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Edition, Concept, Realization
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Builders taking on the challenge of erecting a modern, innovative and groundbreaking office building today with the objective of providing 1,000 m² or even 2,000 m² of usable floor space find themselves confronted with a complex task.

Numerous factors have to be taken into account. In the very early stages of the project planning process, comprehensive decisions have to be made that define the qualities and capabilities of a building for years to come. This brochure offers a guideline for this decision making process in reference to the targeted building quality, amenities and technical equipment. It makes transparent the various approaches to solutions, the parameters and interdependencies. The aim of the authors is not only to come up with the one and only perfect solution, but also to highlight how to mindfully make the best use of the design options and general conditions.

Given the undercut of the maximal solar influx values, as well as the optimization of internal storage capacities and other regulations, office buildings with facades made entirely of glass, lightweight interior walls and improvident interior design planned for lighting and PCs, which are still quite common today, are no longer in compliance with the state-of-the-art and also not with pertinent laws.

Consequently architects are now called upon to team up with builders to develop and implement new architectural plans, new energy concepts and new operational solutions. The first order of business, just like in any other investment process is the definition of objectives and control factors and to utilize same as the basis for the conception of financial, energy and operational concepts for the future building.
Fundamental Decision:
Building Type and Amenities Standard

Building with standard amenities:
EUR 1,200/m² uncooled

Building with optimized amenities
EUR 1,400 -1,600/m²
silent cooling – concrete core activation
– zone cooling

Building with luxury amenities
> EUR 1,600/m²
air conditioning with humidification and de-humidification

Target and control factors
Temperatures and humidity
Air exchanges
Statutes and standards
Investment and operating costs:
Heating, cooling, ventilation, lighting

Cost effectiveness analysis
Investment costs
operating costs
[energy, service, maintenance costs]
Subsidies

Operational management
Quality control
Facade design

Insulation
Storage
Air tightness

Heating energy
Cooling energy
Ventilation
Lighting

Administration
Energy management
(dynamic data recording and needs-adequate control)
Re-powering
Structured Project Planning

The Planning Process
Every building planning process begins with the fundamental decisions pertaining to the building type and its amenities. The chosen quality – standard amenities, optimized or luxury amenities – determines the building project budget. The options for the technical building amenities concepts are obviously more comprehensive if the building is designed with luxury amenities costing more than EUR 1,600/m² than for buildings with standard amenities budgeted at approx. EUR 1,200/m².

Simply structured standard buildings can usually be erected only without mechanical cooling given their respective budgets and consequently have to be equipped with such architectural and technical concepts that they can be used during hot summer months all the same. Buildings with optimized amenities, which cost anywhere from EUR 1,400 to EUR 1,600 can definitely be equipped with silent cooling, concrete core activation or zone cooling; i.e. energy optimized concepts.

Energy Concept
At the beginning of the planning concept, objectives and general conditions are defined within the scope of the energy concept. Temperatures and humidity levels as well as the ventilation volume have to be defined in compliance with the intended use and requirements of the builder. They have to be stipulated for the following planning processes. The fundamental statutory requirements, such as the EnEV (Energy Savings Act), which will be effective in 2009, must be factored in and bindingly defined for the subsequent phases of the planning process.

An initial overview over the investment and subsequent operating costs is obtained within the scope of the energy concept definitions for the disciplines of heating, cooling, ventilation and lighting. This is where the energy concept and the financing concept interface. The basic cost effectiveness data can now be determined. Investment costs, future operating expenses and subsidy funding are included in the calculation and allow builders to realize long term cost saving measures for the building, such as energy consumption reducing lighting or optimal operational management and energy controlling systems.

Operating Concept
The operating concept defines the quality control measures for the architectural and HVAC concept as well as the subsequent operational management. Carefully calculated benchmark data derived from the operating, financing and energy concept allow builders to take the first critical step in the planning process:

Architecture and Design
Based on the general data on usage requirements, the energy, financing and operating concept, the location and topography of the potential construction site have to be examined at the beginning of the architectural planning process.

In terms of the structural direction of the building and the resulting facade design, the builder has a variety of options to influence same to optimize the building’s future energy consumption. The facade, which usually also has to meet representation expectations should absolutely be built in such a manner that it does not overheat in the summer, especially given the restrictions of the EnEV regarding the maximum solar influx value. The following principle applies: the setting evening sun at the western facade requires efficient external shading from the sun and a minimized facade opening.

Materials and Building Supplies
The architectural design of the building dictates the requirements in terms of insulation, which must be compared with the reference building defined pursuant to EnEV. The storage capacity and the solar influx via the facades must be selected in such a manner that any overheating during the summer months can be ruled out.

Technologies
The final phase deals with issues of heat and cold energy conversion, ventilation systems and application systems such as lighting, EDP equipment and other uses.

In congruence with the procedure of the planning process, measures stipulated in the energy concept are now being implemented: the sum total of technologies, architecture and building materials guarantees that a sustainable office building will be built.
According to the EnEV 2007 a reference building with similar geometry, orientation, net floor space and use will have to be depicted for each building to calculate the primary energy demand. The energy demand of the planned building or building parts must not exceed that of the reference building.

Cooling energy demand will require special attention. The energy required for cooling cannot be applied to the reference building. This means that the required energy for cooling of the new building must be saved on heating energy; which can, for instance, be achieved through particularly efficient insulation or energy provision.

Renewable energies improve the primary energy demand of an office building, their use must be verified.

The requirements of the building envelope are defined in the EnEV 2007 with the thermal coefficient of transmission. The efficient prevention of summer overheating is claimed by compliance with the maximal solar energy influx value pursuant to DIN 4108-2:2003-07 article 8.

Other cooling relevant requirements are the energetic inspections of air-conditioners and the obligation to install new devices with automatic control system.

The EnEV 2007 meets demands of energy efficiency in buildings. The type of construction does not impose any special technical requirements and can be well resolved from both, the technical, as well as the architectural point of view. The requirements imposed on the reference buildings for hot water supply, solar equipment, BTU technology and optimized distribution reflect the current technically economic state-of-the-art.

The DIN V 18599 is based on the EnEV and a highly effective tool, which prescribes precisely the calculation methods based on the form of utilization.

An amendment of the current Energy Savings Act is planned for 2009. With the EnEV 2009 the requirements of the maximal primary energy demand, the thermal coefficient and the maximal solar energy influx value will be further tightened. Furthermore, minimum requirements for insulation of cold water tubes and fittings for cooling supply are discussed to be prescribed. As well heat recovery from air conditioners and central ventilation appliances that at least meet the classification H3 pursuant DIN EN 13 053:2007-09 are discussed to be compulsory.

### Requirements for Building Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Recommended thermal conductivity values for office buildings [W/m²K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls facing exterior air</td>
<td>0,20</td>
</tr>
<tr>
<td>Walls facing unheated or undeveloped roof areas</td>
<td>0,20</td>
</tr>
<tr>
<td>Walls facing other buildings on land or construction site boundaries</td>
<td>0,20</td>
</tr>
<tr>
<td>Soil contact walls and floors</td>
<td>0,25</td>
</tr>
<tr>
<td>Windows, doors with windows and vertical transparent components facing exterior air, exterior doors</td>
<td>1,00</td>
</tr>
<tr>
<td>Ceilings facing exterior air, facing roof areas (with air flowing through or not insulated) and across drive through areas as well as inclined roof areas facing exterior air</td>
<td>0,15</td>
</tr>
<tr>
<td>Interior ceilings facing unheated parts of the building</td>
<td>0,25</td>
</tr>
</tbody>
</table>
Building Type and Amenity Standards

Building and amenity types are divided into three categories:

1. Administrative buildings with standard amenities
   > lowest investment costs and target compliance with statutory elementary conditions

2. Administrative buildings with optimized amenities
   > best investment cost/operating cost, utilization quality and value retention ratio

3. Administrative buildings with luxury amenities
   > maximum conveniences, representative building and use of highly efficient technologies

Modern administration buildings and office buildings have to fulfill numerous tasks. They provide job sites for employees who have to handle a variety of functional assignments and also represent the company.

The fundamentals for the next work steps in the planning process and the architectural design emerge from the definition of the building type based on the financing and utilization concept and taking into account the future operating costs. Administrative buildings with standard amenities and specific costs of EUR 1,200 per square meter can comply with the current statutory requirements if architecture, building materials and technologies are utilized in an optimized fashion. These buildings are efficiently heated and usually do not require cooling.

Optimally equipped administrative buildings usually call for investments per square meter that are EUR 200 to 400 higher. The applicable utilization and efficiency class that applies to these buildings is quite different. These building types can already come in below the current legal maximum values. The structures provide high utilization quality, can be operated in an economically optimized fashion and retain their values sustainably.

A luxury representative administrative building requires investments of EUR 1,600 to 3,000 per square meter and is equipped with innovative, intelligent technology that attains excellent cost-benefit ratios thanks to its modern systems.

The principal rule that applies here is obviously that energy efficient administrative buildings with optimized interior performance do not only generate low investment costs, but that they also offer savings potentials of 30 to 40 percent in a comparison with the operating costs of a fully equipped building with ventilation system, humidification and dehumidifier and outside temperature independent air conditioning.
After an average of just 12 years, the operating costs for heating and cooling frequently outpace the investment costs for technical equipment such as heating and cooling systems.

Buildings are long term investments. Planning decisions do have far reaching effects and erroneous decisions can frequently only be corrected at a substantial expense. Conveniences, utilization capabilities and operating costs determine the sustainable ability to lease the building and also its future sales value.

Scientific projections indicate that

> the number of summer days per year with temperatures reaching more than 25 degrees Celsius will double

> the number of high heat index days per year with temperatures reaching more than 30 degrees Celsius will quadruple

> the number of frost days per year will see a drop of 50 percent

Human performance capacity is contingent upon room climate

<table>
<thead>
<tr>
<th>Control factor operating costs</th>
<th>Main floor space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity/cooling</td>
<td>15 - 40 EUR / m²a</td>
</tr>
<tr>
<td>Cleaning</td>
<td>15 - 35 EUR / m²a</td>
</tr>
<tr>
<td>Inspection and maintenance</td>
<td>5 - 35 EUR / m²a</td>
</tr>
<tr>
<td>Value retention maintenance</td>
<td>5 - 15 EUR / m²a</td>
</tr>
<tr>
<td>Heating</td>
<td>5 - 15 EUR / m²a</td>
</tr>
</tbody>
</table>

source: Leitfaden Nachhaltiges Bauen, Dt. BM für Verkehr, Bau und Wohnungswesen
Utilization requirements
Office buildings must be designed in such a way that they provide their users with optimum conditions for creative and productive work environments. Deficits in building quality translate into declining performance, health impediments and ultimately a reduction in the level of motivation exuded by highly qualified staff members.

The climate is changing
Recently published studies and projections agree: the average temperature will rise by 2 or 3 degrees Celsius over the next two decades. This makes it evident that we will be facing a new challenge imposed by the climate as well, in particular in regard to the appropriateness of buildings for occupation during the summer months.

Room Temperature and Economy
If the room temperature is increased by a mere 4 degrees Celsius, the ability to concentrate and consequently the productivity of an employee is reduced by 15 to 20 percent!

In buildings, where the interior temperatures during the summer months are significantly higher than the exterior temperatures, this can translate into a loss in productivity equaling 37 hours per year and per employee. In a building occupied by 100 employees who cost an average of EUR 70 per hour and head, this results in a loss of EUR 259,000 per annum for a business.

Moreover, a further increase of energy costs is already foreseeable. At the beginning of 2008, the oil price per barrel first crossed the EUR 100 threshold and pertinent discussions already consider the crossing of the EUR 200 threshold a possibility; the only question remaining is actually at what point in time this price level will be reached.

Investments instead of energy costs
A new building that can be heated at the rate of 15 kWh/m² and year only utilizes about a fifth of the energy of an existing building. Moreover, in combination with the utilization of renewable energy, it can be optimized to a level where future oil and gas price developments no longer have to cause headaches. In other words, the strategy for success applied to the planning processes of modern and economically sustainable office buildings can only be the following:

invest into energy efficiency today instead into energy costs tomorrow.

Sustainability: CO₂-optimization
It is already evident that the management of CO₂-emissions costs will be the key control tool in the European region. Even today, the aversion of CO₂-emissions can be measured in tons and therefore monetary value. In Europe, the current value allocated to each ton of CO₂ ranges between EUR 15 and 25.

Sustainability thanks to energy efficiency
A new administrative building consumes energy when it is:
> heated and cooled,
> consumes lighting,
> hot water,
> requires ventilation and
> operates devices.

The actual energy consumption is determined by the quality of the building envelope, the technical amenities of the building and the behavior of its users.

Heating still makes up the largest portion of the overall energy balance sheet. However, given the foreseeable trend toward increasing exterior temperatures during the summer months, it is safe to assume that the portion of energy consumption dedicated to cooling will increase significantly.

The new building code requirements governing the heating and cooling requirements to be met by newly erected non-residential buildings call for a limitation of the heating demand to 10 to 27 kWh/m²a (depending on how compact the building is).

Deciding factors for the financing concept driven by economized climate protection
The taking into account of the described economic standards results in new factors related to the financing concept of a new building, which, along with the reduced energy costs and the high utilization and resale value of the building, provides completely new decision-making criteria.
Based on the earlier described control factors
> Target temperature and humidity levels
> Air quality and ventilation
> Building materials and resulting storage mass
> Optimization of interior performance in the energy concept and choice of building and amenity type, architecture and design do have a huge impact on the energy balance sheet of a building.

The location and topography determine the direction of the building and the facade design. Construction that is optimized for solar energy use prevent summer heat loads and take advantage of winter time energy influx generated by solar radiation.

During this phase of the planning process, proposals and requirements can be submitted to the planning team as well. A dynamic building simulation, for instance, provides critical decision-making fundamentals. Every change made in terms of insulation, ventilation, glass use, usage and utilization of devices has an impact on the investment and operating costs that can be mathematically calculated. Within the scope of a dynamic building situation, which takes into account numerous factors, it is possible to calculate the future energy requirements of a building as well as the consequences of potential overheating days during summer. This makes it possible to optimally assess the utilization quality.

The following fundamentals apply:
> The insulation standard must be maximized
> The ventilation must be optimized (perform 0.5 to 1.5 air exchanges per hour and room)
> Optimize shading
> Optimize the use of daylight
> Optimize interior temperature and humidity levels

> Reduce interior sources (to 300 W per person)
The costs for the performance of a dynamic building simulation range from EUR 3,000 to 5,000 for a building comprising 1,000 to 2,000 m².

Materials and building supplies
The statutory minimum thermal conductivity values are critical for the selection of the appropriate building materials. A second aspect, which also has to be taken into account, is the thermal insulation the individual materials provide. It is necessary to give buildings storage capacity and mass to reduce or completely rule out summer overheating.

In addition to a choice of building materials with high density and high storage capacities, such as concrete, brick and loam, the market today also offers modern and innovative building materials such as phase change materials that optimize the storage mass through the phase transition provided by small wax particles and stucco cardboard.

Conserving energy (i.e. the energy efficiency of the building’s envelope) is more important than efficient production.

Besides architecture, materials and building supplies are also contingent upon the building design. Quality management must be integrated into the construction process from the very beginning. All companies involved have to be aware of the fact that construction surveillance is being performed under energy efficiency aspects.

Air tightness tests for buildings
One of the highly effective quality monitoring tools prior to the final acceptance and in compliance with building code requirements is the testing of the construction’s air tightness. Pursuant to building code requirements, the building’s envelope is checked for air tightness prior to the final acceptance inspection. The building is qualified by way of a so-called nL 50-value. During the inspection, the building is subjected to over and under pressure. In a building with a mechanical ventilation system, the air exchange must not exceed a maximum value of 1.5/h under a pressure level of 50 pa.

Technologies
Once the target values have been defined in the architectural concept and the materials as well as the building supplies have been selected, the next decision to be made pertains to the technology to be used. The following rule applies:

Storage mass optimization ensures thermal insulation (1,500 kg/m²).

The first priority is to optimize the building in such a manner that it requires as little heating and cooling as possible. Only at this point does the utilization of innovative technologies to cover the energy needs become a critical topic. Among other things, this means
> Optimization of interior sources such as PCs, printers and servers
> Target value for interior performance is a maximum of 300 W per person
> Optimization of lighting (daylight dependent controls and efficient technology)
> Optimization of solar influx into a building through external sun shades
> Optimization of ventilation patterns (0.5 to 1.5 air exchanges per hour)

Depending on the type of amenities and location of the building, builders have at their disposal a variety of heating and cooling technologies to be decided upon during the planning process; pertinent building code requirements apply.

The Energy Certificate as a quality feature
According to building code requirements, the Energy Certificate for non-residential buildings documents the efficiency class the building has been allocated to. In the long term, it will have a critical impact on the ability to lease and retain the value of the building. The Energy Certificate
> is an energy rating label for a building
> establishes a seal of approval for the energy quality of buildings
> shows the energy consumption and energy efficiency of buildings
> ensures transparency, comparability and competition for planners, builders, owners, landlords, prospective buyers and tenants.
Architecture and Design

The effects of solar radiation
A simulation model, such as the one depicted on the right, is used to test the interior effects of solar radiation on the room, which is particularly important for work spaces. It makes it relatively easy to plan with foresight.

Dependence of indoor climate on influential factors direction and percentage of glass cover
Shows the maximum temperatures in offices if exterior temperatures reach 32°C – windows with exterior sun shading, window ventilation (crevice opened at night), median occupation density:

<table>
<thead>
<tr>
<th>Direction of window front</th>
<th>Percentage of window areas</th>
<th>30%</th>
<th>50%</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>east - south</td>
<td></td>
<td>31,8°C</td>
<td>34,3°C</td>
<td>36,8°C</td>
</tr>
<tr>
<td>south - west</td>
<td></td>
<td>31,8°C</td>
<td>34,4°C</td>
<td>36,9°C</td>
</tr>
<tr>
<td>southeast - southwest</td>
<td></td>
<td>31,7°C</td>
<td>34,3°C</td>
<td>37,6°C</td>
</tr>
<tr>
<td>northwest - northeast</td>
<td></td>
<td>29,7°C</td>
<td>31,2°C</td>
<td>32,8°C</td>
</tr>
</tbody>
</table>

Daily progress in a south-west facing corner office
Temperature curve over a 24-hour period
The graphic shows how the room temperature changes within a time frame of 24 hours in an interior room – in relation to the window covered portion of the building’s facade.
The heating/cooling ceiling consists of a double floor; basic lighting is integrated into the ceiling. The steel concrete construction has a three-floor U-shape provides the footprint. The interior courtyard is vast and covered by 40 earth warmth probes buried all around the building, which reach depths of 100 m. The soil, which is always 10 degrees cooler than the ambient air temperature, absorbs excess heat from the building and stores it to reuse it if needed to preheat the cold fresh ventilation air. It goes without saying that this extremely efficient energy storage system also works vice versa and assists with the cooling of the building.

In combination with the long water basin, an earth storage device improves the air quality in the central foyer considerably. The interior courtyard is vast and covered by 40 earth warmth probes buried all around the building, which reach depths of 100 m. The soil, which is always 10 degrees cooler than the ambient air temperature, absorbs excess heat from the building and stores it to reuse it if needed to preheat the cold fresh ventilation air. It goes without saying that this extremely efficient energy storage system also works vice versa and assists with the cooling of the building.

The steel concrete construction has awning-like ceilings to create a room without support beams. It is ideal for a variety of office concepts and divisions. Cubicle-style, combination and open floor office plans are possible. The supply infrastructure (power, etc.) is provided through a double floor; basic lighting is integrated into the ceiling.

Energy concept/insulation

The fundamentals of the climatization concept were developed during the conceptual competition in partnership with engineering firm Ove Arup and were subsequently optimized. The concept calls for the tempering of the rooms to be achieved entirely through the ceiling surface. The heating/cooling ceiling consists of capillary tubes integrated into the stucco, which allows it to activate its storage mass. The atrium provides the buffer zone and allows solar gains in the spring and in the fall. During the summer months, it is converted into an exterior room via "pillows" that can be opened. In the winter it is heated to an intermediate temperature by the heat radiated by the office sections. The room is ventilated by natural thermal convection. Earth channels temper the incoming fresh air. The facade, which can be individually controlled, allows the natural influx of fresh air and the suctioning off of exhaust air from the offices. Only the interior zone is mechanically ventilated by a source ventilation system via outlets on the floor.

In combination with the long water basin, an earth storage device improves the air quality in the central foyer considerably. The interior courtyard is vast and covered by 40 earth warmth probes buried all around the building, which reach depths of 100 m. The soil, which is always 10 degrees cooler than the ambient air temperature, absorbs excess heat from the building and stores it to reuse it if needed to preheat the cold fresh ventilation air. It goes without saying that this extremely efficient energy storage system also works vice versa and assists with the cooling of the building.

Optimum percentage of glass covered surfaces – If a building cools off inside or overheats, complex and costly measures have to be taken to compensate for these fluctuations. Consequently, the glass covered areas of the Energon facade total an optimum 44 percent. The building does not require protruded segments and views are therefore unobstructed. The building is shielded from excessive solar radiation by mechanically operated exterior light control blinds that can be individually controlled.

Effective insulation – The innovative building located in Ulm’s Science Park II is based on a passive solar structure concept. The steel concrete skeleton construction boasts an airtight building exterior made from highly heat insulated wood elements and a mechanical ventilation system with waste heat recovery. The Energon building walls and covers are insulated with virtually no heat bridges: 35 cm insulation thickness in the facade, 20 cm below the building foundation and up to 50 cm on the roof. Modern triple pane window perfectlys the concepts.

Electricity utilization concept – An intelligent lighting system makes substantial contributions to electrical energy conservation. The Energon structure also

Energon, Ulm

Principal builder:
Software AG Stiftung, Darmstadt

Ventilation concept – A deciding factor for the sustainable operation of the building is its ventilation system for fresh air and exhaust air. The ventilation concept in this case is convincing thanks to its intelligence and simplicity. Fresh exterior air is suctioned in by a wide, 28 m long concrete pipe. The surrounding soil warms or cools the air depending on the season. The air is subsequently filtered, additio-
boasts a 328 m² photovoltaic system installed on the roof outside the atrium roof. This translates into the self-production of 12,000 kWh electrical energy.

Electronic control - A highly innovative building automation system monitors and controls the various systems that supply the building infrastructure. Temperature and air quality in the atrium are continuously measured and optimized through the controls of the fresh air fan and the ventilation flaps. The waste heat recovery is controlled in compliance with target values and depends on the fresh air and exhaust air temperatures.

Lighting concept - The building boasts an optimized concept for daylight and artificial lighting as well as an electricity conservation concept for lighting and devices in the building. The percentage of glass surfaces of the exterior facade has been optimized in terms of heat and lighting requirements. Sun shading is provided on an as needed basis by light controlled exterior blinds in front of the office windows and by semi-transparent foil blinds integrated into the roof of the atrium.

Special features - Other special features of the building include the roof covering material consisting of flexible photovoltaic foil, the harmonious color concept and the ecologically designed landscaping. This extraordinary structure has recently been certified as an exemplary passive solar house.

Building parameters in reference to the net floor space:
- Heating energy req. max. 15 kWh/m²a
- Electrical energy required for building technology approx. 5 kWh/m²a
- Primary energy dem. app. 68 kWh/m²a
- Operating costs approx. 2.9 EUR/m²a
- Building costs 1,400 EUR/m²

Office Building
Deutsche Bahn AG, Hamm

Location: Hamm, Westfalen
Investments, subsidies: 1,130 EUR/m²
NFG (KG 300 a. 400); 628,275 EUR
Subsidies provided by BMW (SolarBau)

Project description
The principal builder of the Deutsche Bahn AG office building in Hamm is an investor. The compact structure of the U-shaped building encompasses an atrium opening to the east from the first to the fourth floor. The ground floor below the atrium receives its lighting through sky-lights and is thermally separated from the air space located above it. The air space is a buffer zone that is not to be heated. The main entrance is located in the east on the glass encased side of the atrium.

The floor plan of the building is divided into various functional areas: the inserted sectional spaces (houses inside of a house) are located in the west, along with ancillary space and infrastructure. The southern and northern sections of the house are used as office space in a variety of ways. The ground floor houses service areas and additional offices. The new construction has a basement only in the west. It accommodates warehouse and technical rooms. The five floors comprise a total net floor space of close to 6,000 m².

The central focus of planning was on a largely naturally ventilated and lighted office building without active regular office climatization. A specifically aligned building design and the interaction of effective sun shading, fair faced concrete ceiling providing storage mass, night time ventilation and a 1.8 km long air/soil register counter act summer time overheating. The atrium is a critical component of the ventilation concept. The architectural plans were the result of a tender competition. The architects collaborated with energy planners at Karlsruhe University from the start. The role of the principal builder during the planning phase was assumed by the future user.

Building data thermal insulation:
- Thermal conductivity value (roof) = 0.23 W/m²K
- Thermal conductivity value (floor) = 0.52 W/m²K
- Median thermal conductivity value (entire building) = 0.57 W/m²K

Costs and efficiency
The constructions costs for the office building totaled 1,130 EUR/m², in reference to the net floor space (cost estimate pursuant to DIN 277, KG 300 and 400).

- building construction (KG 300) made up 777 EUR/m²
- technical equipment (KG 400) made up 353 EUR/m².

A subsidiary of EUR 628,275 was awarded for the expanded planning and the monitoring of the administrative building by the German Federal Minister of Economy and Labor (Bundesministerium für Wirtschaft und Arbeit; BMWA) within the scope of its support program SolarBau.

Kresing Architects, Münster
Project participants:
- Büro Brandhorst, Bonn (structural physics);
- Morhenne+Partner GbR, Wuppertal (TGA); Fraunhofer Institut für Bauphysik, Stuttgart/Holzkirchen (measuring technology/building physics);
- Dr. Löfflad, Köln (structural ecology)

Principal builder: HWK Münster (Chamber of Crafts Trades); Office completion: 2004
Location: Franz-Meis-Str. 2, Münster

The Demonstrationszentrum Bau und Energie (Demonstration Center Construction and Energy) is designed as a comprehensive model for integral building planning. The building complex consists of two structures: a two-story duplex, which combines work space and residential space and a large building comprising a multi-sectional house and a foyer of 150 m².

The forum building is a four floor glass foyer with a diagonal wood frame. It houses the consulting and exhibition spaces. In addition to a reading counter on sustainable building, it provides a material library examining the entire spectrum of sustainable construction materials.

Just like the building technology, the heating and cooling systems comprise a wide spectrum of innovative options: from the wood pellets heating system to a heat pump, an efficient waste heat recovery system to solar cooling to an absorption cooling system. The HVAC data is recorded across 500 measuring points and partially made accessible to visitors online. As a result, the exhibition objects are effectively complemented by measuring data and analyses.
Examples > Best Practice

Insulation
Two building components were added to the glass encased forum as additional exhibits. They were implemented in different construction and energy standards. The three-section house complex next to the forum comprises a low energy house and lime sand stone walls and cellular insulation behind a back ventilated wood facade and a passive solar house, as well as a minimal energy house in wood frame construction with various renewable insulation materials. Unlike the passive solar house, the minimal energy house is largely solar heated.

The second free-standing building complex comprises a duplex built from porous adobe and pumice stone with mineral foam insulation and the adobe with wood fiber insulation panels.

The different construction styles are evident on the facade of the duplex. Additional different styles of construction, wall and ceiling structures have been implemented on the interior of the buildings for demonstration purposes.

Users describe the comfort level within the buildings as excellent.

BOB, Aachen

Architects:
Architekturbüro Hahn Helten, Aachen
Project participants: VIKA Ingenieur GmbH, Aachen (energy concept, technical building equipment); Ingenieurbüro für Bauwesen Burkhard Walter, Aachen (frame planning); enervision GmbH, Aachen (building control and communication system)
Principal builder: builders' association, among others VIKA Ingenieur GmbH, Aachen
Completion: 2002

Energy concept
One of the key features of the BOB is its energy concept. With its very minimal energy needs, the building is one of Germany's 25 most energy efficient office buildings and is therefore receiving subsidies from the federal support program "SolarBau".

The heating energy requirements of BOB 1 with a total floor space of 2,100 m² is the equivalent of that of a standard single family home. This low level of energy consumption is attained thanks to a concept combining a compact building with high level thermal insulation and the generation of the heating and cooling energy required from geothermal sources.

Moreover, day light controlled lighting systems were complemented with a building control and communication system, rain water catchment, concrete core tempering as well as a fresh air and exhaust air system with waste heat recovery. A total of 28 soil drill holes were completed at depths of up to 45 m. During the winter, the geothermal heat is increased to the required temperature level by a downstream heat pump. During the summer, the geothermal cooling energy can be obtained straight from the soil. The installation of a costly and energy intensive air conditioning system was therefore not necessary. Electrical power is only required for the water pump drives and the revolving pumps, which are required in any event.

Based on a total electrical energy consumption of 19 MWh per annum, the geothermal system provides 133 MWh to operate the building. Concrete core tempering is used to heat the building. It is based on the principle of surface heating, which makes operation at minimal uploading temperatures possible and consequently allows the best possible utilization of geothermal heat. As a result, the temperatures inside the building remain virtually unchanged. The fluctuations between summer and winter reach a maximum of 2° Celsius (median value based on 2003) while the outside temperatures may fluctuate by up to 20° Celsius. Thanks to this optimum balance between hot and cold temperatures, the monthly energy costs of building BOB 1 total only 0.22 EUR/m² floor space. In conventional buildings, the energy costs incurred range from 0.50 to 2.00 EUR. The energy required for heating, cooling, ventilation and lighting totals 25 kWh/m²a.

Solar construction
Solar construction is part of the energy concept described above. The building is facing north/south, access is provided on the north end. An open, flexible floor plan layout warrants the optimum use of day light.

Thanks to the optimization of window sizes and glass quality, no exterior sun shading is required; all that is needed is interior shielding from blinding light. The solar heating and cooling energy is indirectly activated by the energy stored in the soil, which is generated by earth probes.

Electrical planning/HVAC
A building control and communication system ensures intelligent controls. A central PC controls all switches, ventilation devices, heating and cooling technology and lighting via BUS cables. The artificial lighting is dimmed automatically. Day light controlled blinds ensure non-blinding lighting of the rooms during the summer season.

The BUS technology allows changes in switch control at any time, and also the modification of timer settings, etc., which can be easily reprogrammed on the central computer. New wiring is not required. The modular technical structure also allows the reconfiguration of offices (individual, double, group, combined or open space offices) without any new installation. This flexibility is further supported by the clear horizontal and vertical distribution of the technology, thanks to the fact that technical installations on the interior walls do not exist.

The building control and communication system is connected to the Internet. The BOB developers offer their building users a complimentary energy check each year. Moreover, the owners of the building have the option to check the equipment technology from their homes. They can also turn off the lights and control the temperature in the same fashion.
Solar energy
Solar energy is the earth’s largest usable energy resource. It enters the earth atmosphere in the form of radiation and holds about 1,360 W/m² of power. As it travels through the atmosphere, solar energy is reduced through the absorption streams and reflection; the actual radiation that hits the earth still totals about 1,000 W/m². The global radiation fluctuates depending on season, elevation and radiation angle.

Solar energy can also be integrated into the planning process for energy efficient office buildings. Passive solar utilization is achieved through structural measures that take advantage of solar energy for heat production during the winter season and for the production of room lighting. Active solar energy utilization is secured either through solar-thermal usage or through photovoltaic systems.

Solar thermal systems for heating and cooling
The use of solar energy in solar thermal systems is technically mature and a standard solution for the preparation of hot water in private households. Even in administrative/office applications, solar thermal equipment is an ideal solution for the production of highly efficient hot water supply systems, which can be utilized if the building requires hot water for showers, hot water for kitchen, hot water for cleaning purpose, etc.

The integration of solar thermal equipment into a building’s heating system is always expedient if low temperature systems have been installed in a building. This approach allows the feeding of floor heating, wall heating and concrete core activation systems with solar energy during the transitional period.

Innovative options, such as solar cooling, are also available. In combination with an absorption cooling system, administrative buildings can be cooled with solar energy, which is converted into cooling energy by the absorber and transported into the office spaces via surface cooling devices such as capillary cooling and concrete core activation.

Photovoltaic systems
Photovoltaic systems allow the direct conversion of solar energy into electrical energy. The largest yield is attained if the building is south facing and sits at an inclination of approximately 30°. However, deviations toward the SE / SW (45°) only reduce the yield by 5–10 percent. Facade integrated systems do not only generate energy, can also be used as design elements and emphasize the environmental awareness of the company. The investment costs for small systems (1–3 kWp) range from about EUR 4,500 to 5,000 per kWp; the specific costs drop dramatically as the size of the system increases. At this time, government subsidies for PV are available in the form of an increased feed-in rate.

Concrete core activation
Concrete core activation requires the installation of water transporting tubes into the concrete construction (usually into ceilings). This option allows the provision of heating and cooling energy at economically reasonable costs. Thanks to the large storage mass, energy is used very effectively during low temperature operation; and the heating and cooling is very comfortable from a physiological point of view. This system does not require maintenance.

Concrete core activation offers limited controllability, i.e. users have no option to directly control or set the temperature. When the work day begins in the morning, the components are cooled down to 20°C and as the day progresses during the summer months the temperatures rise slowly and can reach up to 26° or 27°C. If an employee feels too cold, a window can be opened to increase the temperature; however, it is not possible to spontaneously decrease the temperature.

The room is experienced as an agreeably cool place, but one does not get the impression that it is being refrigerated. If the system is set up optimally, the temperature perception meets the human need for comfort. Throughout the entire summer, the room acts like a thick walled and thermally indolent old building at the start of a period of hot weather.

Concrete core activation is contingent upon the availability of unrestricted heat or cold air radiation into the room. Consequently, it cannot be used in conjunction with lowered ceilings. This may lead to acoustic problems in the interior room, for which compensation measures must be considered in the planning process.

Concrete core activations work as free cooling systems very well during transitional periods. To this end, the cooling energy generated from a probe, a flat collector or well and cold water (10 or 12 degrees) is directly fed into the concrete core activation; no heat pump is required. As a result, this solution can produce comfortable room temperatures for 3 to 5 months out of the year without a cooling machine having to be operated. The sole expense stems from the operation of the hydraulic pumps that pump the water into the ground and cause it to stream through the concrete core activation in the ceiling.

Green IT
The integration of innovative information technology into modern administrative buildings is of critical importance for businesses. Under the heading Green IT, topics such as the electricity consumption of computers at work stations and of servers, are now frequently discussed hot issues. New ground breaking technologies are emerging all the time.

Server rooms once occupied by individual servers and storage disks will soon house highly efficient devices that require nothing but a single rack to provide the server performance needed for 100 to 200 work stations. One of the key components driving this trend is the improved computer capacity utilization by virtual servers.

Natural cooling in server rooms
Optimized server rooms boasting cooling capacities of 5 to 7 kW are now commonplace thanks to water cooled racks that can be recooled by earth probes. Both sides of the rack have water cooled surfaces as well as a fresh air/exhaust air system that cools the electronic installations. The cooling water temperature of 18°C combined with cooling capacities of 8 kW and an earth probe warrant adequate server room cooling in direct operation. Depending on the price of the probes used, the investment into such solutions can be amortized within 3 to 5 years; while the operating and maintenance costs as well as the failure security of the system deliver clear arguments in favor of the state-of-the-art development trend towards natural server cooling.
Influential Factors
Controlling the Energy Needs

Direction of the building
The attainment of compliance with the statutory target requirements and the best possible classification in the Energy Certificate is influenced by various factors, including the direction into which the building is facing. Building sites or developments cannot always be randomly designed and it is not always possible to align the building with energy efficient aspects. However, it is always possible to optimize the set-up through the sequencing of rooms, offices, and meeting rooms. From an energy technical point of view, north-facing windows are ideal for office buildings. The daylight is largely non-blinding and it is far less likely that the rooms will be overheated in the summer than it would be in rooms facing east or west. South-facing rooms do not pose any major problems either, since the sun is usually sitting at its zenith by noon and therefore the rays do not reach into these rooms. East and west-facing rooms are much more complex. They require external sun shades, especially, when the sun is setting, to avert overheating.

To optimize the protection from the sun while taking advantage of the day light, the direction and design of the building therefore calls for different facade structures depending on the direction they are facing.

Energy efficient and storage mass optimized buildings with optimum daylight utilization and simultaneous sun protection have larger north-facing windows than south-facing windows. Pointing east and west, they have optimized minimal window areas with external sun shades, which ensure that they fulfill all of the aspects an energy efficient building must meet.

Sun shades are essential components for modern office buildings
If external sun shades are used on all sides of the building, the direction the office is facing is no longer a critical aspect. The differences in energy consumption total less than 2 percent if a dual tract office building is rated at a rate of 90 percent. Sun shading systems are divided into two categories:
- passive fixed sun shades
- active mobile sun shades

Fixed overhangs, cantilevers and shields above windows are used as passive sun shades. Given the radiation angle, these measures are only effective on south-facing facades, while they do not completely prevent radiation from entering the rooms on the other sides of the building. All they do on the other facades is reducing the influx of daylight.

Active sun shading systems can be located in front of the facade, in between window panes or on the interior. However, it is important to remember that only sun shading systems installed on the exterior of the building do have an effective impact on the energy balance sheet of the building. The shading efficiency of the sun protection system varies depending on the bulge, adjustment angle and reflection level of the slats.

Internal heat gain – a key aspect
The internal heat gain is a key aspect in regard to the summer climate to be anticipated. The more densely an office building will be occupied, the more difficult it will be to do without a supporting cooling system.

Model calculations have shown that a minimum office space of 10 m² per employee (based on standard building amenities) is the absolute minimum required for an office to be operable during the hot summer months with night time window ventilation only.
Influential Factors
Controlling the Energy Needs

Night time window ventilation is based on the following principle: throughout the day, the active storage masses of the room are charged by interior sources and external heat gain. Overnight, the charged energy can be released into the room and subsequently into the cooler night air through the air exchange occurring through the open window. As a result, the room temperature in the office in the morning is comfortable enough for it to be used and heats up again throughout the day.

However, if the storage masses are inadequate or the internal heat sources are excessive, or if the summer nights are too hot for any air cooling to take place, the building heats up as the week progresses and by Wednesday or Thursday the usability of the rooms is already limited. The rooms’ interior temperatures are consequently substantially higher than those on the outside.

300 W per person
maximum heat influx

To be able to operate a building with basic amenities that does not have air conditioning or a cooling system during the summer months, the optimization of the interior performance is an absolute necessity.

Only if a value of 300 Watts per person is not exceeded, will night time cooling suffice to release the influx energy back into the outside air. This means that the internal loads have to be optimized and priority must be given to materials and building supplies with high storage capacities.

Taking into account the heat radiated by humans, which equals 80 to 100 Watts, an office equipped with a PC, a monitor and a charging device as well as 50 Watts lighting easily reaches the limit of 300 Watts per person and therefore has to be optimized already during the planning
Key element: energy efficient lamps
The currently most efficient system available is the T5 fluorescent lamp (16 mm diameter) which delivers a 25 – 45 percent greater light yield than the old T8 standard.

<table>
<thead>
<tr>
<th>Type of lamp</th>
<th>heat</th>
<th>light</th>
<th>luminous efficacy (lumen/watts)</th>
<th>durability (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard bulb</td>
<td>95%</td>
<td>5%</td>
<td>8 - 15</td>
<td>~ 1,000</td>
</tr>
<tr>
<td>Halogen bulb</td>
<td>93%</td>
<td>7%</td>
<td>12 - 25</td>
<td>~ 2,000</td>
</tr>
<tr>
<td>IRC-halogen bulb</td>
<td>91%</td>
<td>9%</td>
<td>25 - 30</td>
<td>~ 5,000</td>
</tr>
<tr>
<td>Energy saving bulb</td>
<td>75%</td>
<td>25%</td>
<td>38 - 66</td>
<td>~ 6,000 - 12,000</td>
</tr>
<tr>
<td>Standard fluorescent</td>
<td>71%</td>
<td>29%</td>
<td>47 - 83</td>
<td>~ over 8,000</td>
</tr>
<tr>
<td>T5 fluorescent lamp</td>
<td>67%</td>
<td>33%</td>
<td>67 - 104</td>
<td>~ 16,000</td>
</tr>
</tbody>
</table>

Key element: efficient lights
Optimum light reflectors and maximum possible direct light percentage determine the light operating effectiveness. The correct choice has a deciding impact on the overall energy required.

<table>
<thead>
<tr>
<th>Type of lights</th>
<th>lights operating efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lights with opal cover, old</td>
<td>50%</td>
</tr>
<tr>
<td>Lights with prismatic cover, old</td>
<td>55%</td>
</tr>
<tr>
<td>Lights with prismatic optics, new</td>
<td>77%</td>
</tr>
<tr>
<td>Direct/indirect secondary reflector light, new</td>
<td>67%</td>
</tr>
<tr>
<td>BAP light with high gloss parabolic mirror matrix, new</td>
<td>83%</td>
</tr>
</tbody>
</table>

Electronic ballast
The obsolete versions of ballasts required for ignition and power limitation still produce performance losses of 13 W, while modern electronic ballasts attain values of 5 W lost performances and should absolutely be used in modern office buildings given their additional investment capital amortization of less than 1.5 years.

Lighting management
Automated lighting control is a key factor for an efficient overall system along with manual operation.

Such systems comprise:
- Motion detectors
- Daylight dependent controls with light sensors and daylight control
- Central lighting control through integration of lighting into the building’s technical control system, automated switching, controlling, regulation or BUS systems

> Plan the use of daylight, pay attention to providing non-blinding lighting and proper sun shading

> Use efficient lamps, lights and electronic ballasts, motions detectors and daylight sensors

> LENI recommended value for office buildings: 32.2 kWh/m² and year
Efficient office machines

Inefficient office machines hit the cash register twice: the increased power consumption has a negative impact on the operating costs and their radiated heat contributes to overheating in the summer time, which has to be compensated for through cooling and air conditioning, both of which consume large amounts of energy.

When purchasing office devices, energy efficiency should be a critical requirement. The "Energy Star" label provides helpful information. Criteria for PCs, printers, copy machines, multi-functional devices, scanners and fax machines offer excellent buying assistance. The Energy Star database lists the models with the lowest energy consumption and the Energy Star standard (www.eu-energystar.org).

Office devices consume most of their power not during actual operation, but when they are idle in ‘stand by’ mode. The stand by portion makes up more than 90 percent of the consumption in some models. Consequently, users should pay special attention to the electricity consumption of office machines in various modes of operation. When acquiring office machines, make sure the guideline values stipulated in the table in terms of maximum rated power are not exceeded. It is recommended to include these values into tenders for bids on office devices.

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### Efficient office machines

**efficient offices**

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**Share of operation conditions at the electricity consumption of any average scanner**

- **Sleep Mode** 46,0 kWh/a
- **Stand-by Mode** 5,2 kWh/a
- **Normal Mode** 46,0 kWh/a

**Share of single hardware at the electricity consumption in an average office**

<table>
<thead>
<tr>
<th>max. power consumption (Watt)</th>
<th>On-Modus</th>
<th>Sleep-Mod.*</th>
<th>Off-Mod.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop PC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard office application</td>
<td>50</td>
<td>3,0</td>
<td>2,0</td>
</tr>
<tr>
<td>High performance application</td>
<td>90</td>
<td>3,0</td>
<td>2,0</td>
</tr>
<tr>
<td>Monitors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15/16 inch</td>
<td>23</td>
<td>2,0</td>
<td>1,0</td>
</tr>
<tr>
<td>17 inch</td>
<td>30</td>
<td>2,0</td>
<td>1,0</td>
</tr>
<tr>
<td>18/19 inch</td>
<td>35</td>
<td>2,0</td>
<td>1,0</td>
</tr>
<tr>
<td>20/21/22 inch</td>
<td>53</td>
<td>2,0</td>
<td>1,0</td>
</tr>
<tr>
<td>Notebooks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard office application</td>
<td>14</td>
<td>1,7</td>
<td>1,0</td>
</tr>
<tr>
<td>High performance application</td>
<td>22</td>
<td>1,7</td>
<td>1,0</td>
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**Format**

<table>
<thead>
<tr>
<th>Printer</th>
<th>S/m*</th>
<th>max. conspt. Sleep-Mode**</th>
<th>Sleep-Mode*</th>
<th>max. consumption in Off-Mode***</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3/A4</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 10</td>
<td>4 W</td>
<td>&lt; 60</td>
<td>&lt; 30</td>
<td>&lt; 5 min</td>
</tr>
<tr>
<td>11 - 20</td>
<td>4 W</td>
<td>&lt; 60</td>
<td>&lt; 30</td>
<td>&lt; 5 min</td>
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<tr>
<td>21 - 30</td>
<td>5 W</td>
<td>&lt; 60</td>
<td>&lt; 30</td>
<td>&lt; 5 min</td>
</tr>
<tr>
<td>31 - 44</td>
<td>9 W</td>
<td>&lt; 60</td>
<td>&lt; 60</td>
<td>&lt; 5 min</td>
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<tr>
<td>&gt; 44</td>
<td>13 W</td>
<td>&lt; 60</td>
<td>&lt; 60</td>
<td>&lt; 5 min</td>
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</table>

**Multi-functional devices**

<table>
<thead>
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<th>Printer</th>
<th>S/m*</th>
<th>max. conspt. Sleep-Mode**</th>
<th>Sleep-Mode*</th>
<th>max. consumption in Off-Mode***</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3/A4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 10</td>
<td>14 W</td>
<td>&lt; 60</td>
<td>&lt; 15 min</td>
<td>1 W</td>
</tr>
<tr>
<td>11 - 20</td>
<td>14 W</td>
<td>&lt; 60</td>
<td>&lt; 15 min</td>
<td>1 W</td>
</tr>
<tr>
<td>21 - 30</td>
<td>16 W</td>
<td>&lt; 60</td>
<td>&lt; 15 min</td>
<td>2 W</td>
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<td>31 - 44</td>
<td>20 W</td>
<td>&lt; 60</td>
<td>&lt; 15 min</td>
<td>2 W</td>
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<tr>
<td>&gt; 44</td>
<td>24 W</td>
<td>&lt; 60</td>
<td>&lt; 15 min</td>
<td>2 W</td>
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</tbody>
</table>

**Fax**

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<th>max. conspt. Sleep-Mode**</th>
<th>Sleep-Mode*</th>
<th>max. consumption in Off-Mode***</th>
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<tbody>
<tr>
<td>A3/A4</td>
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<td>1 - 20</td>
<td>14 W</td>
<td>&lt; 60</td>
<td>&lt; 15 min</td>
<td>1 W</td>
</tr>
<tr>
<td>21 - 30</td>
<td>16 W</td>
<td>&lt; 60</td>
<td>&lt; 15 min</td>
<td>1 W</td>
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<tr>
<td>31 - 44</td>
<td>20 W</td>
<td>&lt; 60</td>
<td>&lt; 15 min</td>
<td>1 W</td>
</tr>
<tr>
<td>&gt; 44</td>
<td>24 W</td>
<td>&lt; 60</td>
<td>&lt; 15 min</td>
<td>1 W</td>
</tr>
</tbody>
</table>

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* S/m = Quantum of DIN A4 pages per minute, one DIN A3 equals 2 DIN A4 print outs  
** Device in sleep mode  
*** Device is switched off and has no function, but is not entirely cut from electricity
Integral Planning and Technical Design

Even if the planning is absolutely optimum, the building design and construction cannot realize the desired interior room climate without the pertinent technical equipment. Heating, lighting and possibly also the cooling system have to be aligned with the specific conditions of the building within the scope of an integral energy concept.

Heating

Even if the walls and covers of the building are optimally insulated, it will still require heating in the winter, which has a substantial impact on the energy balance sheet of the building. The type of heat generation also depends on the general conditions at the location. In compliance with building code requirements, the use of alternative energy systems such as>

- Energy systems based on renewable sources of energy
- Combined heat and power plant
- Remote and block heating power plants
- Remote and block cooling
- Heat pumps

must be explicitly reviewed if the net floor space exceeds 1,000 m².

Generation of heat

As a matter of principle, the energy resources available at the building location and the statutory requirements determine the options available for heat generation. The connection to a remote or nearby heating network is viable for ecological reasons. Partial solar room heating, i.e. a heating system supported by a solar system, is an alternative to conventional heating systems.

If fossil fuels are used for heating, the best possible available technology should be used to attain a high utilization level and to reduce emissions and fuel consumption. To this end, the use of highly efficient thermal value equipment would be expedient.

Heat pumps used in heating systems utilize the ambient heat and electrical power to generate heat. The performance and work parameter is used to determine the efficiency of a heat pump. The performance value COP indicates the ratio of the radiated heat to the electrical power required to produce it. The work parameter refers to the ratio of the heat volume radiated in comparison to the energy used. While the performance value reflects the current value (performance), the annual work parameter provides a more precise statement as to the actual efficiency of the heat pump under real operating conditions.

Make sure that the heat pump attains a minimum annual work parameter. It must be calculated in compliance with Guideline VDI 4650. For geothermal heat pumps and water heat pumps it should be at least 4.5. The annual work parameter can be easily determined with the assistance of the heat volume meter and the electrical meter for the heat pump and its supporting drives.

Heat distribution

Lower upstream temperatures in low temperature heating systems are advantageous for the use of renewable energies (e.g. heat pumps, solar energy, etc.) and are principally desirable. Depending on the energy medium used, the heat is usually distributed through water as a medium.

Cooling - fundamentals

The debate as to what appropriate cooling systems and sustainable, energy effective systems of supply are is increasingly not only a hot topic among engineers and architects, but also among decision makers at investors and at corporations.

To make such decisions, those involved have to have basic knowledge of the terms and technical options. Just like in numerous other technological and business disciplines, the systems can be allocated to various categories and differentiated based on their performance capabilities. Cooling technologies and applications are primarily divided into>

- passive structural systems
- silent cooling with environmental energy sources
- active cooling systems with ventilation
- and if applicable also with air conditioning.

Passive cooling

Passive cooling is achieved without the involvement of mechanical drive systems and is solely based on structural measures such as facade and shading optimization, the utilization of storage masses, overnight cooling and design of a micro-climate. The first task in hand is to optimize the structure of the building, i.e. to use passive systems to achieve cooling effects.

The direction of the building, the percentage of window surface and the directions the windows are facing are key control factors for the minimization of cooling efforts required once the building is occupied.
The utilization of modern building materials and the optimization of the storage capacity play critical roles in terms of the cooling efficiency of a building. Last but not least, the amenities have to be optimized so that the internal loads of the building are limited to the extent where they no longer exceed 300 Watts per person.

Silent cooling systems:
Energy efficiency and comfort
Silent cooling systems, such as concrete core activation, floor cooling systems or capillary ceiling or wall heating bring energy into the and out of the building using water as the medium. Geothermal sensors, flat collectors below the building or parking lot may be used as heating or cooling potential; even fountain systems with drawing and sink hole wells make it possible to control the temperature inside the building without using a refrigeration device. Another silent system is the controlled overnight cooling through window ventilation, which makes it possible to discharge the storage capacities of the building throughout the night while maintaining compliance with safety and security technical aspects and protects against potential torrential downpours.

Active cooling systems:
Delivering high performance in conjunction with luxury amenities
Active systems are divided primarily into water medium and air medium cooling. The transportation of cooling effects through water as a medium translates into powerful systems: cooling ceilings, cooling sails, but also concrete core activation and capillary ceilings.

Systems working with air as the medium transport a substantial portion of the heating and cooling energy through the mechanical air inflow and outflow. One differentiates between partial air conditioning without humidification and full air conditioning systems that also control the humidity levels in the room.

The active cooling systems can be operated by a variety of systems. Compressors based on stroke pistons, screws, scrolling or turbo machines, which deliver the cooling effects in combination with a recoupling plant, are commonly used.

In optimized use, a combined heat-power-cooling plant, i.e. the simultaneous production of heating and cooling energy, can also be an efficient solution. Absorption and adsorption cooling machines use environmental energy resources. The absorption process, for instance, allows the use of solar energy. In combination with the absorption cooling machine an entire solar cooling system can be created.

Focal points of the energy concept
During the heating period:
Insulation replaces heating.
In the summer:
Storing replaces cooling.

Capillary heating
The capillary heating system is mounted on the finished wall as a bundle of plastic tubes and covered with stucco. Much like concrete core activation, capillary heating takes advantage of the storage activities of the building, albeit to a lesser extent. However, capillary heating systems can be adjusted more quickly and can also be used in renovation projects.

Consequently, it is a highly efficient system. Its integration into the construction process is considerably more complex and the costs are substantially higher than those incurred with concrete core activation. If the cooling or heating capacity of the wall heating system is not sufficient, it can be complemented with a cooling convector mounted to the ceiling of the office. In this combination, it provides an optimally controllable system.

Floor cooling system
A floor cooling system, which principally works just like a floor heating system, provides significantly less cooling output. At the rate of 15 to 20 W/m² it can transport heat out of the room and is easy to control, albeit the required investment costs are considerably lower. It can be used for heating or cooling purposes as needed.

The only conditions that must be met affect the choice of the floor covering, which must have good heat and cooling

### Specific costs for cooling machines with recooling plant without tubing

<table>
<thead>
<tr>
<th></th>
<th>0-250 kW</th>
<th>250-500 kW</th>
<th>500-1000 kW</th>
<th>1000-3000 kW</th>
<th>3000-9000 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scroll</td>
<td>480 €/kW</td>
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<tr>
<td>Stroke piston</td>
<td>300 €/kW</td>
<td>280 €/kW</td>
<td>240 €/kW</td>
<td>220 €/kW</td>
<td>160 €/kW</td>
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<tr>
<td>Screw as of 125 kW</td>
<td>265 €/kW</td>
<td>250 €/kW</td>
<td>210 €/kW</td>
<td>175 €/kW</td>
<td>160 €/kW</td>
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<tr>
<td>Turbo</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Absorber</td>
<td>2,000 €/kW</td>
<td>1,500 €/kW</td>
<td>1,400 €/kW</td>
<td>1,340 €/kW</td>
<td>1,400 €/kW</td>
</tr>
</tbody>
</table>

Source: Gertec Ingenieurgesellschaft

### Specific costs for cooling ceilings, component activation and fan convectors in cassette devices

<table>
<thead>
<tr>
<th></th>
<th>without distribution</th>
<th>without distribution</th>
<th>complete with tubing and cooling energy production, no electricity</th>
<th>125-150 €/kW</th>
<th>40-50 €/kW</th>
<th>1,300-1,500 €/kW</th>
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</thead>
<tbody>
<tr>
<td>Cooling ceilings</td>
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<tr>
<td>Component activation</td>
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<tr>
<td>Cassette devices</td>
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<tr>
<td>Splitter devices</td>
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<tr>
<td><strong>Ceiling/Cassette devices</strong></td>
<td></td>
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</tr>
<tr>
<td>Wall/Cassette devices</td>
<td>7-14 kW</td>
<td>520 €/kW</td>
<td>heating and cooling</td>
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<td>Wall/Ceiling devices</td>
<td>2-14 kW</td>
<td>420 €/kW</td>
<td>cooling</td>
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<tr>
<td>Window air conditioner</td>
<td>2-8 kW</td>
<td>265 €/kW</td>
<td>cooling</td>
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</tr>
</tbody>
</table>

Source: Gertec Ingenieurgesellschaft
Passive Cooling Systems

- Energy transportation in the room
  - Optimization of exterior loads
    - Window surfaces and qualities
    - Wall surfaces and qualities
    - Sun shading
  - Optimization of interior loads
    - Equipment (PC, monitors, devices, . . .)
    - Access to masses (no lowered ceilings)
  - Innovative building materials (PCM)
  - Night cooling

- Energy transportation at low temperature levels (12-17°C)
  - Concrete core activation
  - Capillary ceilings and walls
  - Floor cooling
    (via floor heating systems)
  - Cooling sails

- Silent syst. and air conditioning via fresh air and exhaust air syst.
  - without humidification
  - with humidification
    (+30% for self-use)
  - with waste heat recovery for central ventilation systems

- Ceiling systems (cassettes)
  - with cold water supply
  - with refrigerant supply (split)

Silent Cooling Systems

- Silent Cooling Systems
  - Energy transportation at low temperature levels (12-17°C)
    - Concrete core activation
    - Capillary ceilings and walls
    - Floor cooling
      (via floor heating systems)
    - Cooling sails

Active Cooling System and Climitization

- Silent syst. and air conditioning via fresh air and exhaust air syst.
  - without humidification
  - with humidification
    (+30% for self-use)
  - with waste heat recovery for central ventilation systems

- Ceiling systems (cassettes)
  - with cold water supply
  - with refrigerant supply (split)

Energie-Compilation

- Environmental potential
  - Earth probes
  - Earth collectors
  - Fountains/wells
  - Rivers and lakes
  - Recooling plant
    (hybrid systems with humidification)

- Technical cooling
  - Compression cooling machines

Conduction properties. What makes floor cooling systems ideal is the fact that they instantaneously absorb the solar energy entering the room without increasing the temperature in the room. If the level of comfort of room occupants (cold feet) is adversely affected, the floor heating can also be operated only at night.

Cooling ceilings

Cooling ceilings are among the most powerful cooling systems for office use – however, they are also among the most expensive. With a performance potential of 80 to 120 W/m² they can be integrated into modern office buildings and are easy to control.

Cooling sails (swamp coolers)

Cooling sails or swamp coolers are particularly helpful when installed during renovation projects. They consist of surface or cooling elements that are hung from the ceiling. With cooling outputs of 60 to 80 W/m², they are easy to control and provide a powerful solution that can be installed in each standard office at an average cost of EUR 2,000 to 2,500 per room or cooling sail. Depending on the installation system, they must be coordinated with the lighting system. Cooling sails can improve the room acoustics considerably.

Concrete core activation with ventilation

The limited controllability of concrete core activation systems can be optimized if the system is used in conjunction with a ventilation solution. Principally, ventilation systems are of critical importance for the air hygiene of interior rooms.

By feeding ventilation air into the room, both hot and cool air can be channeled into the room. As a result the interior room temperature and the fundamental load can be quickly and individually adjusted through the concrete core activation.

Heating and cooling with air

If a central ventilation system is installed in the interest of air hygiene, the inflowing air can be heated or cooled to control the room temperature. However, this solution is only adequate as the sole heating or cooling source in extremely well insulated passive buildings.