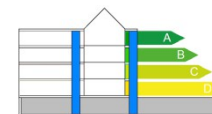
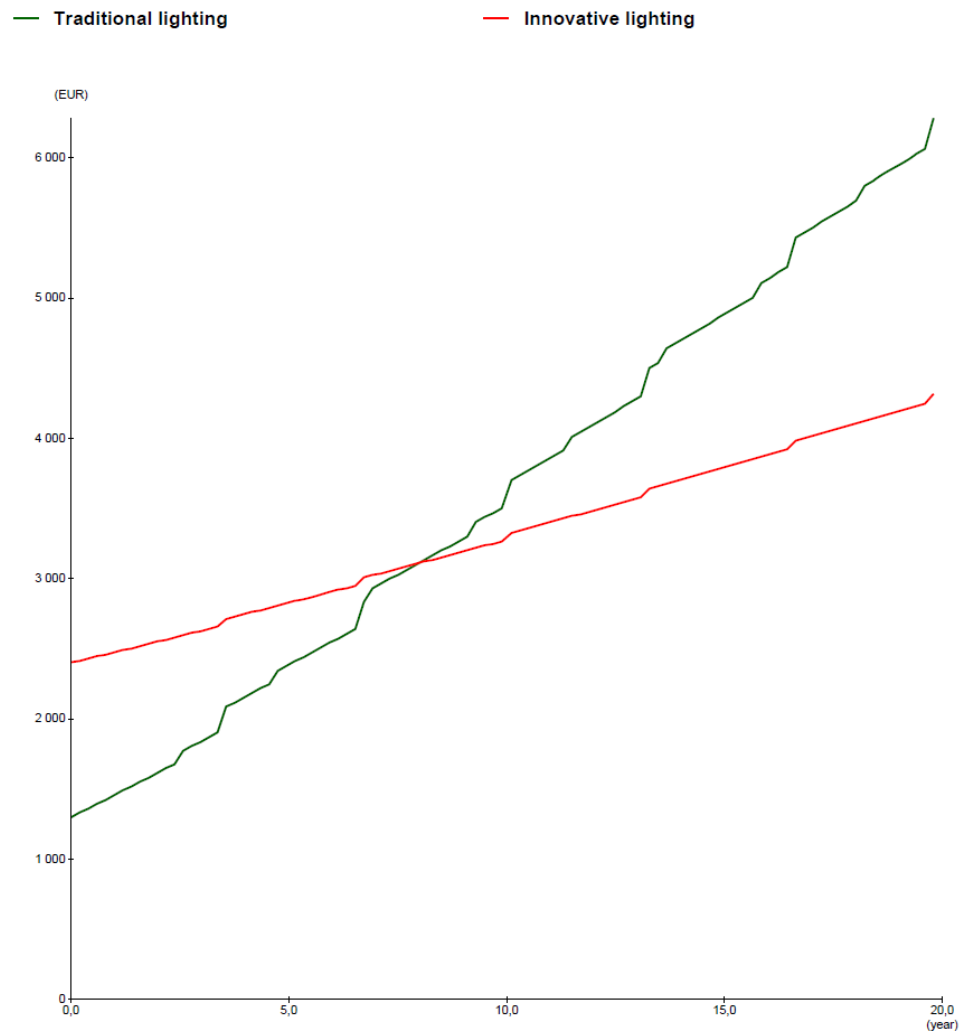
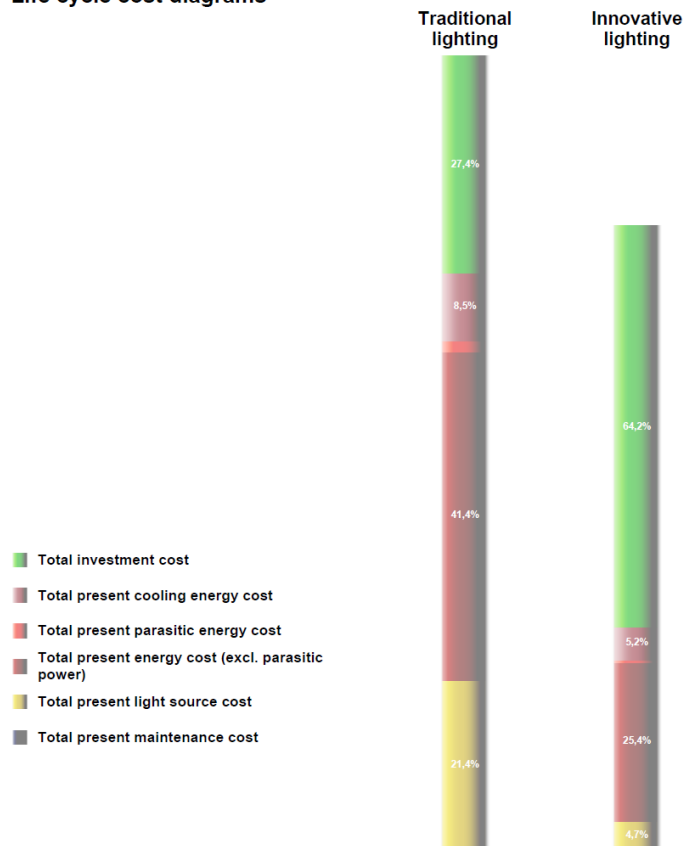
~34,6 kWh/m², year



Patient room

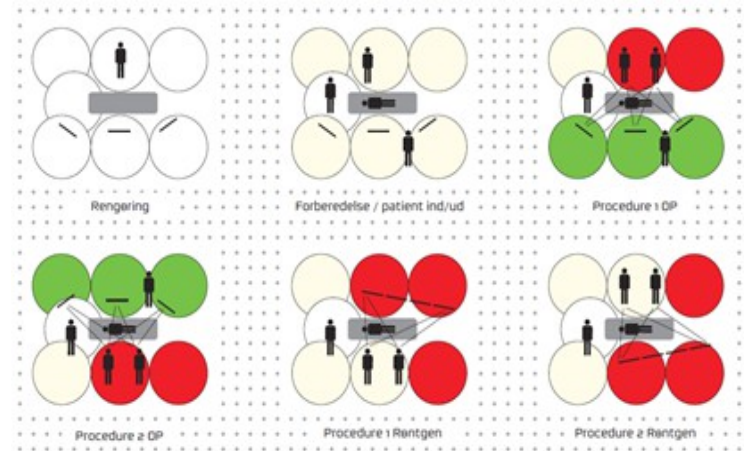
Cost growth comparison

Life cycle cost diagrams



Operating room

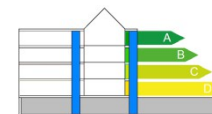
- operating, x-rays and monitors
- no glare
- no daylight during operation procedures
- task lighting for operation (40000-160000 lx)
- ergonomic lighting, light color
- color temperature, control
- different lighting scenes



Operating room

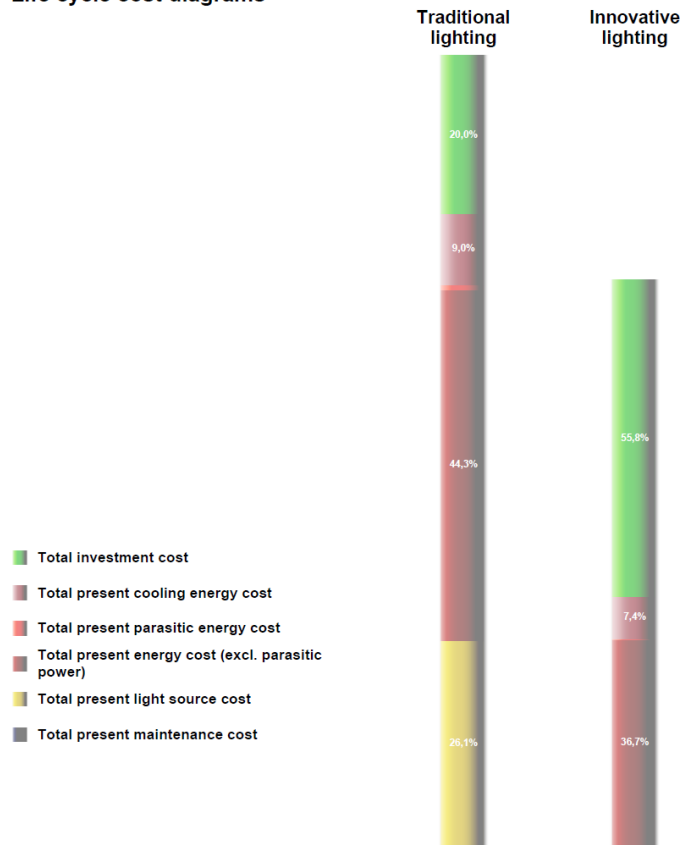
Luminaire solution cost comparison

General information		Traditional lighting	Innovative lighting
Existing solution (reference solution for pay-off calculation)		No solution is existing	
Number of luminaire types		1	1
Luminaire type		9 - M T5	12 - M LED
Light source type		FDH (T16) 4x24W	LED 49W
Total number of luminaires		9	12
Total number of light sources		36	12
Investment cost			
Total luminaire cost (incl. light source)		3 600 EUR	7 200 EUR
Total light source cost		0 EUR	0 EUR
Total installation cost		0 EUR	0 EUR
Total material and labour cost		0 EUR	0 EUR
Total investment cost		3 600 EUR	7 200 EUR
Energy cost			
Total installed wattage		891 W	588 W
Average usage factor		100,0 %	90,0 %
Total usage wattage		891,0 W	529,2 W
Average operating hours		5 824 h/year	5 824 h/year
Total energy consumption (excl. parasitic power)/year		5,189184 MWh/year	3,0820608 MWh/year
Total parasitic wattage		27,0 W	6,0 W
Average time for parasitic power		2 936 h/year	2 936 h/year
Parasitic energy consumption		79,3 kWh/year	17,6 kWh/year
Total luminaire energy consumption		5,268456 MWh/year	3,0996768 MWh/year
Cooling system usage factor	50,0 %		
Cooling efficiency	2,5		
Cooling energy consumption		1,054 MWh	619,935 kWh
Total energy consumption/year		6,3 MWh	3,7 MWh
Energy price	0,1 EUR/kWh		
Total energy cost/year		632 EUR	372 EUR
Total present energy cost		9 712 EUR	5 714 EUR
Light source cost			
Light source name		FDH (T16) 4x24W	LED 49W
Total number of light sources		36	12
Total light source replacement cost		1 080 EUR	0 EUR
Total present light source cost		4 701 EUR	0 EUR
Maintenance cost			
Total maintenance cost		0 EUR	0 EUR
Total present maintenance cost		0 EUR	0 EUR
Total luminaire solution cost		18 013 EUR	12 914 EUR
LENI		~116,5 kWh/m ² , year	~68,6 kWh/m ² , year

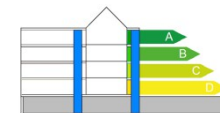
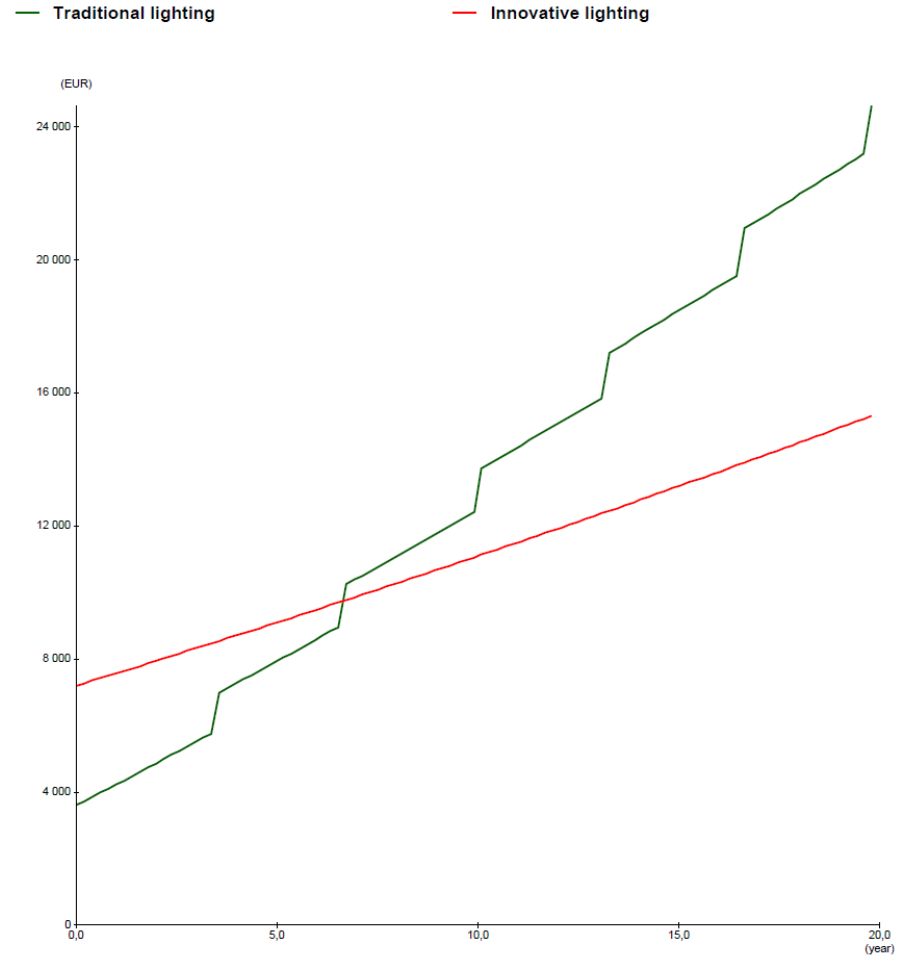


Operating room

Life cycle cost diagrams



Cost growth comparison



Conclusion

The “Low energy hospitals” research project energy simulations confirmed the high energy reduction potential for best-practise lighting systems in patient rooms, polyclinics, office areas, corridors, examination rooms regarding to lighting and cooling. In some hospital areas the simulations showed more than 50% reduction between use of traditional lighting and innovative lighting.

The LCC calculations benefitted from energy reductions for both lighting and cooling.

