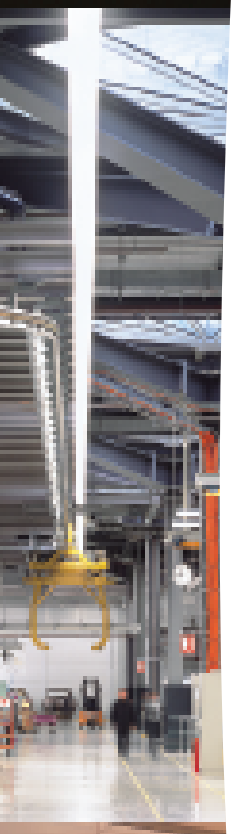

Market Study

Human Centric Lighting: Going Beyond Energy Efficiency

LightingEurope
German Electrical and Electronic Manufacturers' Association (ZVEI)

July 2013

LIGHTINGEUROPE
THE VOICE OF THE LIGHTING INDUSTRY

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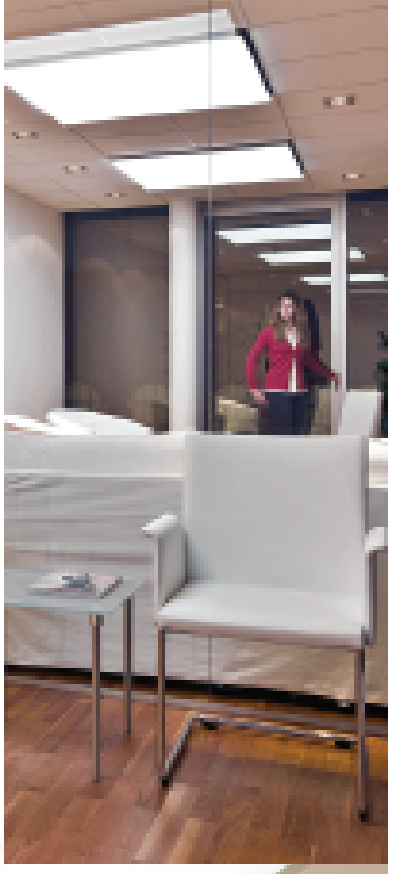
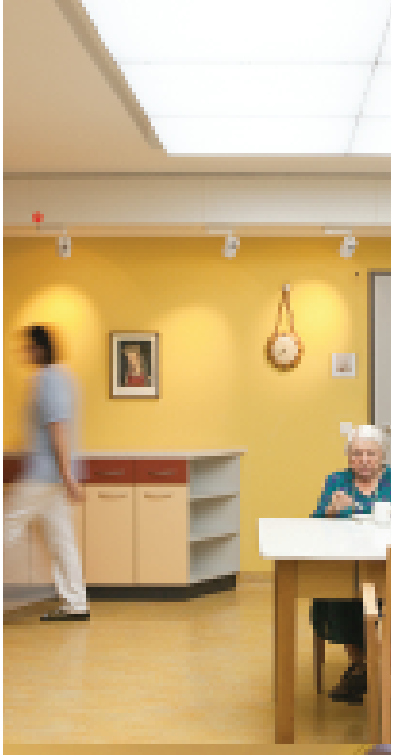


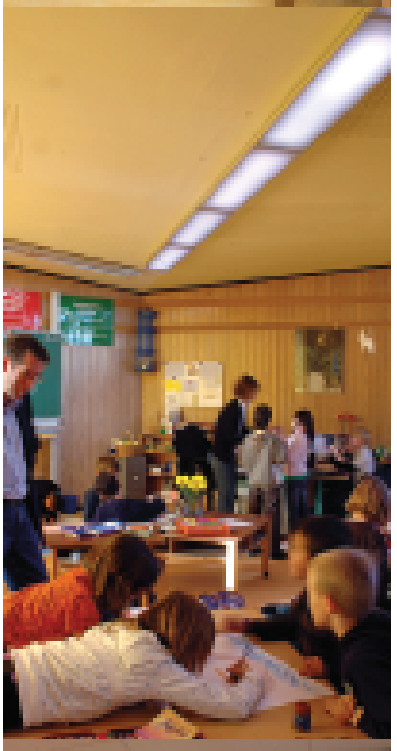

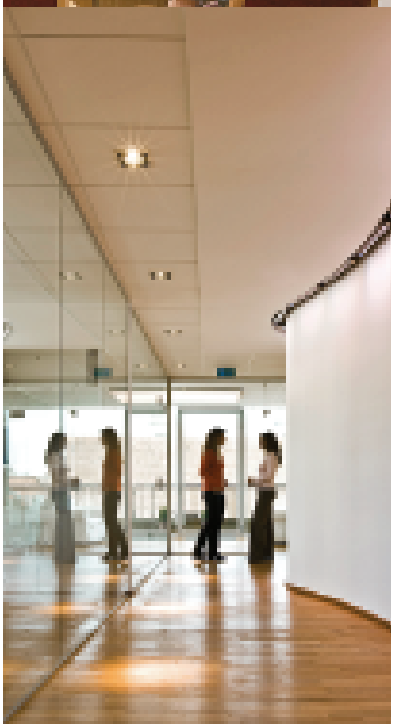
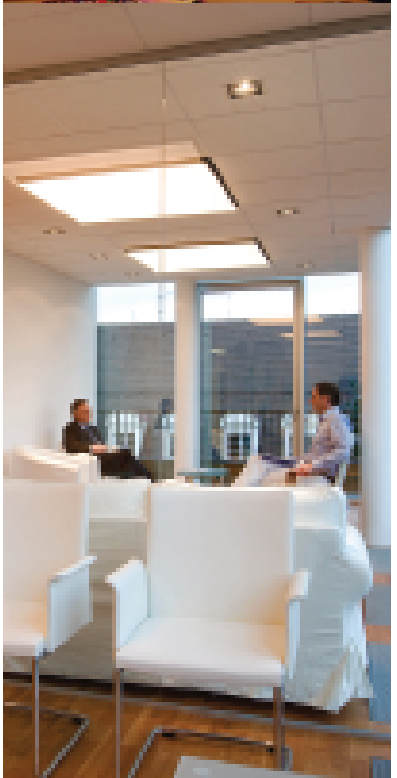
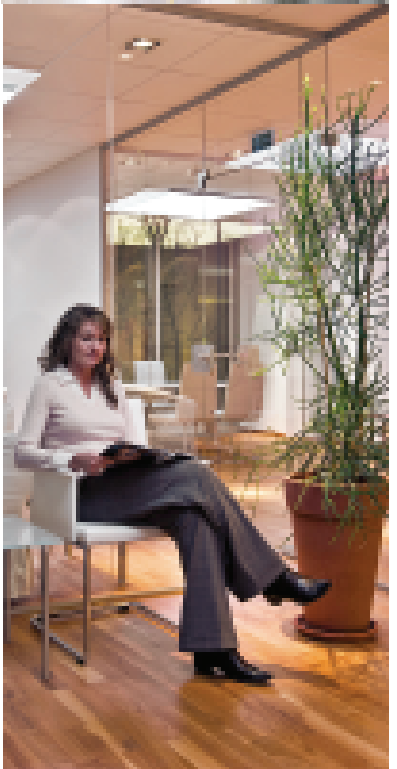

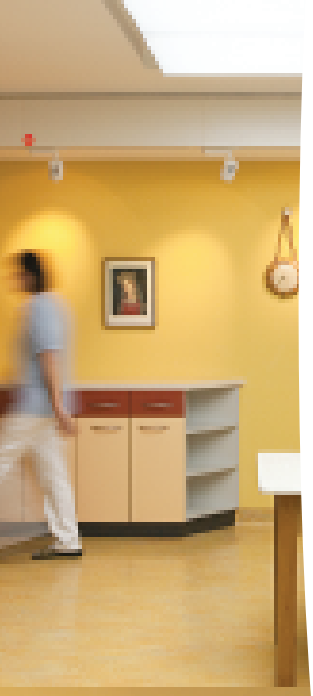

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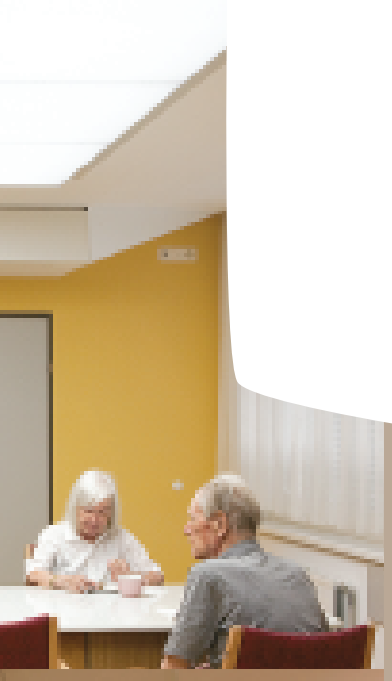

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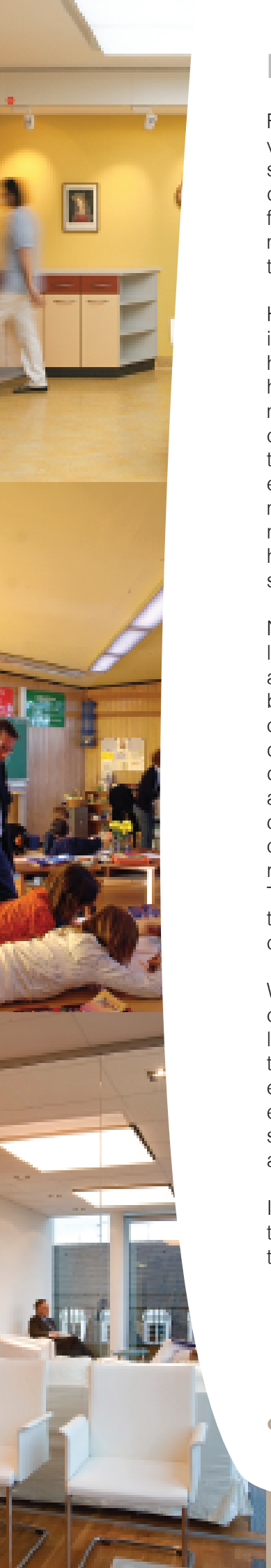
Executive Summary

For the first time, a joint study of LightingEurope, the German Electrical and Electronic Manufacturers' Association (ZVEI) and A.T. Kearney shows that human centric lighting can become a multibillion-euro business, covering around 7 percent of the general lighting market in Europe. Human centric lighting is intended to promote a person's well-being, mood and health. It can improve concentration, safety and efficiency in workplace or educational environments. It can support healing processes and prevention of chronic diseases among persons with irregular daily routines or in elderly care. An outstanding growth trajectory is expected for this market, which has not been the focus of customers, industry and policy makers so far. This growth is fueled by the technology transition from conventional light sources to LED modules. While the energy efficiency and durability of LED modules is widely known in the market, little attention has been paid to their advanced controllability and related applications. The European industry is well positioned to take a leading role in this sector if policy makers and industry players work hand in hand to leverage Europe's native strengths, including its innovation capabilities, integration competence and solution-oriented understanding of customer requirements.



Introduction: Effect of light on human beings

For a long time, the lighting industry has designed products to fulfill our visual needs. With the economic crisis persisting and the awareness of sustainability increasing, customers, policy makers and industry have discovered the energy savings potential of light sources, such as compact fluorescent lamps and LED. While energy efficiency and durability of LED modules is widely known in the market, little attention has been paid to their advanced controllability and related applications.

However, modern trends of people migrating to cities, spending more time in interior rooms, and living longer have amplified efforts to provide a healthier indoor environment. Lighting is not neutral in terms of human health, and adverse effects, such as disturbance of sleep/wake cycles, mood disorders and possibly even cancer pathologies may be the consequences of ignoring new findings on non-visual effects of light. For this purpose, a diversity of light sources with different biological effectiveness, bigger surfaces that reflect or emit light and light management systems that control the proper timing of lighting are needed. Improving lighting quality has a known impact for vision and health. Therefore, there are possibilities for application in nearly all situations of our daily lives.

Nevertheless, little is known in public and politics about human centric lighting. A general consensus in society that good lighting is essential for a person's well-being has prevailed for a long time. But discussions have been superficial and are often not driven by facts. This is the result of the challenges of separating causes and effects, which often seem vague and depend on individual appraisal of surrounding conditions. After the 2001 discovery of a third photoreceptor in the human eye, in addition to rods and cones[1], effects on circadian rhythms could be related to specific light conditions. This discovery scientifically manifested the general public consensus. It represented a major leap forward, facilitating further research and development activities by both academia and industry. Today, specific lighting solutions can be produced and installed in ways, that specifically support the human circadian rhythm, enhance concentration, prevent sleeping disorders and improve overall well-being.

Within the range of human centric lighting systems, two major distinctions can be made: On one hand, biologically effective lighting represents lighting systems that are appropriate to stimulate the biological organism, thus improving cognitive performance. On the other hand, emotionally effective lighting systems are designed to create emotionally stimulating environments and appealing atmospheres. Thus, human centric lighting simultaneously takes into account our requirements for good vision as well as our emotional and biological needs.

In this study, we introduce the reader to this fascinating topic, which has the potential to become the next big step in advanced lighting technologies, going beyond pure energy efficiency.

1. *See Brainard et al., Thapan et al.*

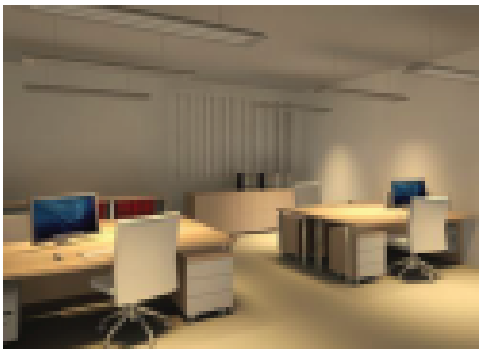
Attractive application of human centric lighting

Several lighting systems sold in stores today can support the emotional and biological effects of lighting. These solutions rely on electronic light management systems, creating artificial lighting within buildings, which is synchronized with the human circadian rhythm[2]. The distribution of light is adjusted to the different daylight conditions and specific requirements of individuals throughout the day. This way, dynamic changes of color temperature and illuminance, along with a wide distribution of light from both direct and indirect light sources, stimulate the human organism.

The different visual effects of a conventional and a human centric lighting system are depicted in Figure 1: Frequently, conventional lighting systems rely on a unidirectional, time-constant distribution of light, whereas human centric lighting systems leverage not only control dynamics, but also the combination of multiple directions, color temperatures and illuminance.

Figure 1: Examples of common lighting systems

Conventional Lighting System



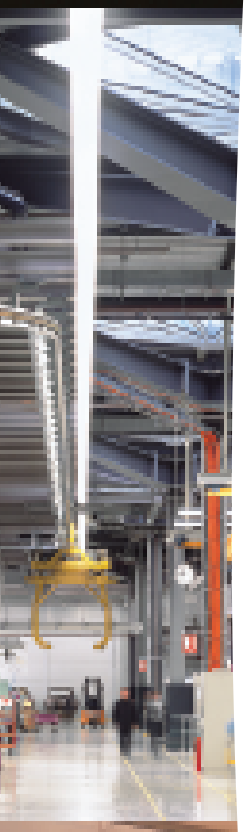
Human Centric Lighting System

Source: Osram GmbH

More than 90 percent of human centric lighting products are based on compact or linear fluorescent lamps. More expensive LED modules haven't gained significant market share yet. Considerably higher prices and skepticism of customers towards LED have prevented a stronger uptake so far. However, we expect that the technology split for human centric lighting will evolve until 2020, with LED taking over a strong share beyond 90 percent from conventional light sources.

Diverse positive effects of human centric lighting allow its usage along various dimensions of our everyday life. It can be used in offices and our homes, in schools and retirement homes, for industrial and even recreational purposes. Its benefits can be brought into every household, hospital or modern factory and workspace, as outlined in Figure 2.

2. This study focuses on stationary lighting systems, which are installed in residential and non-residential buildings. Portable lighting products, e.g., for therapy purposes, have been taken out of scope.



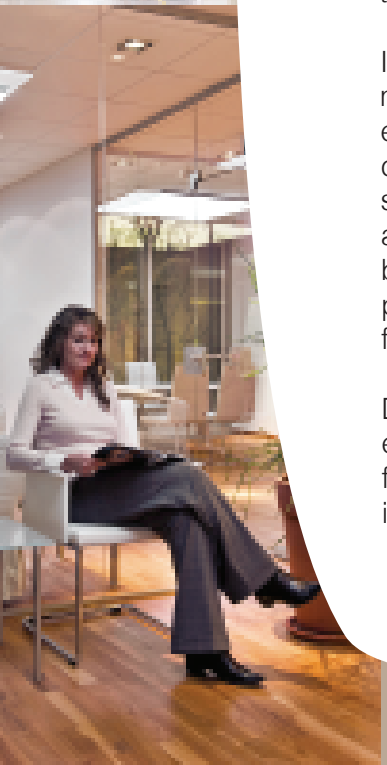


Figure 2: Application-specific effects of human centric lighting

- Enhanced drug efficacy, e.g., of antidepressants
- Reduced therapy times and capacity requirements

- Decreased fatigue and shortened wake-up times
- Extended and deepened concentration periods

- Increased employee motivation and commitment
- Individualized maximization of concentration and energy

- Improved output and error rates of repetitive work steps
- Biorhythm adjustment for nightshift workers

- Daylight-compatible product presentations
- Extended daytime in shopping malls

- (Colored) accentuation of architecture and design
- “Mood support” in wellness and dining areas

- Prevention of depression and dementia
- Integrated wake-up and relaxation support

Source: LightingEurope JWC, A.T. Kearney, Thinkstock

In residential settings, i.e., at home or in elderly care, human centric lighting can reduce sleep disorders, thus limiting the need for cost-intensive medication and reduce nursing efforts. In retirement homes, higher illuminance, high color temperatures and dynamically adjusted light distribution levels reportedly improve the well-being and activity of the elderly during the day.

In schools, specific lighting solutions can significantly improve concentration and cognitive performance and lead to improved test results. For example, error rates dropped from a first to a second test by about 45 percent (comparison group with common lighting only 17 percent)[3] and cognitive speed improved by 9 percent (comparison group only 5 percent)[4]. In addition, such lighting solutions can reduce motor restlessness, support alertness in the morning and improve social behavior.

In offices, increased energy and motivation of employees are just two of many advantages brought along by human centric lighting solutions. For example, typical productivity gaps after lunchtime can be alleviated by dynamic adjustments of light direction, illuminance and color temperature, supported by warm direct lighting and indirect lighting. Wholesale, retail and hospitality can benefit from new lighting solutions, and products can be presented in new ways. For example, fashion products can be presented under true daylight conditions, even deeply in-house, far away from any window.

Despite all qualitative effects on human well-being and mood, there is evidence that the utilization of human centric lighting solutions has a clear financial benefit as well, as outlined in a case study for a factory workshop in Figure 3.

3. See Barkmann et al.
4. See Keis et al.

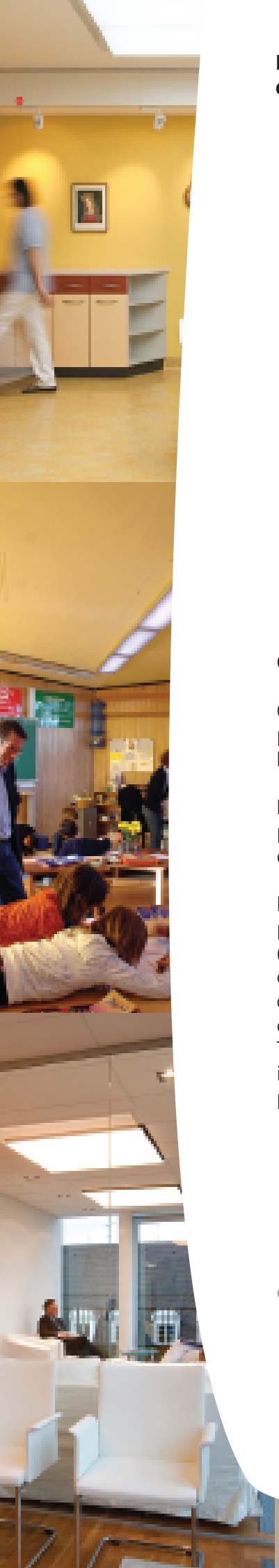
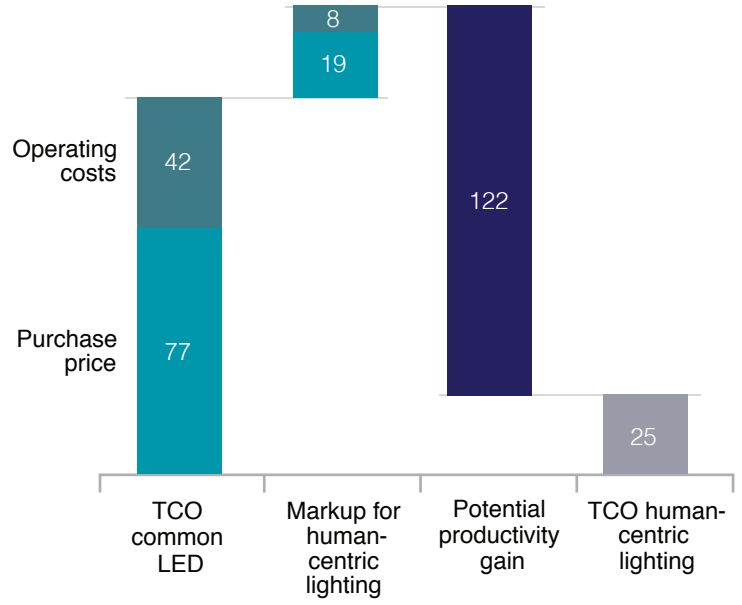


Figure 3: Total cost of ownership (TCO) of human centric vs. common LED lighting (in € k)



Source: LightingEurope JWG "Light and Health", A.T. Kearney

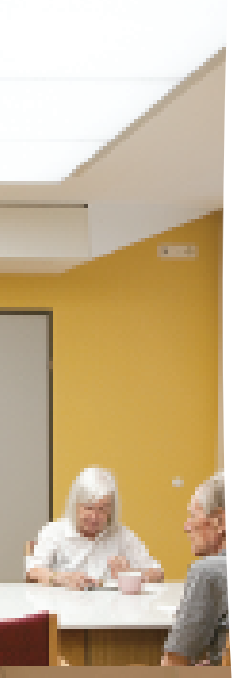
Case study of a factory workshop:

Compared to common LED systems, we assume a 25 pecent markup on purchase prices and 20 percent markup on power consumption for human centric lighting systems[5].

For a workshop with an area of 1,500 square meters, a 1.7 percent productivity gain is needed to offset this additional cost of ownership, calculated over a period of 10 years.

However, studies indicate that productivity gains of up to 7.7 percent are possible in blue-collar environments, e.g., due to higher concentration (less failures) or improved motivation (more output). Assuming that 10 employees each completed six tasks per day with a contribution margin of €12/task under common lighting conditions, human centric lighting could facilitate an absolute productivity gain of up to €12.2k per year. Thus, human centric lighting would allow a win-win situation, not only influencing the workers' mood positively but also leading to improved productivity, offsetting the initial investments quickly.

5. Source: A.T. Kearney, Canazei et al., Licht.wissen 19 (p. 30)

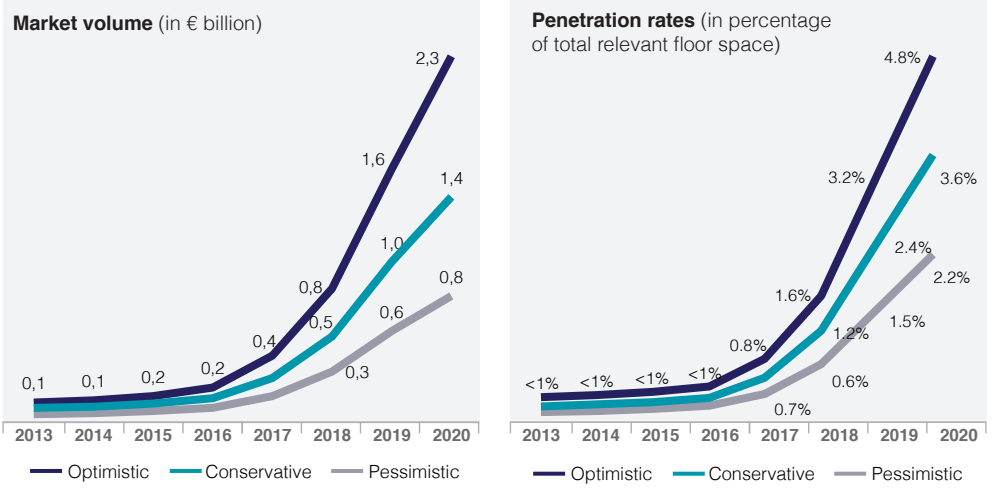


Significant market potential across Europe

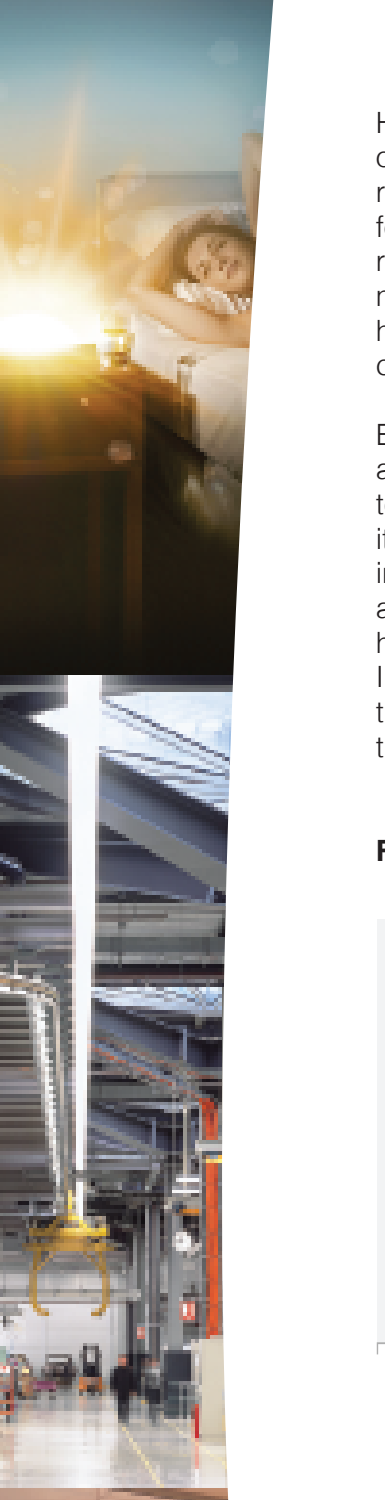
Human centric lighting is expected to become an important market in Europe, across various applications and lifestyles. The underlying market model is based on the floor space that becomes available annually for being equipped with human centric lighting solutions through new buildings and renovations of the building stock. The market volume is derived from segment- and region-specific estimates of relevant floor space, penetration rates and prices. In order to determining the business potential of human centric lighting, the model analyzes three different scenarios. The conservative scenario is regarded as the most probable, assuming selective government support, joint industry initiatives and considerable marketing investments. The more optimistic scenario is regarded as less probable in light of the current economic developments, as it assumes the resolution of the currently persisting economic crisis and extensive government support for human centric lighting. The pessimistic scenario is also considered as being less probable, assuming a fundamental worsening of the economic crisis, poor private investments and little government support.

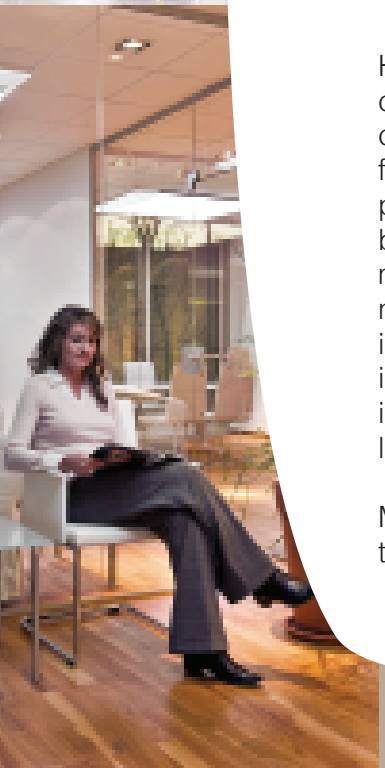
In the conservative growth scenario, human centric lighting is expected to become a billion-euro business in Europe, equaling up to €1.4 billion in 2020 as seen in Figure 4. This revenue potential would cover around 7 percent of the European general lighting market in 2020 and 20 to 25 percent of its high-end market segment. Within the human centric lighting market, biologically effective lighting will represent the major share with 65 percent market share. In addition, Figure 4 shows that around 4 percent of new installations and renovations in 2020 will include human centric lighting solutions, meaning that nearly every 25th newly installed lighting system will contain human centric control capabilities by the end of this decade. Nevertheless, the share of human centric lighting within the installed base is estimated to be much lower.

Figure 4: European human centric lighting market (by scenario)



Source: A.T. Kearney Human Centric Lighting market model

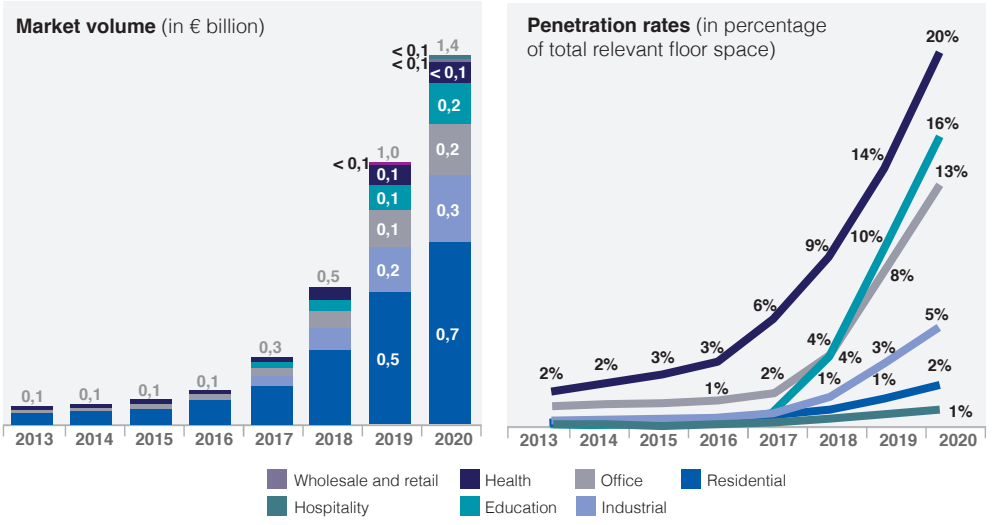




Human centric lighting is expected to reach high market penetration first in office, health and education segments, as indicated in the penetration rates in Figure 5. In 2013, there is already some considerable acceptance for human centric lighting solutions in the health sector, however, with little reflection in absolute figures due to the small relevant floor space. Over the next years, the office sector will gain further relevance, whereas today human centric lighting solutions are partially in use in state-of-the-art commercial centers.

By 2020, educational applications will have overtaken the office segment and become the second most important segment after the health sector in terms of penetration rates. Even though education has slow initial uptake in its penetration rate, it is expected to be strongly boosted by public investments and funding initiatives. In comparison to these application areas, the residential segment has a relatively small penetration rate, but a highly significant base of floor space relevant for human centric lighting. Including the majority of elderly care applications, residential will become the largest market segment in absolute terms, accounting for 45 percent of the market in 2020.

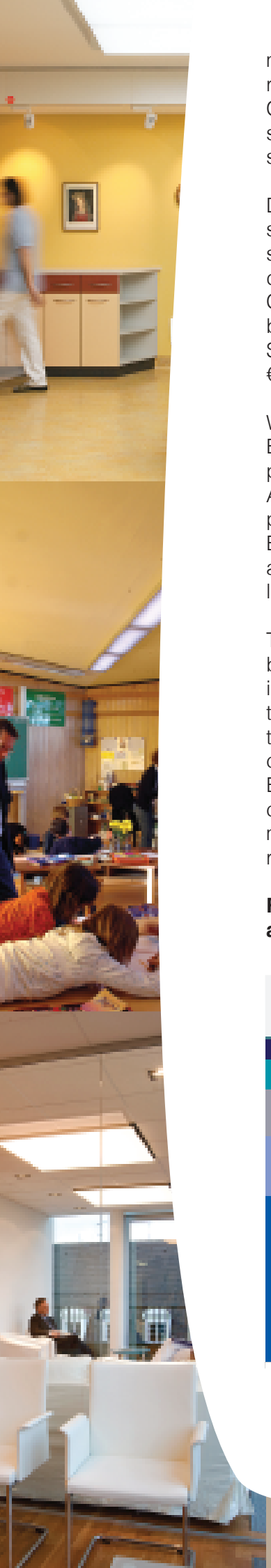
Figure 5: European human centric lighting market (by application)



Source: A.T. Kearney Human Centric Lighting market model

Human centric lighting solutions touch upon a multitude of professions and can create new employment opportunities. The complex nature of human centric lighting solutions offers opportunities not only for light source and fixture manufacturers, but also for planning engineers, architects, software providers and installers. Human centric lighting consequently represents a business opportunity for individual craftsmen and large enterprises. The market potential for installation activities will continue to grow. By 2020, nearly 25 percent of the human centric lighting market will be comprised of installation activities, equaling more than €300 million. On one hand, increasingly complex solution designs strengthen the need for special installation services. On the other hand, decreasing equipment prices will lead to rising shares of installation costs.

Most of the human centric lighting installations are expected to take place in building renovations, representing



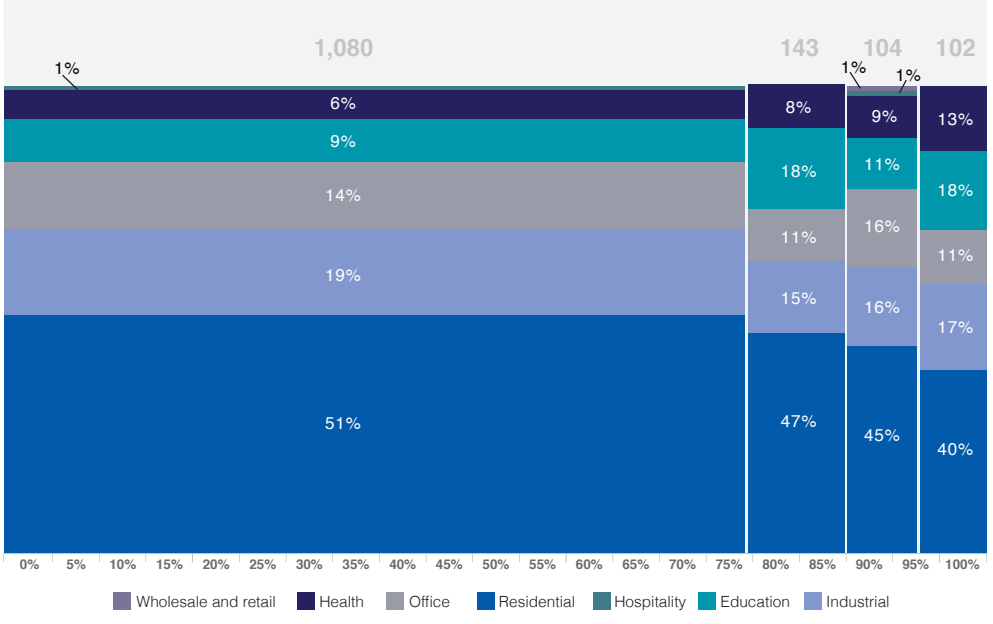
more than 80 percent of the market. This considerable strength of the renovations market is based upon expected initiatives from the European Commission and local governments in the context of energy efficiency, seeking to increase building renovation rates throughout this decade significantly.

Despite differing developments in application areas, there are also significant regional differences in human centric lighting application shares across Europe. These discrepancies are rooted in the different degrees of industrialization at hand. As shown in Figure 6, Western and Central Europe will be the region with the largest market (more than €1 billion) by 2020 followed by Northern Europe (more than €143 million), Southern Europe (around €104 million) and then Eastern Europe (around €102 million).

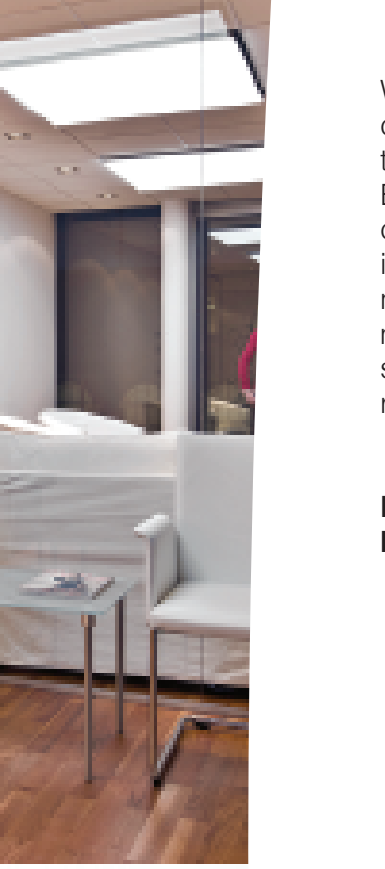
Western and Central Europe represent by far the largest market region in Europe, with its strength based on the huge floor space and the economic power of countries such as Germany, France and the United Kingdom. Accordingly, we assume higher acceptance, government support and prices in this region than in Eastern and Southern Europe. While Northern Europe is expected to exceed Central and Western Europe in these aspects, the relatively small floor space in Northern European countries limits its total market potential.

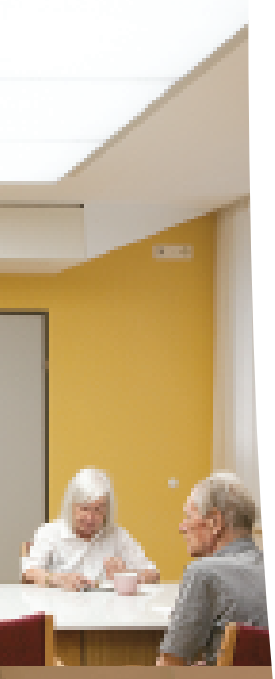
The share of residential applications is very high across all regions because of its large relevant floor space potential. Due to their high industrial maturity, Western and Central Europe have the highest share of the industrial segment with 19 percent. In Northern and Eastern Europe, the 18 percent share of educational applications can be explained by considerable public investments in education, whereas the Eastern European health share results from a disproportionately large floor space covered by this segment. Additionally, the lower relevance of the manufacturing industry and relatively few inhabitants in Northern Europe reduce the share of applications in the industrial and office segment.

Figure 6: European human centric lighting market 2020 (by application and by region)



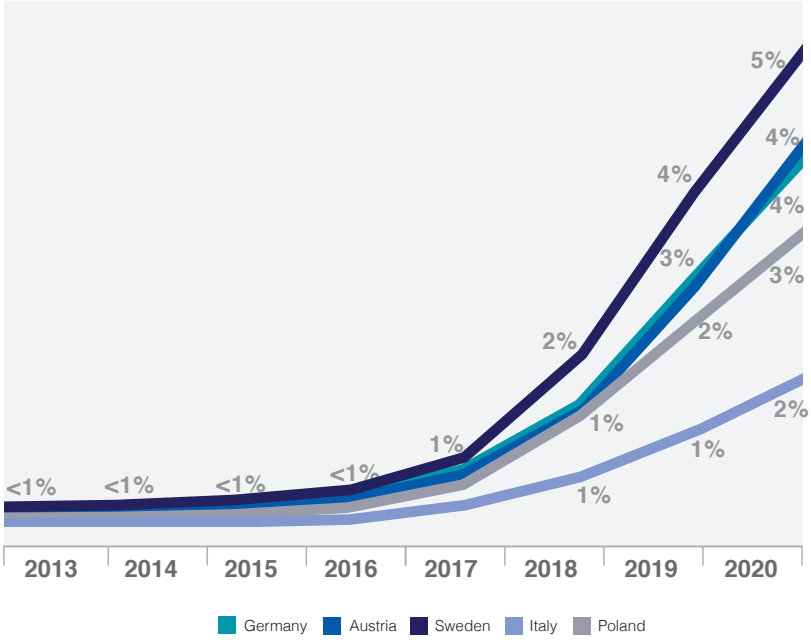
Source: A.T. Kearney Human Centric Lighting market model





Whereas Western and Central Europe will be the largest market by far, covering more than 75 percent of the European market, Figure 7 shows that the highest relative market penetration is expected in Northern Europe. This development is driven by strong acceptance in Nordic countries such as Sweden due to long dark periods in winter. The market in Southern Europe is comparably small as seen in Figure 6, as it is negatively affected by the persisting economic downturn and the austerity measures as well as public spending cuts. Another reason for the relatively small Southern European market for human centric lighting is the limited relevance of such lighting solutions during winter times.

Figure 7: Country-specific market penetration of human centric lighting (percentage of total relevant floor space)



Source: A.T. Kearney Human Centric Lighting market model

Figure 8 provides detailed information on the development and structure of the largest and fastest growing country markets in Europe, i.e., Germany and Sweden. For Germany, we expect residential, office and health applications to be first movers. The reasons for this are an already existing market of residential applications and high innovation acceptance in the office segment. Additionally, government investments are expected to benefit human centric lighting in health applications. Governmental initiatives aimed at fostering the market acceptance of human-centric lighting have been kicked off, but are expected to assume more momentum in the future[6].

We expect Sweden to have a significant market for educational applications with €12 million in 2020. In addition, health applications will be first movers in Sweden, which are related to the comprehensive Swedish welfare state and strong public investments into the health (and education) sector. Finally, extended darkness phases during winter are a considerable demand driver. In the residential segment, however, this effect is partially offset by the acceptance of emotionally effective lighting.

6. For example, the European Commission announced its financial support of projects that are "promoting SSL and analyzing its effects in applications where there are benefits for people's health and well-being." See European Commission

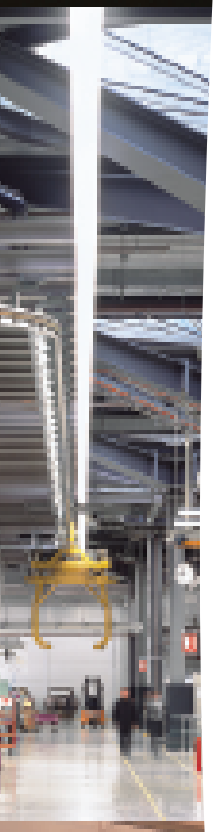
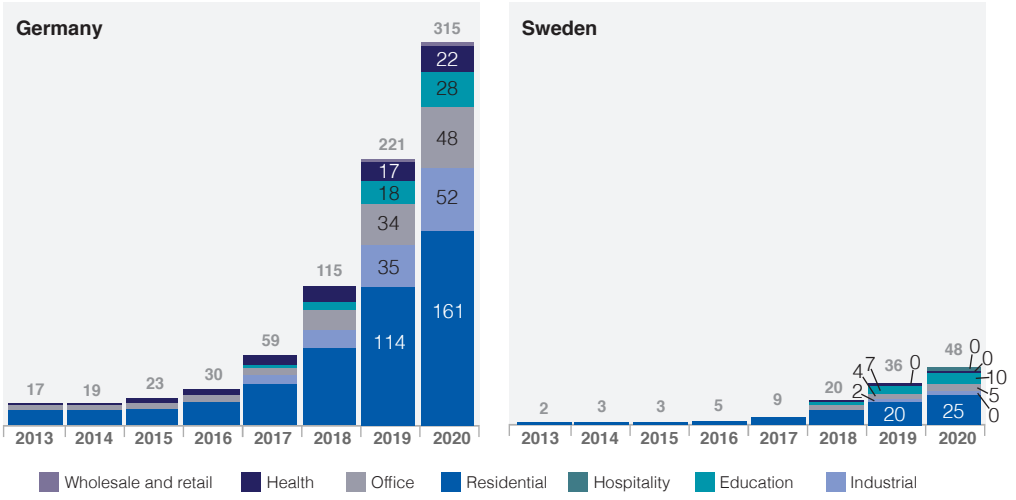
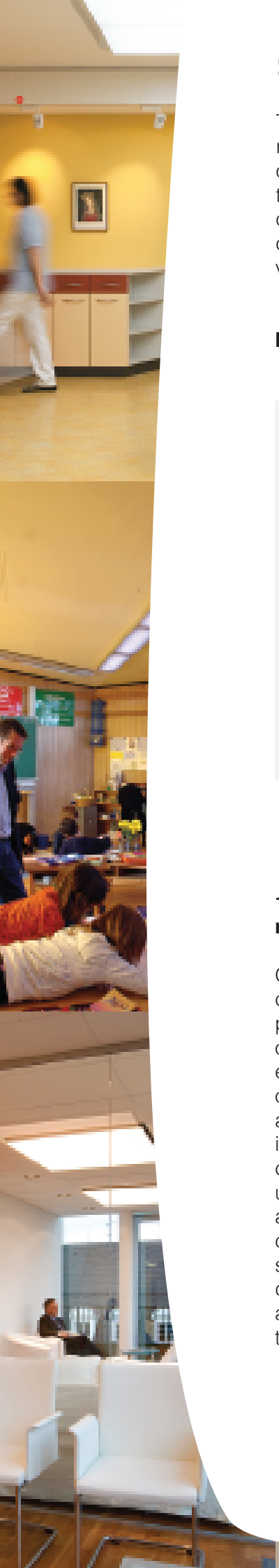


Figure 8: Deep dives - German and Swedish human centric lighting market (by application in € million)



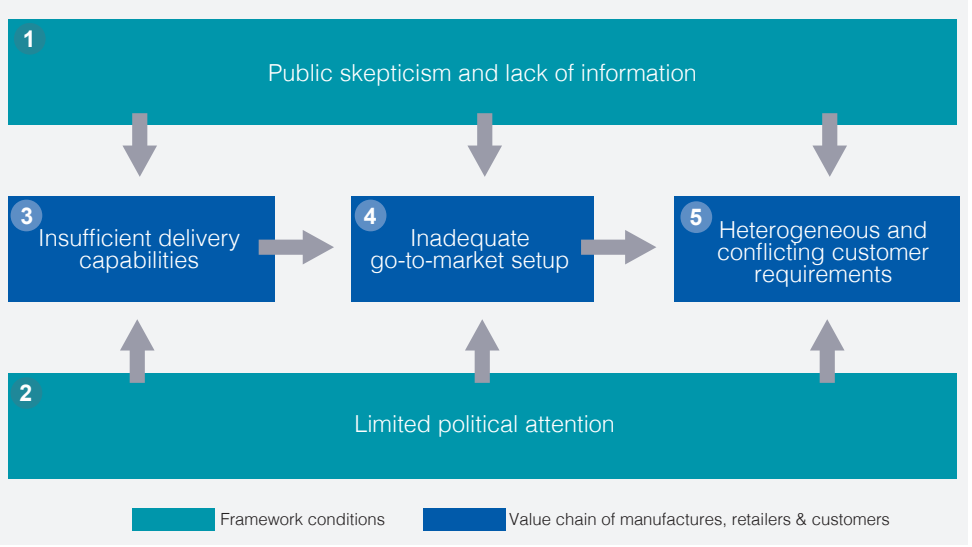
Source: A.T. Kearney Human Centric Lighting market model



Substantial growth barriers to overcome

The realization of this attractive market potential is not a given, but requires joint efforts of European industry players and policy makers to overcome various hurdles. We have identified six main growth barriers that hinder the realization of the market potential along two thematic clusters: The first two barriers are rooted within the overall framework conditions of the market whereas the remaining three are linked to the value chain of manufacturers, retailers and customers.

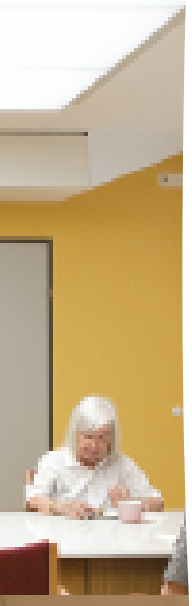
Figure 9: Overview of main growth barriers

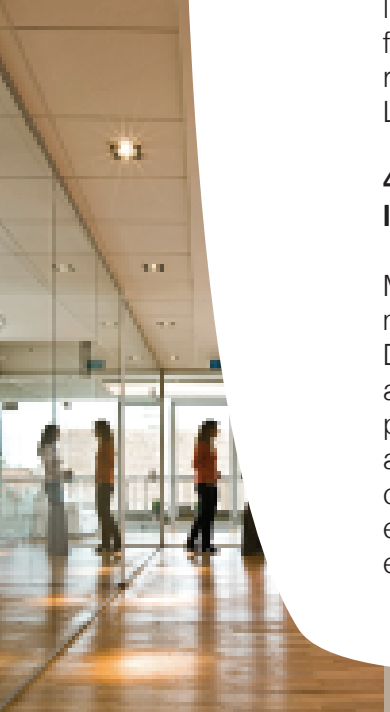


Source: LightingEurope JWG "Light and Health", A.T. Kearney

1. Human centric lighting solutions suffer from public skepticism, rooted in a lack of information

One of the main reasons for the limited market penetration of human centric lighting solutions today is the limited awareness of its scientifically proven effects among decision makers. Skepticism towards this topic is often prevailing among policy makers, architects and customers. Also, economic effects of human centric lighting, such as total cost of ownership or returns on investment are doubted. The little knowledge available to the public is often shaped by a general skepticism towards industry initiatives. Additional obstructions can be expected from conservative occupational health and safety requirements, which are upheld by unions or safety organizations. Human centric lighting solutions are partially regarded as manipulation and productivity measures conflicting with the interests of employees, while they should rather be seen as the best possible indoor translation of the healthy effects of daylight, thus supporting people's well-being. Overall, such limited awareness and broad skepticism towards this topic is directly related to the next hurdle.





2. Political attention towards human centric lighting is limited due to other high-urgency topics on the European agenda

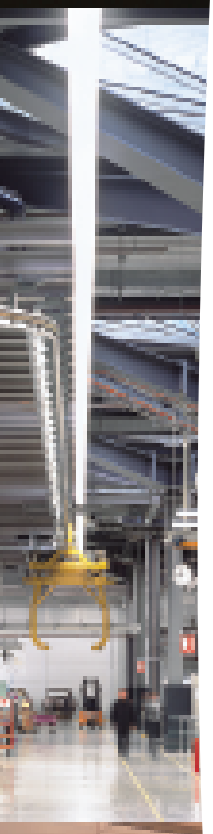
The worsening of the global economic crisis leads to a general uncertainty across markets and geographies, reducing customers' inclination to invest. Budget restrictions and austerity measures, especially in the Eurozone, reduce the availability of public funding and investments. This can potentially lead to cannibalization between investments in human centric lighting and other public measures improving the situation in areas such as teaching staff or IT infrastructure. So far, policy makers have focused on energy efficiency when regulating the lighting sector, thus limiting their attention to other topics. One result of this singular focus could be fixed-value energy efficiency requirements in the future, which might inhibit the market introduction of human centric lighting solutions: Due to the dynamic adjustment of illuminance and color temperature, peak load energy consumption could be above those restrictive thresholds, whereas the average could still be more energy efficient than a conventional system. Similarly, the limited consideration of human centric lighting characteristics in building or workplace standards and norms might hinder planning engineers from introducing these lighting solutions, e.g., in case of fixed-value illuminance requirements for workplaces.

3. Capabilities to deliver human centric lighting solutions are insufficient due to the fragmented value chain structure

The public is not alone in its limited awareness of human centric lighting. The value chain of fixture manufacturers (including electronics, smart home, and software engineering) is in a similar position. For example, the traditional product separation of fixture and control unit is causing insufficient collaboration among manufacturers along the value chain. In general, industry knowledge about customer requirements and specifications for human centric lighting is limited, particularly in the business-to-customer (B2C) realm. Furthermore, this situation is worsened by a lack of employees with cross-functional qualifications in areas such as chronobiology, lighting, electronics and computer science. In addition, few R&D, marketing and sales resources are dedicated to human centric lighting products, thus limiting the development of relevant professional experience and specialization. Even worse, there is a comparably slow learning process of fixture manufacturers embracing the new LED technology in general. As this technology is expected to become highly relevant for human centric lighting systems (due to its good controllability), these knowledge gaps may defer market penetration of human centric lighting systems from a supply perspective. As long as manufacturers of fixtures, light sources and control units don't collaborate effectively, they run the risk of leaving the field to competitors that leverage the potential of LED proficiently and can offer integrated human centric lighting systems.

4. Go-to-market setups don't meet the requirements of human centric lighting solutions with rising complexity

Marketing human centric lighting systems requires a paradigm shift for many of the prevalent sales channels used by fixture manufacturers today: Due to a more complex nature, human centric lighting systems require an advanced, solution-oriented selling approach instead of a straight-forward, product-based business model. With the increased need for consulting and planning activities in the selling process, requirements towards the capabilities of wholesalers and direct sales force employees expand as well. Not all of the existing channel partners



and sales agents will be able to fulfill these. Further down the value chain, apprenticeships for professions like a “building automation craftsman” are missing, i.e., experts with integrated technical knowledge as would be required for installing human centric lighting systems. Whereas planning engineers may develop the required knowledge easily, even their most popular planning software packages are missing sufficient interfaces for planning and designing human centric lighting solutions.

5. Customer requirements - across geographies, segments and stakeholders - are heterogeneous and sometimes conflicting

The value chain for human centric lighting ends with a variety of customers, which differs by geography, segment and stakeholders. Most prominently, technical customer requirements follow the different daylight characteristics and esthetical user needs from Northern to Southern Europe. On one hand, Scandinavian customers need to cover a considerable variation in daylight conditions throughout the year and tend to prefer very low (“warm”) color temperatures to offset the lack of daylight during the winter with a “cozy” ambience inhouse.

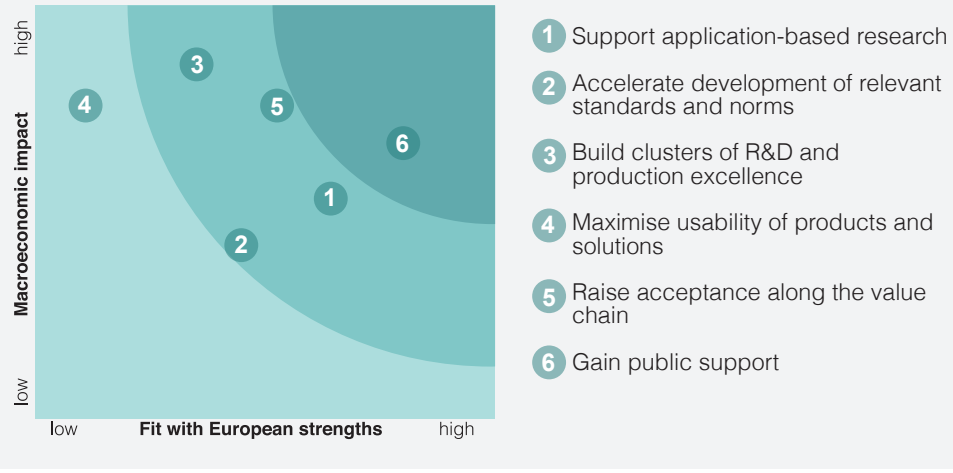
On the other hand, Southern Europeans need to cover a more limited variation of daylight over the year, thus tending to prefer high (“cool”) color temperatures, that correspond with the spectrum of the midday sun. In the healthcare segment, particular conflicts of interest can be expected due to a general fear of lost revenues and budget cuts, e.g., on the part of pharmaceutical manufacturers, health insurers and hospital owners. In the wholesale/retail segment, daytime-specific color variations of human centric lighting systems may conflict with the goal of presenting products in the most advantageous light settings.

These heterogeneities and potential conflicts have to be taken into consideration as part of region- and segment-specific go-to-market approaches, allowing a sufficient adaptation to customer needs. Regardless of applications and market segments, the landlord-tenant dilemma may inhibit investments into human centric lighting systems due to diverse return and investment flows, particularly in case of short-term real-estate investors with exit strategies. While tenants benefit from the effect of human centric lighting, landlords need to recover the required investments. Furthermore, the expected price sensitivity of customers may conflict with markups for human centric lighting.

Joint efforts of European industry and policy makers needed

In order to overcoming these barriers to an attractive growth trajectory, Europe can leverage the native strengths inherent in its high-tech industry in general and in its lighting industry in particular. The European industry is well positioned to take a leading role in human centric lighting if policy makers and industry players work hand in hand to leverage Europe's native strengths, including its innovation capabilities, integration competence and solution-oriented understanding of customer requirements. However, there is still a long way to go for Europe to realize its potential: Actions need to be initiated and coordinated as soon as possible to prepare frameworks for success. We have identified six action areas to be addressed by the lighting industry and policy makers. These levers are defined and prioritized along the lines of their macroeconomic impact and their fit to the existing European strengths, as depicted in Figure 10.

Figure 10: Overview of main growth levers

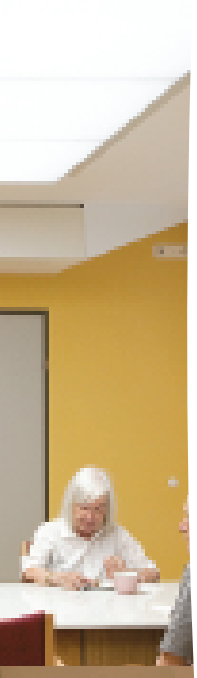


Source: LightingEurope JWG "Light and Health", A.T. Kearney

1. Public and industry support of application-based research facilitates the development of customer-centric solutions, providing even more extensive proof of concept and quantification of macroeconomic benefits from human centric lighting. In the health segment, evidence from clinical trials may be required to foster funding on behalf of health insurances and hospital networks. For this purpose, industry associations and manufacturers are called to collaborate, both multilaterally and with research institutions. From a government perspective, respective frameworks and an increased funding of application-based research could further catalyze this process.

2. Accelerated development of relevant standards and norms supports customer pull effects, e.g., via the integration of requirements beneficial for human centric lighting solutions into occupational health and safety standards or building certification schemes. Industry associations need to channel these requirements into the respective standardization committees, ensuring that technical specifications are kept aligned with the specifics of this new application. Nonetheless, users' health and safety should not be compromised in this context.

3. Introduction of regional clusters of excellence allows European industry players to co-develop R&D and production capabilities and leverage existing synergies at the same



time. In order to avoid a subcritical size, clusters of excellence should not be introduced on a national level, but rather on a regional or even pan-European level. Whereas joint R&D would contribute to innovativeness and development of cross-functional expertise, joint production facilities would further improve the flexibility and reduce the cost base of European manufacturers.

4. Maximized usability of products and solutions reduces potential skepticism of customers, given a solid understanding of market requirements and a sufficient integration of product components, including fixture, electronic control and software. Instead of maximizing performance and variety of adjustable control parameters, manufacturers need to focus on integrating products and components into well-configured, stable lighting systems. In addition, they need to simplify and link user interfaces to smart-home solutions and mobile control devices, e.g., handhelds or tablets via WiFi. A high usability, combined with sufficient possibilities for individualizing usage patterns, may increase the acceptance of human centric lighting solutions at the workplace among employees. Similarly to the “bring your own device” trend in office communications, an amplifying pull effect may be generated through the B2C segment.

5. Dedicated communication and training measures along the value chain raise the acceptance not only among customers, but also among important stakeholders, including planning engineers, wholesalers and electricians. Manufacturers need to drive joint industry marketing initiatives, allowing an efficient distribution of human centric lighting know-how to respective stakeholders. Industry associations can provide platforms for coordinating these initiatives, both on a national and a pan-European level. On top of that, the development of contracting offerings and the introduction of human centric lighting requirements into public and corporate tender processes will further support realization of the growth trajectory.

6. Gain public support: Initial public investment support and incentives reinforce the inclination to invest among customers. With the majority of human centric lighting installations being in the context of building renovations, positive incentives can be expected from the ongoing efforts of European governments to achieve a more energy-efficient building stock over the next decades. Industry associations need to link human centric lighting aspects with existing public funding initiatives and accompany the introduction of future incentives for renovations and energy efficiency improvement.

Most of the six growth levers can be addressed today, except for the introduction of clusters of excellence, which is strongly dependent on the political willingness to cooperate and invest multinationally. However, the full impact of these growth levers will be realized over time, staggered along the years to come. As depicted in Figure 11, the course must be set as soon as possible to ensure that the benefits of the projected market growth can be reaped by the European industry.

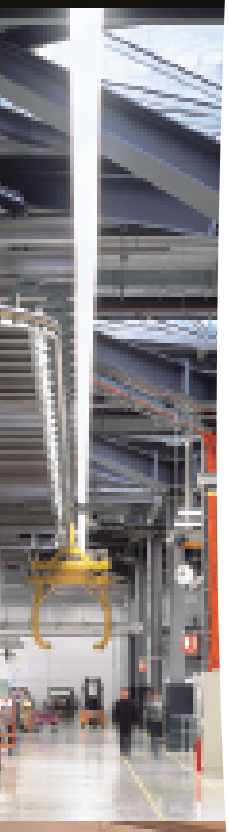
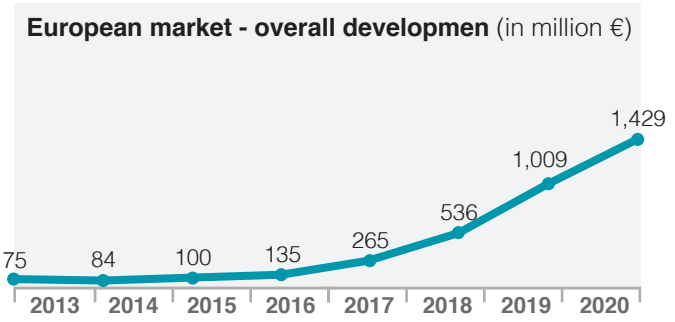
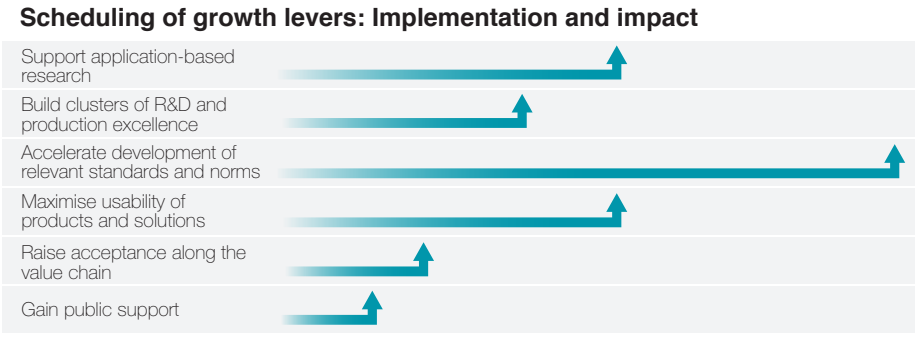


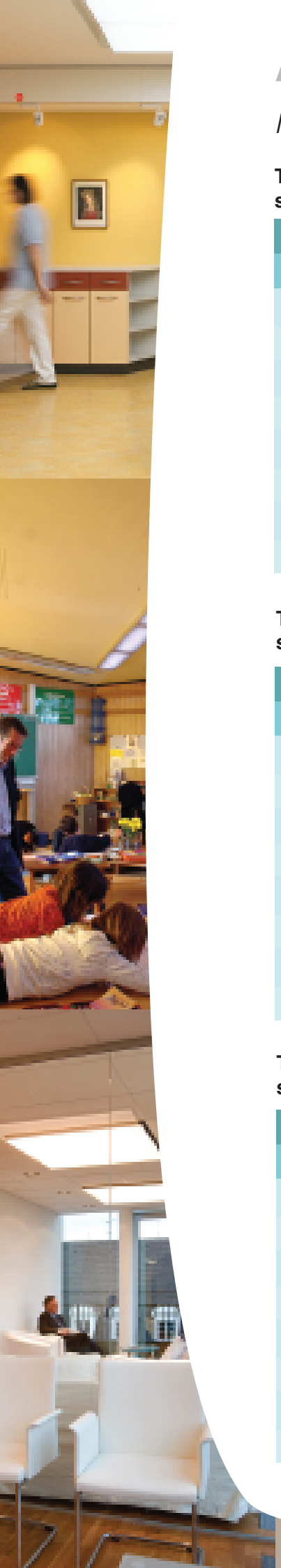
Figure 11: Timing of implementation and impact of defined levers





Source: LightingEurope JWG "Light and Health", A.T. Kearney

European decision makers have it in their hands: If policy makers and lighting manufacturers address these action areas in a joint effort and without major delays, Europe is well positioned to become a leading player in the innovative, attractive market for human centric lighting. Europe's innovation potential, integration competence and solution orientation allow the generation of a sustainable competitive advantage in a high-tech industry, which is still strongly rooted within the European borders – so far.



Appendix

Market volumes – scenarios

Table 1: European human centric lighting market volume, conservative scenario (€ million)

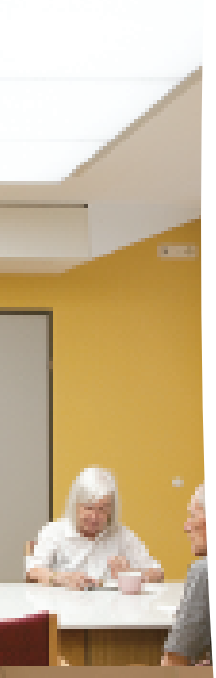
Application	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL	75.1	83.7	99.9	135.4	264.5	536.4	1009.2	1428.6
Office	18.1	18.3	20.7	24.4	30.5	66.8	137.3	196.8
Wholesale and Retail	0.0	0.5	0.8	1.3	2.4	3.9	4.8	5.5
Industrial	0.0	0.2	0.7	2.2	34.6	79.4	175.9	259.4
Education	0.0	0.1	0.4	1.5	9.8	41.9	101.4	152.4
Health	8.8	10.8	13.4	18.0	31.4	50.9	76.6	103.9
Hospitality	0.0	0.3	0.6	1.2	2.5	4.9	7.3	9.4
Residential	48.3	53.4	63.2	86.8	153.4	288.6	506.0	701.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2: European human centric lighting market volume – optimistic scenario (€ million)

Application	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL	112.7	123.5	151.1	206.6	409.3	840.6	1610.4	2332.1
Office	27.2	27.4	32.0	38.7	49.6	111.1	231.7	341.2
Wholesale and Retail	0.0	0.6	1.0	1.5	3.0	4.9	6.3	7.4
Industrial	0.0	0.4	1.1	3.5	58.6	139.2	318.0	482.6
Education	0.0	0.2	0.6	2.4	16.2	71.1	176.3	270.9
Health	13.2	16.2	20.7	28.8	51.4	85.9	132.6	184.1
Hospitality	0.0	0.4	0.8	1.7	3.4	6.8	10.4	13.7
Residential	72.4	78.4	94.8	130.0	227.1	421.7	735.0	1032.3
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3: European human centric lighting market volume – pessimistic scenario (€ million)

Application	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL	37.6	43.8	53.0	74.4	149.2	305.9	571.0	795.3
Office	9.1	9.1	10.2	11.7	14.4	31.0	62.1	88.2
Wholesale and Retail	0.0	0.5	0.7	1.1	2.0	3.1	3.8	4.2
Industrial	0.0	0.1	0.4	1.0	15.8	35.3	75.9	108.9
Education	0.0	0.1	0.2	0.7	4.5	19.1	45.3	66.8
Health	4.4	5.4	6.5	8.6	14.7	23.4	34.4	45.7
Hospitality	0.0	0.2	0.5	0.9	1.8	3.5	5.1	6.4
Residential	24.1	28.4	34.5	50.7	96.0	190.7	344.4	475.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



Market volumes – countries

Table 4: Austrian human centric lighting market volume (€ million)

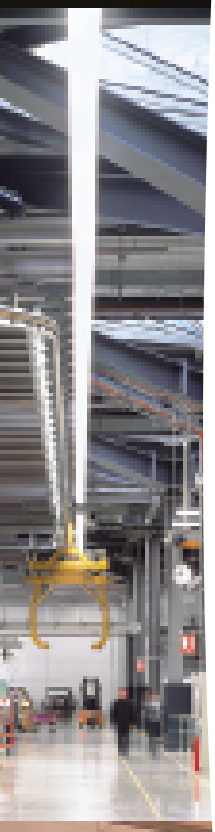
Application	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL	1.6	1.7	1.9	2.6	5.0	10.2	19.9	29.7
Office	0.4	0.4	0.4	0.5	0.6	1.2	2.4	3.8
Wholesale and Retail	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Industrial	0.0	0.0	0.0	0.0	0.7	1.5	3.4	5.0
Education	0.0	0.0	0.0	0.0	0.2	0.8	1.9	3.2
Health	0.2	0.2	0.2	0.3	0.4	0.8	1.8	2.6
Hospitality	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3
Residential	1.0	1.1	1.3	1.8	3.1	5.8	10.2	14.7
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5: German human centric lighting market volume (€ million)

Application	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL	17.0	19.0	22.6	29.9	58.6	115.4	220.9	315.4
Office	4.1	4.2	4.9	5.9	7.0	15.9	34.2	48.6
Wholesale and Retail	0.0	0.1	0.1	0.2	0.4	0.6	0.8	0.9
Industrial	0.0	0.0	0.0	0.0	7.2	15.4	35.1	52.2
Education	0.0	0.0	0.0	0.0	1.3	7.1	18.5	28.3
Health	2.1	2.8	3.6	5.0	8.8	12.5	16.6	22.2
Hospitality	0.0	0.1	0.1	0.2	0.5	1.0	1.6	2.1
Residential	10.8	11.9	13.9	18.6	33.5	63.0	114.0	161.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 6: Italian human centric lighting market volume (€ million)

Application	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL	3.1	3.5	4.4	6.0	10.3	20.1	35.2	49.6
Office	0.7	0.7	0.8	0.9	1.4	2.8	5.0	8.2
Wholesale and Retail	0.0	0.1	0.1	0.1	0.2	0.3	0.3	0.3
Industrial	0.0	0.0	0.1	0.3	0.9	2.5	5.7	8.5
Education	0.0	0.0	0.1	0.2	0.6	1.9	4.1	6.1
Health	0.4	0.4	0.4	0.4	0.7	1.6	3.2	4.5
Hospitality	0.0	0.1	0.1	0.2	0.3	0.6	0.7	0.8
Residential	1.9	2.3	2.8	3.9	6.1	10.5	16.2	21.4
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



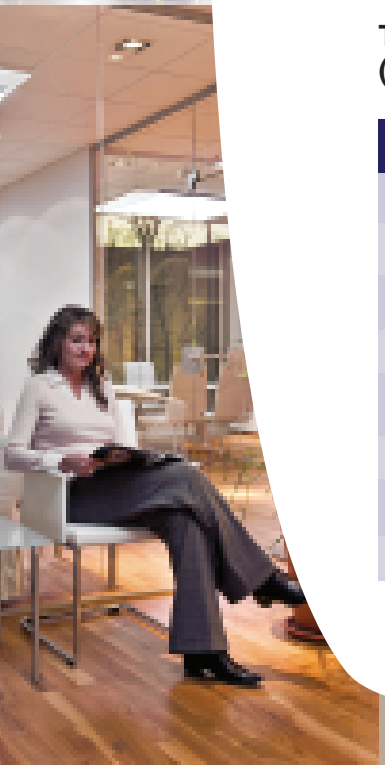


Table 7: Polish human centric lighting market volume (€ million)

Application	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL	2.3	2.4	3.0	4.6	8.5	19.0	32.4	43.9
Office	0.6	0.6	0.6	0.7	1.0	2.1	3.7	5.1
Wholesale and Retail	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Industrial	0.0	0.0	0.1	0.4	1.2	3.3	6.0	8.3
Education	0.0	0.0	0.1	0.3	0.9	3.1	6.2	8.8
Health	0.3	0.3	0.4	0.5	0.9	2.6	4.6	6.3
Hospitality	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Residential	1.4	1.5	1.9	2.7	4.4	7.7	11.6	15.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 8: Swedish human centric lighting market volume (€ million)

Application	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL	2.5	2.7	3.2	4.7	8.8	19.8	35.9	48.1
Office	0.6	0.6	0.6	0.7	1.0	2.0	3.8	5.3
Wholesale and Retail	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Industrial	0.0	0.0	0.0	0.1	0.4	1.2	2.4	3.4
Education	0.0	0.0	0.1	0.2	0.8	2.9	6.8	10.1
Health	0.3	0.3	0.3	0.3	0.6	1.5	3.0	4.2
Hospitality	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
Residential	1.6	1.8	2.1	3.3	5.9	11.9	19.7	24.8
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Penetration rates – countries

Table 9: Austrian penetration of human centric lighting (percentage of total relevant floor space)

Application	2013	2014	2015	2016	2017	2018	2019	2020
Office	1.4%	1.4%	1.4%	1.6%	2.0%	4.0%	8.8%	15.0%
Wholesale and Retail	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%
Industrial	0.0%	0.0%	0.0%	0.0%	0.7%	1.6%	3.8%	6.0%
Education	0.0%	0.0%	0.0%	0.0%	0.7%	4.0%	9.8%	18.0%
Health	1.5%	1.5%	1.5%	1.8%	2.6%	5.7%	13.3%	21.0%
Hospitality	0.0%	0.0%	0.1%	0.1%	0.2%	0.4%	0.6%	0.9%
Residential	0.2%	0.2%	0.3%	0.4%	0.6%	1.4%	2.6%	4.0%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

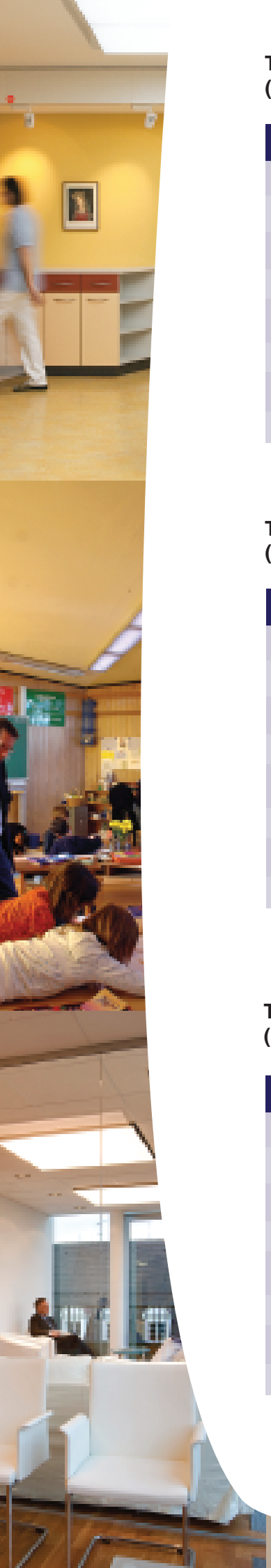


Table 10: German penetration of human centric lighting (percentage of total relevant floor space)

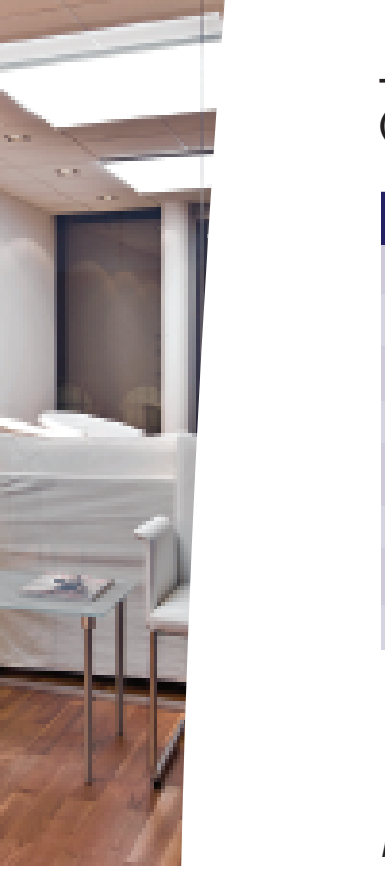
Application	2013	2014	2015	2016	2017	2018	2019	2020
Office	1.2%	1.3%	1.4%	1.6%	1.8%	4.3%	9.8%	15.0%
Wholesale and Retail	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.2%	0.2%
Industrial	0.0%	0.0%	0.0%	0.1%	0.7%	1.6%	3.8%	6.0%
Education	0.0%	0.0%	0.0%	0.0%	0.7%	4.0%	11.0%	18.0%
Health	2.2%	3.0%	3.7%	4.8%	8.2%	11.9%	16.8%	24.0%
Hospitality	0.0%	0.0%	0.1%	0.1%	0.2%	0.4%	0.6%	0.9%
Residential	0.2%	0.2%	0.2%	0.3%	0.5%	0.9%	1.6%	2.3%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 11: Italian penetration of human centric lighting (percentage of total relevant floor space)

Application	2013	2014	2015	2016	2017	2018	2019	2020
Office	0.5%	0.5%	0.5%	0.5%	0.8%	1.7%	3.4%	6.0%
Wholesale and Retail	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%
Industrial	0.0%	0.0%	0.0%	0.1%	0.2%	0.6%	1.5%	2.4%
Education	0.0%	0.0%	0.1%	0.2%	0.6%	2.0%	4.6%	7.2%
Health	0.7%	0.7%	0.8%	0.7%	1.1%	2.7%	5.5%	8.4%
Hospitality	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%
Residential	0.1%	0.1%	0.2%	0.2%	0.4%	0.7%	1.1%	1.6%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 12: Polish penetration of human centric lighting (percentage of total relevant floor space)

Application	2013	2014	2015	2016	2017	2018	2019	2020
Office	0.9%	0.9%	0.9%	1.1%	1.6%	3.3%	6.1%	9.0%
Wholesale and Retail	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%
Industrial	0.0%	0.0%	0.1%	0.2%	0.5%	1.3%	2.5%	3.6%
Education	0.0%	0.0%	0.1%	0.3%	1.0%	3.3%	7.0%	10.8%
Health	0.5%	0.5%	0.6%	0.9%	1.5%	4.5%	8.5%	12.6%
Hospitality	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.4%	0.5%
Residential	0.2%	0.2%	0.2%	0.3%	0.6%	1.2%	1.8%	2.4%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%



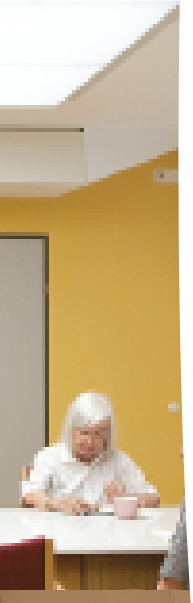
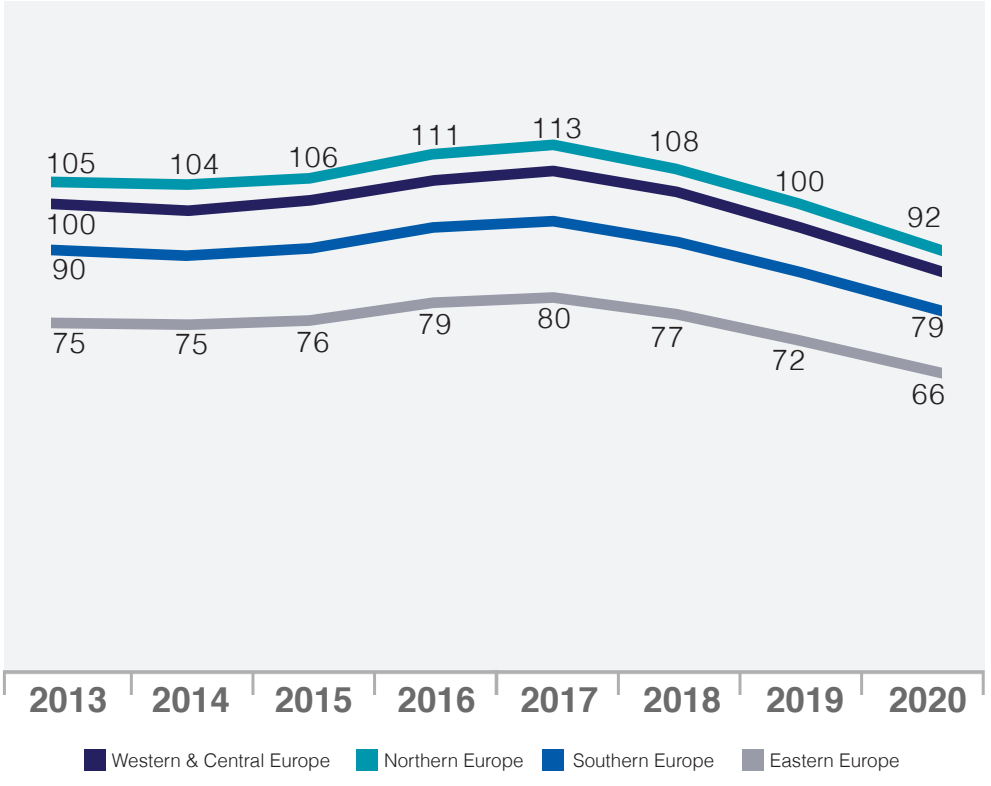


Table 13: Swedish penetration of human centric lighting (percentage of total relevant floor space)

Application	2013	2014	2015	2016	2017	2018	2019	2020
Office	1.9%	1.9%	1.9%	2.0%	2.8%	6.0%	12.0%	18.0%
Wholesale and Retail	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.2%	0.3%
Industrial	0.0%	0.0%	0.1%	0.2%	0.7%	2.2%	4.7%	7.2%
Education	0.0%	0.0%	0.1%	0.4%	1.4%	5.5%	13.5%	21.6%
Health	1.7%	1.7%	1.7%	1.8%	3.1%	8.0%	16.6%	25.2%
Hospitality	0.0%	0.0%	0.1%	0.1%	0.3%	0.6%	0.8%	1.1%
Residential	0.2%	0.2%	0.3%	0.4%	0.7%	1.4%	2.0%	2.8%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Normalized price development

Table 14: Normalized prices for human centric lighting systems (indexed price per square meter)



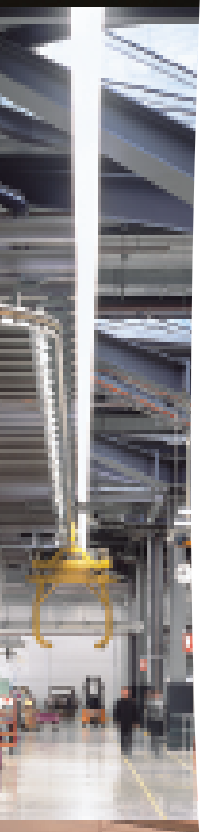
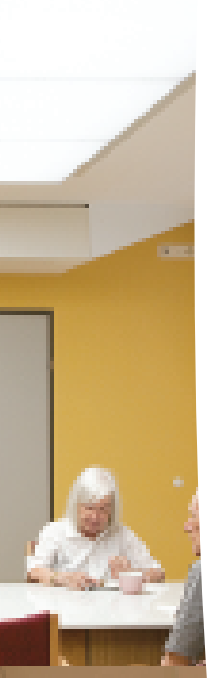


Table of figures

Glossary

Term	Definition
Eastern Europe	*Consisting of Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Estonia, Latvia, Lithuania*
LED	*Light-emitting diode*
Northern Europe	*Consisting of Denmark, Finland, Norway, Sweden*
R&D	*Research and development*
Southern Europe	*Consisting of Cyprus, Greece, Italy, Portugal, Malta, Spain*
SSL	*Solid-state lighting*
TCO	*Total cost of ownership*
Western and Central Europe	*Consisting of Austria, Belgium, France, Germany, Ireland, Luxemburg, Netherlands, Switzerland and the United Kingdom*



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