Human Centric Lighting

Quantified benefits of Human Centric Lighting

Final Results
Frankfurt, April 2015

ATKearney

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For the first time, the quantified benefits of Human Centric Lighting have been estimated…

Executive summary

- Human Centric Lighting is the inclusion of visual and non-visual (biological) needs of humans in the design of lighting applications.
- Our project aimed at delivering arguments for the use of human centric lighting from a customer perspective and simulated segment-specific economic benefits on micro and macro level
- On the micro level (perspective of individual investors, e.g. facility owners):
  - Most significant quantified benefits are realized in industrial segments due to the dominant impact of productivity increases
  - Medical and elderly care segments show less attractive quantified benefits, as most savings cannot be realized by the investor, but by other stakeholders, e.g. insurance companies
- On the macro level (perspective of the general public, e.g. health insurances):
  - Macro level simulations yield Human Centric Lighting effects for Europe in 2020 of up to € 0.87 bn assuming a realistic market penetration[1] and € 12.8 bn if the 2020 lighting market was fully penetrated by Human Centric Lighting
  - In most segments, benefits for owners and investors dominate
  - However, additional social and public benefits can also justify Human Centric Lighting markups

… and requires more studies to convert several estimated benefits into scientifically confirmed benefits

1. As estimated in the market study “Human Centric Lighting: Going beyond energy efficiency” by ZVEI, Lighting Europe and A.T. Kearney
Source: A.T. Kearney

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Content

- Introduction and overview
- Quantified benefits of Human Centric Lighting
  - Micro level benefits
  - Macro level benefits

Introduction and overview

Non-visual (biological) effects of human centric lighting can be clustered along three groups

Non-visual (biological) effects

	Effect	Definition	Examples
Feelings	Mood	Emotional state describing positive or negative disposition that is influenced by personality traits, sleep, (social) context and behavior	Affective state, prevented depression, prevented anxiety
	Energize	Bringing the body and mind into a state of general wakefulness and readiness for activities	Raised level of activation, vitality
	Relaxation	The emotional state of low tension and low emotional pressure, while feeling at ease	Reduced level of activation, reduced stress
Functioning	Alertness	The state of active attention by high sensory awareness	Increased concentration, vigilance, accident & error prevention
	Cognitive performance	Mental performance, that include working memory, producing and comprehending language, learning, reasoning, problem solving, complex reaction, decision making	Improved memory, learning, creativity, motivation
Health	Sleep-wake-cycle	A stable 24 hour rhythm of rest and activity, controlled by the biological clock of an individual, is essential for optimized functioning during daytime and a good and recovering sleep at night. Thus it supports a robust health.	Disease/disorder prevention, treatment and alleviation (a.o. dementia, SAD, ADHD, schizophrenia, sleep disturbances), social jetlag, chronomedication, better healing environments

1. ADHD: Attention Deficit Hyperactivity Disorder, SAD: Seasonal Affective Disorder, DSPD: Delayed Sleep-Phase Disorder
Source: WG Light for Life, A.T. Kearney

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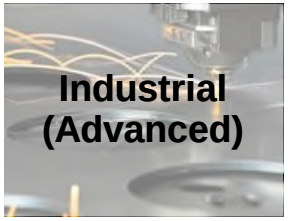
We differentiated seven indoor segments for further analysis

Relevant application segments for human centric lighting

- Repetitive, manual work, e.g. piecework with little to no automation
- Focus on day shifts



- Advanced manual work with little to some automation, e.g. tool making
- Focus on day shifts

- Desk work in dedicated office areas/buildings
- Excluding home offices

- Classrooms in primary (6-12 yrs) and high schools (12-18 yrs)
- Focus on students (and teachers)

- Hospitals, in particular corridors, recreation and ward rooms
- Focus on patients (and medical staff)

- Care homes for elderlies with and without physical constraints
- Focus on elderlies (and staff)

- Both own and rented flats and houses
- All income segments
- Including home offices

Source: ELC, A.T. Kearney, Thinkstock

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We simulated segment-specific economic benefits on micro and macro level

Model overview

Input parameters

- Non-visual (biological) benefits
  - Energize
  - Alertness
  - Cognitive performance
  - Circadian stability
  - Sleep quality
  - Mood
  - Relaxation
- Other, e.g.
  - Labor costs
  - Typical error rates
  - Investment needs

Calculation model

Micro model

- Covering the perspective of individual investors, e.g. facility owners
- Based on use cases with exemplary quantities

Macro model[1]

- Covering the perspective of the general public, e.g. health insurances
- Extrapolated to 2020 market size based on previous market study

Segment profiles

- Use case description
- Key selling arguments incl. main drivers (e.g. error rates, productivity)
- Micro level benefits
- Macro level benefits
- Key assumptions

1. Scope of the macro model is Europe. It shows the benefits of new and renovated lighting installations in 2020 (1) at a realistic penetration rate and (2) at 100% penetration rate, if all new and renovated European lighting installations in 2020 would use Human Centric Lighting

Source: WG Light for Life, Lighting Europe & ZVEI (2013) Human Centric Lighting: Going Beyond Energy Efficiency, A.T. Kearney

Quantified benefits of Human Centric Lighting

- **Micro level benefits**
- Macro level benefits

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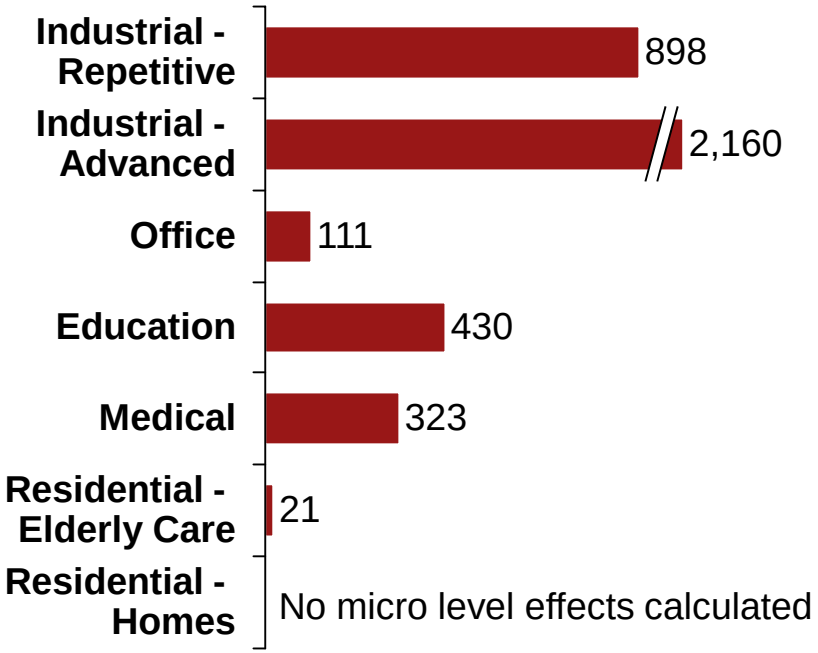
On the micro level, most significant effects from Human Centric Lighting are realized in industrial segments

Micro level benefits of Human Centric Lighting

Highly sensitive to assumptions[1]



# of people in use case	Annual benefits/ annual electricity costs
750 workers	16.6
1,000 workers	40
200 office employees	12.3
1,000 students, 80 teachers	4
1,000 beds, 1,500 employees	1.9
100 beds, 63 employees	3
N/A	N/A

Macro level effects of Human Centric Lighting require further justification from scientific long-term studies to confirm the benefits

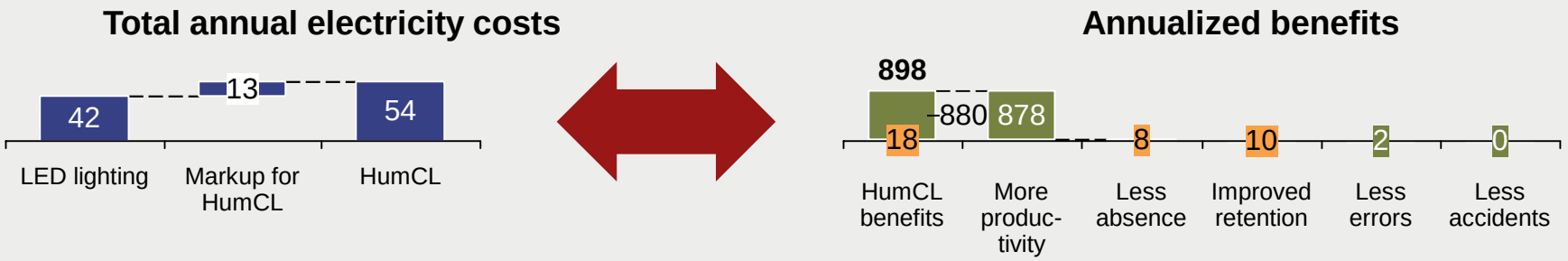
1. Benefits highly sensitive to underlying assumptions, some of them needing further research
Source: A.T. Kearney simulation model incl. detailed source references

For repetitive tasks in industrial settings, effects from Human Centric Lighting are dominated by productivity increases

Industrial (Repetitive) – Micro level effect

Highly sensitive to assumptions[1]

Quantified Human Centric Lighting benefits (annualized, in €k)



Description of use case and key assumptions

- Factory with 750 workers executing highly repetitive tasks such as assembling electronic products
- To have an effect in the industrial setting a 2000 lux setup is considered for Human Centric Lighting
- 1 operation per minute, contributing € 0.91 revenue each with a contribution margin of 30%
- Average error rate of 1%
- Labor cost per worker per month: € 2685

Reasoning for benefits

- More productivity (4.5% vs. LED lighting), less errors (1%) and less accidents (1%) due to increased alertness and energizing effect
- 1% less sick days and 1 year improved retention due to higher physical robustness (mid- to long-term effect)

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

1. Benefits highly sensitive to underlying assumptions, some of them needing further research

Source: A.T. Kearney simulation model incl. detailed source references

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For advanced manual tasks, effects from Human Centric Lighting are very attractive due to high revenue contribution

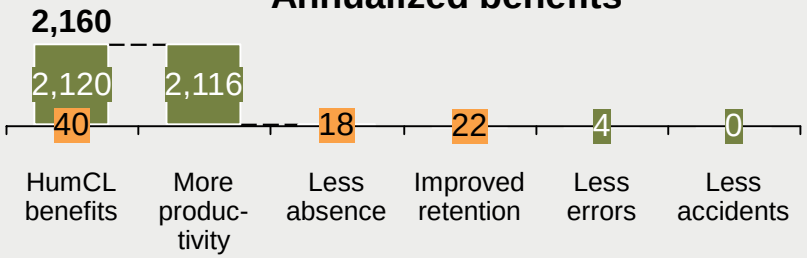
Industrial (Advanced) – Micro level effect

Highly sensitive to assumptions[1]

Quantified Human Centric Lighting benefits (annualized, in €k)

Total annual electricity costs

Annualized benefits



Description of use case and key assumptions

- Factory with 1000 workers executing repetitive, but advanced tasks, such as metal machining
- To have an effect in the industrial setting a 2000 lux setup is considered for Human Centric Lighting
- 0.5 operations per minute, contributing € 2.56 revenue each with a contribution margin of 35%
- Average error rate of 2%
- Labor cost per worker per month: € 2,954

Reasoning for benefits

- More productivity (4.5% vs. LED lighting), less errors (2%) and less accidents (2%) due to increased alertness and energizing effect
- 1% less sick days and 1 year improved retention due to higher physical robustness (mid- to long-term effect)

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

1. Benefits highly sensitive to underlying assumptions, some of them needing further research
Source: A.T. Kearney simulation model incl. detailed source references

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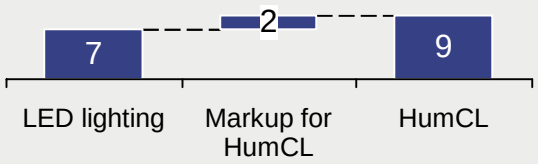
In the office segment, increased productivity can result in significant labor cost savings

Office – Micro level effect

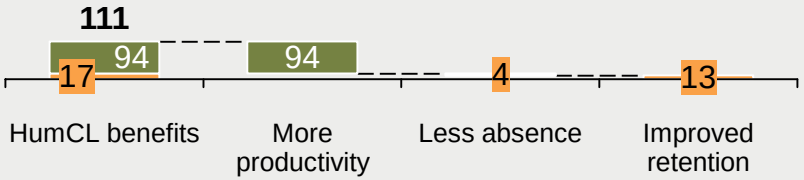
Highly sensitive to assumptions[1]

Quantified Human Centric Lighting benefits (annualized, in €k)

Total annual electricity costs



Annualized benefits



Description of use case and key assumptions

- Office with 200 employees executing desk work, such as accounting department of a manufacturing firm
- 3600 m² office space, 2600 m² relevant for Human Centric Lighting
- € 4000 monthly labor costs per employee
- Initial productivity of 85%
- 11.7 average sick days per employee per year
- Recruitment costs per employee in % of labor costs: 10%
- # of days to reach full productivity for a new employee: 60

Reasoning for benefits

- + 1.15% productivity due to increased alertness and energizing effect (~ extra output worth 2 hours per month) → some research even justifying productivity increases of up to 19%
- - 1% sick days due to better well-being
- + 1 year duration of employees staying

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

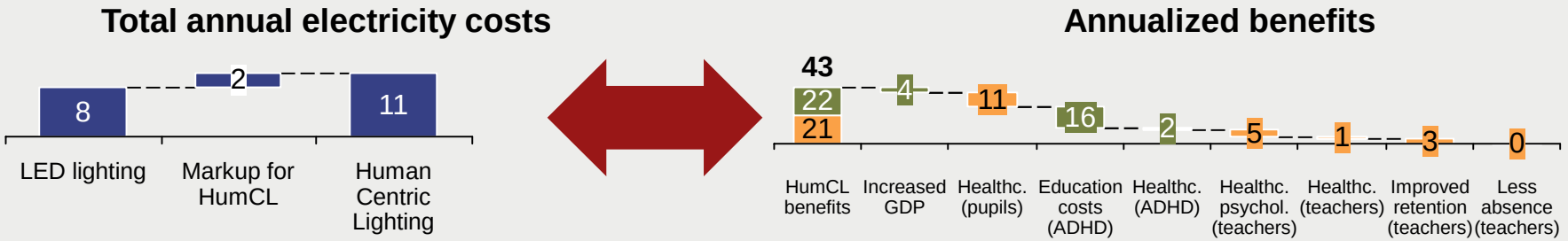
1. Benefits highly sensitive to underlying assumptions, some of them needing further research
Source: A.T. Kearney simulation model incl. detailed source references

In the educational segment, public cost savings for ADHD and healthcare of normal students are the main benefits

Education – Micro level effect

Highly sensitive to assumptions[1]

Quantified Human Centric Lighting benefits (annualized, in €k)



Description of use case and key assumptions

- School with 1000 students and 80 teachers
- € 2780 average monthly labor cost per teacher
- 5.3% of pupils suffering of ADHD, thereof only 50% treated medically
- 11.7 sick days per teacher, thereof 25% due to mental disorders (stress, burnout, etc.)
- Public extra educational costs per ADHD pupil: € 6,000

Reasoning for benefits

- GDP increase due to 15% improved cognitive performance of affected pupils[2]
- 10% reduced healthcare and education costs due to less ADHD effects
- 18% improved treatment efficacy for mental disorders
- + 2 years duration of employees staying

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

1. Benefits highly sensitive to underlying assumptions, some of them needing further research, 2. Effect broken down to single school from macro model. Too small to be quantified as a share of total European GDP

Source: A.T. Kearney simulation model incl. detailed source references

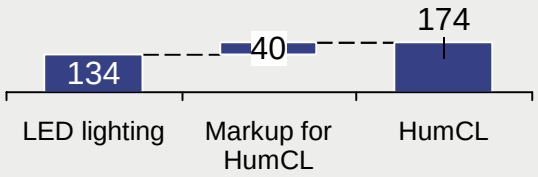
In the medical segment, several effects are expected, but are not well researched yet

Medical – Micro level effect

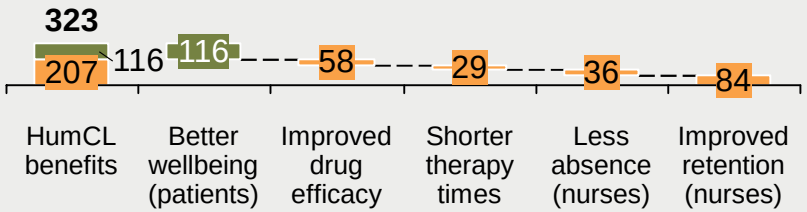
Highly sensitive to assumptions[1]

Quantified Human Centric Lighting benefits (annualized, in €k)

Total annual electricity costs



Annualized benefits



Description of use case and key assumptions

- Hospital with a capacity of 1,000 beds and 1,500 employees
- 100k m² floor space, 48k m² relevant for Human Centric Lighting
- Capacity utilization of 75%
- Average stay of 7 days per patient, i.e. ~39,000 patients per year
- Average diagnostic related flat rate: € 3,000
- Average sick days per employee: 11.7
- Share of medication cost of “diagnostic related flat rate” and of total average health care costs: 20%

Reasoning for benefits

- + 0.1% capacity utilization due to better well-being of patients (higher attractiveness for new patients)
- - 0.25% treatment costs due to reduced treatment times
- - 0.25% medication costs due to higher drug efficacy
- - 1% sick days (nurses) due to better well-being
- + 2 years duration of employees staying

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

1. Benefits highly sensitive to underlying assumptions, some of them needing further research
Source: A.T. Kearney simulation model incl. detailed source references

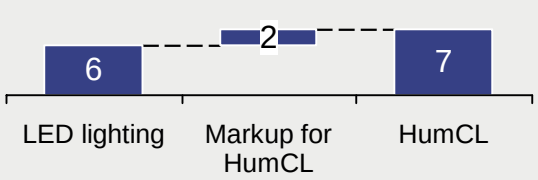
For retirement homes, capacity utilization can significantly improve due to better well-being of residents

Residential (Elderly Care) – Micro level effect

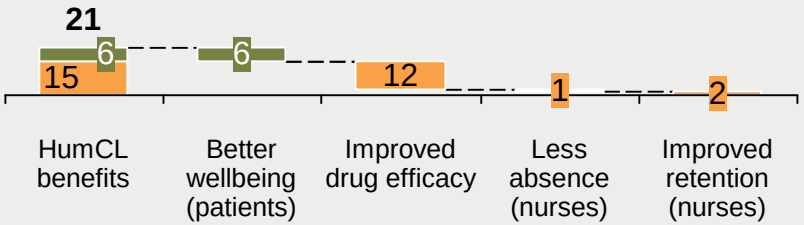
Highly sensitive to assumptions[1]

Quantified Human Centric Lighting benefits (annualized, in €k)

Total annual electricity costs



Annualized benefits



Description of use case and key assumptions

- Retirement home with 100 beds, 90 inhabitants and 63 employees → implies an intensive care setting
- 3,000 m² floor space, 2,010 m² relevant for Human Centric Lighting
- Fee per patient per year: € 30,000
- Capacity utilization of 90%
- Gross contribution margin of 45%
- € 2,568 monthly labor cost per employee
- 0.15 falls per bed per year

Reasoning for benefits

- + 0.5% capacity utilization due to fewer accidents and better well-being of patients (higher attractiveness for new patients)
- Higher effect than in medical care, because patients and their relatives actively chose the care facility
- + 1% capacity utilization due to reduced medication levels (higher attractiveness for new patients)

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

1. Benefits highly sensitive to underlying assumptions, some of them needing further research

Source: A.T. Kearney simulation model incl. detailed source references

Typical consumer expenditures indicate willingness to spend ~200-300 EUR p.a. for healthy lifestyle products

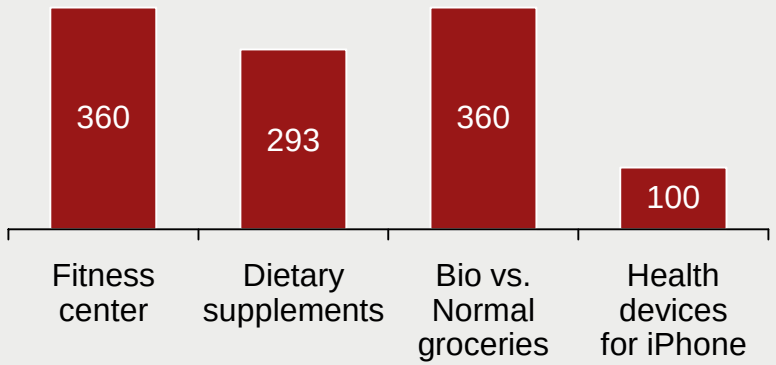
Residential (Homes) – Micro level effect

Highly sensitive to assumptions[1]

Description of use case

- Rented/owned houses/flats with 2.3 inhabitants per household
- 90 m² average floor space per household
- Thereof 67% or 60.3 m² relevant for Human Centric Lighting

"Competing" spend[3] (Annually per person, in €)



Description of use case and key assumptions

- € 275 annual spend for Human Centric Lighting installation incl. electricity costs per person[2]
- €30 monthly spending on gym
- € 0.81 daily spending on dietary supplements like vitamins, fish oil and glucosamine
- 30% mark-up for bio food on a € 100 basket
- € 200 for smartphone gadget, that lasts 2 years

Reasoning for benefits

- Hardly quantifiable economic effects for residential customers (long-term nature, healthcare costs covered by health insurance and/or employers)
- Human Centric Lighting should be regarded as a healthy lifestyle product like sports and healthy nutrition by consumers, but there is a need for consumer education
- Little evidence of residential customers buying lighting solutions based on quantification of economic benefits

1. Benefits highly sensitive to underlying assumptions, some of them needing further research, 2. Based on 10 year product life time, 3. Other consumer expenditures, which are potentially competing with/substituting human centric lighting
Source: A.T. Kearney simulation model incl. detailed source references

Quantified benefits of Human Centric Lighting

- Micro level benefits
- **Macro level benefits**

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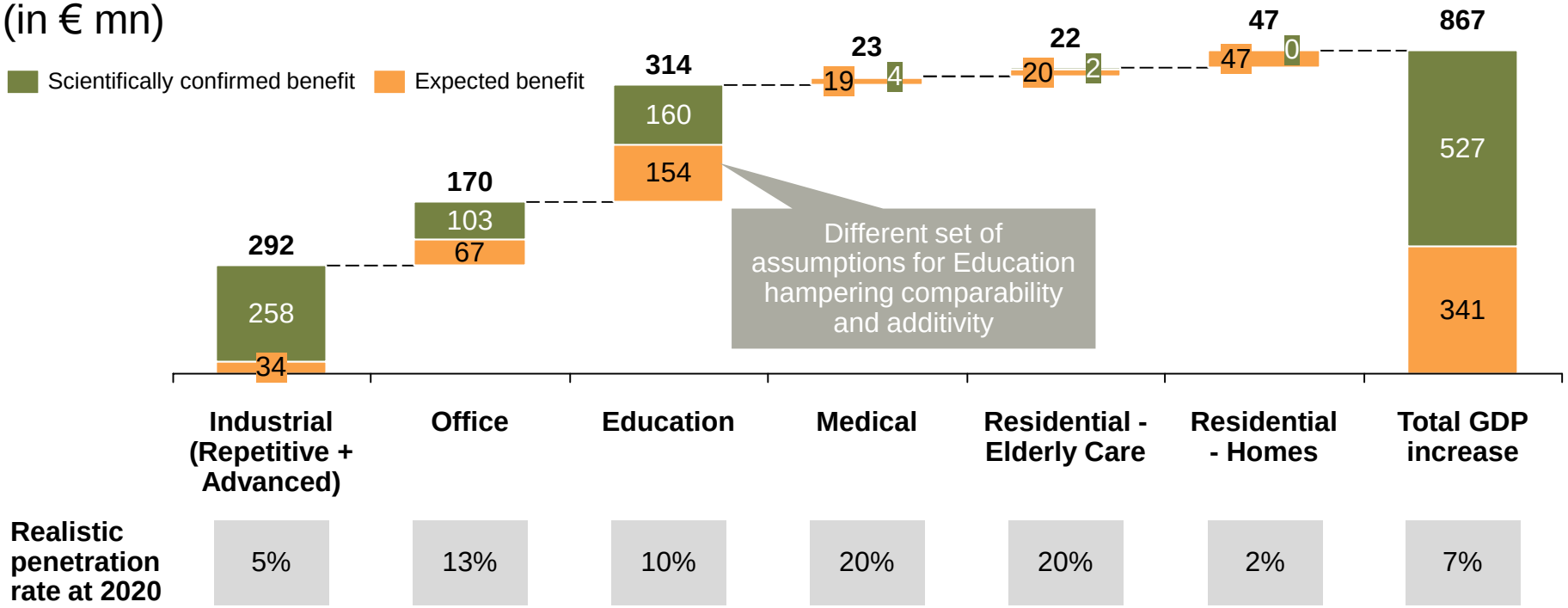
At realistic market penetration macro simulations yield Human Centric Lighting effects up to € 0.87 bn in 2020 in Europe

Macro level effects of Human Centric Lighting in 2020

(in € mn)

Highly sensitive to assumptions[1]



Macro level effects of Human Centric Lighting require further justification from scientific long-term studies to confirm the benefits

1. Benefits are highly sensitive to the underlying assumptions, especially effects of Human Centric Lighting, which mostly needs further research

Source: A.T. Kearney simulation model incl. detailed source references

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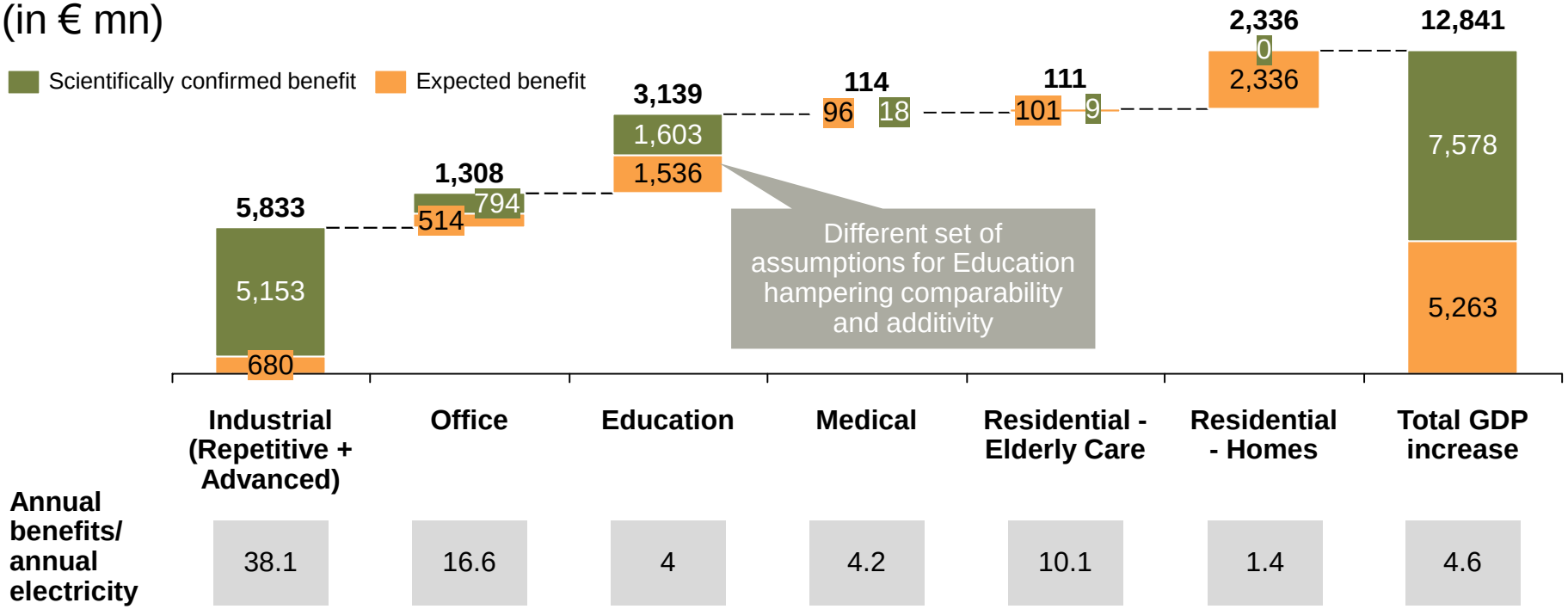
At full market penetration macro simulations yield Human Centric Lighting effects of up to € 12.8 bn in 2020 in Europe

Macro level effects of Human Centric Lighting at 100% market penetration in 2020
(in € mn)

Highly sensitive to assumptions[1]



Macro level effects of Human Centric Lighting require further justification from scientific long-term studies to confirm the benefits

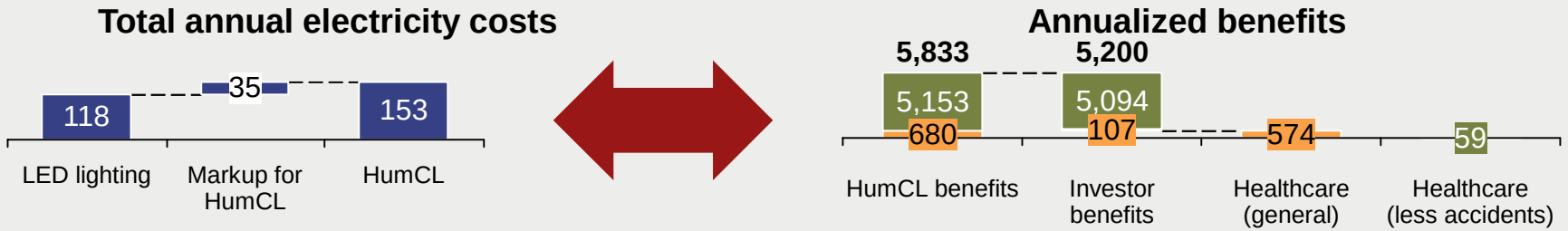
1. Benefits are highly sensitive to the underlying assumptions, especially effects of Human Centric Lighting, which mostly needs further research
Source: A.T. Kearney simulation model incl. detailed source references

On a macro level, benefits for industrial owners and investors dominate – additional public benefits are negligible

Industrial (Repetitive+Advanced) – Macro level effect

Highly sensitive to assumptions[1]

Long-term quantified Human Centric Lighting benefits (annually, in € mn)



Description of use case and key assumptions

- 100% Human Centric Lighting market penetration in the industrial segment in 2020 (all relevant new and renovated floor space equipped with Human Centric Lighting)
- About 20% highly repetitive, 60% more advanced and 20% fully automated industrial work in Europe
- > 25 mn workers affected in Europe by new and renovated lighting installations in 2020
- Average healthcare costs per worker of €2,171 p.a.

Reasoning for benefits

- Micro level investor benefits are extrapolated to Human Centric Lighting market size in 2020 at 100% penetration
- Benefits dominated by productivity increases
- 1% savings on general healthcare due to higher physical robustness of employees (mid- to long-term effect)
- Savings on healthcare for work accidents due to increased alertness and energizing effect

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

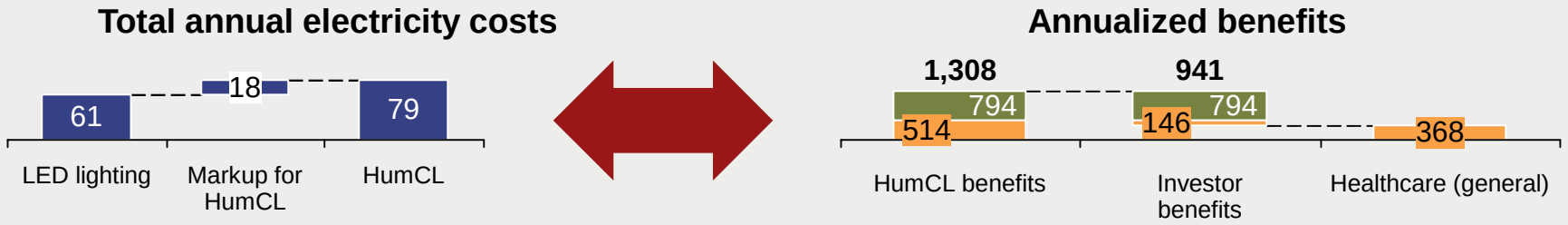
1. Benefits highly sensitive to underlying assumptions, some of them needing further research
Source: A.T. Kearney simulation model incl. detailed source references

In offices, significant additional benefits are realized for the public healthcare system

Office – Macro level effect

Highly sensitive to assumptions[1]

Long-term quantified Human Centric Lighting benefits (annually, in € mn)



Description of use case and key assumptions

- 100% Human Centric Lighting market penetration in the office segment in 2020 (all relevant new and renovated floor space equipped with Human Centric Lighting)
- >17 min office employees affected by new and renovated lighting installations in 2020
- Average sick days per office employee of 11.7 day p.a.
- Average healthcare costs per office employee of € 2,171 p.a.

Reasoning for benefits

- Micro level investor benefits are extrapolated to Human Centric Lighting market size in 2020 at 100% penetration
- Benefits dominated by productivity increases
- 1% savings on general healthcare costs due to higher physical robustness of employees (mid- to long-term effect)

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

1. Benefits highly sensitive to underlying assumptions, some of them needing further research

Source: A.T. Kearney simulation model incl. detailed source references

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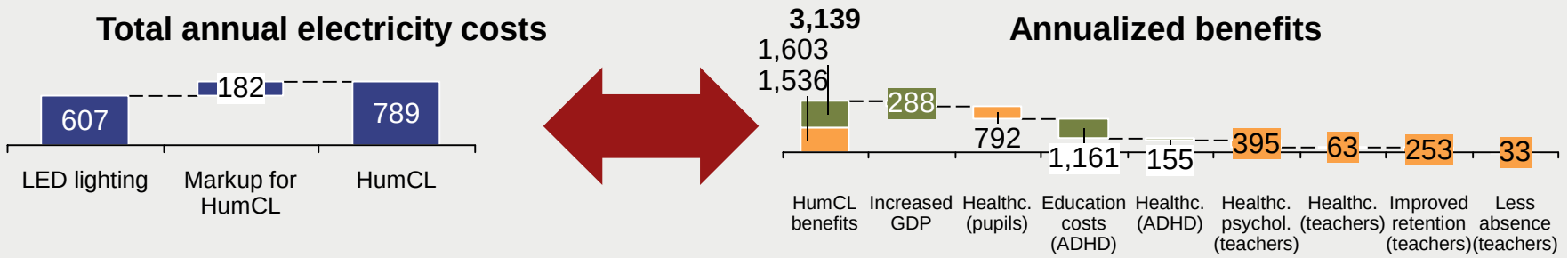
In the educational segment, public cost savings for ADHD and healthcare of normal pupils are the main benefits

Educational – Macro level effect

Highly sensitive to assumptions[1]

Long-term quantified Human Centric Lighting benefits (annually, in € mn)



Description of use case and key assumptions

- 100% of European pupils and teachers exposed to Human Centric Lighting solutions[2]
- € 2,780 average monthly labor cost per teacher
- 5.3% of pupils suffering of ADHD, thereof only 50% treated medically
- 11.7 sick days per teacher, thereof 25% due to mental disorders (stress, burnout, etc.)
- Public extra educational costs per ADHD pupil: € 6,000

Reasoning for benefits

- 0.1% GDP increase due to 15% improved cognitive performance of affected pupils
- 10% reduced healthcare and education costs due to less ADHD effects
- 18% improved treatment efficacy for mental disorders
- + 2 years duration of employees staying

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

1. Benefits highly sensitive to underlying assumptions, some of them needing further research, 2. Different from other macro cases, where the potential based on 2020 market size is shown. For educational the full long-term cumulative potential is shown.
Source: A.T. Kearney simulation model incl. detailed source references

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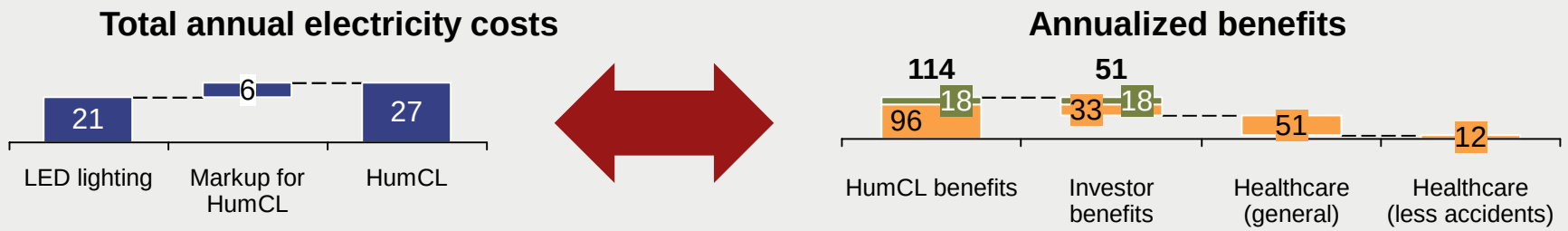
In the medical segment, additional benefits are realized for the public healthcare system

Medical – Macro level effect

Highly sensitive to assumptions[1]

Long-term quantified Human Centric Lighting benefits (annually, in € mn)



Description of use case and key assumptions

- 100% Human Centric Lighting market penetration in the medical segment in 2020 (all relevant new and renovated floor space equipped with Human Centric Lighting)
- > 2.3 mn medical employees affected by new and renovated lighting installations in 2020
- ~ 180,000 serious hospital accidents by affected patients per year in Europe
- € 7,200 average healthcare costs per hospital accident
- Average healthcare cost per medical employee of € 2,171 p.a.

Reasoning for benefits

- Micro level investor benefits are extrapolated to Human Centric Lighting market size in 2020 at 100% penetration
- 1% savings on general healthcare costs due to higher physical robustness of employees (mid- to long-term effect)
- 1% less accidents (e.g. falls) due to increased alertness by patients and staff reduces public healthcare costs

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

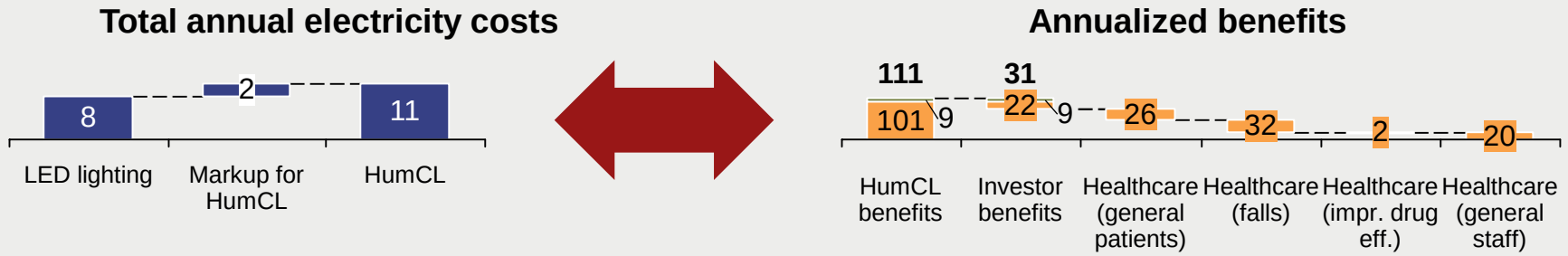
1. Benefits highly sensitive to underlying assumptions, some of them needing further research
Source: A.T. Kearney simulation model incl. detailed source references

In elderly care, there could be significant additional benefits for the public healthcare system

Residential (Elderly care) – Macro level effect

Highly sensitive to assumptions[1]

Long-term quantified Human Centric Lighting benefits (annually, in € mn)



Description of use case and key assumptions

- 100% Human Centric Lighting market penetration in elderly care segment in 2020 (all relevant new and renovated floor space equipped with Human Centric Lighting)
- > 1 mn patients affected by new and renovated lighting installations in 2020
- > 0.9 mn elderly care employees affected by new and renovated lighting installations in 2020 Average healthcare costs per capita of € 2,171 p.a.
- Average healthcare costs per elderly of € 2,497 p.a. (incl. € 499 medication costs)

Reasoning for benefits

- Micro level investor benefits are extrapolated to Human Centric Lighting market size in 2020 at 100% penetration
- 2.5% reductions in accidents (falls) due to increased alertness by patients and staff
- 1% saving on general healthcare costs for patients and nurses, due to higher physical robustness

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

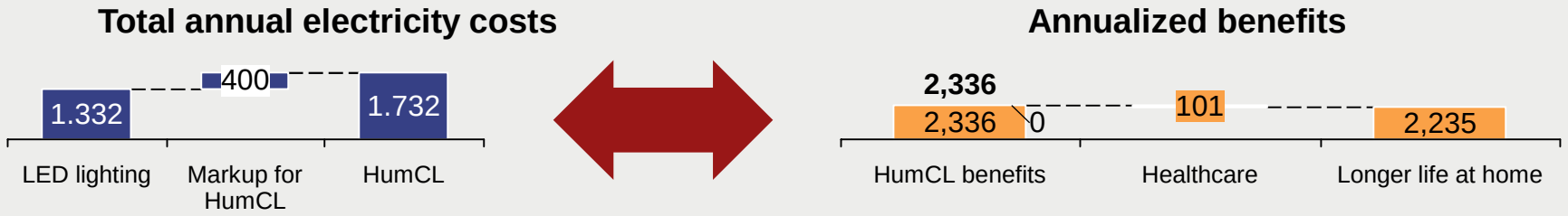
1. Benefits highly sensitive to underlying assumptions, some of them needing further research
Source: A.T. Kearney simulation model incl. detailed source references

In the residential segment, additional benefits are mainly driven by the deferred need for institutional care

Residential (Homes) – Macro level effect

Highly sensitive to assumptions[1]

Long-term quantified Human Centric Lighting benefits (annually, in € mn)



Description of use case and key assumptions

- 100% Human Centric Lighting market penetration in residential (home) segment in 2020 (all relevant new and renovated floor space equipped with Human Centric Lighting)
- > 4.5 mn affected residents in Europe (that are retired, stay at home and are significantly exposed to Human Centric Lighting)
- Average time in elderly care facility: 3 years with basic lighting, 2 years with LED lighting (because elderlies can see better at home and have less accidents)
- Average public cost per patient in public care facility: € 12,000 p.a.

Reasoning for benefits

- Big benefit for public care costs, because residents can reduce their average time in elderly care from 2 to 1.9 years due to increased physical robustness. Assuming that 40% of affected residents will eventually go into an elderly care facility
- 1% savings on general healthcare costs for affected residents, due to higher physical robustness

Annual electricity costs | Scientifically confirmed benefit | Expected benefit

1. Benefits highly sensitive to underlying assumptions, some of them needing further research
Source: A.T. Kearney simulation model incl. detailed source references

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