Solar and energy-efficient architecture – building envelope and system technology

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Solar and energy-efficient architecture deal with the use of renewable energy and a reduction of energy consumption in the construction and operation of buildings. In Germany, 46 % of final energy consumption occurs in buildings. 90 % of this is accounted for by low temperature heat (< 80°C), chiefly used in heating. Renovation of old buildings has shown that it is possible to save 70 % of final energy consumption using currently available technologies. In newly built homes it has been possible to reduce consumption by over 80 % using the available standard technologies.

Many different concepts are available:

- 3-liter home
- Passive solar home
- Zero energy home
- Plus-energy home

Architects and their clients thus have a wide range of options to choose from when designing a solar energy building. For new residential buildings, the three-litre standard is currently the advanced standard; here, the house is designed so that residents can make do with 3 litres of heating oil per square meter per annum.

Passive homes are a further development that includes a ventilation system with heat recovery. Both of these methods primarily attempt to reduce heat loss. Zero energy homes have also proven successful in practice, though they have not been produced in such numbers to make them generally affordable. However, a proper marketing strategy could increase sales of such homes enormously in the next few years.

In office buildings, integrated total energy concepts (heating, cooling, electricity, light) and the use of passive systems (such as cooling with night ventilation or heat-storing materials) can achieve a 50 % reduction in energy consumption – for the most part without adding greatly to the cost of construction.

Research and development requirements

R&D should aim to conserve energy in buildings and increase the share of renewables used while simultaneously offering the same or higher standards of comfort. The tasks of research and development can be divided into system technologies and technological/ conceptual improvements to the building envelope.

The building envelope is the interface with the environment, influencing heat flows through windows and walls. Loss can be reduced through good insulation, heat can be gained through transparent thermal insulation, and daylighting can be used. It is a functional and design element into which new technologies from the field of renewable energy sources can be integrated (such as photovoltaics, facade collectors).

In the past few years, the development of highly insulating vacuum panels has been an important step in the optimization of building envelopes. Such panels offer the same installation as conventional insulating layers that are some five to ten times thicker. In particular, research is required for the optimization of service life and the integration of systems in buildings and the construction process.

While opaque walls ensure very low thermal conductivity (K value), windows are still thermal weak points in the building envelope – unless we take account of solar energy gains. Double or complex triple glazing provides for values below 0.5 W/(m^{2}K).

Vacuum glazing represents an interesting option. Here, the space between the panes is evacuated down to below 10-3 mbar, which almost completely eliminates thermal conductivity. HVAC systems used play a decisive role in a building's energy efficiency (heaters, control systems, and use of the overall system).

A focal point of research is the replacement of high-performance, active systems based on fossil fuels by systems that use heat sources and heat sinks in the environment, such as in the ground, ambient air, or groundwater (low exergy systems or “LowEx” for short). For instance, the heat storage capacity of light-weight construction can be improved to the level of heavy construction if phase-change materials (PCMs) can be used inside. Rooms would then heat up much less. The heat stored during the day in the PCMs could then be released again at night, when the outdoor area is cooler. If such systems are properly designed no other cooling technologies will be aditionally necessary anymore.

Natural and artificial lighting in indoor meeting points also provide practical visual ambience. At the same time, building illumination must also be included in the calculation of the building’s overall energy consumption. Researchers have developed a number of planning instruments that allow for natural and artificial illumination concepts to be created and optimized. Entire facades can be designed to optimize energy consumption for illumination, and tests can be conducted to determine how these facades affect the energy demand for lighting.

In addition to the further development of materials and encapsulation procedures, system development plays an important role today. Furthermore, robust overall concepts need to be developed so that new components and systems can work together smoothly without a reduction in building comfort. Current approaches utilize simulation-based building management concepts, some of which even take into account weather forecasts and user response.

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The main goals of solar architecture include:

- High-quality building outer shell with especially good heat insulation, consistent avoidance of heat exchangers, and airtight design.
- Compact structures to reduce heat-exchanging components in order to lower costs and reduce energy consumption.
- Solar-optimised windows with switchable transmission properties leading to a positive total annual energy balance whilst at the same time preventing overheating in the summer months and allowing extensive use of daylight, especially in office buildings (improved thermal insulating layers with high solar transmission, electrochromic and gas-chromic glazing, microstructured types of glazing in order to redirect daylight and give shading from the sun).
- Solar-active opaque facade elements to store solar heat in the exterior walls. In principle, transparent thermal insulationoffers great potential for use if technological systems can be successfully developed for simple practical application.
- Other very elegant approaches include systems that allow a variable amount of energy to pass through them so that solar heat can be used effectively in the winter even as a shade is provided in the summer (switchable insulation) as well as systems that combine the functions of heat and cold storage and the use of daylight by integrating phase-change materials in light-permissible components.
- Daylight systems for the interior lighting of buildings, systems for the redirection and distribution of daylight with implemented switchable transmission properties. They allow a better use of natural radiation for lighting, achieving greater lighting comfort and a reduction in the cooling load.
- Examples include optical fibres with low losses and great colour trueness, highly reflective light tubes, and sunscreen systems backed cast shade effectively even though they are transparent.
- New approaches in construction planning that allow for passive cooling in buildings not used for residential purposes, including concepts for nightly ventilation, for instance, and building-integrated water circulation for heat removal. Furthermore, with flat heat storage elements with great energy density should be developed for implementation in walls and ceilings (such as phase-change materials).
- Functional materials with low thermal emissivity can considerably lower the amount of energy that enters buildings through heat radiation in the summer. Such layers are therefore being optimized and means of application, such as woven glass fibres and materials for use in textile architecture, are being developed. The implementation of efficient technologies for passive cooling, such as radiative cooling, poses another challenge.

- New approaches for the development of the multifunctional facades. This field covers the function of energy generation and storage, shading, noise and heat insulation, visual protection and daylighting, ventilation, and design aspects. Examples include building-integrated photovoltaics facades that combine the use of daylight, provide shading and visual protection, and generate electricity.
- Interesting overlapping occurs here, such as when photovoltaics facades are combined with window blinds. Window blinds that react automatically to the amount of daylight or weather conditions also represent attractive, inexpensive architectural solutions that can be further optimized. Automatic thermohydraulic drives are also an interesting form of this combination.
- System management in buildings is the key to the effective integration of innovative technologies. Future system management concepts intelligently take account of current user behaviour and external conditions when computing controls for individual components. The development and implementation of such concepts is a crucial challenge in future research and development.
- Generally, high-quality energy carriers, generally fossil fuels, are used to heat and cool rooms. New developments aim to use the potential of the energy, called "exergy", sparingly. Keeping system temperatures down is one step towards that end. Therefore, innovative systems run with very small temperature differences between the heating/cooling medium and the target room temperature. In this way, renewable sources of energy can be used very effectively, such as thermal solar for heating and the natural cool of subsoil for cooling. Taking account of and optimizing exergy flows in buildings can help identify potential for additional increases in efficiency.
- The energy certificates for buildings that have been recently launched require the determination under standardized conditions of the energy demand of the planned new buildings or existing buildings if no consumption values are available. Parameters and tools that are suitable for our planning and consulting have to be developed so that values can be confirmed, feasibility studies undertaken, and properties optimized. Such tools must be further developed in order to fulfil the requirements of current building codes (such as DIN V 18599 for the assessment of a building's overall energy efficiency) and of future standards.