Energy efficient office buildings

Guidelines

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Modern administrative and office buildings serve a number of purposes. They are the work environment for employees, thus have to meet various functional demands, and also represent the company.

Administrative buildings with standard facilities and an average cost of 1,200 Euros per square meter can, with an optimised combination of architecture, building materials and technologies, meet the applicable regulations. These building are heated efficiently and usually there is no need for cooling.

For administrative buildings with optimised facilities the investment per square metre is as a rule 200 to 400 Euros higher. This results in a different efficiency level. With this type of building the relevant regulatory guidelines are excelled. Operation quality of these buildings is high, they can be run in an economically optimised way and hold their value long term. For a well equipped, representative administrative building investment costs between 1,600 and 3,000 Euros are necessary. Its innovative and intelligent technologies enable a very good cost-benefit-ratio.

Energy efficient administrative buildings with optimised internal loads not only cause lower investment costs, there is also a potential for saving 30 to 40 percent in operation costs compared to a fully equipped building with a ventilation system, air humidification and dehumidification and air-conditioning that is independent of outdoor temperatures.

Buildings represent a long term investment. Planning decisions have a lasting effect and wrong decisions often can only be rectified at great expenses. Comfort, convenience and running costs are deciding factors for long-term rentability and the future selling value of the building.

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### Reduce running costs – preserve the environment

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Source: Leitfaden Nachhaltiges Bauen / Guideline Sustainable Building
Dt. BM für Verkehr, Bau und Wohnungswesen / German Federal Ministry for Traffic, Building and Housing
The climate is changing

Recently published studies and forecasts all point in the same direction: The average temperature will rise by 2 to 3 degrees Celsius in the next decades. This highlights that we are faced with new requirements especially when it comes to the performance of buildings in summer.

Fit for the future through energy efficiency

The energy consumption in a new administrative building is caused by
- Heating
- Cooling
- Lighting
- Hot water
- Ventilation
- Appliances.

The actual levels of energy consumption are determined by the quality of the building shell, the technical equipment of the building and user behaviour. Heating still represents the main bulk of the total energy balance. Considering the current development towards rising summer temperatures it is to be expected that the energy demand for air conditioning will increase considerably.

The new building regulations on energy consumption for heating and cooling in new “non-residential buildings” specify a limit for heating energy of 10 to 27 kWh/m²a (depending on the building’s compactness).

Room temperature and efficiency

If the room temperature is only 4 degrees Celsius to high, an employee’s concentration and productivity levels already drop by 15 to 20 percent! In buildings where the room temperatures in summer markedly exceed outdoor temperatures, this can lead to a productivity loss of 37 hours per year per employee. In a building with 100 employees and an hourly wage of 70 Euros this would result in an annual loss of 259,000 Euros for a company.

Scientific forecasts show that
- the number of summer days per year with over 25 degrees Celsius will double
- the number of hot days per year with over 30 degrees Celsius will quadruple
- the number of frost days will decline by 50 percent.
The location and topography determine the orientation of the building and the design of the house front. Through solar-optimised building, heat loads in summer can be avoided and solar energy gains can be effectively used in winter. In this stage of the planning process the planning team can be assisted by target figures and guidelines. Dynamic building simulations, for example, offer an important basis for decision-making. Every adjustment in insulation, air ventilation, glazing, operation and appliances has calculable effects on investment and running costs. With dynamic building simulation and through taking a number of factors into account, the future energy demand of a building can be calculated, but also aspects like the consequences of possible overheating in summer. This enables an accurate assessment of the quality of use and operation.

Basic recommendations:
- Optimise insulation standard
- Optimise air change (between 0.5 and 1.5 air changes per hour and room)
- Optimise shading
- Optimise use of daylight
- Optimise room temperature and air humidity
- Reduce internal sources (to 300 W per person)

The costs of dynamic building simulation lie between 3,000 and 5,000 Euros for a building of 1,000 to 2,000 m².
Determining factors for energy demand

Orientation of the building

An important aspect is the orientation and design of the building. It is recommendable to structure the building fronts in accordance with the compass points to optimise both protection from the sun and use of daylight. Energy efficient buildings with optimum storage capacity have bigger windows on the North facing front than on the one facing South. Towards East and West the windows occupy smaller, optimised spaces with external sun protection.

Protection from the sun

If external solar shading structures are uses throughout the building, it is not crucial anymore which compass point the office faces. The differences in energy consumption then amount to less than 2 percent when the office building is rotated by 90 percent.

There are two main types of solar shading systems:
• passive / fixed solar shading
• active / mobile solar shading.

Fixed protrusions, eves and blade profiles above windows serve as passive solar shading. Due to the radiation angle these measures are only effective on the South façade. On the other faces of the building they cannot completely prevent solar penetration but reduce the influx of daylight. Active solar shading systems can be on the outside, between window panes or inside the building. Only solar shading on the outside can effectively influence the building’s energy balance. The protection level of the solar shading system varies according to concavity, angle and reflectance of the blades.

Internal heat gains – a key aspect

Calculations have shown that with 10 m² office space or more per employee (assuming a standard building and equipment) airing the office by opening windows at night can be sufficient to achieve an agreeable temperature even during a hot summer.

Ventilation through open windows at night is based on the following principle: During the day internal sources and external heat gains charge the building’s active storage capacities. Through the open windows at night and the resulting air change the stored thermal energy is emitted into the cooler night air. In the morning the office temperature is agreeable and can rise again throughout the day. In case the storage capacities are not sufficient, the internal heat gains are too high or the hot temperatures of summer nights do not allow the office to cool down, the building heats up throughout the week. This means that from Wednesday or Thursday onwards the usability of the office is limited. Room temperatures can then exceed outdoor temperatures considerably.

Source: Handbuch der passiven Kühlung
To be able to efficiently run a building with standard equipment without air conditioning in summer it is indispensable to optimise internal loads. The stored thermal energy can be emitted through natural cooling at night only when 300 W per person are not exceeded. This means that internal loads have to be optimised, and high storage capacities become a crucial factor for the choice of building materials. If human exhaust heat of 80 to 100 Watt is taken into account, an office with a PC, a computer screen, a charger and 50 Watt lighting easily exceeds the limit of 300 Watt per person. This should already be considered in the planning process.
Integrated planning and technical scheme

Even with optimum planning the desired indoor climate cannot be achieved only through the design and construction of the building without appropriate technical equipment. Heating, lighting and if necessary air conditioning must be customised to the specific requirements of the building as part of an integrated energy concept.

Heating

Even if the building is fitted with optimum insulation, the heating demand in winter is a crucial determining factor for the energy balance of the building. The type of heat generation is, among other aspects, dependent on the parameters and legal framework of the building location. In accordance with building regulations it is obligatory to assess the use of alternative energy systems when the net building space exceeds 1000 m²:
- Energy systems based on renewable energy sources
- Combined heat and power systems
- Communal heating and power stations
- Communal cooling and power stations
- Heat pumps

Cooling – the basics

The debate surrounding suitable cooling systems and sustainable, energy efficient supply sources used to be limited to the circles of technicians and architects, but nowadays decision makers in companies and investors become increasingly aware of this important topic. To make sound decisions a basic knowledge of technical possibilities and terms is indispensable. Like in a lot of other technological and scientific areas the different systems can be grouped and distinguished according to their capacity.

The main distinctions in cooling technology are:
- Passive, constructional systems
- Passive cooling (“stille Kühlung”) with environmental energy
- Active cooling systems with ventilation
- and optionally with air conditioning as well.

Passive cooling

Passive cooling works without mechanical drive systems and is based on constructional measures like optimising the façade, solar shading, utilising storage capacities and cooling at night as well as modifying the micro climate. First of all the construction of the building should be optimised by using passive cooling systems. The orientation of the building, the share of window space and where the windows face are major determining factors for minimising the demand for cooling. Modern building materials and optimised storage capacities are crucial for the building's cooling efficiency. Facilities should be optimised to limit the internal loads of the building in order not to exceed 300 Watt per person.
Passive cooling systems: Energy efficiency and comfort

With the measures of passive cooling, for example concrete core cooling, underfloor cooling or capillary ceiling or wall heating, energy is fed into or extracted from the building through water. Ground probes or flat collectors underneath the building or the car park can serve as sources for heating or cooling. Well systems also allow to achieve the right indoor temperature without using cooling appliances. Through regulated cooling by opening windows at night the building’s storage capacities can be discharged. Safety-related aspects or issues like the possibility of heavy rain at night have to be taken into consideration.

Active cooling systems: High performance through sophisticated facilities

Active systems can primarily be divided in water- and air-based cooling systems. Water-based cooling enables high performance systems: ceilings with integrated cooling, cooling sails, but also concrete core cooling and capillary ceilings can be used as active systems. Air-based systems carry a major part of the heating and cooling energy via incoming air and exhaust air. There are air conditioning systems without air humidification and comprehensive systems that also regulate air humidity.

Active cooling systems can be supplied with different methods. Compressors based on pistons, screws, scroll or turbo machines, which in combination with a recooling plant supply cooling energy, are used. Combined power, heating and cooling generation can be a very economic option when used in an optimum way. Absorption and adsorption cooling systems enable the utilisation of environmental energy. In the absorption process, for example, solar energy can be used, thus including the absorption cooling system in a comprehensive solar cooling concept.
Integrated planning and technical scheme

Capillary heating

The capillary heating system is applied on the finished wall as a bundle of plastic pipes and then plastered. Similar to concrete core cooling the capillary heating makes use of the building structure’s storage capacity, but on a reduced scale. In comparison the capillary heating system is more responsive and thus quicker to regulate, it can also be used in refurbishing and is a very efficient technology. It takes more effort to integrate capillary heating into the building process, and the costs are considerably higher compared to concrete core cooling. If the cooling and heating capacity of the wall heating system is not sufficient, it can be complemented by a "Baffel", a cooling convector on the office ceiling. This combination can function as a very well adjustable system.

Floor cooling

Floor cooling in principle works like a floor heating system. Its cooling capacity is considerably lower. At markedly lower investment costs and with 15 to 20 W/m², floor cooling is easy to regulate and can be used for both heating and cooling. It is important that a floor finish with high thermal conductivity is chosen, so there are few limitations when it comes to flooring. With a floor cooling system incoming solar energy is immediately absorbed, so there is no rise in room temperature. If the floor heating or cooling system is perceived as uncomfortable (e.g. causing cold feet) it can also be operated at night only.

Ceilings with integrated cooling

Ceilings with integrated cooling count among the most efficient cooling systems for office use, they are also one of the most expensive solutions. With a performance potential from 80 to 120 W/m² they can be integrated in modern office buildings and are excellent to regulate.

Cooling sails

So called cooling sails are fixed to the ceiling and work similar to radiators in a heating system. They have a large surface area that cools the surrounding air and can also be used in refurbishing. This high performance system with a cooling capacity from 60 to 80 W/m² is good to regulate. For an average office it can cost between 2,000 and 2,500 Euros per room or per cooling sail. Depending on how it is mounted to the ceiling, the lighting concept has to be adjusted. Cooling sails can also improve the acoustics in a room.

Concrete core cooling with ventilation

The limited adjustability of concrete core cooling can be offset in combination with a ventilation system. Ventilation systems are a very important factor for air hygiene in buildings. When air is fed into the building, the room can be heated or cooled down. Through concrete core cooling the room temperature can be adjusted flexibly and short term with the base load.

Heating and cooling with air

When a ventilation system is installed for air hygiene purposes, heating and cooling can be supplied by the heated or cool air that is fed into the building. If this is the only source for heating or cooling, it is only sufficient in extremely well insulated passive buildings.
For concrete core cooling, water based pipes are integrated into the concrete construction (as a rule in the ceilings). This enables heating and cooling at an economically sensible cost. Due to the big thermal storage capacities energy use is very efficient at low temperature operation. Heating and cooling are supplied in a physiologically sound way. Maintenance is not necessary. The scope for regulation is limited with concrete core cooling, the users cannot control or specify the temperature directly. In the morning the building is cooled down to 20 degrees Celsius, throughout a summer day the room temperatures slowly rises to 26 or 27 degrees. If employees perceive the office as too cold, the temperature can be increased by opening the window. Reducing the temperature short term is not possible with this system.

The room is perceived as cool, but not cooled. With well tuned systems they produce an indoor climate and temperatures that instill a sense of well-being. Throughout the summer the building feels like a weighty old building with thick, thermally steady walls. Concrete core cooling requires unrestricted emission of heat and cold into the room, suspended ceilings are therefore not compatible with this system. This can possibly cause acoustic problems that have to be considered and counteracted in the planning process.

Concrete core cooling is a very suitable cooling system for the in-between season. “Cooling energy” from 10 to 12 degrees cold water derived from a probe, a flat collector or a well is directly fed into the concrete core cooling system without using a heat pump or cooling appliance. Thus for 3 to 5 months in the year agreeable indoor temperatures can be achieved without the need for a cooling appliance. The only requirement are hydraulic pumps that pump the water into the ground and feed it into the concrete core cooling system in the ceilings.

The efficient integration of up-to-date information technologies is of great importance for modern administrative buildings. Under the heading of “Green IT” there have been intense debates on the electricity consumption of computers, and new sustainable technologies have been launched. A while back, server rooms have been packed with numerous single servers and storage devices, in the future these will be replaced by highly efficient appliances. A single rack will be sufficient to provide the server capacity for 100 to 200 workplaces. The more efficient utilisation of computer capacity through virtual servers will play a crucial part.

Water cooled racks with recooling via ground probes and 5 to 7 kW cooling capacity are very suitable for optimised server rooms. Water cooled areas and a ventilation system that cools the electronic parts are mounted on both sides of the rack. With a water temperature of 18 degrees Celsius and a cooling capacity of 8 kW, the direct operation of a ground probe can warrant sufficient cooling for the server room. Depending on the initial costs of the probes, the investment pays off after about 3 to 5 years. The operation and maintenance costs as well as the reliability of this system clearly speak in favour of the trend “natural cooling for servers”.

**Supplement: Concrete core cooling**

**Supplement: „Green IT“**
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