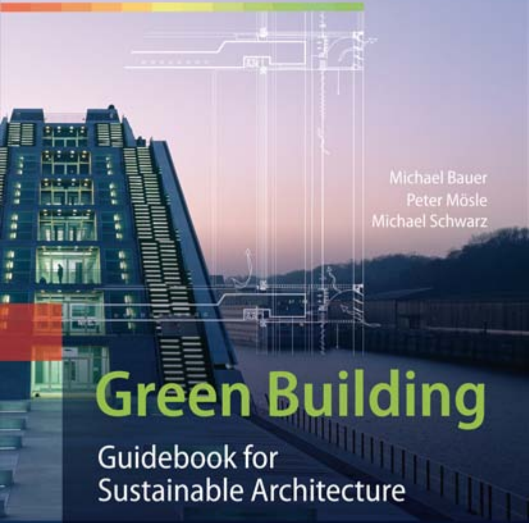

Michael Bauer
Peter Mösle
Michael Schwarz

Green Building

Guidebook for Sustainable Architecture

Springer

Prof. Dr. Michael Bauer
Peter Mösle
Dr. Michael Schwarz

Drees & Sommer Advanced Building Technologies GmbH
Obere Waldplätze 11
70569 Stuttgart
Germany

info.green-building@dreso.com

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By Michael Bauer, Peter Mösle and Michael Schwarz

Green Building – Guidebook for Sustainable Architecture

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Preface by the Authors

There are essential challenges for the future, such as taking a responsible approach towards nature. Also, there is the search for an environmentally-friendly energy supply that is easy on resources and climate. A further challenge is the search for clean sources of drinking water. Aside from novel and more efficient technologies than are currently in place, additional emphasis will thus need to be placed on reducing energy and water requirements without decreasing either comfort level or living standard. The building sector worldwide uses up to 40% of primary energy requirements and also a considerable amount of overall water requirements. Meanwhile, the service life of both new and renovated buildings reaches far into the future. Hence, these buildings considerably influence envisioned energy and water needs for the next 50 to 80 years. This means that, even today, they must be planned, constructed and run according to the principles of energy efficiency, climatic aspects, and water conservation. This applies even when global outlines to counteract climate change seem to lie too far in the future to grasp. Buildings that show these attributes of sustainability are called Green Buildings. They unite a high comfort level with optimum user quality, minimal energy and water expenditure, and a means of energy generation that is as easy as possible on both climate and resources, all this under economic aspects with a pay-back span of 5 to 15 years. Green Buildings are also capable of meeting even the most stringent demands for aesthetics and architecture, which is something that the examples given in this book clearly show. Planning these buildings, according to an integrated process, requires the willingness of all those involved: to regard the numerous interfaces as seams of individual assembly sections, the synergies of which are far from being exhausted yet. An holistic and specific knowledge is needed, regarding essential climatic, thermal, energy-related, aero-physical and structural-physical elements and product merits, which does not end at the boundaries of the individual trades. Further, innovative evaluation and simulation tools are being used, which show in detail the effects throughout the building's life cycle. The examples in this book show that a building can indeed be run according to the principles of energy and resource conservation when – from the base of an integrated energy concept – usage within a given establishment is being consistently tracked and optimized. The resulting new fields of consulting and planning are called energy design, energy management and Life Cycle Engineering. In this particular field, Drees & Sommer now has over 30 years of experience, as one of the leading engineering and consulting firms for the planning and operation of Green Buildings. Our cross-trade, integrated knowledge stems from Drees & Sommer's performance sectors of Engineering, Property Consulting and Project Management.

The contents of this book are based on the extensive experience of the authors and their colleagues – during their time at Drees & Sommer Advanced Building Technologies GmbH – in planning, construction and operation of such buildings. It documents, through examples, innovative architectural and technical solutions and also the target-oriented use of specialist tools for both planning and operation. This book is directed primarily at investors, architects, construction planners and building operators, looking for an energy approach that is easy on resources. It is meant as a guideline for planning, building and operation of sustainable and energy-efficient buildings.

At this stage, we would also like to thank all the renowned builders and architects together with whom, over the last years, we had the honour of planning, executing and operating these attractive and innovative buildings. The level of trust they put in us is also shown by the statements they gave us for this book and the provided documentation for many prominent buildings. For their kind assistance in putting together this book, a special thanks is due.

We would be pleased if, by means of this book, we succeeded in raising the level of motivation for erecting Green Buildings anywhere in the world, whether from scratch or as renovation projects. Engineering solutions to make this happen are both available and economically viable. Our sustainability approach goes even further, incidentally. The CO_2 burden resulting from the production and distribution of this book, for instance, we have decided to compensate for by obtaining CO_2 certificates for CO_2 reducing measures. Hence, you are free to put all your energy into reading this book!

We would now like to invite you to join us on a journey into the world of Green Buildings, to have fun while reading about it, and above all, to also discover new aspects that you can then use for your own buildings in future.

Heubach, Gerlingen, Nuertingen

Michael Bauer
Peter Mösle
Michael Schwarz

A

B

The Motivation behind the Green Building Idea

C D

Fig. A3 State Office Building in Berlin. Architects: Petzinka Pink Technologische Architektur®, Duesseldorf

Increased Public Focus on Sustainability and Energy Efficiency

Man's strive for increased comfort and financial independence, the densification of congested urban areas, a strong increase in traffic levels and the growing electric smog problem due to new communication technologies all cause ever rising stress levels in the immediate vicinity of the individual. Quality of life is being hampered and there are negative health effects. All this, coupled with frequent news about the global climate change, gradually leads to a change of thought throughout society.

In the end, it is society that must bear the effects of economic damage caused by climatic change. Due to the rising number of environmental catastrophes, there was in increase of 40% between the years of 1990 to 2000 alone, when compared to economic damage sustained between 1950 and 1990. Without the implementation of effective measurements, further damage, which must therefore still be expected, cannot be contained. Companies across different industries have meanwhile come to realize that only a responsible handling of resources will lead to long-term success. Sustainable buildings that are both environmentally and resource-friendly enjoy an increasingly higher standing when compared to primarily economically oriented solutions.

Aside from social and economic factors, steadily rising energy costs over recent years facilitate the trend towards sustainability. Over the past 10 years alone, oil prices have more than doubled, with an annual increase of 25% between 2004 and 2008. Taking into account both contemporary energy prices and price increases, energy saving measures have become essential in this day and age. A further reason for the conscientious handling of resources is a heavy dependency on energy import. The European Union currently imports more than 60% of its primary energy, with the tendency rising. This constitutes a state of dependency that is unsettling to consumers and causes them to ask questions about the energy policy approach of the different nations. Since energy is essential, many investors and operators place their trust in new technologies and resources in order to become independent of global developments.

Real Estate, too, is starting to think along new lines. End-users look for sustainable building concepts, with low energy and operating costs, which offer open, socially acceptable and communication-friendly structures made from building materials that are acceptable from a building ecology point of view and have been left in as natural a state as possible. They analyze expected operating costs, down to building renaturation, and they run things in a sustainable manner. Aside from looking at energy and operating costs, they also take an increasing interest in work performance levels, since these are on the

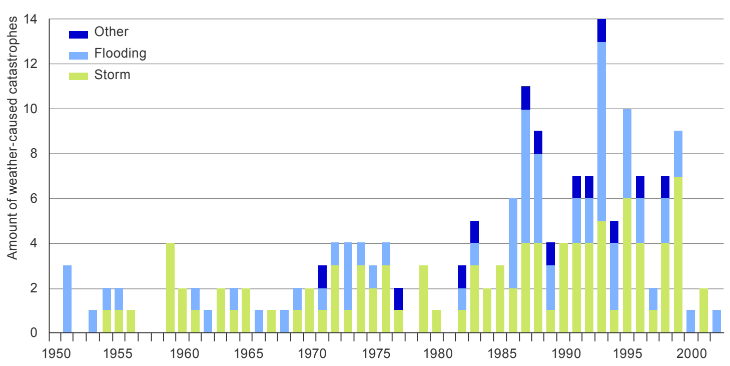


Fig. A1 Major weather-caused catastrophes from 1950 to 2000

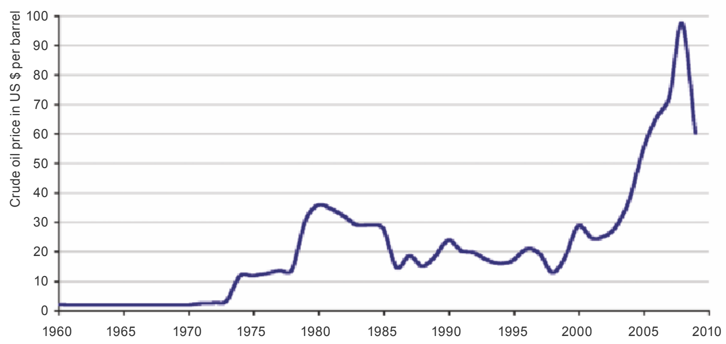


Fig. A2 Nominal Development of Crude Oil Prices from 1960 onward

rise for workers in Europe. Only when people feel good and are healthy they can work at their optimum performance level. By necessity, this means providing both a comfortable and healthy environment. Investors also know they should use sustainable aspects as arguments for rental and sale, since nowadays tenants base their decisions in part on energy and operating costs and are looking for materials that are in accordance with building ecology considerations. Green Buildings always offer a high comfort level and healthy indoor climate while banking on regenerative energies and resources that allow for energy and operating costs to be kept as low as possible. They are developed according to economically viable considerations, whereby the entire building life cycle – from concept to planning stage, from construction to operation and then back to renaturation – is taken into account. Green Buildings, therefore, are based on an integrated and future-oriented approach.

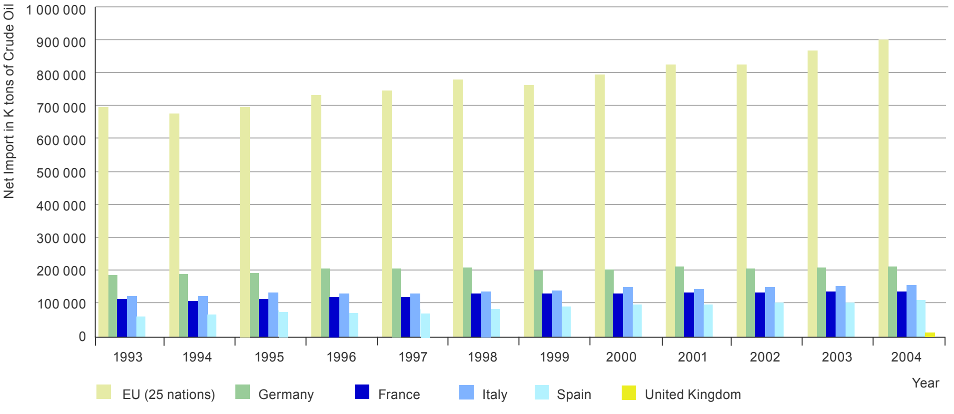


Fig. A4 European Union Dependency on Energy Imports

Supportive Framework and General Conditions

Owing to rising public interest in sustainable and ecological solutions, the last few years have resulted in the establishment of numerous framework conditions that facilitate the use of energy-saving technologies, energy sources that are easy on resources and sustainable products for the property sector.

The base of a sustainable energy policy can be found in various national, European and International laws, standards, norms and stipulations that specify measurable standards of energy efficiency for buildings and facilities. Further, the norms define the minimum standard for energy efficiency of buildings and facilities. The norms also set minimum standards for thermal comfort, air quality and visual comfort.

Across Europe, there is currently a drive to unify these standards. On an international level, however, the different nations are setting their own guidelines and these cannot necessarily be directly compared to each other. The standards are being supported by a variety of available and targeted grants for promising technologies that are currently not yet economical on a regenerative level. Examples for this in Germany would be the field of photovoltaics, for instance, or of near-surface geothermics, solar thermics, biogas plants or energy-conserving measures for the renovation of old buildings.

In the currently available laws, standards and stipulations, however, not all the essential building and facility areas are being considered. This means that many of these areas are unable to fulfil their true potential when it comes to the possibility of optimisation on an energy level. Further, legally defined critical values for energy consumption are generally below those required for Green Buildings. These critical values are usually set in a manner that allows for marketable products to be used. Laws and stipulations will, therefore, always be backward when compared to the actual market possibilities for obtaining maximum energy efficiency.

This gap can be bridged by the use of Green Building labels, guidelines and quality certificates, since these can at least recommend adherence to more stringent guidelines. The higher demands placed on true energy efficiency can also be justified by the fact that the technology in buildings and facility has a great lifespan. This means that a CO_2 emission limit specified today will have long-ranging effects into the future. Today's decisions, therefore, are essential aspects in determining future emission levels.

CO_2 Emission Trade

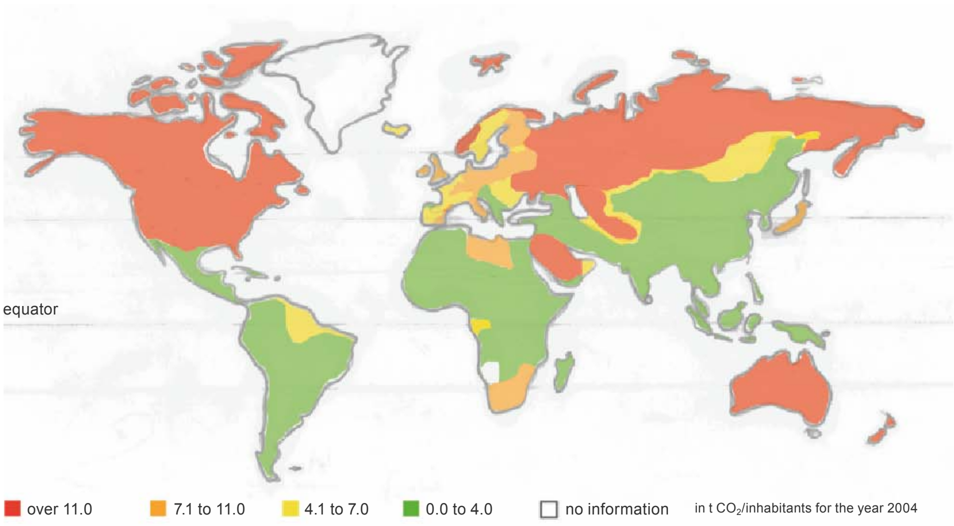


Fig. A5 CO_2 Emissions Distribution levels per Capita, World Population, for the year 2004

From February 2005, the Kyoto protocol applies. It is meant to reduce the levels of global greenhouse gas emissions. The origin of this protocol can be traced back to 1997. It stands for an international environmental treaty where the 39 participating industrial nations agreed, by 2012, to reduce their collective emission of environmentally harmful gases, like, for instance, carbon dioxide (CO_2) by a total of 5% when compared to 1990 levels. Within the European Community, the target reduction level is 8%, in Germany even 21%. As *Figure A6* shows, most industrial nations fall far short of meeting their targets at this time.

By means of CO_2 trade, a long-term corrective measure is supposed to be achieved for the human-caused greenhouse effect. The environment is hereby considered as goods, the conservation of which can be achieved through providing financial incentives.

Politicians have now recognized that environmental destruction, resulting from climatic change, firstly cannot only be counteracted by purely economic means and secondly must be regarded as a serious global problem. For the first time, the idea behind the CO_2 trade clearly unites both economical and environmental aspects. How precisely does CO_2 emissions trading work, then? For each nation that has ratified the Kyoto protocol, a maximum amount of climate-damaging greenhouse gases is assigned. The assigned amount corresponds to maximum permitted usage. The Greenhouse Gas Budget, which goes back to 1990, takes into account future development for each participating nation. Economies that are just starting to rise as, for instance, can be found in Eastern Europe, are permitted a higher degree of CO_2 emissions. Industrial nations, however, must make do every year with a reduced greenhouse budget.

For each nation, a certain number of emissions credits are assigned on the basis of the national caps on the emissions in that nation. These credits are assigned to the participating enterprises, according to their CO_2 emissions level. If the emissions of a given enterprise remain below the amount of emission credits that it has been assigned (Assigned Allocation Units or AAUs), for instance as a result of CO_2 emission reduction due to energy-savings measures applied there, then the unused credits can be sold on the open market. Alternatively, an enterprise may purchase credits on the open market if its own emission-reducing measures would be more costly than the acquisition of those credits. Further, emission credits can be obtained if a given enterprise were to invest, in other developing or industrial nations, into sustainable energy supply facilities. This means that climate protection takes place precisely where it can also be realized at the smallest expense.

In Germany, during the initial stage that runs up to 2012, participation in the emissions trade process is only compulsory for the following: operators of large-size power plants with a thermal furnace capacity in excess of 20 MW and also operators of power-intensive industrial plants. With this, ca. 55% of the CO_2 emissions potential directly participates in the trade. Currently, neither the traffic nor the building sectors are part of the trade in either a private or commercial manner. However, in Europe, efforts are already underway to extend emissions trading to all sectors in the long run. In other, smaller European nations like, for instance, Latvia and Slovenia, plants with a lower thermal output are already participating in the emissions trade. This is explicitly permitted in the Emissions Trade Bill as an opt-in rule. The evaluation and financing of buildings based on their CO_2 market value is something that, in the not-too-distant future, will reach the property sector as well. A possible platform for building-related emissions trade already exists with the EU directive on overall energy efficiency and with the mandatory energy passport. Our planet earth only has limited biocapacity in order to regenerate from harmful substances and consumption of its resources. Since the Nineties, global consumption levels exceed available biocapacity. In order to reinstate the ecological balance of the earth, the CO_2 footprint needs to be decreased. Target values that are suitable for sustainable development have been outlined in *Figure A7*.

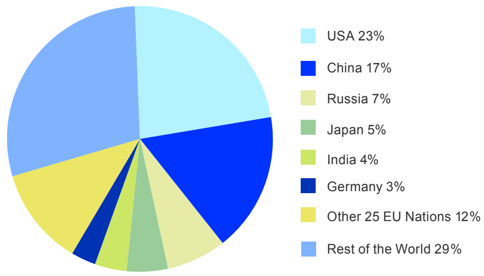


Fig. A8 Distribution of CO_2 Emissions by World Nations for the Year 2004

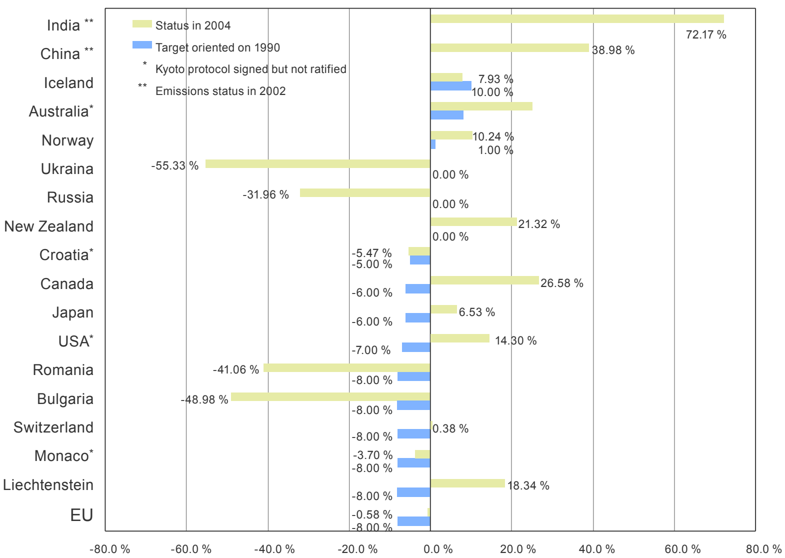


Fig. A6 Reduction Targets, as agreed in the Kyoto Protocol, and current Standing of CO_2 Emission Levels for the worldwide highest global Consumers

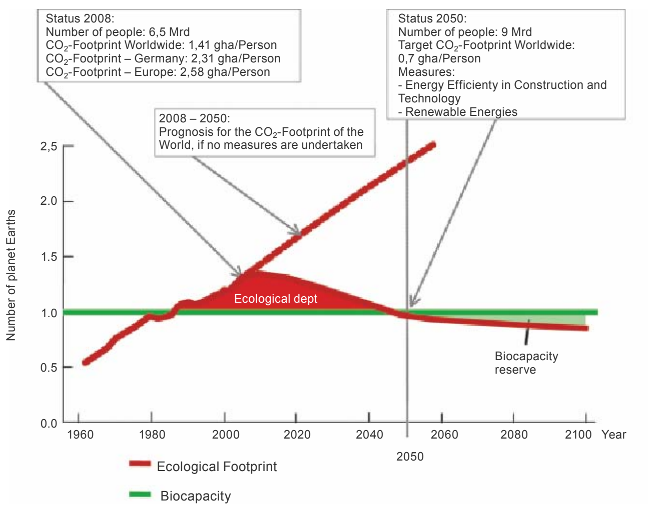


Fig. A7 Sustainability wedges and an end to overshoot

Rating Systems for Sustainable Buildings

Rating systems have been developed to measure the sustainability level of Green Buildings and provide best-practice experience in their highest certification level. With the given benchmarks, the design, construction and operation of sustainable buildings will be certified. Using several criteria compiled in guidelines and checklists, building owners and operators are given a comprehensive measurable impact on their buildings' performance. The criteria either only cover aspects of the building approach to sustainability, like energy efficiency, or they cover the

System (Country of origin)	DGNB (Germany)	BREEAM (Great Britain)	LEED (USA)	Green Star (Australia)	CASBEE (Japan)	Minergie (Switzerland)
Initiation	2007	1990	1998	2003	2001	1998
Key Aspects of Assessment & Versions	- Ecological Quality - Economical Quality - Social Quality - Technical Quality - Process Quality - Site Quality Purpose of the DGNB Certificate: Application for buildings of any kind (Office high-rises, detached residential homes, infrastructure buildings etc.) DGNB for: - Offices - Existing Buildings - Retail - Industrial - Portfolios - Schools	- Management - Health & Well-being - Energy - Water - Material - Site Ecology - Pollution - Transport - Land consumption BREEAM for: Courts, EcoHomes, Education, Industrial, Healthcare, Multi-Residential, Offices, Prisons, Retail	- Sustainable Sites - Water Efficiency - Energy & Atmosphere - Material & Resources - Indoor Air Quality - Innovation & Design LEED for: New Construction, Existing Buildings, Commercial Interiors, Core and Shell, Homes, Neighborhood Development, School, Retail	- Management - Indoor Comfort - Energy - Transport - Water - Material - Land Consumption & Ecology - Emissions - Innovations Green Star for: - Office – Existing Buildings - Office – Interior Design - Office – Design	Certification on the basis of "building-environment efficiency factor" BEE=Q/L Q … Quality (Ecological Quality of buildings) Q1 - Interior space Q2 - Operation Q3 - Environment L … Loadings (Ecological effects on buildings) L1 - Energy L2 - Resources L3 - Material Main Criteria: (1) Energy Efficiency (2) Resource Consumption Efficiency (3) Building Environment (4) Building Interior	4 Building standards are available: (1) Minergie - Dense building envelope - Efficient heating system - Comfort ventilation (2) Minergie-P additional criteria to (1): - Airtightness of building envelope - Efficiency of household applicances (3) Minergie-Eco additional criteria to (1): - Healthy ecological manner of construction (optimized daylight conditions, low emissions of noise and pollutants) (4) Minergie-P-Eco Adherence to criteria of Minergie-P and Minergie-Eco
Level of Certification	Bronze Silver Gold	Pass Good Very good Excellent Outstanding	LEED Certified LEED Silver LEED Gold LEED Platinum	4 Stars: ‚Best Practice' 5 Stars: ‚Australien Excellence' 6 Stars: ‚World Leadership'	C (poor) B B+ A S (excellent)	Minergie Minergie-P Minergie-Eco Minergie-P-Eco

Fig. A9 Comparison of different Rating Systems for Sustainable Buildings

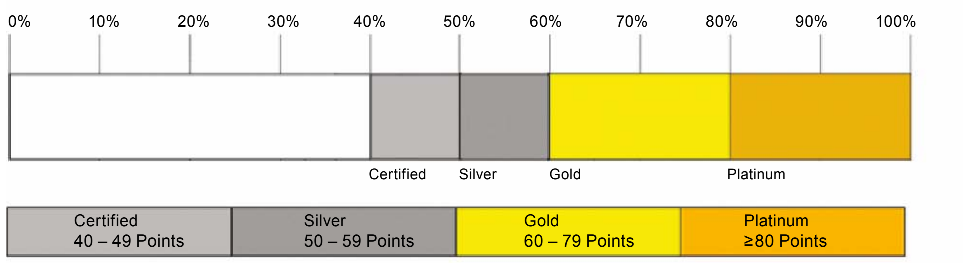


Fig. A12 LEED® Certification

whole building approach by identifying performance in key areas like sustainable site development, human and environmental health, water savings, materials selection, indoor environmental quality, social aspects and economical quality.

Furthermore, the purpose of rating systems is to certify the different aspects of sustainable development during the planning and construction stages. The certification process means quality assurance for building owners and users. Important criteria for successful assessments are convenience, usability and adequate effort during the different stages of the design process. The result of the assessment should be easy to communicate and should be showing transparent derivation and reliability.

Structure of Rating Systems

The different aspects are sorted in overall categories, like ›energy‹ or quality groups ›ecology‹, ›economy‹ and ›social‹ demands (triple bottom line). For each aspect, one or more benchmarks exist, which need to be verified in order to meet requirements or obtain points. Depending on the method used, individual points are either added up or initially weighted and then summed up to obtain the final result. The number of points is ranked in the rating scale, which is divided into different levels: The higher the number of points, the better the certification.

LEED® – Leadership in Energy and Environmental Design

The LEED® Green Building Rating System is a voluntary, consensus-based standard to support and certify successful Green Building design, construction and operations. It guides architects, engineers, building owners, designers and real estate professionals to transform the construction environment into one of sustainability. Green Building practices can substantially reduce or eliminate negative environmental impact and improve existing unsustainable design. As an added benefit, green design measures reduce operating costs, enhance building marketability, increase staff productivity and reduce potential liability resulting from indoor air quality problems.

The rating systems were developed for the different uses of buildings. The rating is always based on the same method, but the measures differentiate between the uses. Actually, new construction as well as modernization of homes and non-residential buildings are assessed. Beyond single and complete buildings, there are assessments for neighborhoods, commercial interiors and core and shell. The rating system is organized into five different environmental categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources and Innovation.

Fig. A10 LEED® Structure

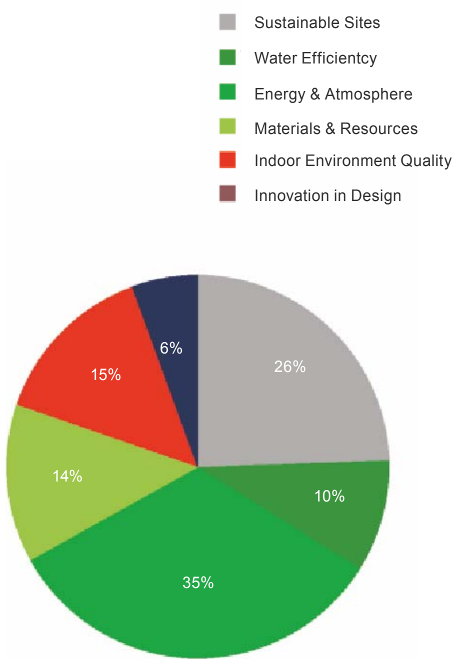


Fig. A11 LEED® Weighting

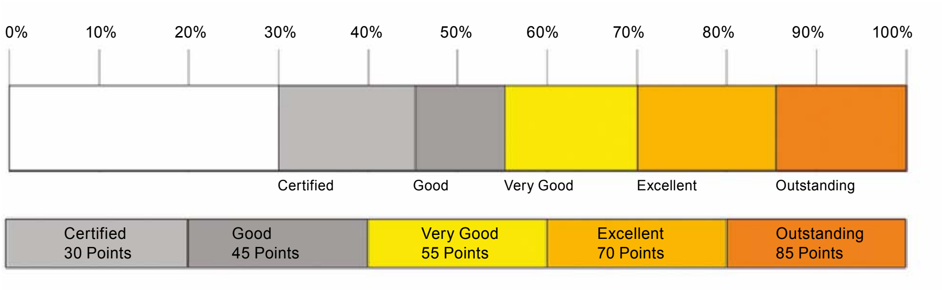


Fig. A15 BREEAM Certification

BREEAM – BRE Environmental Assessment Method

The assessment process BREEAM was created by BRE (Building Research Establishment) in 1990. BRE is the certification and quality assurance body for BREEAM ratings. The assessment methods and tools are all designed to help construction professionals understand and mitigate the environmental impacts of the developments they design and build. As BREEAM is predominately a design-stage assessment, it is important to incorporate details into the design as early as possible. By doing this, it will be easier to obtain a higher rating and a more cost-effective result. The methods and tools cover different scales of construction activity. BREEAM Development is useful at the master planning stage for large development sites like new settlements and communities.

Different building versions have been created since its launch, to assess the various building types. Currently, the evaluation program is available for offices, industry, schools, courts, prisons, multiple purpose dwellings, hospitals, private homes and neighborhoods. The versions of assessment essentially look at the same broad range of environmental impacts: Management, Health and Well-being, Energy, Transport, Water, Material and Waste, Land Use and Ecology and Pollution. Credits are awarded in each of the above, based on performance. A set of environmental weightings then enables the credits to be added together to produce a single overall score. The building is then rated on a scale of certified, good, very good, excellent or outstanding and a certificate awarded to the design or construction.

Fig. A13 BREEAM Structure

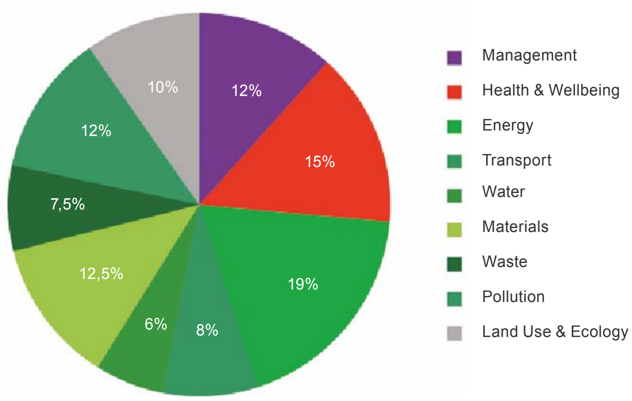


Fig. A14 BREEAM Weighting

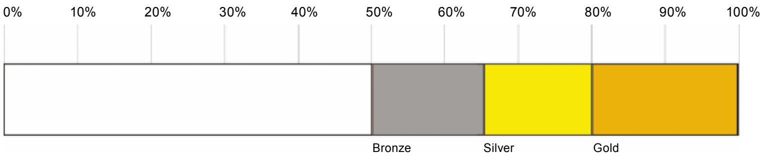


Fig. A18 DGNB Certification

Fig. A19 Certification medals with DGNB Gold, Silver, Bronze

DGNB – German Sustainable Building Certificate (GeSBC)

In contrast to comparable systems, the GeSBC label takes all three sustainability dimensions in account in its assessment structure, examining ecological, economic and socio-cultural aspects.

As the result of legislation, the German real estate industry already has a high standard of sustainability. In addition to the Energy Passport, the GeSBC addresses all items defining sustainability to meet the demands.

The German Sustainable Building Council (DGNB) was founded in June 2007 and created the German Sustainable Building Certificate together with the German Federal Ministry of Transport, Construction and Urban Development. The goal is »to create living environments that are environmentally compatible, resource-friendly and economical and that safeguard the health, comfort and performance of their users«.

The certification was introduced to the real estate market in January 2009. It is now possible to certify at three different levels, »Bronze«, »Silver« and »Gold«. As shown in Fig. A16, site quality will be addressed, but a separate mark will be given for this, since the boundary for the overall assessment is defined as the building itself.

MINERGIE ECO®

Minergie® is a sustainability brand for new and refurbished buildings. It is supported jointly by the Swiss Confederation and the Swiss Cantons along with Trade and Industry. Suppliers include architects and engineers as well as manufacturers of materials, components and systems.

The comfort of occupants living or working in the building is the heart of Minergie®. A comprehensive level of comfort is made possible by high-grade building envelopes and the continuous renewal of air.

The evaluation program is available for homes, multiple dwellings, offices, schools, retail buildings, restaurants, meeting halls, hospitals, industry and depots. Specific energy consumption is used as the main indicator of Minergie®, to quantify the required building quality. The aim of the Standard »Minergie-P®« is to qualify buildings that achieve lower energy consumption than the Minergie® standard. The Minergie and the Minergie-P® Standard are prerequisites for the Minergie ECO® assessment. The ECO® Standard complements Minergie with the categories of health and ecology. The criteria are assessed by addressing questions on different aspects of lighting, noise, ventilation, material, fabrication and deconstruction. The affirmation of the

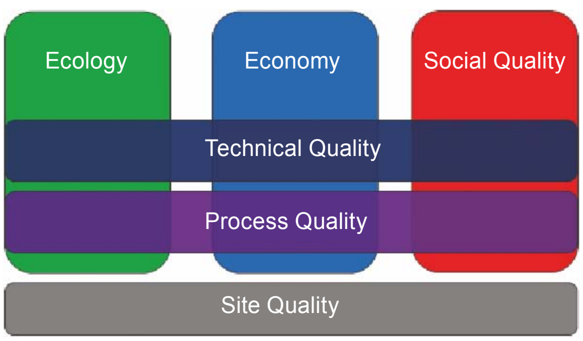


Fig. A16 DGNB Structure

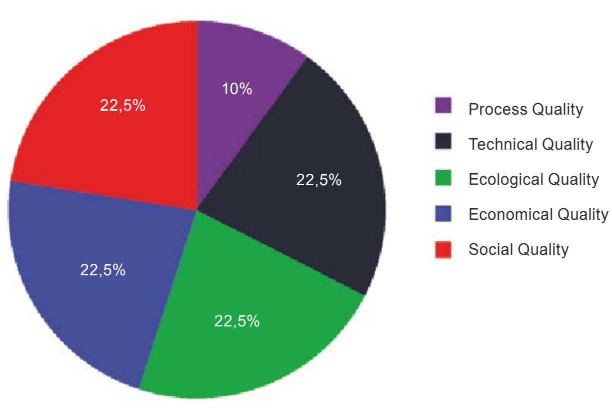


Fig. A17 DGNB Weighting

question must comprise at least 67% of all relevant questions. The assessment includes two different stages: the pre-assessment during the design stage (Fig. A20) and the assessement during the construction stage to verifiy the success of previously planned measures (Fig. A21).

Energy Performance Directive
An important building certification, incorporated by the EU, is the Energy Performance Certificate. They developed the prototype of the federally uniform Energy Performance Certificate. The certificate has been legally compulsory since 2007 as a result of the energy saving regulation, which is a part of the EU building laws. For Germany, Energy Saving Regulation defines maximum values for primary energy demand and the heat loss by transmission for residential and non-residential buildings. The maximum value depends on the type and use of the building. The maximum value for modernization in general lies 40% below the values of new construction. Energy balancing comprises beyond heat loss of transmission heat input of solar radiation, internal heat input, heat loss of distribution, storage and transfer inside the building as well as the energy loss by the energy source through primary production, transformation and transport. »Green Building« is an European program setting target values 25% or 50% below compulsory primary energy demands. Its focus is especially on buildings with non-residential use, like office buildings, schools, swimming pools and industrial buildings.

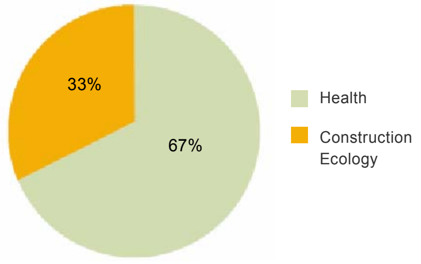


Fig. A20 Minergie ECO®
Weighting Pre-Assessment

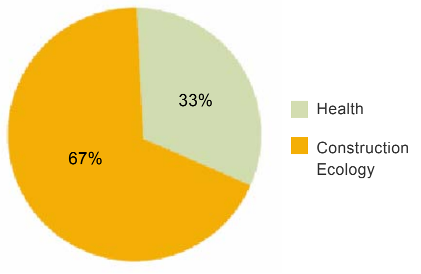


Fig. A21 Minergie ECO®
Weighting Construction Stage

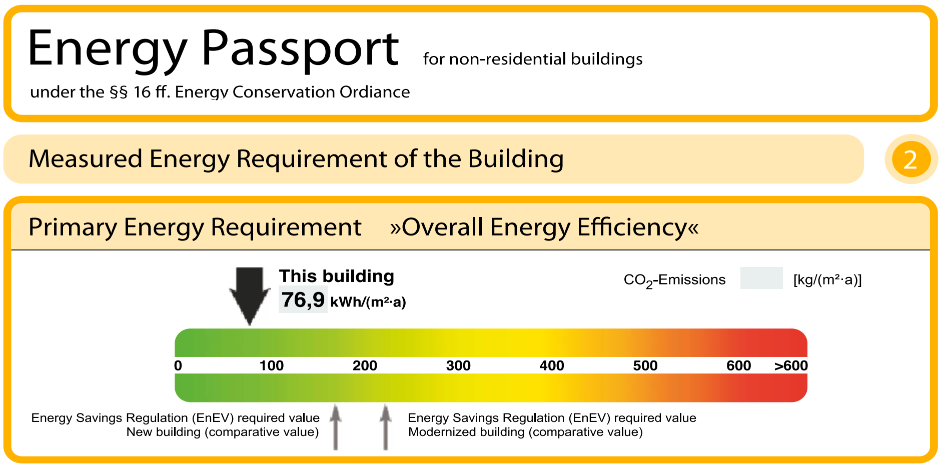


Fig. A22 Energy Passport

An integrated View of Green Buildings – Life Cycle Engineering

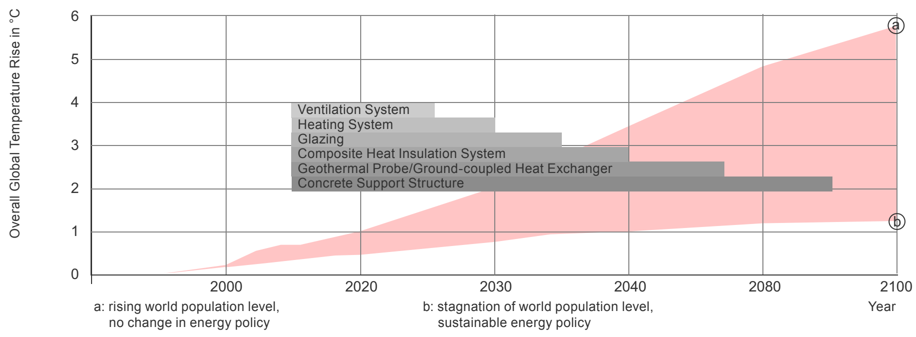
Green Buildings are buildings of any usage category that subscribe to the principle of a conscientious handling of natural resources. This means causing as little environmental interference as possible, the use of environmentally-friendly materials that do not constitute a health hazard, indoor solutions that facilitate communication, low energy requirements, renewable energy use, high-quality and longevity as a guideline for construction, and, last but not least, an economical operation. In order to achieve this, an integrated, cross-trade approach is required to allow for an interface-free, or as interface-free as possible, handling of the trades of architecture, support structure, façade, building physics, building technology and energy while taking into account both usage considerations and climatic conditions. To this end, innovative planning and simulation tools are employed, according to standards, during the design and planning stages for Green Buildings. They allow for new concepts since – by means of simulation of thermal, flow and energy behaviour – detailed calculations can be achieved already during the design stage. Attainable comfort levels and energy efficiency can thus be calculated in advance and this means that, already during the design stage, it is possible to achieve best possible security in regards to costs and cost efficiency. Equipped with these kinds of tools, Green Building designers and planners can safely tread new paths where they may develop novel concepts or products.

Aside from an integrated design and work approach, and the development and further development of products and tools, sustainability must be expanded so that the planners are able to gather valuable experience even during the operation of the buildings. This is the only way that a constructive back-flow of information into the building design process can be achieved, something that, until now, does not apply for contemporary building construction. This approach is to be expanded to encompass renaturation, in order to make allowances for the recycling capability of materials used even during the planning stage. In other industrial sectors, this is already required by law but, in the building sector, we are clearly lagging behind in this aspect. On account of consistent and rising environmental stress, however, it is to be expected that sustainability will also be demanded of buildings in the medium-term and thus not-too-distant future.

The path from sequential to integral planning, hence, needs to be developed on the basis of an integral approach to buildings and is to be extended in the direction of a **Life Cycle Engineering** approach. This term stands for integral design and consultation knowledge, which always evaluates a given concept or planning decision under the aspects of its effects on the entire life-cycle of a given building. This long-term evaluation, then, obliges a sustainable handling of all resources.

The authors consider Life Cycle Engineering to be an integral approach, which results in highest possible sustainability levels during construction. It unites positive factors from integral planning and/or design, the manifold possibilities of modern planning and calculation tools, ongoing optimisation processes during operation, and conscientious handling during renaturation of materials. All this results in a Green Building that, despite hampering nature as little as possible, can provide a comfortable living environment to meet the expectations of its inhabitants.

Fig. A23 Life expectancy of contemporary components when seen inside the time-frame of possible rises of global temperature levels



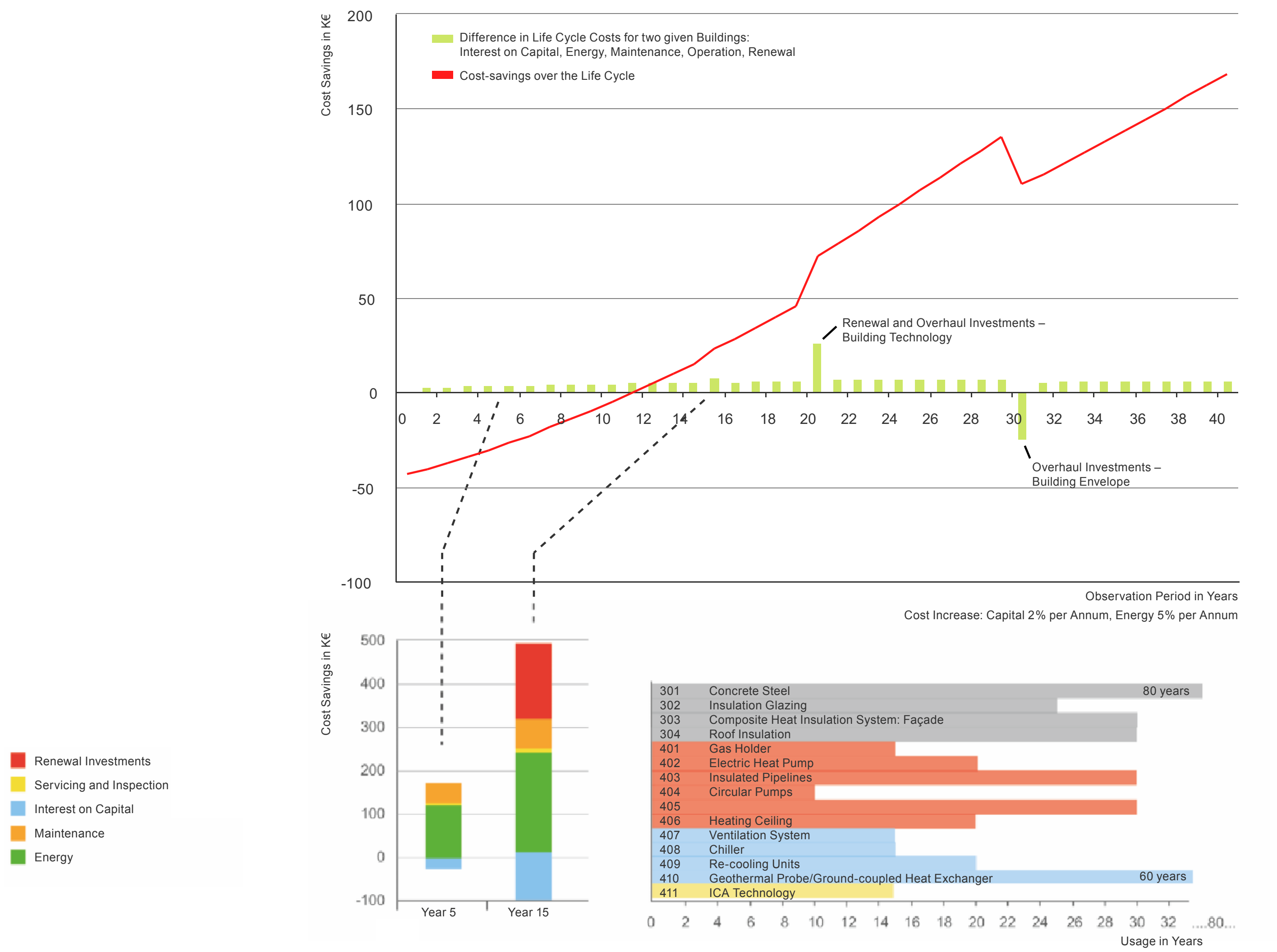


Fig. A24 Cost-savings Green Buildings vs. Standard Buildings – detailed observation over the entire Life Cycle

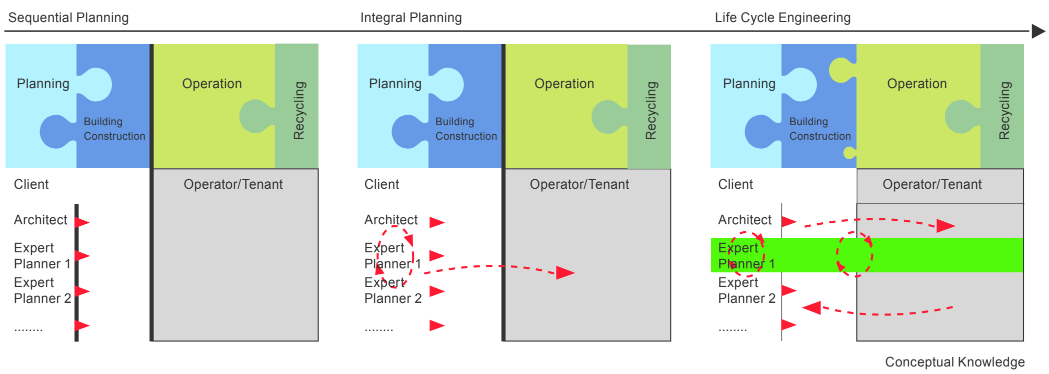
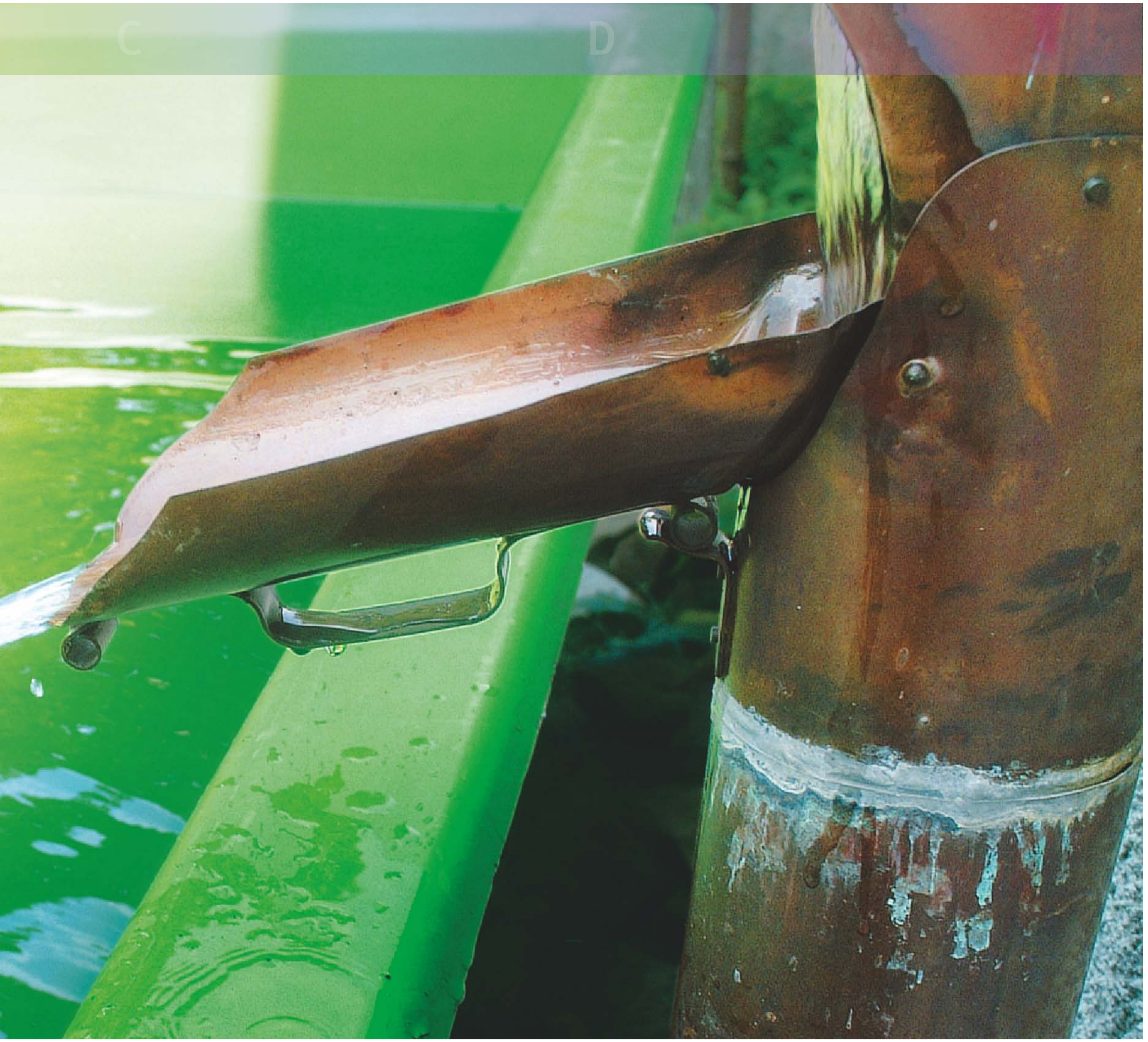


Fig. A25 Development of Planning Methods, from sequential Methodology to Life Cycle Engineering

A

B

Green Building Requirements



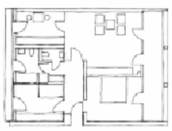
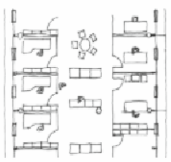
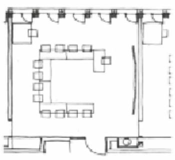
B 1

Sustainable Design

Perceived Use defines the Concept

Whether it is an office building, school, recreational facility or industrial building – aside from climatic considerations, the intended use of a given building plays an important role in the design of energy-efficient buildings.

Usage demands are usually related to the desired comfort level and can be expressed in terms of minimum and maximum indoor temperatures, indoor humidity levels or illuminance. Further, there are time-related stipulations for adhering to the desired indoor conditions. Just think of decrease of room temperature at night. In office buildings, this requirement as a rule only exists for reasons of energy conservation, since no energy consumers are present at night. In residential buildings, however, this requirement can be for comfort reasons also. For instance, the kids' room, especially when it is also being used as a playroom, should be warm enough during the day while, at night, it is rather the cooler temperatures that are desirable for sleeping. The building and facility design ought to make this possible without unnecessary energy expense.

Application	Usage Means and Merit	Requirements	Need	Building and Facility Function
 Living	Few people, Playing, Eating, Living, Cleaning, Watching Television, Hobbies, Parties	High level of thermal comfort, partially also sufficient if achieved per section (reading corner), different room temperatures (day/night), good air quality	Even thermal balance for radiation and convection, flexible system	Heating surfaces, demand-oriented addition of outdoor air, need-based lighting
 Office	Normal amount of people, concentrating on their work	High thermal comfort level, room temperature and humidity kept as comfortable as possible, temperature reduction at night for energy conservation reasons, fast heating-up at the start of operation, very good air quality	Even thermal balance for radiation and convection, flexible system, sufficient outdoor air supply, without draught	Heating and cooling surfaces, sufficient supply of outdoor air, efficient heat recovery, on account of longer operation times: sufficient illumination
 School	Many people studying intensely, break, school operation	Very good air quality, high thermal comfort level covering all areas, short-term turn-off during break	High volume of outdoor air flow, short turn-off times, high level of performance reserves for heating-up process	Efficient ventilation concept, optimal heat supply covering all areas, adequate lighting, energy-saving outflow of heat sources
 Trade Fairs	High people density, high heat source density, short operation times, flexible use	Good air quality, no draught, good thermal comfort level, high cooling loads that are surface-oriented, fast heating-up process	High and surface-related air flow volume, high and surface related cooling performance levels	Locally arranged layered ventilation so that only the user zone is coordinated, quick heating-up process
 Industry	Different density levels for heat and source areas, different activity levels	Good air quality at the work place, high level of thermal comfort depending on degree of activity, locally adaptable	Sufficient outdoor air flow - if possible: without draught, locally adjustable, thermal balance adjustment	Locally arranged layered ventilation for sufficient work place ventilation, layered ventilation also used to efficiently transport source areas out of the populated zones, possibly also localized suctioning of the source areas, heating and cooling surfaces for thermal balance

Tab. B1.1 Details different user applications, according to their merits and requirements

Relationship between Level of Well-Being and healthy Indoor Climate

Buildings, as a kind of third skin, are an important factor for our health and quality of life. A high performance level at work can only be obtained when a high level of well-being exists also. This gives rise to creative processes and ideas and also allows our body to regenerate and heal. The related high performance capacity of man is reflected in both work life and inter-human relationships. Naturally, there are many different influences and sizes of those influences on man's well-being and biorhythm. Some can be physically measured, such as air temperature or indoor noise level. Other factors are of a biological nature, like age and state of health, or ethically different education levels. For thermal comfort levels, it is also important what type of clothing is worn during which activities. Intermediate well-being criteria are also, for instance, whether a colleague in a two-person office is liked or not. There are also other influences that only become noticeable when one is subjected to them over longer periods of time. Among these, for instance, are high-emission materials (for instance, adhesives) and electromagnetic rays that continue to gain ever-increasing influence *(see table B1.2)*.

Factors	Conditions	
Internal surface temperature	Clothing	Nutrition
Air temperature	Degree of activity	Ethnic influences
Relative humidity	Individual control possibility	Age
Air movement	Adaptation and acclimatization	Sex
Air pressure	Day and annual rhythm	Bodily condition
Air quality	Room occupancy	Building design
Electromagnetic compatibility	Psycho-social factors	
Acoustic influences		
Visual influences		

Tab. B1.2 Influence factors for comfort level sensation indoors

Subjective thermal comfort sensation of a human being is determined by the heat flows running through his or her body. Heat generated inside the body must be completely emitted to the surrounding environment in order to maintain thermal balance. The human organism is equipped with the ability to maintain a relatively constant inner core temperature level, minor fluctuations included, independent of environmental conditions and during different physical activities. Under harsh climatic conditions, the human regulating mechanism can become overloaded when trying to adapt body temperature to its surrounding environment, resulting in it either sinking or falling. The infrared images, *B1.1* and *B1.2*, show a person during light and then elevated levels of physical activity

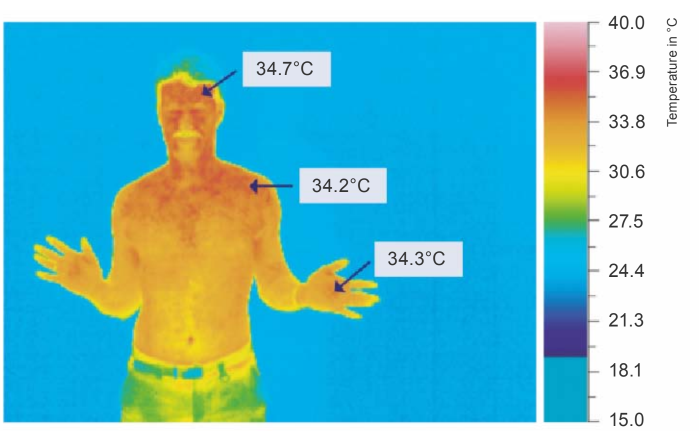


Fig. B1.1 Skin surface temperature of a person during low activity levels and with a surrounding environmental temperature of 26 °C

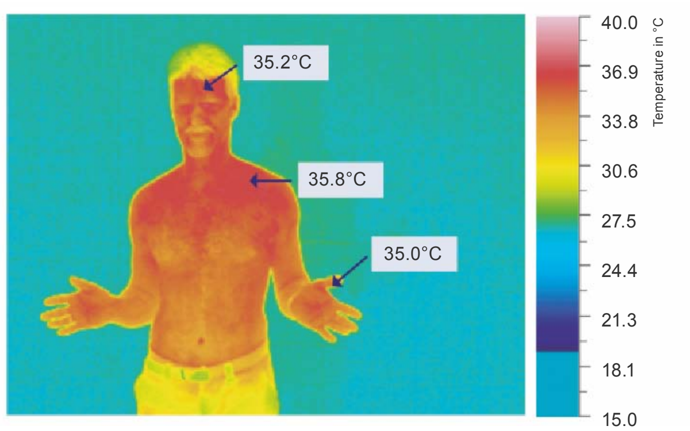


Fig. B1.2 Skin surface temperature of a person during high activity levels and with a surrounding environmental temperature of 26 °C

Relationship between Comfort Level and Performance Ability

and also the corresponding temperature distribution on the skin surface. These differences show that, in both cases, thermal comfort can only be achieved when either the temperature of the surrounding environment or the clothing worn has been chosen according to the situation. Uncomfortable sweating (high level of evaporation) can be largely avoided, for instance, when a skin surface temperature of about 34 °C is not exceeded and the surrounding environmental temperatures range somewhere just below the 26 °C level.

As the infrared images also clearly show, the highest surface temperatures for people are around the head region, the lowest at the point farthest from the heart, the feet region. This allows for the conclusion that thermal comfort can only be obtained whenever surface temperatures of room envelope surfaces are adjusted to human need. A ceiling that is too warm inside a heated room, for instance, prevents heat emission in the head region and quickly leads to headaches. Likewise, cold floors elevate heat loss levels via the feet and increase surface temperature differences of the human body *(Figure B1.3)*.

The work performance level of a person and the required work efficiency level have risen in recent years, especially in industrial nations, on account of global competition. Building owners and tenants have recognized by now that comfortable indoor climate levels are a decisive factor when it comes to upholding productivity levels. If, for instance, a company suffers from an unacceptable indoor climate for 10% of work time, this leads to a more or less noticeable decrease in work performance levels, spread over 200 hours or 25 days per annum per staff member. For service enterprises with daily rates of 500 to 2000 Euro per day, this means a financial loss of between 12 500 to 50 000 Euro per annum per employee. When this is now applied to the gross floor area (GFA) of a typical office building, an annual loss of 500 to 2000 Euros per square meter GFA results. Compare this to the required costs for the installation and operation of a cooling system, which are, on average, only 15 to 25 Euros per square meter GFA per annum. You will see that this is a relatively small amount by comparison. *Figure B1.4* shows physical and mental performance capacity as it relates to room temperature and was determined by past research. It shows that, from room temperatures of about 25 °C to 26 °C upwards, performance capacity noticeably decreases. From 28 to 29 °C onwards, work efficiency clearly decreases.

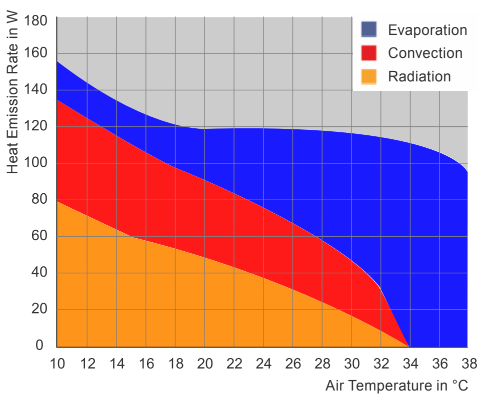


Fig. B1.3 Heat emission rates for a person as it relates to surrounding environmental temperature. From a temperature of 34 °C, the body can exclusively emit heat via evaporation (sweating), since the surface temperature of the human skin is also 34 °C.

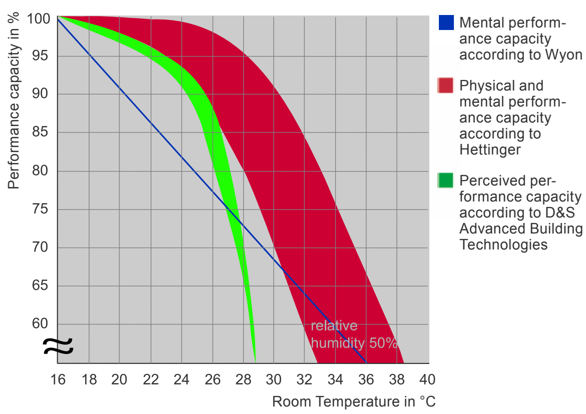


Fig. B1.4 Performance capacity of a person as it relates to room temperature.

Operative Indoor Temperature in Occupied Rooms

Prof. P. O. Fanger of the University of Denmark at Copenhagen, undertook some research into how precisely the level of well-being of people indoors is perceived under different thermal conditions. The basis for the research was the essential influential factors of man on thermal body balance: activity level and type, clothing, air and radiation temperature, air velocity and air humidity levels. Research results were interpreted in such a manner as to allow calculation of prospective and subjective heat sensation, so long as the above-mentioned factors can be determined. They also show that it is impossible to please everyone, on account of the individuality of man. A study with more than 1300 human subjects has shown that at least 5 % of the subjects will perceive the indoor climate as being of an uncomfortable level. For heat sensation, according to valid and current international and European standards, three different categories of thermal comfort have been defined: Category A, the highest (very good) has a probability of 6% dissatisfied, the medium category B (good) has 10% dissatisfied and in category C (acceptable) there is a high probability of the presence of about 15% dissatisfied people.

Temperature is the decisive factor for subjective thermal comfort. Depending on mood, duration of stay and locale, the same situation is being perceived differently by the same person. Direct solar radiation on the body, for instance, can be perceived as pleasant when it happens during relaxation in one's own living room. In stress situations, however, the same heat supply source is perceived as uncomfortable. A person perceives temperature as it results from the adjacent air temperatures, individual temperatures of surrounding surfaces and, possibly, direct solar radiation. This temperature is known as operative temperature.

For rooms with a longer duration of stay, the criteria used are the mean operative temperature without direct solar radiation. To simplify matters, this becomes the mean value, resulting from the present surface temperatures of interior surface areas and indoor temperature in general. Surface temperatures are also known as radiation temperatures. The relation between radiation and air temperatures can be changed by means of heat insulating merits of the façade system, building mass present or through the technical facilities that are in use. In *Figures B1.5* and *B1.6*, comfort criteria for winter and summer respectively are shown. The highest degree of satisfaction is achieved at an operative indoor temperature of 22 °C in winter and 25 °C in summer. Depending on outdoor climate, physical material properties of components and the type of technological systems in use, different surfaces inside a room may present different temperatures. Care should be taken that these temperatures do not differ too much from room temperature. Further, they should be as closely matched

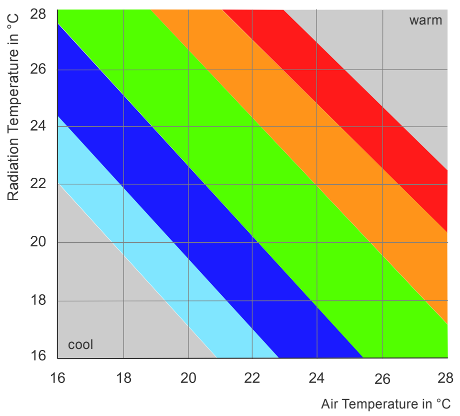


Fig. B1.5 Comfortable room temperature range in winter, with matching clothing (light sweater). High surface temperatures balance cooler outside temperatures.

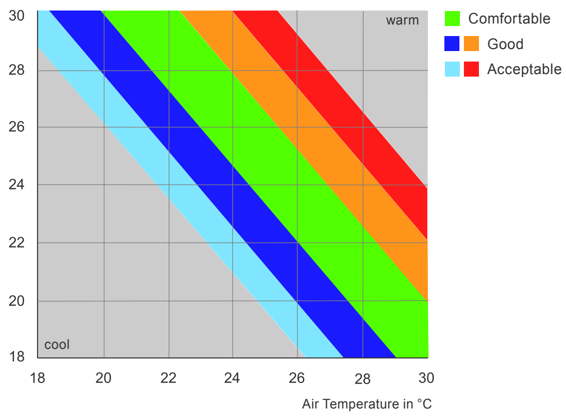


Fig. B1.6 Comfortable room temperature range in summer, with matching clothing (short-sleeved shirt). Low surface temperatures balance warmer outside temperatures.

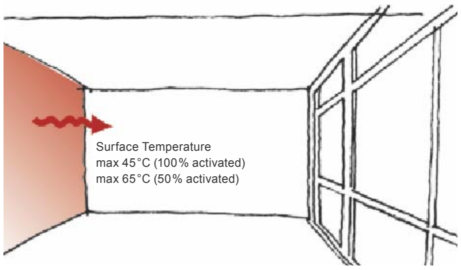


Fig. B1.7 Comfortable temperature range for warm wall surfaces

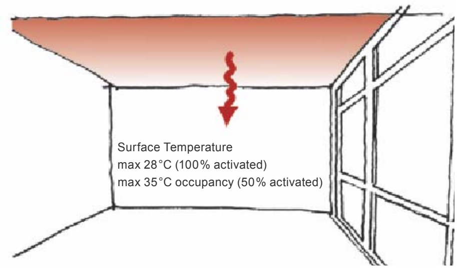


Fig. B1.8 Comfortable temperature range for warm ceiling surfaces. In order to maintain head region temperature at a constant 34°C, ceiling temperature should be maintained below 35°C

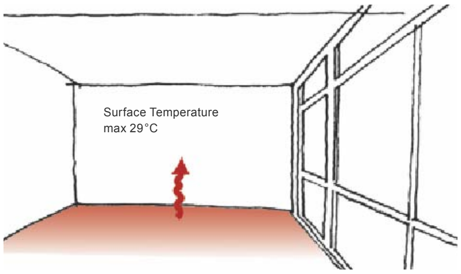


Fig. B1.9 Comfortable temperature range for warm floor surfaces with shoes worn

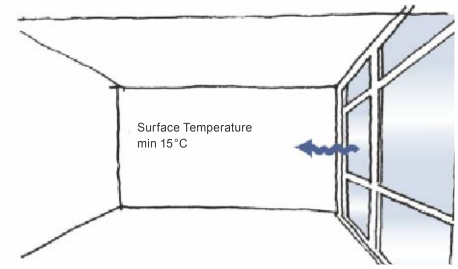


Fig. B1.10 Comfortable temperature range for cool window areas. Uncomfortable radiation asymmetries result when inner surface temperature of the façade is less than 15°C. This means cold air drop can be avoided

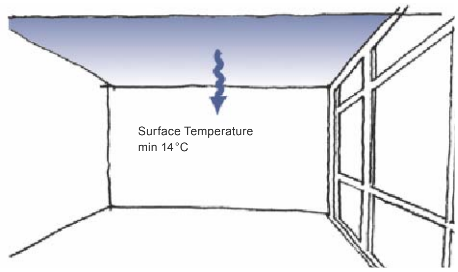


Fig. B1.11 Comfortable temperature range for cool ceilings. High levels of uncomfortable indoor radiation asymmetries can be avoided in summer when surface temperatures of cool ceilings do not exceed 14°C

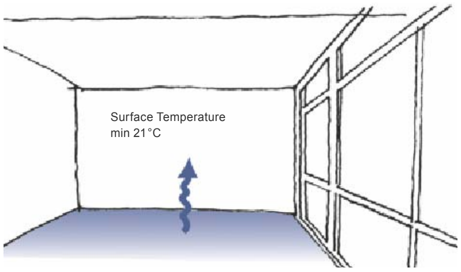


Fig. B1.12 Comfortable temperature range for cool floor surfaces with shoes worn

as possible since thermal comfort levels are influenced especially by local surface temperatures. If this is not the case, we speak of so-called radiation asymmetry. *Figures B1.7 to B1.11* show recommended maximum discrepancies for winter and summer settings, as they were determined by empirical research. During the planning stages, however, these critical values ought not be exploited to the limits. It is much better to keep surface temperature discrepancies small, already from the concept-stage onward, for this saves the later need for having discussions about the validity of empirically defined comfort limits.

The floor is a component with direct human contact. For this reason, it makes sense to define maximum and minimum temperatures within the range of the human comfort level for this particular building component. The values, however, are dependent on such factors as the thermal effusivity of the floor surface and heat insulation characteristics of shoes as well as duration of floor contact *(Figures B1.9 and B1.12)*. For shorter contact duration, like, for instance, at circulation areas, the acceptable temperature range is much larger (ca. 12 to 32°C) than in steadily populated areas with longer contact duration (ca. 21 to 29°C).

Aside from the differences in surface temperature, it is also important for local comfort levels that the difference between air temperature in the head region and that in the foot region is kept to a minimum. A cool head and warm feet are no problem in this; however, when there is a higher temperature in the head than foot region, it is perceived as uncomfortable. For sophisticated populated areas, the maximum temperature difference between head and foot region should remain within the 2K range.

Operative Temperature in Atria

Evaluation criteria for common rooms cannot be applied to atria and halls in anything but a limited manner since these areas are, as a whole, used as circulation areas and only at times also serve as settings for functions. As a guideline for design, in this case, we need rather to look at operative outdoor temperatures in comparison. This depends largely on temperature differences between winter and summer, wind velocity and sunlight influence. In *Figure B1.14*, the magnitude of influence on physically operative temperature (PET) is depicted: aside from the known magnitudes of influence like air temperature, surface temperature and air velocity, in this case there is also a relationship to be taken into account between direct solar radiation and the resulting operative temperature. When designing halls and atria for Green Buildings, hence, it is important to obtain an indoor climate – by the exclusive use of construction means and natural resources – that for most of the year will be experienced as being nicer

Fig. B1.13 Deichtor Center in Hamburg. Architects: BRT Architects Bothe Richter Teherani, Hamburg than outdoor climate. In winter, operative temperature in the outdoor area – depending on wind speed and sunlight influence – can lie well below the 5 to 10 K range. In *Figure B1.15* the range of possible operative temperatures in the outdoor area is depicted for an outdoor temperature of -5 °C. In comparison, there is the operative temperature for an atrium with different outside climate. Without heating, and in case of a airtight and heat insulating building envelope, an operative temperature of 5 °C is reached. In case of a high level of direct solar radiation, operative temperature inside the atrium can quickly rise to 15 to 20 °C. This is very comfortable for the atrium stay.

For users of adjacent common rooms, however, this can also have a negative effect since direct weather contact and the related temperature fluctuations are only possible in a limited manner.

In summer, for most atria, there is thermal stratification with temperatures rising toward the roof area. In order to maintain inside conditions for the atrium at a level that is still perceived as comfortable, the operative temperature inside the atrium needs to be noticeably below operative temperature in the outdoor area, so that, when entering the atrium, the difference will be consciously felt.

In *Figure B1.16*, operative temperatures for the outside area and the atrium are depicted for different settings and for an outdoor air temperature of 30 °C. Operative temperature under the influence of direct sunlight, and with no wind, is at 45 °C. In the bottom region of the atrium, it reduces by 10 K. If additional means are implemented also, like, for instance, plants or awnings, then operative temperature is reduced by a further 5 K. This approach clarifies that atria are also acceptable to users if they boast higher temperatures than the adjacent common rooms. During the design stage, however, it also needs to be kept in mind that the specified operative temperature levels are really achieved through application of constructional undertakings. If the louvers are too small, or there is awkward glazing quality, this can easily lead to operative temperatures inside the atrium for summer not being too far below those for winter conditions or even exceeding

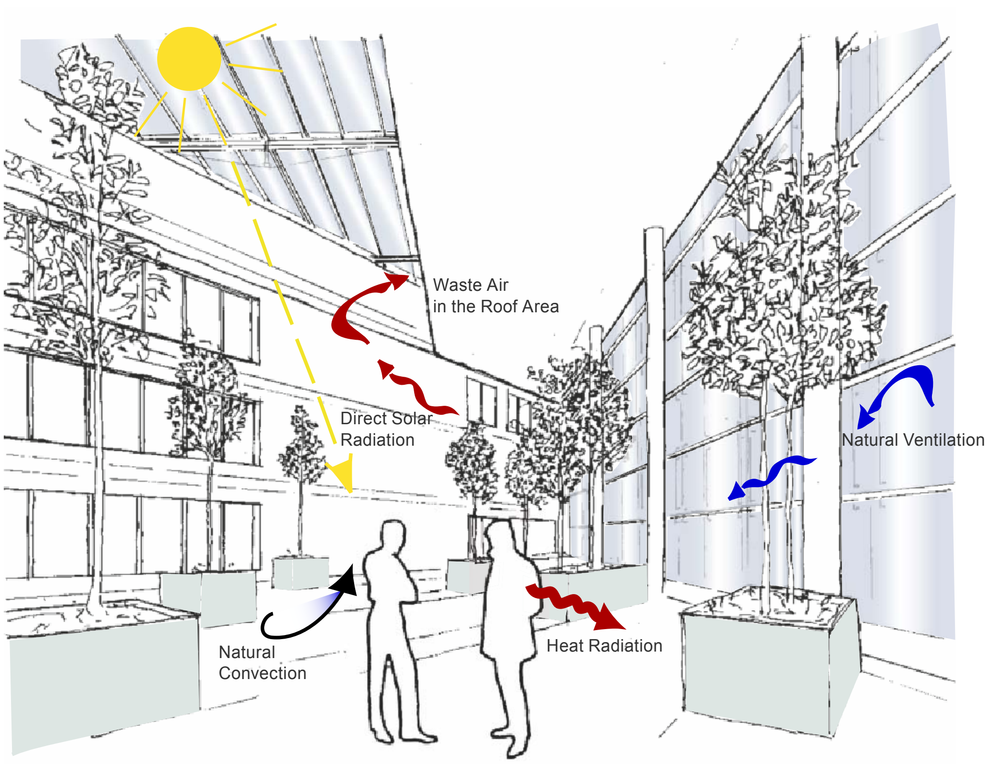


Fig. B1.14 Measurable magnitude of influence of thermal comfort inside atria. Aside from heat exchange through convection and long-wave infrared radiation, we often need to consider the influence of direct solar radiation on a person and as it relates to operative temperature.

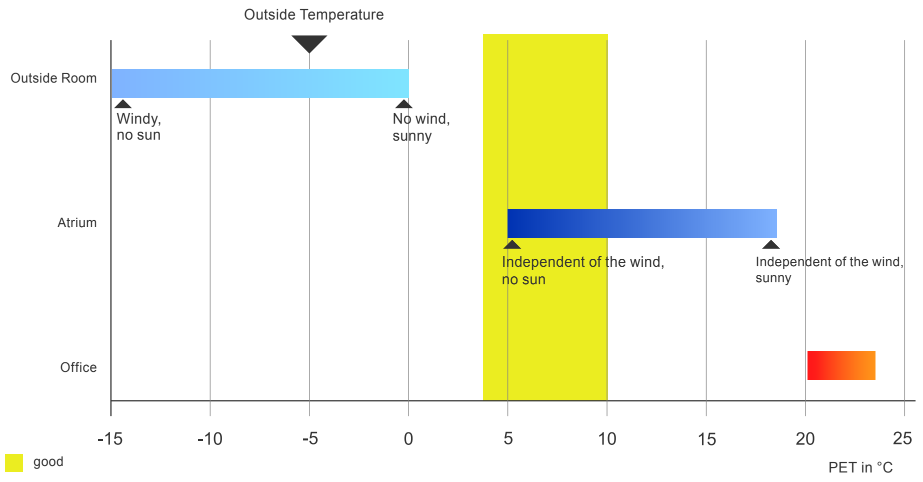


Fig. B1.15 Comfortable winter climate in atria, at outside air temperature of -5 °C, in comparison to outside area and heated populated areas (e.g. office)

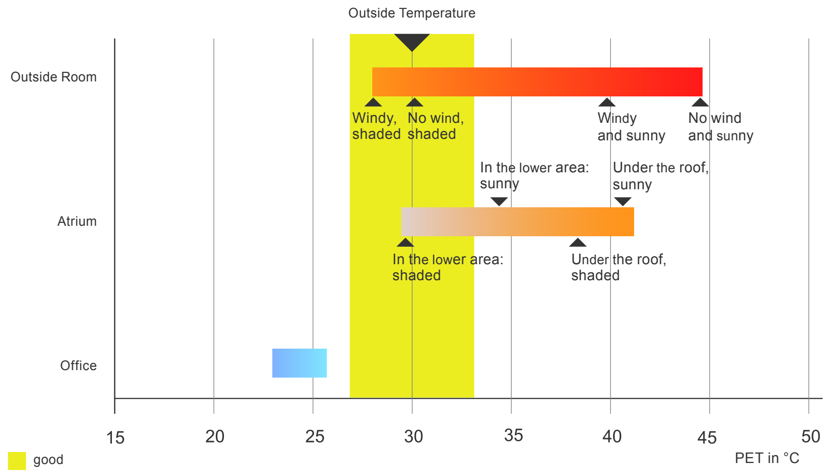


Fig. B1.16 Comfortable summer climate in atria, at outside air temperature of 30 °C, in comparison to outside area and cooled populated areas (e.g. office)

them. If this is the case, then the atrium cannot be used properly. Of importance when designing atria is also that work stations located inside the atrium are equipped with a so-called microclimate adhering to thermal requirements for work stations. In order to achieve this, most rooms will need to be designed with a sectioned box equipped with the relevant indoor climate technology.

Indoor Humidity

Humidity levels only have a negligent influence on temperature perception and thermal comfort indoors as long as air temperature is within the usual range, activity levels of the persons inside are fairly low and indoor humidity range lies between 30 and 70%. Therefore, a room with a relative humidity level that is higher by around 10% is perceived as being as warm as temperatures that are 0.3 K higher. For higher indoor temperature and activity levels, humidity influence is larger because people then emit heat primarily through evaporation (sweating). High levels of humidity, however, make this process more difficult or even impossible, meaning that operative temperature rises and discomfort results.

Even at regular indoor temperature levels, a lasting, very low or very high humidity level can negatively influence well-being. Humidity levels below 30% lead to drying out and to mucous irritations of the eyes and airways while humidity levels above 70% can cause mould through condensation. The latter, aside from being hazardous to health, can also damage the building. Whether additional technological measures need to be undertaken, in order to control indoor humidity levels, depends on the frequency of occurrence of indoor humidity levels that are either too high or too low.

Figures B1.17 and *B1.18* show the amount of utilization hours that are

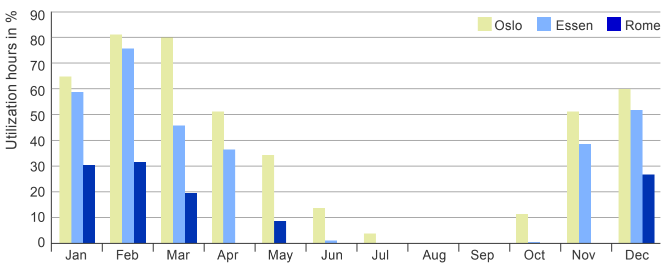


Fig. B1.17 Amount of required utilization hours (Monday to Friday, 8 am to 6 pm) for the humidification of added outside air in order to obtain a relative room humidity level of 35 %

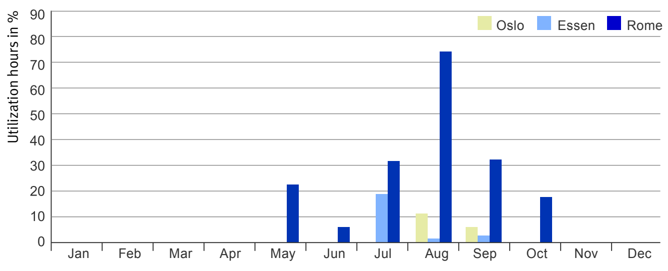


Fig. B1.18 Amount of required utilization hours (Monday to Friday, 8 am to 6 pm) for the dehumidification of added outside air in order to obtain a relative room humidity level of 60 %

required to humidify and dehumidify the air, for different climatic regions across Europe. If requirements for humidity balance are not very high, e.g. relative minimum indoor humidity of more than 35% then, at least for middle European regions, active humidification is not required. In these regions, on average, very dry outside air only occurs for less than 15% of utilization time. However, in very airtight buildings, where air exchange only works through ventilation units, care should be taken to provide for sufficient sources of humidity. This means that passive measures, like humidity recovery through rotation wheels in automatic ventilation units, should be undertaken. In Northern Europe, on the other hand, cold and dry outdoor air occurs much more frequently, so that it could constitute an advantage to humidify indoor air.

In middle and southern Europe, the air is often muggy in summer. If this does not happen often, then there is no need for mechanical dehumidification of rooms. It may be possible, under some circumstances, to store room humidity inside the materials. However, if muggy outside air conditions prevail over a longer period of time, then at least partial dehumidification of the outside air that was added mechanically is to be recommended.

On account of the latent amount, dehumidification requires a large amount of energy. Hence, for Green Buildings, processes are recommended that do not dehumidify through energy-intensive cooling of the outside air but that dry out the air through, for instance, the use of absorptive materials. These processes are being developed jointly with those of solar cooling and, especially for regions with high outside air humidity levels, they offer significant energy and CO_2 saving potential.

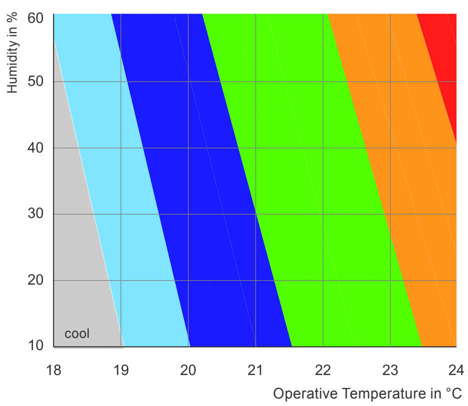


Fig. B1.19 Relative humidity influence on operative indoor temperature in winter

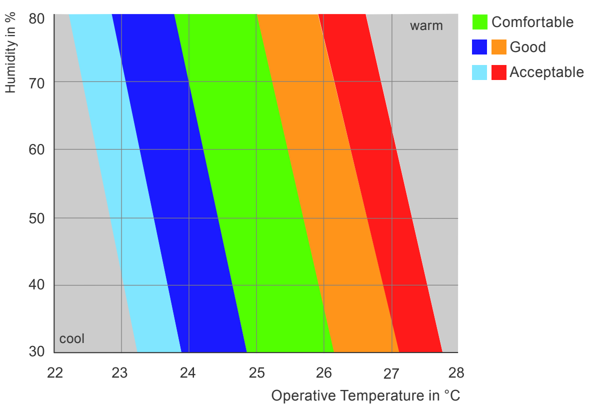


Fig. B1.20 Relative humidity influence on operative indoor temperature in summer

Air Velocity and Draught Risk

Local thermal discomfort is especially perceived when the body's energy turnover is very low. This happens mainly with sitting work. For a higher degree of activity, for instance when walking or undertaking other physical tasks, local heat sensation is not as prominent. In that case, there is much less danger for local discomfort. When judging the influence of draught occurrence on thermal comfort levels, these circumstances always need to be checked out first, before technological or constructional systems are applied.

For sitting people in office, residential, school and conference settings, draught is the most frequent cause for local discomfort. Excessive heat emission and draught can be caused, on one hand, passively through the cold air temperature drop from cool surfaces (e.g. badly insulated walls or tall glass façades). On the other hand, they can be actively caused through mechanical and natural ventilation systems. The effect is the same in both cases, however: a localized cooling of the human body occurs, caused by higher air velocity and the resulting higher amount of heat transfer. Depending on air velocity, fluctuation (turbulence) and air temperature, air movement is being more or less accepted. This means that air movement in winter, with a cold air stream, can become uncomfortable very quickly, while slightly warmer outside air in summer, via vents, can feel very good, indeed, since it actively supports heat emission by the body. Air movements are accepted much better, incidentally, when brought about by the user through manual processes (e.g. opening of windows) or when the user places no demands on a high level of comfort (e.g. atrium).

Figures B1.21 and *B1.22* show critical values for three different comfort level categories in order to obtain even and turbulent ventilation. In common rooms, values for the highest category should be adhered to while, in entrance or circulation areas, the lowest category provides a sufficient level of comfort on account of the temporary utilization.

However, constantly populated rooms and the reception area need to be regarded apart, especially since, there, frequent complaints about discomfort ensue. If this happens, then a separate local microclimate needs to be created for these areas.

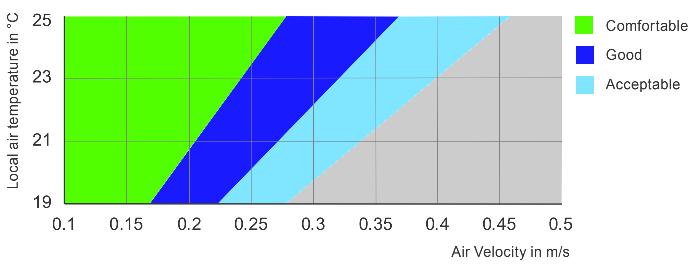


Fig. B1.21 Comfortable air velocities at an even flow level (turbulence degree: 10%), dependent on air temperature

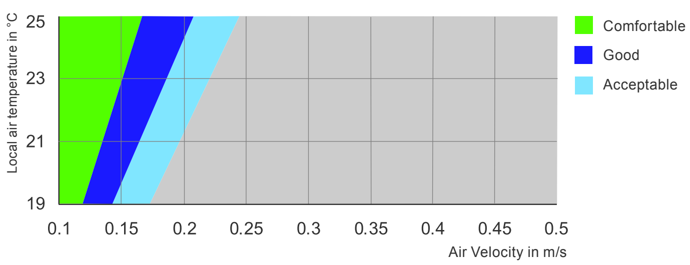


Fig. B1.22 Comfortable air velocities with turbulent flow (turbulence degree: 50%), dependent on air temperature

Clothing and Activity Level

The type of clothing a person wears has a significant influence on his or her thermal well-being. Having said that, a common definition of comfort cannot be achieved without taking into account the situation or mood at the time. If direct solar radiation is perceived as comfortable while at home wearing a warm sweater or when it happens on a nice winter's day, the same operative temperature is perceived as disturbing in a stress situation. The same applies to different degrees of activity: sitting people react much more sensitively to air movement and temperature fluctuations than people who move about a lot. The influence of clothing and activity level on local comfort, therefore, must be taken into account during building design. Requirements differ depending on utilization.

Figure B1.23 shows the influence of clothing on operative indoor temperature in summer. In regular common rooms, for building arrangement, it is assumed that the user will wear long trousers and sleeves in winter. This means that indoor temperature perceived as optimal will be at 22 °C. In summer, an indoor temperature of between 25 °C to 26 °C will only be perceived as optimal when short-sleeved shirts can be worn. For those utilizations where the occupants wear suit and tie year round, indoor temperature needs to be set at 2.5 °C lower, in order to achieve the same comfort level.

For building areas like gyms or atria, where activity level of the occupants is significantly higher than in populated areas with sitting activity, comfort temperatures are significantly lower. Depending on clothing, indoor temperatures for standing activities or light exercise will be perceived as being quite comfortable from 15 to 18 °C *(Figures B1.24* and *B1.25)*.

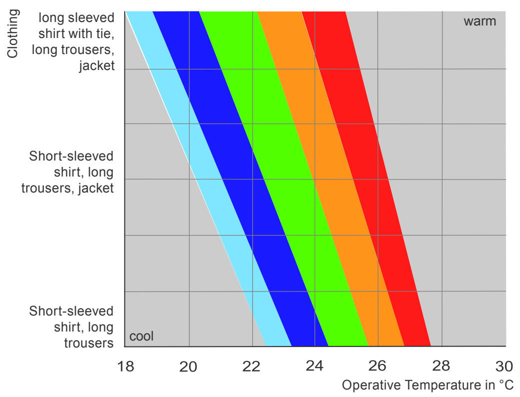


Fig. B1.23 Influence of clothing on thermal comfort during summer

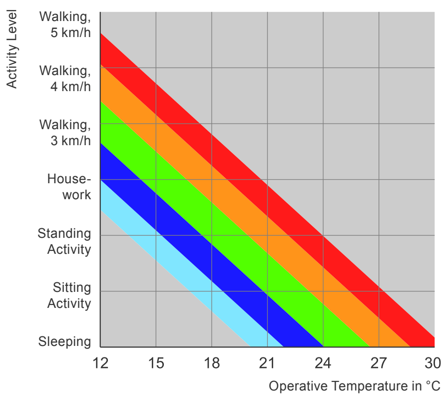


Fig. B1.24 Influence of activity level on thermal comfort when wearing a suit

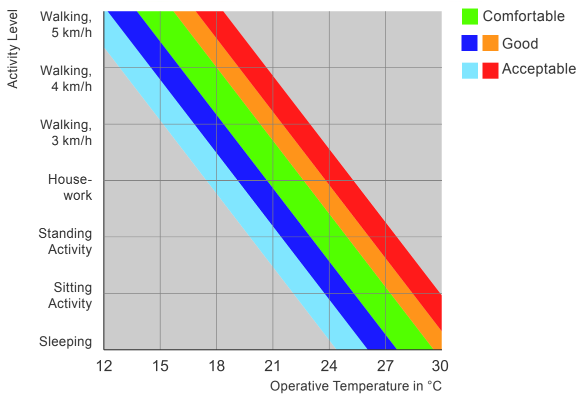


Fig. B1.25 Influence of activity level on thermal comfort when wearing summer sportive clothing (short-sleeved shirt and short pants)

Visual Comfort

The degree of visual comfort is decided by both daylight and artificial lighting levels. Generally, these two lighting means can be evaluated separately, since artificial lighting is provided for those situations when there is no or insufficient daylight present. In Green Buildings, however, there is frequently an interaction between these two light sources and/or their control and regulation. This leads to a soft transition between daytime and evening illumination.

The evaluation of visual comfort in an **artificial lighting** setting is based, in essence, on these factors:

- Degree of illuminance, both horizontally and vertically,
- Evenness of illuminance distribution through the room,
- Freedom from glare for both direct and reflex glare settings
- Direction of light, shading and colour
- Reproduction and light colour

Illuminance course is defined especially through direction of beam and capacity of beam of the lamps used. The advantages of indirect illumination are a high degree of evenness and a low potential for glare effects. Advantages of direct illumination include low electricity consumption, better contrasts and demand-oriented regulation. *Figures B1.26* and *B1.27* show room impression for direct and indirect illumination. For indirect illumination, the only way the same illuminance level of 500 Lux can be achieved, on the work plane, as for direct lighting is by using twice the amount of electricity. While evenness of room illumination is still achieved, it is monotonous, however, on account of missing shades. With exclusively direct illumination of the room, vertical illuminance is so low that is restricts perception of the room. This does not allow for comfortable communication among the occupants and, further, there is uneven illuminance also at the working plane level. It is by the combination of these two lighting means that, most often, both the visual and economic optimum is achieved. Each task requires a different illuminance level. The minimum limit for tasks requiring a certain amount of concentration is 300 Lux. In *Figure B1.28*, minimum illuminance requirements as outlined in the European directives, are summarized. Office readings show that, with daylight illumination,

Fig. B1.26 Room presentation with exclusively direct illumination

Fig. B1.27 Room presentation with exclusively indirect illumination illuminance of 300 Lux is perceived as comfortable. Unfortunately, these settings are not included in the standards for artificial lighting, although they have been demonstrated to apply in practice.

The prevailing lighting atmosphere inside the room is determined by the reflection characteristics of surface areas, light colour and colour reproduction of the illuminants used. Contemporary, quality illuminants are capable of setting light moods for the room that are similar to those in daylight. Available illuminant colours are off-white, neutral white and daylight white. Usually it is off-white and neutral white light that is perceived as comfortable by office occupants. Daylight white light, at 500 Lux, is rather perceived as being cold and uncomfortable. Only at much higher illuminance levels does this particular light colour start to be accepted. Colour reproduction merits of a lamp, on the other hand, stand for its ability to reproduce the colours of people and objects as close to life as possible. For a good level of colour reproduction, the illuminants used should have, at the very least, a colour rendering index of $R_a = 80$ or, better still, of $R_a = 90$ and higher.

Evaluation of visual comfort in a daylight setting, independent of artificial lighting used, is much more complex since it is not only the stationary situation that needs to be taken into account but also changes in brightness levels

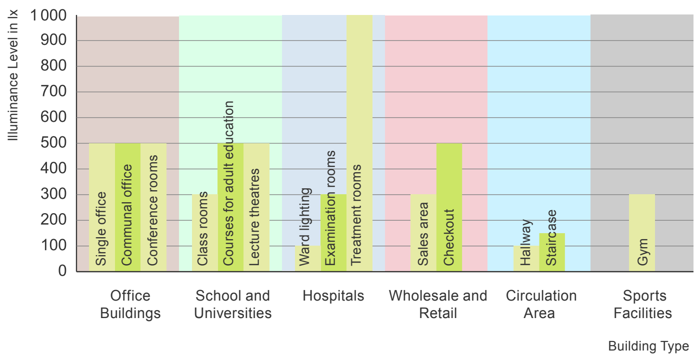


Fig. B1.28 Illuminance levels for different user applications

over the course of an entire year. Room shape, immediate vicinity obstruction, and chosen lighting-technological merits of the façade are all decisive factors for determining daylight quality inside a room. All three factors, however, are linked to architectural and thermal requirements, so that an optimum illumination can be achieved only through an integrated approach. Good daylight quality levels are given when:

- Indoor brightness, as opposed to outdoor brightness in winter and summer, reaches certain critical values (Daylight Factor and Sunlight Factor)
- Natural lighting inside the room is evenly distributed
- Indoor brightness changes according to outdoor brightness so that a day-night rhythm can be felt (this especially applies for rooms not oriented to the North, since they receive sunlight for parts of the year)
- An outside relationship can be established with concurrent sufficient solar protection
- Glare, especially as it occurs with work place monitors, can be avoided (near and far field contrasts)
- A large proportion of lighting, during usage hours, stems exclusively from daylight, without the use of electric power or artificial lighting (daylight autonomy).

Correct façade design for maximum use of natural daylight potential present, while also adhering to solar protection considerations and limitation of glare, is one of the most difficult tasks of building design. The reason for this is the high variability factor of sun and sky conditions over the course of the day *(Figure B1.32)*. Horizontal illuminance encompasses readings from 0 to 120 000 Lux, while solar luminance is up to one billion cd/m^2. For rooms with monitor work stations, an illuminance of 300 Lux suffices, window surface luminance should not exceed 1500 cd/m^2. This means that sufficient natural lighting is achieved if a mere 0.3% of daylight in summer and 6% in winter can be transported onto the work planes. The degree of difficulty is mainly due to the fact that sky luminance simultaneously needs to be reduced to between 3 and 13%, and solar luminance to 0.0002%.

Daylight and solar factors define daylight quality inside a room. Both values define the relationship of illuminance on the working plane to outdoor brightness. The daylight factor is calculated for an overcast sky, in order to evaluate a given room independent of any solar protective devices or systems. The solar factor, on the other hand, is calculated for a sunny room with solar protection in order to allow evaluation of daylight conditions with solar protection active. This distinction is of importance in order to compare façades, with and without daylighting systems, across the board for any sky condition.

The measurement variable called luminance can be imagined as the level of light perception for the eye. Different luminance levels lead to contrast formation. Contrasts are important so that the eye can even identify objects. Yet, if contrasts are too high, they lead to glare effects that are hard on the human organism. In order to attain a comfortable and sufficient visual level at the monitor, contrasts between working field and near field should not exceed 3:1 and between working field and far field should not be greater than 10:1. The near field runs concentric around the main viewing direction, with a beam angle of 30°C. The far field has twice that opening angle. Research shows that higher contrast levels for both near and far field are acceptable to the user. This can be traced back to the fact that, through the psychologically positive effect of daylight on people, higher luminance levels outside the window are not perceived as bothersome. Contemporary monitors are mainly non-reflecting and boast own luminance levels of between 100 and 400 cd/m^2. *Figures B1.33* and *B1.34* show an evaluation of luminance distribution on that basis, as well as of contrasts for the near and far field.

Contrary to artificial lighting, a high level of evenness for one-sided daylight illumination is much harder to achieve. Illumination equability is defined as the ratio of minimum illuminance level and medium illuminance level of a given area of the room. For artificial lighting, the ratio should be larger than 0.6. For daylight illumination, however, this value can scarcely be achieved, or only

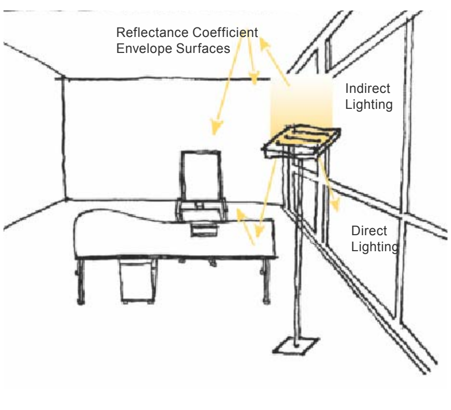


Fig. B1.29 Magnitude of Influence when designing artificial lighting

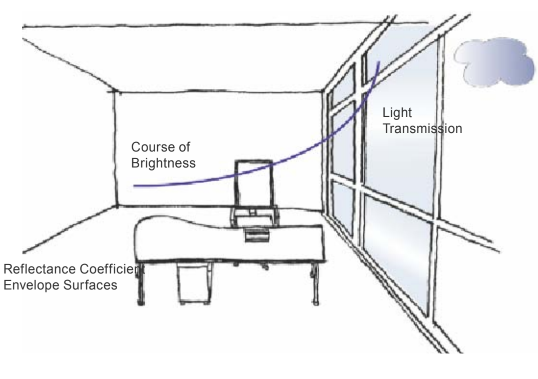


Fig. B1.30 Magnitude of Influence for daylight design (winter)

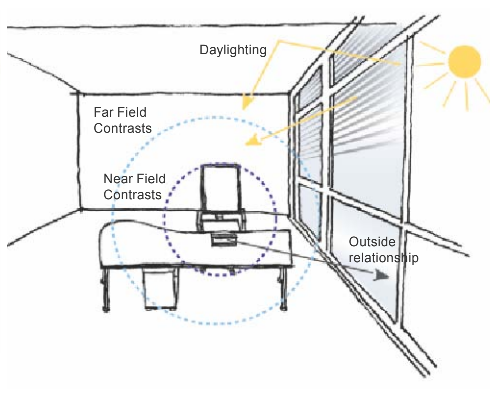


Fig. B1.31 Magnitude of Influence for daylight design (summer)

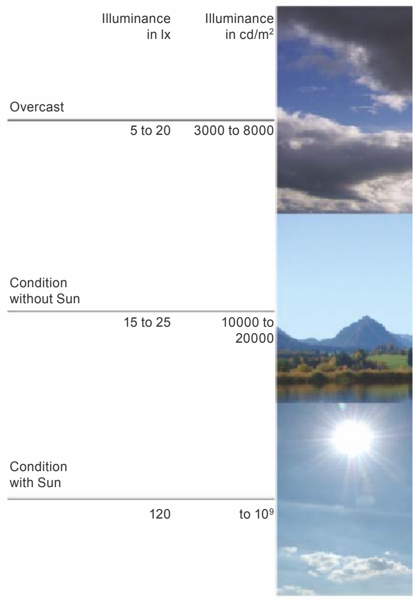


Abb B1.32 Sky illuminance rates and luminance in various settings

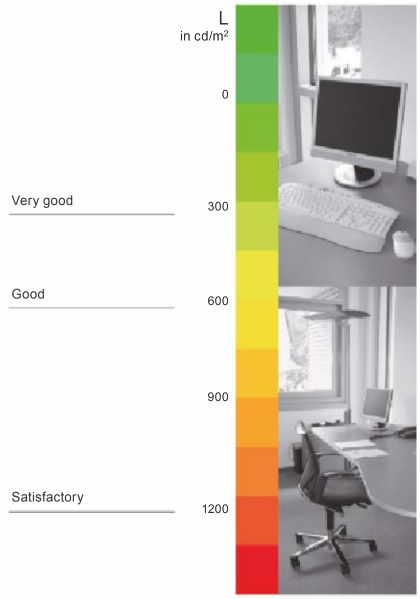


Fig. B1.33 Near field contrasts as luminance distribution for direct work place vicinity (desk)

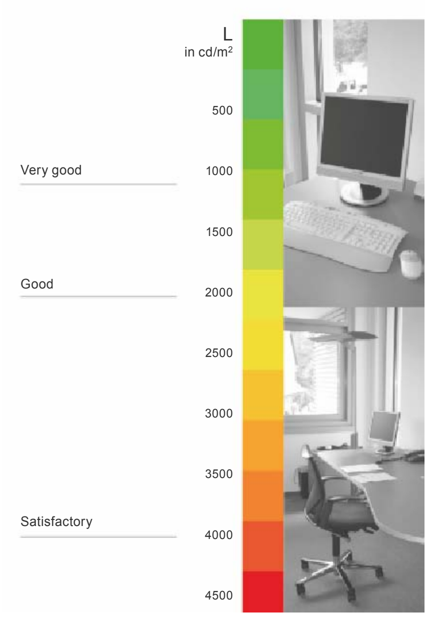


Fig. B1.34 Far field contrasts as luminance distribution for expanded work place environment (windows, inside walls)

by decrease of the overall illuminance level. For this reason, equability evaluations for daylight illumination cannot be based on the same criteria as those for artificial lighting. Rather, practically attainable values need to be consulted. The aim here is to achieve a reading of more than 0.125 for equability. Essential factors of influence in this are downfall size and reflection grades of the materials used indoors.

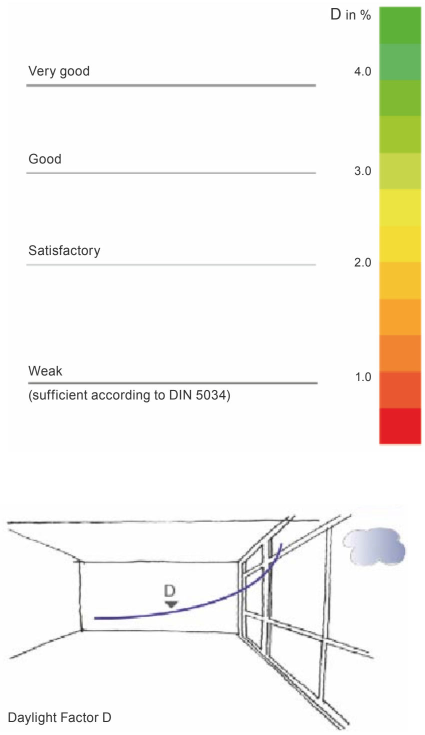


Fig. B1.35 Evaluation of a given room according to daylight factor D. The daylight factor is the ratio of illuminance at 85 cm height to outdoor brightness in overcast sky conditions. Most frequently, the parameter used is the reading at half room depth, maximum of 3m distance from the façade.

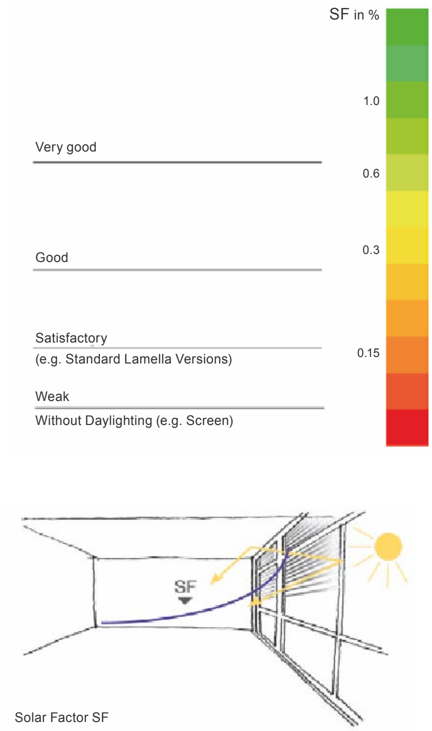


Fig. B1.36 Evaluation of a given room according to solar factor SF. The daylight factor is the ratio of illuminance at 85cm height to outdoor brightness with sunny façade. The façade is being shaded by the planned solar protective device in order to calculate remaining natural brightness inside the room. Most frequently, the parameter used is the reading at half room depth, maximum of 3m distance from the façade.

Fig. B1.38 Measuring Values for typical reverberation times for different utilization

Acoustics

We usually only perceive acoustic influences subconsciously. However, physical and mental well-being can sometimes significantly depend on both the amount and type of sound that we are subjected to. Since it is not possible to close one's ears to sound influence, at the very least it is our subconscious that gets strained by noise. It does not necessarily have to be a permanently high noise level to, literally, get on our nerves. Even heavily fluctuating or impulse-oriented sounds can be very damaging. Inside a building, this frequently includes sound-containing information, fragments of conversation from phone calls or staff discussions, neighbours arguing etc. In the design stage, we distinguish between hampering and harming of our health. The limit which defines from when onward there is real danger to our health depends, aside from the loudness of outside noise, also on the amount of time a person is subjected to the noise. As a general rule, noise levels running somewhere around 85 dB(A) are only reached in industrial and recreational settings.

Outside noise sources that influence levels of concentration and work performance, and also hinder our communication or interrupt required rest phases, are primarily traffic-caused. In this, we distinguish between a permanent noise level (road) and a short-term noise level (airplane, train, cars waiting at a traffic light). In case of even sources, constructional countermeasures can be enacted, like, for instance, double façades or noise protection shields. The amount of stress caused by short noise level caps depends on their frequency and, as a rule, is much harder to evaluate. Since, when moderate outdoor temperatures prevail, most people enjoy ventilating their rooms via the windows, one needs to look at outdoor noise influence for two different settings: closed and open windows. For energy considerations also, natural ventilation is to be preferred during those times of the year that allow for it without hampering thermal comfort in any significant manner. This reduces running times of technical systems and thus also energy demand. Depending on window arrangement, different levels of indoor noise are being reached. Decisive is, however, how high the disturbance factor really is and whether it is being accepted inside the room on an ongoing basis. Practice shows that, for the sake of natural ventilation through the windows, occupants are frequently willing to accept higher levels of noise interference from the outside. In contrast, smaller noise levels from ventilation units are not accepted as well. *Figure B1.39* shows an evaluation of indoor noise levels for different applications.

Interior noise sources result from other people, technological systems or other devices. In this, we need to distinguish between the need for total noise elimination or whether there is merely the need to render conversation fragments incomprehensible. For settings with only temporary stay rates (restaurants, department stores), for instance, higher noise levels are accepted than would be the case in bedrooms or meeting rooms. For sectioned rental areas, be it for residential or office applications, a high degree of insulation is required. Within the flat or the entire rent-

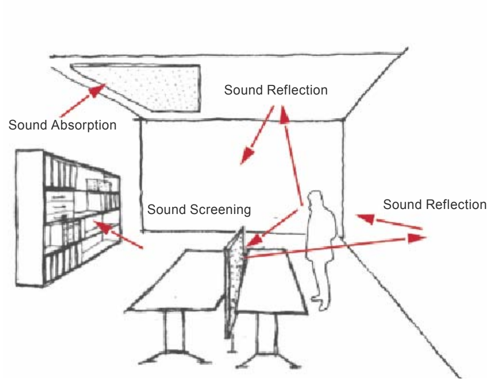


Fig. B1.37 Factors of influence on reverberation time and acoustic comfort

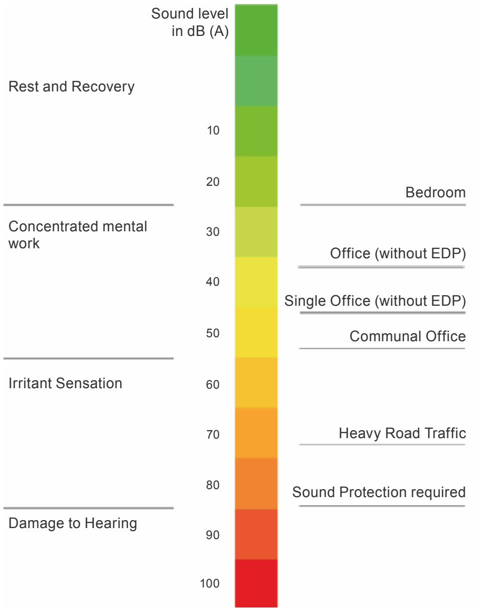


Fig. B1.39 Classification of indoor noise levels, dependent on activity and utilization

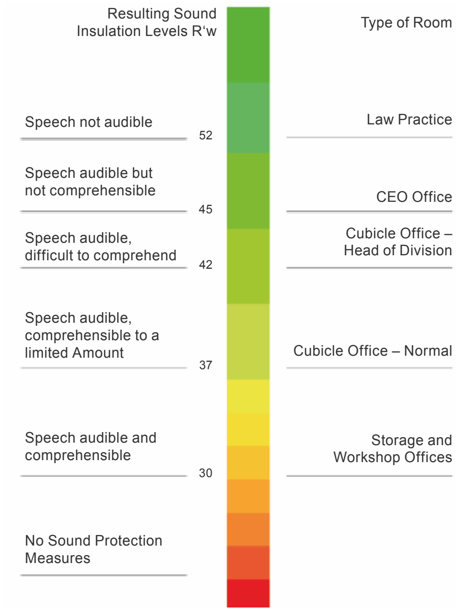


Fig. B1.40 Sound insulation classification for dividing walls in office areas according to utilization

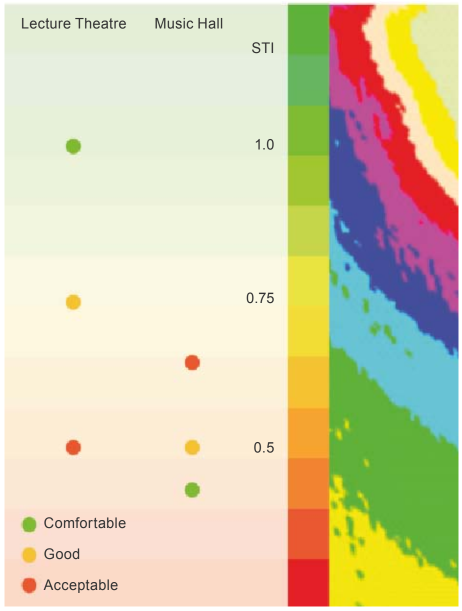


Fig. B1.41 Measuring values for speech comprehension for different utilization

al area, there are highly differing quality levels for sound insulation, which depend to a large extent on their area of application *(Figure B1.40)*.

A high level of acoustic comfort is obtained when noise interference for the individual utilization sector is minimized while speech comprehension levels are increased. Demands placed on the materials used for this, however, are of differing natures. For materials like glass, metal and visible concrete, it is becoming increasingly more essential to reduce echo inside rooms through acoustically effective facing framework, like suspended ceilings. This allows for pleasant acoustic indoor conditions but it renders ineffective to a large extent the concrete steel ceiling for thermal storage. Individual optimisation shows clear disadvantages in this for achieving the overall target of a comfortable and energy-efficient building.

Echo time, also called reverberation time, is a measuring value that provides readings for the type of sound inside a room. It is significantly influenced by the sound absorbing or reflecting characteristics of room surface areas and by room volume. Aside from equability of sound distribution, it is the most influential measuring value for evaluating the acoustic merits of a room. For sectors with a high demand for communication, a minimum reverberation time is required in order to allow for concentrated work. On the other hand, when enjoying music, a longer reverberation time is actually of advantage *(Figures B1.37* and *B1.38)*. Calculations for small to medium sized rooms usually span a frequency range of 125 to 400 Hz for the respective medium third frequencies.

Complementary to reverberation time calculation it is essential, for complex room geometry or high acoustic demand, also to calculate detailed measuring values for indoor acoustics. These are, as a rule:

- Speech Transmission Index (STI)
- Articulation Loss of Consonants (ALC)
- Equability of noise levels in communal rooms

STI and ALC are measuring values that determine the degree of speech comprehension but also the acoustic completeness of musical performances *(Figure B1.41)*. In order to achieve the same comfort level for all the people inside a concert hall or auditorium, sound level distribution needs to be as even as possible. This can be achieved primarily through the correct choice of room shape and the material characteristics of inner surfaces. With the assistance of modern simulation techniques, tracing sound ray path and thus calculating sound distribution, these criteria can already be evaluated in the early design stages. In this, it is important that – during the design phase – there is a simultaneous optimisation of indoor acoustics and thermal and visual comfort, in order to achieve overall utilization optimisation.

Air Quality

Air is vital to life for human beings. Air quality not only determines our level of well being while at home, at school or at work, in hospital or during recreational activities. It also affects our health. Hence, assuring optimal air quality is an important consideration in building design. Requirements will generally depend on utilization and duration of stay. For very airtight buildings like green buildings or passive houses, on account of lower requirements for heating and cooling, there must be very careful design that cannot fall back on »experience shows« kind of values.

The required air exchange rate is no longer merely dependent on density of occupancy but also on outdoor air quality, the kind of ventilation system used and the type of emitting materials used in the building.

»Bad Air Quality« is often given as a reason by people suffering from a wide array of ailments and complaints, such as eye-nose-airway or occasionally also skin irritations, headaches, tiredness, general feelings of being unwell, vertigo and concentration problems. Among experts, these types of complaints are referred to as Sick-Building-Syndrome.

The causes, however, are manifold and can be found either in psychological factors (stress, work overload) or in physically measurable values. Aside from lack of hygiene for ventilation systems, or insufficient ventilation in general, there are other factors responsible also: high emission levels of health-damaging and stench-intensive materials from the components, uncomfortable indoor climate (temperature too high, humidity level either too low or too high, bothersome and constant noise interference, glare from monitors at work).

Pollutants outside the Rooms

Outdoor air in the vicinity of the building can have a negative effect on indoor air quality, by means of pollutant influx from traffic, heaters, industrial and corporate operations. The most significant pollutants are:

- Suspended matter like dust or particulate matter/fine dust (PM10, diesel soot)
- Gaseous pollutants (carbon monoxide CO, carbon dioxide CO_2, sulphur dioxide SO_2 (E-220), nitrogen oxide Nox and other volatile organic compounds (VOC), e.g. solvents and benzene) and also
- Mould fungi and pollen.

Outdoor air ozone content, as a rule, is not relevant for interior rooms since ozone is a very reactive substance and therefore, its concentration levels drop rapidly once in the room. Natural

Location Description	Concentration Levels CO_2 ppm	CO mg/m³	NO_2 µg/m³	SO_2 µg/m³	Overall-PM mg/m³	PM_{10} µg/m³
Rural Areas, no significant Sources of Emission	350	< 1	5 to 35	< 5	< 0.1	< 20
Small towns	375	1 to 3	15 to 40	5 to 15	0.1 to 0.3	10 to 30
Polluted Downtown Areas	400	2 to 6	30 to 80	10 to 50	0.2 to 1.0	20 to 50

Tab. B1.3 Examples for mean annual concentration levels of outdoor air pollution

or mechanical ventilation decisions, therefore, are primarily based on building location and the prevailing levels of air pollution. Depending on outdoor air quality levels, all the possibilities and limits of air supply in respect to natural ventilation via the windows, filtering and cleaning of outdoor air, must be taken into account during the planning phase *(Table B1.3)*.

Indoor Air Quality

The required amount of air exchange primarily depends on the number of people in the room, what kind of activities they engage in (e.g. cooking) and the kind of emissions present from materials or appliances. Human emissions, also, place a strain on indoor air quality, depending on degree of motion of the persons concerned. Pollution levels can be fairly easily determined by looking at carbon dioxide concentration levels in the air *(Figure B1.42)*. CO_2 concentration has proven to be an excellent indicator, provided that no significant dust-containing air pollutants are present. Oxygen transport rates in the body decrease with rising CO_2 load and this leads from headaches and decline of performance levels all the way to dizziness.

Emissions from Building Components and Furniture

Aside from humans, materials can also contribute to changes in indoor air quality – by means of their own emissions. This especially applies to building materials used for interior extensions. Building material emissions contribute to raising pollutant levels for indoor air. To secure indoor air quality, therefore, careful choice of ventilation system is important and thus a concept for air pollutant avoidance must be designed prior to deciding on the system to be used. Materials that have a negative application effect on air quality should not even be used in the first place.

In addition to using low-emission or emission-free extension materials and furniture, a well-adjusted and verified cleaning concept needs to be present also. All too often, building cleaning companies make their own decisions as to which cleaning agents are to be used. In this, air quality and ecological aspects usually are not taken into consideration. However, it should be standard to use biodegradable materials only (according to OECD recommendations). High solvent and acid ratios of more than 5% can be avoided also, provided that the products are carefully selected. Likewise, for regular applications, it is possible to completely do without biocides, phosphates and visual brighteners in cleaning agents. Ingredients of cleaning agents proposed by the cleaning companies should be tested, prior to initial use, by a construction biologist. The absence of health-hazardous components needs to be determined and precise dosage instructions defined. This must

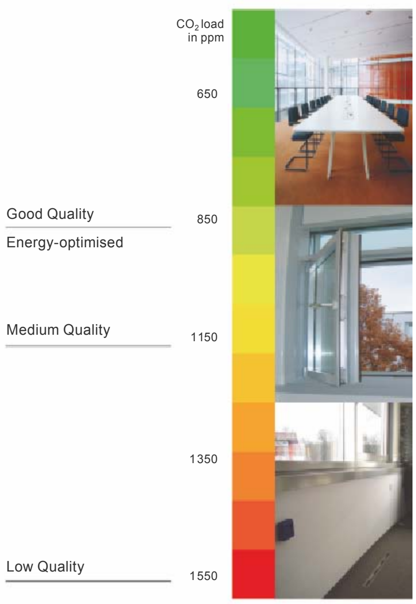


Fig. B1.42 Values for indoor CO_2 concentration

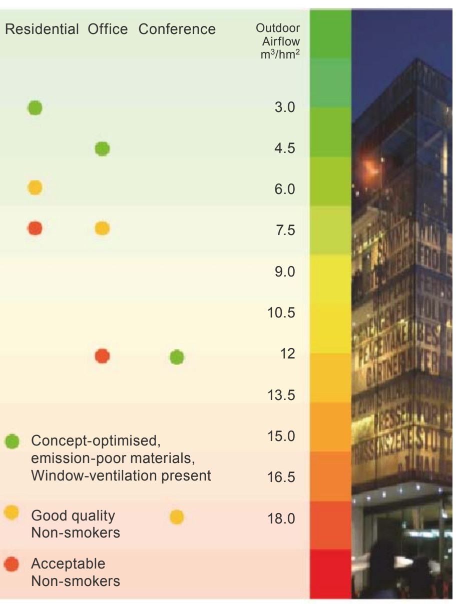


Fig. B1.43 Hygienically required surface-related outdoor airflow rates for different ulilizations be done so as not to endanger a low-emission environment, on the construction side, through unnecessary influx of harmful substances from the outside.

Legal guidelines and stipulations for indoor emission levels are only few and far between. Only for those work stations dealing with hazardous substances is adherence to maximum allowable concentration (MAC) levels compulsory. This is why a task force consisting of members of the Interior Air Quality Commission of the Federal Environmental Agency, and another task force made up of members of the superior health authority of two nations, worked together for defining two standard values. Standard Value II (RW II) is the critical value of concentration levels leading to health hazards for sensitive persons when they stay inside a room for extended periods of time. Immediate action is essential. RW I is the standard value for concentration levels of those materials that, provably and according to current findings, do not damage health even during life-long exposure. This value, in redevelopment, serves as the target value and readings should stay below it, if possible *(Table B1.4)*.

Since there are a number of organic compounds present in indoor air, and since people also tend to complain of adverse health effects when critical values for the individual compounds have not been exceeded, there are further some guidelines for concentration levels of volatile organic compounds (VOC). In indoor settings with a VOC concentration between 10 and 25 mg/m^3, duration of stay should be brief. For longer-term stays, concentration levels should lie between 1 and 3 mg/m^3 and ought to not be exceeded. Target values for good air quality readings lie below a VOC concentration of 0.3 mg/m^3.

Hygienic Requirement for Air Exchange

In order to keep pollutant load in a room to a minimum, the room needs to be supplied with outside air that is as clean as possible. This can happen through natural ventilation, via the windows, or mechanical means like ventilation systems. If pollution is measured solely on CO_2 concentration levels, a person needs at least 20 m^3 of outdoor air for adherence to the hygienically acceptable critical value of 1500 ppm for CO_2 concentration levels in the room. If harmful substance emissions from building components are taken into account also then, with this level of CO_2 concentration, the air is no longer perceived as being fresh and hygienic. *Figure B1.43* lists surface-related outdoor airflow rates as they are to be recommended if the following criteria apply: sufficient ventilation of the room, low-emission extension materials, and energy-efficient sensible consideration.

Compound	(Maximum Value) RW II (mg/m^3) 1)	(Target Value) RW I (mg/m^3) 2)
Toluol	3	0.3
Nitrogen Oxide	0.35 (1/2 h) 0.06 (1 Week)	–
Carbon Monoxide	60 (1/2 h) 15 (8 h)	6 (1/2 h) 1.5 (8 h)
Pentachlorphenol	1 $\mu g/m^3$	0.1 $\mu g/m^3$
Methylene Chlorid	2 (24 h)	0.2
Styrene	0.3	0.03
Mercury (metallic Hg-Steam)	0.35 $\mu g/m^3$	0.035 $\mu g/m^3$

1) Immediate action required when exceeded
2) Redevelopment target value

Tab. B1.4 Reference Values for Pollutant Concentration Levels for Indoor Air

Electromagnetic Compatibility

Ever since his origins, man has been subjected to natural electromagnetic radiation from space: light and heat are forms of very high frequency electromagnetic radiation. Aside from direct sunlight however, naturally occurring radiation levels are rather low. However, through technological advance, additional radiation sources ensued and these impact us humans. *Figure B1.44* shows frequently occurring radiation sources, arranged according to their frequency ranges and their effect on humans. High-frequency radiation, like UV light and X-rays, has an ionising effect and has been proven to harm body cells. Other frequency ranges have proven heat and irritation effects on humans: electromagnetic fields, as they are caused by, for instance, communication media, can be absorbed by the human body. This leads to tissue warming and, depending on intensity and duration, also to health damage like high blood pressure. Further, short- and long-term impact biological effects are as yet not known. There are occasional experiments and studies, however, which show that high levels of electromagnetic radiation in the frequency range of communication media can certainly have a negative impact on sleeping patterns, brain performance capacity, the immune system and also the nervous and cellular systems. For certain, with the rapid rise in communication media presence, electromagnetic load

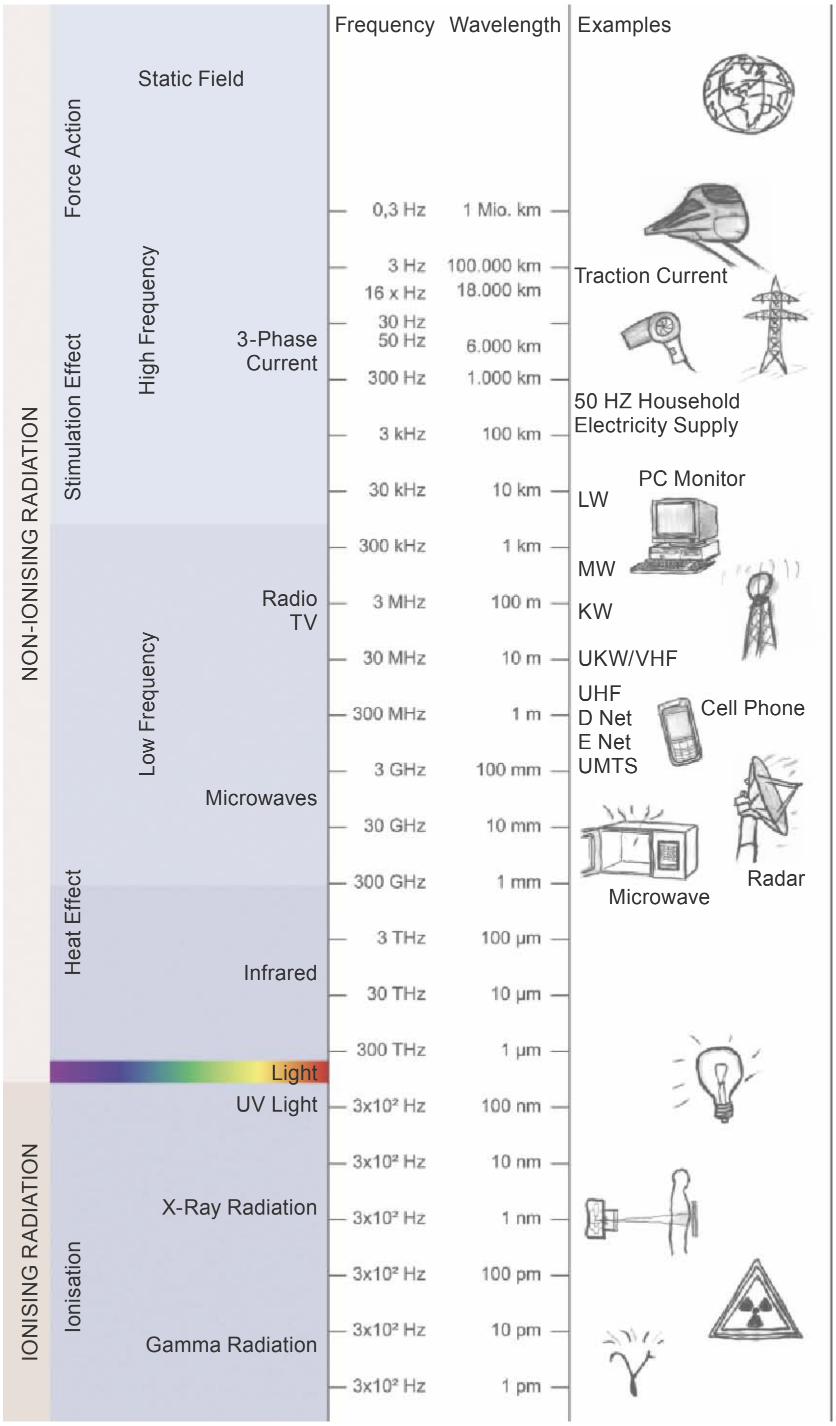


Fig. B1.44 Overview of different radiation sources with their corresponding frequency ranges

Germany	10 – 400 MHz	2 W/m²
	400 – 2000 MHz	2 – 10 W/m²
	2000 – 300000 MHz	to 9.8 W/m²
	Mobile Phone C Net	2.3 W/m²
	Mobile Phone D Net	4.4 W/m²
	Mobile Phone E Net	9 W/m²
Other Nations (mobile telephony)	Australia/New Zealand	2 W/m²
	Italy	0.1 W/m²
	Poland	0.1 W/m²
	Czech Republic	0.24 W/m²
	Russia	0.02 W/m²
	Salzburg and Salzburg County (Recommendation)	0.001 W/m²
	Switzerland (Prevention Value)	1/10 of ICNIRP Critical Values

Tab. B1.5 Critical Values for Electromagnetic Radiation in various Nations

on humans has increased also. Until current long-range and short-term studies have been scientifically interpreted, both communal rooms and the buildings themselves should be designed with preventative aspects in mind: existing critical values and recommendations of international expert panels ought to be adhered to, and there should also be a detailed analysis of particularly critical areas with high radiation load.

Essential decisive factors for human tissue warming through electromagnetic radiation are: frequency range, field intensity, distance to emitter and length of exposure. Radiation intensity can be measured with the unit Watt per square meter (W/m²) whereby output decreases about squarely with distance. This means that an emitter with higher capacity (cell phone antennae) may be less harmful at larger distance than a small emitter in direct body vicinity (cell phone). Radiation load from a cell phone at the ear is 100 times more than at 1 meter distance from the body. International guidelines for mobile telephony critical values have been incorporated in the German Electric Smog Ordinance *(Table B1.5)*. International recommendations, however, when compared to applications in some other nations, are at times between 10 and 100 times higher. The large variability range for critical values only goes to show how widely spread the lack of knowledge about the biological effects of harmful radiation really is.

For Green Buildings, in the interest of prevention, there needs to be a concept – right from the start of the project – for lessening electromagnetic radiation loads. In this, occupant work tools like telephone systems and cell phones ought to be taken into account also. Radiation emission characteristics of a mobile end device are being defined through the Specific Absorption Rate (SAR), the unit of which is Watt per kg of body weight. Operation of a device with a SAR reading of 2W/kg, for instance, and with direct radiation influence on the human body, leads to an elevation of body temperature by about 0.5 °C. Currently, scientists are working with research models to investigate penetration depth and SAR distribution levels inside the human body for different age groups. State-of-the-art cell phones are required to remain below a cap SAR value of 2W/kg. However, for prevention agreements, the critical value proposed by the BMU, of 0.6W/kg, can safely be recommended.

Individualized Indoor Climate Control

Humans are individuals who, depending on character, sex, mental and physical condition, have different needs and wants. Buildings serve humans, on one hand as a protective shell against harmful outside weather influence, on the other as a platform to use for running their lives. For Green Buildings, there has to be the right balance between control of the occupant for indoor climate and automatic regulation. Occupants are supposed to feel comfortable but the required comfort level can fluctuate individually with better energy efficiency application.

One option for **indoor temperature** control ought to be present already through heating and cooling, or both – dependent on climate zone. Temperature control is dependent on outside temperature also because it is significant how often it needs to be implemented. This is also a decisive factor for overall economical considerations as they apply to the building.

For Green Buildings, operative indoor temperature will be similar to air temperature, on account of the large amount of winter and summer heat insulation. Further, the difference between day maximum and night maximum indoor temperatures, as a rule, will be no more than 6K – whether it is in winter or summer. Therefore, it suffices completely to arrange zone temperature control for 2 to 3 °C in order to meet individual requirements.

In climate zones with mean annual outdoor temperatures between 0 and 20 °C, with simultaneous moderate outdoor humidity levels, **window ventilation** serves to save electricity, usually required for mechanical ventilation and cooling generation, and to raise thermal comfort levels. Further, there are psychological factors for availing a window to the occupant. Behind closed façades, people tend to feel locked in and restricted in their free actions. A connection to the outside is established not merely through transparency but through the actual action of opening a window, and then hearing the sounds outside and the feeling the outside air on the skin. Survey among tenants have shown that windows that can be opened are among the most significant criteria when it comes to making a decision on renting a building or parts thereof. This even applies for the King Fahad National Library Project in Riad, Saudi-Arabia. The occupant placed immense emphasis on windows that can be opened, even though outdoor temperatures there only drop below 20 °C from December to January during the day.

Transparency, then, and establishing a connection to the outside are both important characteristics for building where the occupants feel comfortable. Daylight, also, has a very positive effect on human well-being. An individually controllable **anti-glare device** is then inevitable, depending on utilization. The **solar protection device** ought to be individually controllable whenever the room becomes very shaded and thus connection to the outside is restricted. However, an additional automatic control is also essential in order to operate the building in an energy-efficient manner, independent of occupant behaviour.

Lighting should be individually controllable, similar to temperature regulation, owing to different human requirements. It needs to be ascertained, however, that artificial lighting automatically goes off when sufficient daylight illumination is present. This is done in order to operate on an energy-efficient level. It needs to be kept in mind that the addition of artificial light, in that case, does not contribute significantly to the elevation of illuminance.

Variable **indoor noise levels** can still be created nowadays through opening and closing of windows. Further, there are concepts that elevate overall quality of indoor noise levels and thus serve to counteract sound propagation even in large rooms. Unfortunately, this is no solution for an individually controllable interior noise level and the resulting speech comprehension. For office buildings, the future path would lead toward controllable high-tech absorbers in order to fully exploit the advantages of open space areas while at the same time matching them to individual demand. There are already absorbers for multi-purpose halls that function either as sound reflecting or sound absorbing, depending on rotational angle, and therefore can adapt to conditions at hand.

Indoor Air Quality (IAQ) ought to be able to be influenced through opening the windows, depending on outdoor temperature and outdoor climate. Only when low-emission extension materials are used and the design has provided for a good level of airflow, can mechanical ventilation rates be reduced to a minimum. Even so, intermittent airing for special situations is important. Effective window ventilation depends on window size and type. Whether window ventilation suffices for air exchange should be evaluated also in case of complex façades, since in most cases it constitutes an important component of the overall concept.

Occupant / User Acceptance

Most buildings serve humans for purposes of working, living, relaxing and recovery. The average person living in an industrial nation spends about 85% of lifetime indoors. Buildings, thus, can be considered as a kind of third skin for humans. They can and may be designed differently according to mentality and origin of the users, yet they should have something in common: adherence to indoor comfort levels within a certain tolerance range and the use of non health-hazardous material. The tolerance range is determined primarily by ethnic and national-geographic differences. Higher summer indoor temperatures are being accepted better in Northern nations than in nations with a warm climate year round, since maximum indoor temperatures occur there simultaneously with the few hot days of the year. On the reverse, this also applies for minimum temperatures: in Northern Europe, temperatures of 20 °C are frequently perceived as being too cool in winter while, in Southern nations, indoor temperatures of 18 °C – on account of their rare occurrence – are accepted by a large part of

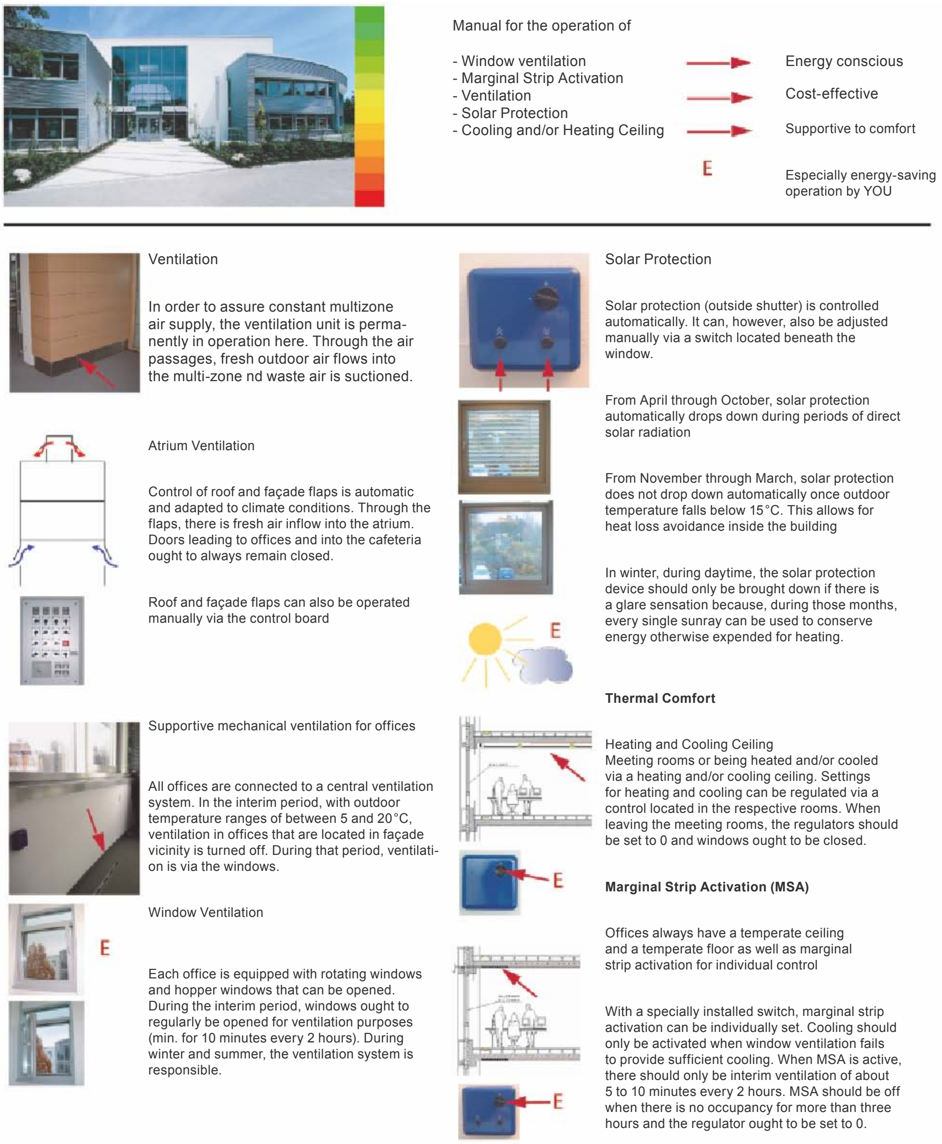


Fig. B1.45 Occupants' brochure for the D&S Advanced Building Technologies building in Stuttgart

the population. These examples show that any type of comfort, as defined by the planner, can only be regarded as a probable comfort that is acceptable to the majority. There will always be exceptions, based on individual preferences and ethnic considerations.

In Europe, needs placed on indoor comfort levels keep rising and so does energy requirement. This applies especially when the buildings are equipped with high quality climate control systems. Surveys show that buildings that have been optimised from a constructional point of view, and are equipped with less technology, are generally well accepted by their occupants if indoor temperatures do not stray too far from optimum levels. Often, such types of buildings are very economical. Purposely, adherence to optimal indoor conditions is foregone for between 3 to 5% of occupancy time but without disregarding comfort consideration. At the same time, these kinds of buildings allow for better incorporation of regenerative energy resources, which means that energy costs are significantly lower than in buildings that are equipped to a sophisticated level. Via modern simulation techniques, winter and summer indoor conditions can be very accurately predicted in their absoluteness and frequency of occurrence. This means that, nowadays, overall economical solutions can already be defined during the early design stages, so long as a certain tolerance level prevails for indoor temperature frequency of occurrence. Our experience shows that the following requirements need to be met, however:

• The rooms have the aforementioned control options and window ventilation
• Slightly higher indoor temperatures only occur in case of very high outdoor temperatures
• Clothing can be adapted to climatic conditions. This means, for instance, that it is possible for the occupants to wear summer clothing with short-sleeved shirts.

If these prerequisites are met, then, additionally, a maximum 28°C indoor temperature needs to be adhered to, at all times, for occupied rooms. Otherwise, performance capacity tends to drop too low. Within this framework, it is quite possible to achieve a higher degree of occupant satisfaction than in buildings that have consistently lower indoor temperatures in summer.