Good Light Group

The socio-economic impact of good light during the day

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Up to $ 2.500 yearly savings per capita might be in reach

Sleep deprivation will result in productivity losses (1,4-2,4 %), mainly due to absenteism and presenteism. Two hours of exposure to good light during the daytime might result in $450-650 of savings per capita per year.
As far as the impact on healthcare cost is concerned even higher numbers might be anticipated. For the five major physical chronic diseases, i.e.: obesity, diabetes, acute myocardial infarctions, strokes and breast cancer, exposure to good light might result in savings on healthcare cost ranging from $1150-1650. For major depressive disorder a saving of $100-200 has been estimated. The overall saving for all chronic diseases combined might reach 18-28% of the annual healthcare cost. This impact however will only be achieved when good light exposure has become an integral part of people's life.

With the onset of the industrial revolution it has become more challenging to live in line with the natural night and day rhythm. Nowadays our activities are increasingly being dominated by the 24/7 economy. Around the turn of the century people already spend up to 90% of their time indoors . To support life and work indoors, humans use artificial light sources, in some cases, like nightwork, all night long. The negative effect of light during the night is well documented in the scientific literature. The beneficial effects of light exposure during the day are far less studied nor documented. Light has a dominant role in synchronizing our biological clock with the natural rhythm of day and night. In addition, it has a direct impact on our alertness, learning ability and mood . Over the last years our understanding about the role of light on health and well-being has drastically increased, culminating in science-based recommendations by the group of 18 specialists in the field, often referred to as the Manchester Group .

Burns et al. have examined the associations between time spent outdoors in daylight and mood, sleep, and circadian rhythm related outcomes. Information was drawn from the UK Biobank involving half a million UK adults. Participants provided detailed information via assessments and touch-screen questionnaires. The participants reported spending on average 2,5 hrs outdoors per day. Statistically significant correlations were found between daylight exposure and ten mood, sleep, and circadian rhythm related key variables. The effect for one additional hour of daylight exposure each day is summarized in the table below.
An Odds Ratio (OR) or an Incidence Rate Ratio (IRR) of 1 indicates that exposure would have no effect on the outcomes. If OR and IRR >1 the impact is positive, while for OR and IRR <1 the impact is negative. The OR values quoted were based on cohorts ranging between 150.000 and 450.000 individuals. The IRR values cover groups of 25.000-30.000 people.
Sleep duration was also extracted, but this variable was only used as a covariate for adjustment. According to the authors there might be a potential confounding role of this variable on time spent in outdoor light, as it directly impacts the time available to spend outdoors. The confounding of sleep duration on time spent outdoors is rather doubtful from my perspective. The data indicate that daylight exposure causes a shift towards earlier chronotypes, so people will go to bed earlier and also will get up much easier in the morning, as indicated by the data in Table 1.

Table 1 - Association with time spent in outdoor lighting

	indicator	Unadjusted model	Adjusted model
Ease of getting up	OR	1,95	1,46
Happiness	OR	1,65	1,45
Tiredness	OR	0,66	0,81
Late chronotype	OR	0,71	0,76
Low mood	OR	0,74	0,89
Anhedonia	OR	0,82	0,96
Major Depressive Disorder	IRR	0,87	0,95
Antidepressant use	IRR	0,88	0,95
Neuroticism	OR	0,90	0,96
Insomnia symptoms	OR	0,94	0,96

In other studies, e.g. the RAND study , sleep duration next to sleep quality is mostly seen as major indicators for people's productivity. The use of sleep duration as a covariate for adjustment probably will result in an overcorrection of the effects studied. The adjustment of the data is based on corrections, next to sleep duration, for age, sex, the season for filling in the questionnaire, the employment, the degree of exercising and socialization. No clear indications are given on how the adjustment was actually performed. Therefore, we based our analysis both on the unadjusted and adjusted data, indicating a plausible range for the impact of daylight. The primary goal of using the adjusted statistical model is to isolate the effect of daylight exposure and to exclude other factors that may bias the outcome of the analysis. When the adjustment is applied, still statistically significant correlations are found between the ten indicators of Table 1 and daylight exposure.

The first economic data on the lack of sleep has been published by Kessler et al. They studied in detail the impact of insomnia on the 2008 productivity cost in the US. The loss in productivity cost was estimated to amount to 63,2 billion dollar per annum. Based on more recent 2016 data the RAND study also has concluded that lack of sleep substantially decreases the cognitive performance and work place productivity of adults. For five major OECD countries, i.e.: the US, Canada, the UK, Germany and Japan the study managed to quantify the effect of a lack of sleep on workplace productivity, caused by absenteeism as well as presenteeism. The direct economic cost has been estimated to amount to 680 billion dollars per year. Half of this cost has been attributed to people sleeping less than six hours a night, the other half to people sleeping between six and seven hours a night. Sleeping less than six hours decreases productivity by 2,4 %, while sleeping between six to seven hours still has a negative impact on the work place productivity, amounting to 1.4%. Sleep deprivation will largely vary from one country to another, but is substantial in all cases (see Table 2).

Table 2 – Average sleep duration of adult population

Fraction (%)	US	UK	Germany	Japan	Canada
< 6 hrs of sleep	18	16	9	16	6
6-7 hrs of sleep	27	19	21	40	20

In the RAND recommendations to change this for the better, light has nowhere been mentioned. Nevertheless, at that moment in time some smaller scientific studies already indicated that light has a substantial positive impact on sleep duration. Boubekri et al. showed that people working in windowless offices sleep, averaged over all days of the week, almost exactly one hour less per night than people working in an office with daylight exposure, while on working days they will sleep 45 minutes shorter. Combining these results with the ones in the RAND report, would indicate that the economic impact of sleep deprivation on work place productivity might almost be halved, by exposing employees to sufficient light during daytime.
The cohort sleeping normally between six and seven hours would get the recommended amount sleep, based on one hour of additional sleep duration, i.e.: between seven and eight hours, bringing their productivity to the level of the reference group and almost completely eliminating the economic loss related to it. A substantial improvement of the work place productivity might be anticipated for the cohort sleeping normally less than six hours, because most of them will sleep longer as well. Based on the available data it is however not feasible to quantify this improvement exactly. In the following table it is assumed that half of the cohort sleeping less than six hours will get 6 to 7 hours of sleep after exposure to "good light" and its productivity consequently will improve. The other half on the contrary would not show sufficient improvement in sleep duration to affect their productivity. Based on the improvement of productivity shown, exposing people to the right light at the right time, might save society up to 410 billion $ in direct costs per annum for the five OECD countries studied (see Table 3), having a population of 655 million people. The savings consequently would amount to $626 per person per year assuming one hour of additional sleep.
When the same approach is applied based on three quarters of an hour extra sleep, the number found on working days, the saving for the first cohort is estimated to reach $90 billion and for the second cohort $200 billion, totalling $290 billion or $443 per person per year for the five OECD countries included in the RAND study.

Table 3 - Economic impact of lack of sleep

Sleep duration	< 6hrs	6-7 hrs	7-9 hrs
RAND	$340 billion	$340 billion	$0
Good light exposure	$170-250 billion	$100-140 billion	$0

The RAND study also shows that insufficient sleep impairs health and well-being, resulting in an increased mortality risk for adults. People sleeping less than six hours a night have a 13% higher mortality risk than people sleeping seven to nine hours, as recommended by the health authorities. The authors however were in no position to estimate the economic impact of the long-term health risks of sleep deprivation.

O. Giuntella and F. Mazzonna have estimated the economic cost of the misalignment between social and biological rhythms arising at the border of the US time-zones in the presence of relatively rigid social schedules (e.g., work and school schedules). This epidemiological research suggests that social and biological time are increasingly drifting apart, coined by the authors as “social jetlag”. Based on existing estimates of the health care costs of obesity, diabetes, acute myocardial infarctions, strokes and breast cancer, they indicated that the care cost for chronic diseases caused by “social jetlag”, while crossing US time zone borders. Based on the RAND data they also estimated the loss of productivity caused by this “social jet lag”. They have concluded that the care cost for chronic diseases would outnumber the cost of productivity loss by a factor of 3.5. In the years 2016-2018 the healthcare cost in the US amounted to 17% of GDP, while for the other four OECD countries mentioned they were at the 10-11% level . Taking the higher US cost into account (see Table 4), we estimate the healthcare cost to be a factor of 2.6 higher for the five OECD countries than the cost of productivity loss. Consequently, the healthcare cost savings by daylight exposure might amount to $1.161-1.640 per person per year.

Table 4 - Healthcare cost (2016-2018)

Country	GDP (billion $)	Healthcare cost (billion $)	Inhabitants (M)	Healthcare cost per capita ($)
US	18.000	3,060	340	9.000
Canada	1.600	168	39	4.300
UK	2.700	285	68	4.200
Germany	3.850	404	83	4.900
Japan	4.700	494	125	3.950
OECD(4)	12.800	1.351	315	4.290
OECD(5)	30.800	4.411	655	6.730

In 2018 the cost for treating Major Depressive Disorder (MDD) in the US reached a level of $326 billion. For the five OECD countries, we use as a point of reference, this would amount to $552 billion. One hour of exposure to daylight might reduce the incidence of MDD by 5-13% (see Table 1). These findings are in line with the recent epidemiological findings (N = 87,000) by Burns et al. that the exposure to abundant daylight lowers the risk of depression by 20%. The Manchester Group recommends an exposure to 250 MEDI lux at the eye level, a level that will be reached under all conditions by daylight. We as the Good Light Group recommend an exposure at the same level for at least 2hrs, preferably in the morning . A two hours exposure would result in a reduction of the cost to treat Major Depressive Disorder with $55-144 billion, or $84-219 per person per year for the five OECD countries under consideration.

One may wonder if daylight exposure might replace the use of antidepressants and sleep medication. From Table 1 it becomes clear that the impact on medication use is rather limited, i.e.: 10-24% for antidepressants 8-12% for insomnia medication after 2hrs of daylight exposure.
Based on the OECD data for 2017 on the intake of antidepressants in Germany, the UK and the US we estimate the intake to be 71M defined daily doses a year at the OECD(5) level. The cost per dose at that moment in time was within the $1.2-1.7 range, meaning the cost saving by reduction of the use of antidepressants would be less than $1 per person per year. Starting from the Statista data on the consumption of hypnotic and sedative medication we estimate the intake of sleep medication to be around 43M defined daily doses a year in 2020 for the five OECD countries. Its cost per dose in 2011 was in the range of $1,7-7.6. Consequently, the cost savings by the reduction in use of sleep medication also in this case would be less than 1$ per person per year.

The major conclusion of this literature survey is summarized in Table 5. Not being in sync with the natural rhythm of night and day has the highest economic impact; in the long run it causes a higher incidence of chronic diseases, resulting in increased mortality risk. Because lack of sleep can result in a substantial loss in productivity for the working population, its economic burden is also substantial. Next to this, adolescents, who typically tend to be later chronotypes, are forced to go to school and college at times they still want to be asleep, resulting in a major impact on their learning performance. Its economic impact however could not be taken into the equation by lack of relevant data. People living in Western Europe, irrespective of their chronotype, are forced in summer to cope with a timing nearly two hours out of sync with the sun. They are only out-beaten by the Xinjiang population, who need to cope with a difference of three hours, living on Beijing time. The plea to return to standard time, becomes more and more backed by culminating scientific evidence . Daylight exposure can have a major impact on people's mood, i.e.: they feel clearly much happier and are less tired during the day. Major depressive disorder also has a substantial economic impact, be it lower than the previously discussed impact on chronic diseases and sleep quality. In this case loss of productivity is also responsible for about 60% of the total cost.

Table 5 – Potential saving per person per year (2016-2018) after 2hrs of exposure to good light

Chronic diseases	$1.161 - 1.640
Sleep deprivation (absenteism & presenteism)	$443 - 626
Major Depressive Disorder	$84 - 219
Antidepressant medication	< $1
Sleep medication	< $1

Over the last years our insights in the role of light on health and well-being has drastically increased. On the basis of these recent insights, academia must be able to design more extensive studies, enabling us to quantify the effect of good light on people's health and well-being more accurately. Notably the major issue to be addressed urgently is the creation of a dose response curve for the effect of good light. In this way we will be able to generate even more reliable data on the impact of good lighting conditions.

From this literature survey it becomes clear that exposure to daylight or to good lighting conditions indoors during the day makes people clearly happier and ensures good health quality, fully underpinning our slogan “**Good Light for a Happier and Healthier Life**”.

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