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Doctor of Philosophy

Thomas Herzog: Pioneer of the 21st Century's New Paradigm

A Dissertation in the Field of Sustainable Architecture

Thomas Herzog: Pioneer of the 21st century's New Paradigm
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ACKNOWLEDGEMENTS

I would like to express my special thanks to my advisor Professor Dr. Ezequiel Uson Guardiola, who has been a tremendous mentor throughout the way for me. I would like to appreciate your valuable guidelines and your sustained guidance in every step of my endeavour. Your advice on both research as well as on my career have been priceless. I would also like to thank all my superiors and colleagues without whose fruitful recommendations this project would not have reached so far.

A special thanks to my family. Words cannot express how grateful I am to my mother and father for all of the sacrifices that you’ve made on my behalf. Your prayer for me was what sustained me thus far.

In the end I would like to express my appreciation to my beloved wife who was always my support in the moments when there was no one to answer my queries.

I dedicate this thesis to my family and my wife for their constant support and unconditional love. I love you all dearly.

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Chapter 1: Performance Form

Chapter 1: Performance Form

1-1 Introduction

1-1-1 Statement of the Problem

Change is inevitable as a part of fundamental human development. It is a simple fact that the building engineering solutions of today will become outdated over time. As engineers, we can contribute significantly to the effort for change but often we do not. Engineers are more typically reliant on “rule of thumb[1]” design or processes that are familiar and proven - an understandable pattern, especially as an engineer’s view must be conservative at times -. But what about intellectual curiosity and the creativity of engineering design? What about using “what if” more often? A stubborn attitude to change is the engineering profession’s heaviest albatross, and yet, at its most fundamental practice, engineering design, or the application of science, has potentially the most to offer in the evolution of the built form. (Kolarevic & Malkawi, 2005)

Prescriptive Design versus performance-based approach

A prescriptive approach is the most commonly adopted approach in engineering design. Prescription implies that there is a set of rules that need to be followed, rules normally outlined by a code or a design guide that is based on previously developed empirical and scientific knowledge. A simple example is the design of a beam from reinforced concrete. (Kolarevic & Malkawi, 2005)

Prescriptive design takes on larger importance when one views it with respect to the larger scale design of systems, such as structural or mechanical systems for buildings. Often due to economic and time pressures, building form is limited in complexity in order to simplify large-scale inputs for engineers, simplifications that manifest themselves in ensuring that the design and the spatial configuration have been seen before and that the design process is predictable. (Kolarevic & Malkawi, 2005)

A prescriptive approach may provide reduced risk, but it can also lead to reduced gains. A performance-based approach may be more tailored to use in a particular project, one where the design problem cannot be simply categorized, or a solution from the past be readily adopted. Performance-based design offers a process that relies more fully on an engineer’s training in creative problem-solving and applying first principles for design. It does not preclude the use of prescriptive areas of design where they may be applicable, either at a component or systems level. But in a performance-based design process, the design inputs have to be carefully developed and meticulously understood. Their effect on the design is critical to the development of an innovative product. The process of design feedback is also critical to the success in performance design. Finally, a design output cannot be prejudged or biased. The

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[1] Rule of thumb: A means of estimation made according to a rough and ready practical rule, not based on science or exact measurement.

process must be relied upon to properly assess inputs to develop and shape an unknown outcome. In this way, emerging computational tools are critical to the process, not as tools for optimization but as technological guideposts for solving complex problems. (Kolarevic & Malkawi, 2005)

It is a fact that prescriptive processes are utilized constantly in building engineering, as our processes for performance-based design are in their infancy. This is for good reason, as performance-based design eliminates several hurdles, the greatest of which is the requirement for integrated design thinking for all members of a design team. For performance-based design to work effectively, it relies on well-communicated feedback loops between different members of a design team. This, in turn, creates a process that is more non-linear than a standard prescriptive approach, a design hysteresis loop that can often be frustrating and time consuming. Again, the use of computational tools can assist and improve this process, but the real challenge is in the management of the design process and in ensuring that design iterations conclude rapidly. An integrated approach to engineering design - one that adapts quickly to other disciplines and is rooted in a fundamental understanding of a variety of building system - is essential to the success of a performance-based approach. (Kolarevic & Malkawi, 2005)

1-1-2 Purpose of the study

To emerge the performance-based design, in which building performances become guiding design principles, to be considered equal or above making the forms. To find out the different performative aspects in Herzog’s works and harmonizing often performance goals conflictions in a creative and effective way.

1-1-3 Hypotheses

The current interest in building performance as a design paradigm is largely due to the emergence of sustainability as a defining socio-economic issue and to the recent developments in technology and cultural theory. Within such an expansive context, building performance can be defined very broadly, across multiple realms, from financial, spatial, social and cultural to purely technical (structural, thermal, acoustical, etc.). (Kolarevic & Malkawi, 2005)

Performance-based design should not be seen as simply a way of devising a set of practical solutions to a set of largely practical problems, i.e. it should not be reduced to some kind of neo-functionalist approach to architecture. The emphasis shifts to the processes of form generation based on performative strategies of design that are grounded, at one end, in intangibilities such as cultural performance and, at the other, in quantifiable and qualifiable performative aspects of building design, such as structure, acoustics or environmental design. (Kolarevic & Malkawi, 2005)

However, Urban planning pilot projects, pioneering buildings, prototypes of building systems and components are created as a result of the knowledge-based design task. All of this is always carried out with a special demand on aesthetic quality. The form is not predetermined, but is created depending on the task as a result of the design process as the case may be. It is called ‘performance form’. Consequently this characterizes the working method of the architectural practice. The problem definition and the specific marginal conditions are examined and interpreted systematically. (“Thomas Herzog + Partner Architekten,” n.d.)

1-1-4 Methods

This study is performed based on reviewing and interpreting the most current resources in green architecture focusing on all the gathered information of Thomas Herzog in the form of case studies and also his techniques will be evaluated based on his designs in different parts of the world.

1-2 Literature review

Thomas Herzog’s Biography

Thomas Herzog, born in Munich in 1941, own practice since 1971,Professor of Architecture since 1974 in KasseL, Darmstadt, and Munich; Dean of the Faculty of Architecture at the Technische Universitat München 2000-06; Guest Professor at Tsinghua University Beijing; Graham Professor at University of Pennsylvania(PENN). Chairman of 4th European Conference on Solar Energy in Architecture and urban Planning 1996. Principal awards: Mies-van-der-Rohe-Prize 1981; Auguste-Perret-Prize for Technology in Architecture 1996; European Prize for "SOLARES BAUEN" 2000; Heinz-Maier-Leibnitz-Medal for excellent research 2005; European Award for Architecture and Technology 2006; International Architecture Award, Chicago, Athenaeum 2007; Global Award for Sustainable Architecture, Paris 2009. (Contal, Revedin, & Herzog, 2009) He established his firm Herzog + Partner in 1983. Since its foundation 1972 the architectural practice ‘Herzog + Partner’ has been committing itself to a development and cultivation of the modern age. The task is to exercise social responsibility and to participate actively in the scientific and technological progress as well as to integrate aspects relevant for the environment in multiple ways – specially the possibilities of solar energy. All of this is always carried out with a special demand on aesthetic quality. The form is not predetermined, but is created depending on the task as a result of the design process as the case may be. It is called ‘performance form’. A dominant interest and scope of the work of the practice is to develop a composition, which includes both, building structures as well as the surrounding landscape and public spaces, to reach a maximum of overall harmony of the architectural design. (“Thomas Herzog + Partner Architekten,” n.d.) In 1993, the German Society of Architects awarded their highest honor-the Gold Medal-to Thomas

Herzog in recognition of his work as a “solar architect”. He is a teacher, researcher and practitioner. His work is innovative yet humane and highly expressive of structure, materials, and the interactions between the building and the natural systems and processes of the site. Throughout his career he has developed new materials and technologies that make possible the creation of increasingly energy and resource-efficient buildings. In promoting the development of ecological architecture, Thomas Herzog is a leader in Europe and is increasingly recognized internationally for his work in this arena. In 1996 the book Solar Energy in Architecture and Urban Planning, edited by Thomas Herzog, was published. Written for an international audience, the central theme is developed around the “European Charter for Solar Energy in Architecture and Urban Planning”, a statement of the principles of solar architecture drafted by Herzog and signed by a thirty leading European architects including practitioners such as Erskine, Foster, Hertzberger and Piano. Directed at planners and architects, the Charter states: The aim of our work in the future must, therefore, be to design buildings and urban spaces in such a way that natural resources will be conserved and renewable forms of energy - especially solar energy - will be used as extensively as possible, thus avoiding many of these undesirable developments [the side-effects of rapid depletion of non-renewable resources]. Not unlike the manifestos developed by early modernists to promote their ideals, Herzog seeks to provide a leadership role in setting the theoretical direction for the work of the next generation of architects. It is interesting to compare both the theoretical aspects and built projects of this new ecological architecture with that of the early modernists. (Pérez-Gómez, 2002)

The background

We might distinguish between two kinds of spatial disposition, effective and affective. In the first, one tries to insert movements, figures, stories, activities into some larger organization that predates and survives them; the second, by contrast, seeks to release figures or movements from any such organization, allowing them to go off on unexpected paths or relate to one another in undetermined ways.

John Rajchman[2]

In the late 1950s, performance emerged in humanities -in linguistics and cultural anthropology in particular- and in other research fields as a fundamental concept of wide impact. It shifted the perception of culture as a static collection of artifacts to a web of interactions, a dynamic network of intertwined, multilayered processes that contest fixity of form, structure, value or meaning. Social and cultural phenomena were seen as being constituted, shaped and transformed by continuous, temporal processes defined by fluidity and mediation; thus a performative approach to contemporary culture emerged.

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[2] John Rajchman, Constructions, Cambridge, MA: The MIT Press, 1998, p. 92.

As a paradigm in architecture, performance origins can be also traced to the social, technological and cultural milieu of the mid-twentieth century. The utopian designs of the architectural avant-garde of the 1960s and early 1970s, such as Archigram's "soft cities," robotic metaphors and quasi-organic urban landscapes, offered images of fantasies based on mechanics and pop culture; they have particular resonance today, as cultural identity and spatial practice are being rethought through performative acts that recode, shift and transform meanings in a true, semiotic sense. (Kolarevic & Malkawi, 2005)

In this spirit, performative architecture can be described as having a capacity to respond to change social, cultural and technological conditions by perpetually reformatting itself as an index, as well as a mediator of (or an interface to) emerging cultural patterns.[3] Its spatial program is not singular, fixed or static, but multiple, fluid and ambiguous, driven by temporal dynamics of socio-economic, cultural and technological shifts. In performative architecture, culture, technology and space form a complex, active web of connections, a network of interrelated constructs that affect each other simultaneously and continually. In performative architecture, space unfolds in indeterminate ways, in contrast to the fixity of predetermined, programmed actions, events and effects.

The description of performative architecture given above is one of many-its paradigmatic appeal lies precisely in the multiplicity of meanings associated with the performative in architecture.[4] The increasing interest in performance as a design paradigm is largely due to the recent developments in technology and cultural theory and the emergence of sustainability as a defining socioeconomic issue. Framed within such expansive context, the performative architecture can indeed be defined very broadly-its meaning spans multiple realms, from financial, spatial, social and cultural to purely technical (structural, thermal, acoustical, etc.). In other words, the performative in architecture is operative on many levels, beyond just the aesthetic or the utilitarian. (Kolarevic & Malkawi, 2005)

It is important to note that the formal "freedom" in the age (1950 to early 1970s) was limited because of the lack of high-performance hardware and software tools ("tools" in the sense of computer program components) in design development and manufacturing. Forms were often found in experiments with scaled physical models,

---

[3] Performative architecture can also be seen as a generator of new cultural patterns. For example, organizers of a recently held symposium on performative architecture in Delft, the Netherlands (March 11, 2004), state that "instead of describing the architectural object, performative architecture focuses on how the architectural object and its process of production perform by producing new effects that transform culture." For more details, see http://www.x-m-l.org/ and also http://www.labau. com/files/doc/performative_architecture.htm

[4] Performance is one of the most used (oftentimes misused and abused) but least defined concepts in architecture. As can be gleaned from this section, the ways in which performance is understood in architecture are often contradictory; the meanings associated with it are often articulated as opposites.

as manifest in the work of Frei Otto or Heinz Isler. The forms they designed through a model-based form finding process were structurally optimized by following the rules of physics.[5] They stand in sharp contrast to the forms designed by form generation processes inspired by nontechnical issues, for example in the work of Frederick Kiesler (who began his architectural formal research before World War II) and later on in the utopian ideas of Archigram and others.

Finding a structurally optimized and geometrically clearly defined form was a necessary condition for building, i.e. for material realization, in the pre-digital era. Frederick Kiesler, however, was not interested in defining forms in a geometrically exact manner that follows physical logic. For his design of "The Endless House" (Figure 1), Kiesler made numerous freehand sketches to visualize his ideas about the form. His naturalistic design was celebrated as the "biomorphic answer and antithesis of the cubistic architecture of modernists."[6] For Kiesler, form does not follow function: form follows vision and vision follows reality. To communicate the spatial complexity of his ideas, he would create physical models just as a sculptor would model an art piece. Unlike the projects by Frei Otto and Heinz Isler, the form of Kiesler's "Endless House" was not inspired by structural optimization but by careful proportioning driven by the scale of human beings in the natural environment.[7] (Kolarevic & Malkawi, 2005)

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[5] Model-based form-finding methods were used in earlier times too. Famous are Antoni Gaudi's physical models for the church of Sagrada Familia in Barcelona. Gaudi was obsessed by finding the structural and material given limits, which is why he investigated every detail in scale models.

[6] Harald Krejci in Frederick Kiesler, Endless House 1947–1961, Frankfurt, Vienna: Hatje Cantz Publishers, 2003, p. 12.

[7] At a Kiesler Symposium at the MMK (Museum of Modern Arts) in Frankfurt, Greg Lynn asserted that Kiesler did not proportion his drawings and models. That is quite true in the sense of a geometrical and architectural proportion theory, such as the harmonic proportion theory of Andrea Palladio. But it seems that Kiesler did proportion consciously his design for "The Endless House." This difference in understanding Kiesler's use of proportion can be illustrated with an analogous difference between the eastern idea of music and the western harmonic theory. Whereas in western culture composers think within a defined geometrical system of standardized pitches, in eastern cultures the atmosphere of the single sound counts, and the rhythm and time is realized as part of the nature. John Cage, for example, has integrated these natural aspects of eastern music in his compositions.

Figure 1: Endless House (1961), architect Frederick Kiesler.

However, In 1967 Progressive Architecture magazine published a special issue on “performance design,” explaining it as a set of practices that had emerged from general systems theory, operations research and cybernetics thirty years earlier, at the end of the World War II.[8] The editors described its practitioners as “systems analysts, systems engineers, operations researchers” and argued that it was a more “scientific method of analyzing functional requirements,” which involved “psychological and aesthetic needs” as well as physical measures of performance. The interest in performance clearly draws on the long history of determinism and functionalism in architecture, understood in large part through the mechanical and organic analogies of the late nineteenth and early twentieth centuries. It is perhaps fitting at the outset to recall that Le Corbusier’s famous description of a house as “machine for living” was his adaptation of the phrase that he and Ozenfant had earlier used to describe painting, a machine a emouvoir, a machine for moving emotions. All the objectivity of functional methods depends on the assessment of subjective needs, of quantified and temporarily stabilized desires. (Kolarevic & Malkawi, 2005)

1-3 Manifestation of performance form in Herzog’s works

Explanation and categorization

Because the sustainable exists for several generations, its form can never be fashionable or avant-garde. “Things are permanent when they are neutral and simple enough to leave space for our changing, multi-faceted lives”. What remains are things that proved themselves as a value, not things which stand out or experiment. It is rather the unagitated, inconspicuous house that possesses the qualities of simplicity and comprehensibility of structure.

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[8] “Performance Design” in Progressive Architecture 48, August, 1967, pp. 105–153.

Herzog's earliest buildings looked 'solar'. The long, angled south-facing glazed walls in the carefully designed and crafted structures also relied on strong geometric forms and efficient structural systems. As his work developed the building form seems to have become more expressive of the materials and techniques of construction. This is a strategy that may help make solar buildings much more acceptable to the mass consumer. Schooled in the work of the early modernists, his buildings are expressive of structure and function (ecological as well as typological) with close attention to formal organization of plan and facade. The projects, research and writings of Thomas Herzog clearly are modernist in origin and inspiration. Like the early proponents of the movement, he, too is compelled to stretch the limits of tradition (even the modernist tradition) and to take a leadership role in "opening the eyes" of the practitioners of today and tomorrow. (Pérez-Gómez, 2002)

However, this chapter of thesis is related to the seven projects of Thomas Herzog's works as case studies which includes five projects of his earliest buildings, 1977-1991, and also the other two projects, Exhibition hall in Linz and DMAG Administration Building.

In one hand, the application of "Performance Form" is flourished in these projects; as a result the interpretations of Thomas Herzog's works, for this chapter, are focused on these suitable projects. In the other hand, in these projects, building design is highly affected by Performance Design both its practices and also its processes by blurring the differences between performance and appearance, analysis and geometry.

Furthermore these examples are successful on integration between architecture and engineering and the process of design is influenced by collaboration and interaction between architecture and engineering which can be defined as "High Performance Buildings".

1-3-1 Thomas Herzog's works 1977-1991

1-3-1-1 House Regensburg 1977-79

Figure 2: Thomas Herzog's 1977 House in Regensburg

Thomas Herzog's 1977 House in Regensburg (Figure 2) is a simple diamond-shaped structure with a sloping glass roof that allows extra light to penetrate the interior. Indicative of the designer's view that environmental architecture should "make necessary technical features visible ... detailing them in an aesthetically effective form," he created a passive solar dwelling using a layered house-within-a-house integration of an intermediate temperature zone.

The visual appearance of the house from some directions is that of a greenhouse[9] facing south, locked into its own cluster of beech trees. The image is high-tech, but it is also comfortably integrated as a result of the use of lean-to timber beams and the feeling that it grows (plant-like) out of its surroundings. The technology applied is visible. It has a glazed southern face (Figure 3), sloping roof for passive solar heat gains, natural limestone floor tiles for radiant heating, stilts to raise the edifice above the high ground water level and protect the beech trees, and the general light-weight construction materials that blend with nature, rather than assert the building's importance. (Pérez-Gómez, 2002)

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[9] Green house: Green House is a Canberra based architectural practice that specialises in environmentally sustainable design with an emphasis on solar winter heating, passive summer cooling, water conservation and the effective use of materials with low embodied energy. We believe in designing to suit your individual living requirements and concentrate on developing construction details that combine visual appeal with structural integrity.

Figure 3: House in Regensburg, glazed southern face

Herzog shows a merging of science and environment as he is guided by both, the laws of physics and the conditions of nature. He believes that progressive architecture “must possess a neutrality that will allow life to develop” and he does not feel “obligated to conform” to the current standard of exhibitionism but instead is content at the cutting edge of “new minimalism[10]”. His advances of technology focus more on natural aspects like infrastructure, site restraints, solar energy and the properties of materials. Such research has leaded him to unusual yet effective concepts including a house in Regensburg, which is a building within another building. As the outer most structure is built much like a green house, it creates a temperate zone, with temperature rising the further inside the second building you go. Herzog has also designed the interior floor plan around this method of insulating the house, with rooms wanting to retain heat towards the center. Along with cheaper heating bills, having a greenhouse outer shell also provides the house with free lighting all day

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[10] Minimalism describes movements in various forms of art and design, especially visual art and music, where the work is set out to expose the essence, essentials or identity of a subject through eliminating all non-essential forms, features or concepts.
The term minimalism is also used to describe a trend in design and architecture where in the subject is reduced to its necessary elements. Minimalist design has been highly influenced by Japanese traditional design and architecture.
Architect Ludwig Mies van der Rohe adopted the motto "*Less is more*" to describe his aesthetic tactic of arranging the numerous necessary components of a building to create an impression of extreme simplicity, by enlisting every element and detail to serve multiple visual and functional purposes (such as designing a floor to also serve as the radiator, or a massive fireplace to also house the bathroom).

and an area between the two structures for temperate plants to grow. The house isn't reliant on the sun however, heat released from under floor heating is absorbed by the wooden framework and kept in by the temperate zone.

The European architect, Professor Thomas Herzog, in his houses at Regensburg (1977) and Waldmor (1982-4), Germany, pursued the concept of the 'building within a building' using the interstitial space between outer and inner skin as a 'buffer zone' often filled with vegetation. ("Greenhouse Effect.," n.d.)

However, Situated between a number of multi-storey buildings dating from the 1950s, the site lies two meters below street level and is distinguished by a stock of tall trees and a small stream. In response to these constraints, the building was oriented to the garden. The line of the pitched roof is continued down to the ground in the form of diagonal glazing, so that the terrace areas and conservatory spaces to the south function as intermediate temperature zones. These spaces are not set additively in front of the building, but form an integral part of the layout. The design reflects the consistent implementation of functional requirements, namely the direct use of solar energy, and the creation of links between the internal spaces and the carefully designed outdoor areas around the house.

The layout is divided into a series of parallel zones. Along the north face (Figure 8) of the building is the external access route. Within the house on this side is a tract containing ancillary spaces and service installations.it is adjoined by a south-facing zone in which the main living rooms are located. These, in turn, give on to greenhouse spaces that face the garden. In winter, the glazed areas of the house serve as a direct means of exploiting solar energy. The rooms in permanent use, therefore, are situated between the heavily insulated zone containing the ancillary spaces to the north and the buffer zone to the south, where solar energy is exploited. Glazed sliding elements allow the living areas to be extended into the greenhouses. The solid floor of the building and the areas of gravel in the conservatories can be used for the temporary storage of thermal energy. The heat stored in this way is released into the house in the evening. Excessive thermal gains can escape via large ventilation openings in the gable areas. The trees, which also form an integral part of the design concept, provide shade in summer. The large areas of glazing (Figure 5) mean that changes in weather conditions - rain, drizzle, etc. - are intensely experienced internally. Snow causes the house to go "blind" - until ultimately it slides down the outer surface in large sheets, cleaning the glass in the process. The triangular cross section of the skeleton frame in glued laminated softwood ensures an efficient form of wind bracing. In view of the high groundwater level, the house was set on piles. The rear-ventilated skin of the heavily insulated outer wall consists of Oregon pine boarding. Technical and constructional details were deliberately left exposed and integrated into the geometric order of the building, lending it an aesthetic effect of its Own. (Herzog et al., 2001)

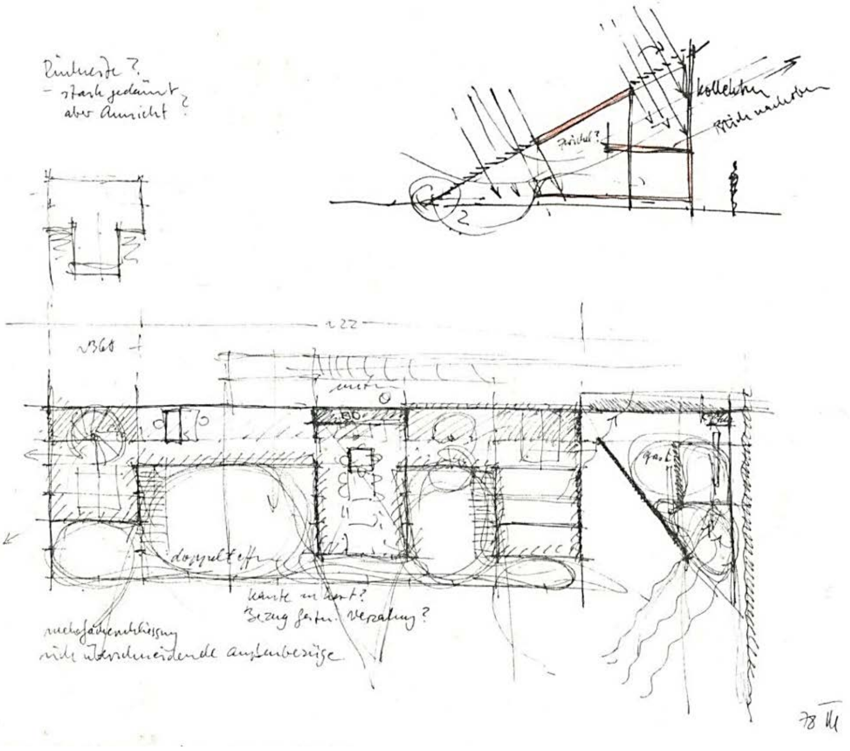

Figure 4: Regensburg House, Conceptual sketches

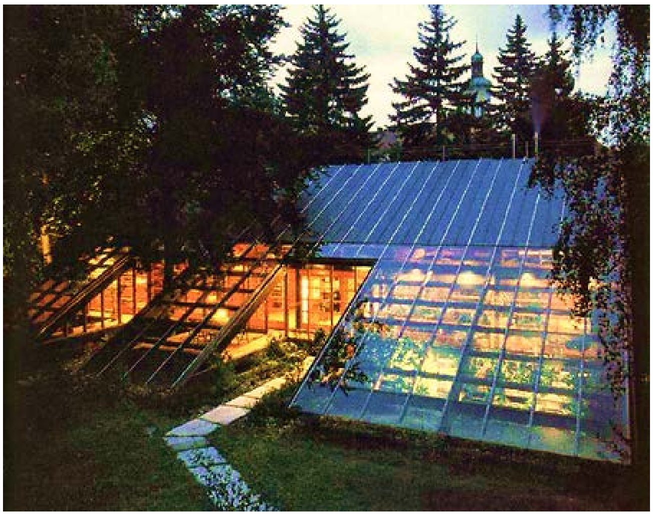

Figure 5: Regensburg House, large area of glazing, southern face

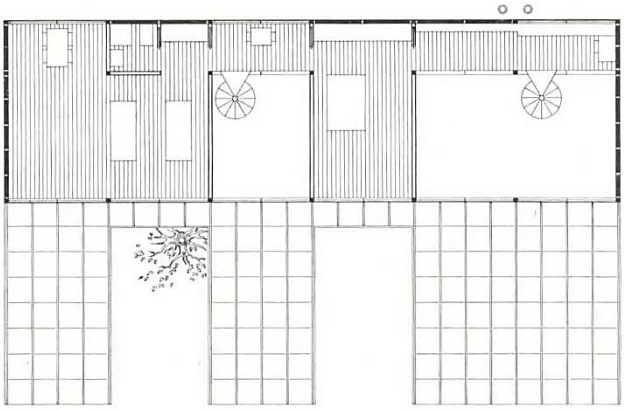

Figure 6: Regensburg House-Upper floor plan

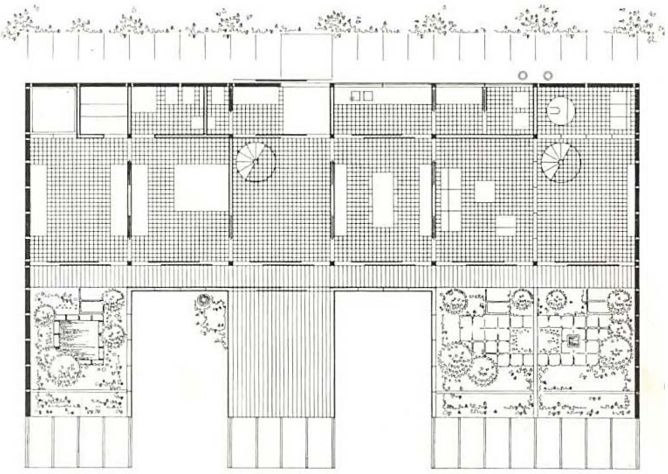

Figure 7: Regensburg House-Ground floor plan

Figure 8: North face

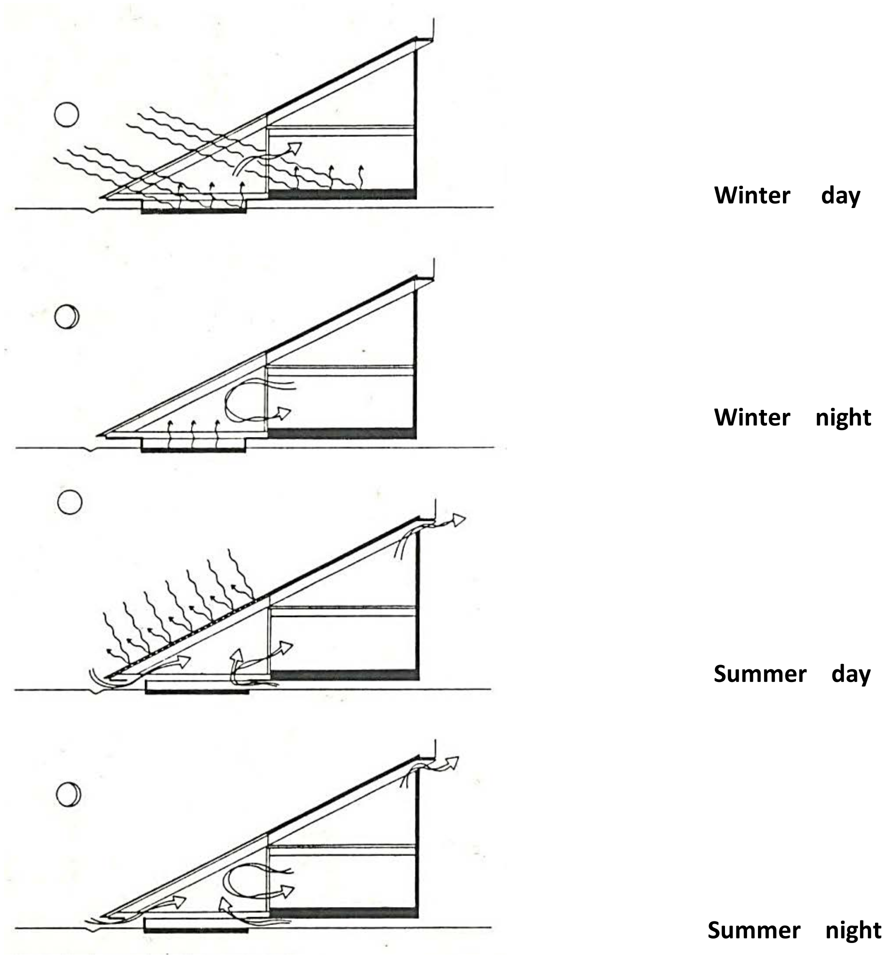

Figure 9: House Regensburg’s energy concept

Figure 10: House in Regensburg, Side view

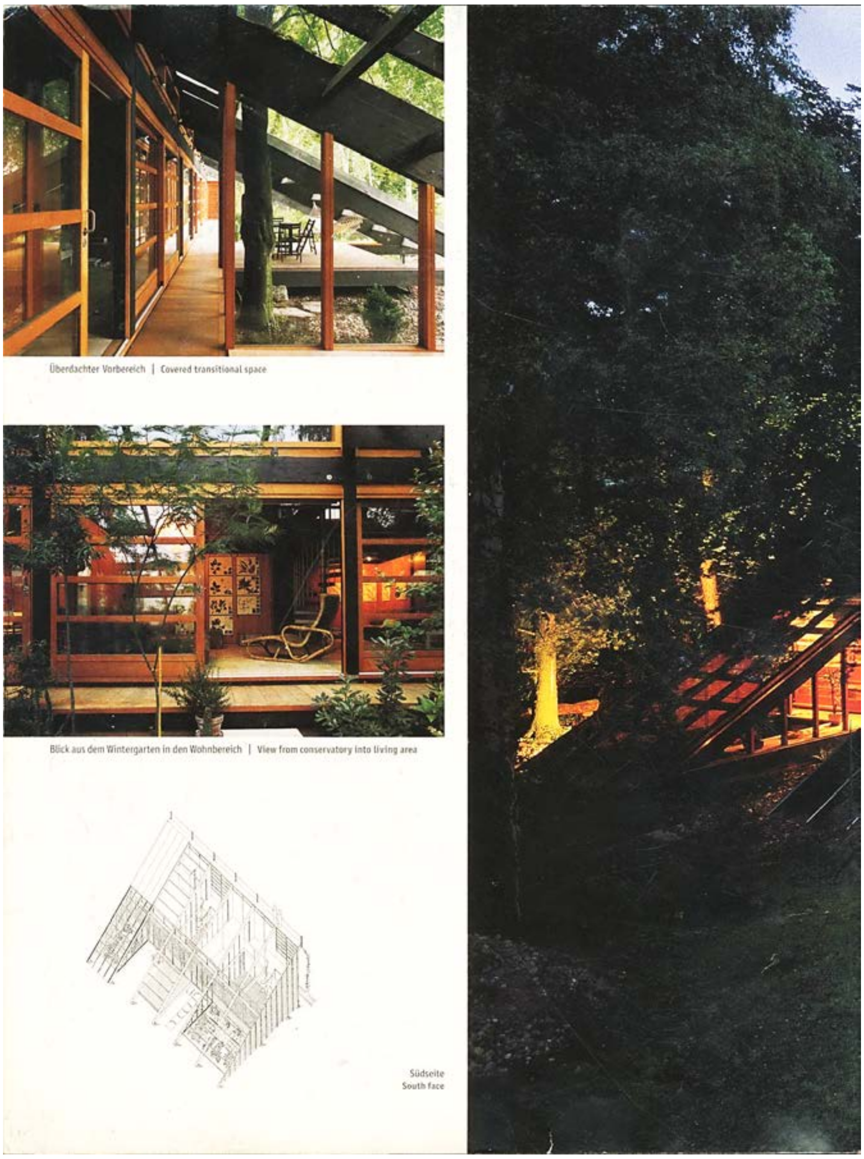

Figure 11: some different views of Regensburg House

Thomas Herzog is elegant in its simplicity, with a form that enables one of the most fundamental principles of sustainable design: passive temperature control through the thoughtful use of material and geometry, coupled with an understanding of how to manage thermal gains from solar energy.

The ‘sunspace’ concept has been in practice since the Victorian era, when conservatories were added to the exterior of buildings to control heat transfer, by providing a space between the exterior and interior to moderate daytime and evening temperatures.
Herzog employs this concept in the House at Regensburg, but within a distinctly modernist, rational form. The sunspaces (also serving as greenhouses) face south, and the structure is divided into zones along the north-south axis. The main enclosed

living space is connected to the sunspaces with an intermediate hallway, as seen in the image of this transitional space below (Figure 12).

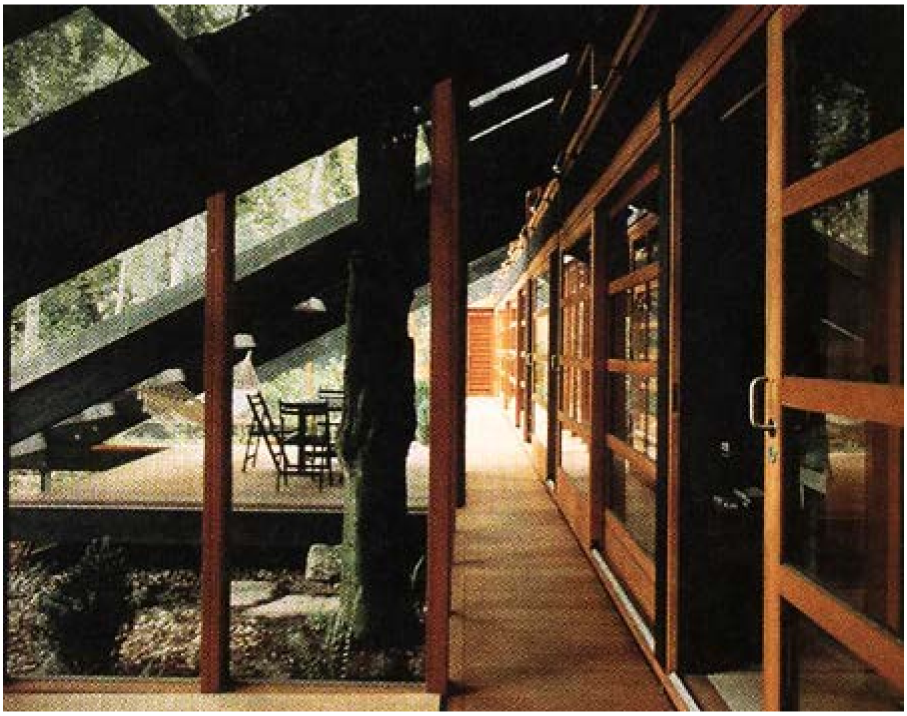

Figure 12: Regensburg House, sunspaces with an intermediate hallway

The entire system of spaces is enclosed by an angled plane of dual pane glass above the sunspace zone that turns into a titanium-zinc roof structure above the living spaces. This spatial integration of solar gain, transitional, and occupied zones allows for a simple triangular form. The visual strength of this form is apparent from the side, clad in locally sourced wood, which softens the minimalist form with contextual, sustainable materials.

A quick analysis of how solar energy is captured, stored, and re-radiated to maintain a comfortable temperature during the winter months is indicated in the section diagrams below (Figure 13).

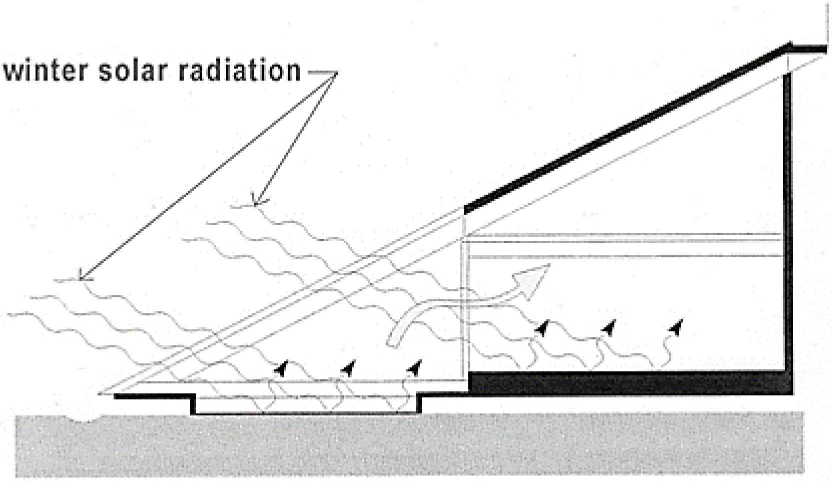

Figure 13: Regensburg House, winter solar radiation

During the daytime in the winter months, solar radiation penetrates into the sunspace, as well as the main living spaces at a low angle, allowing light and heat to enter the home.

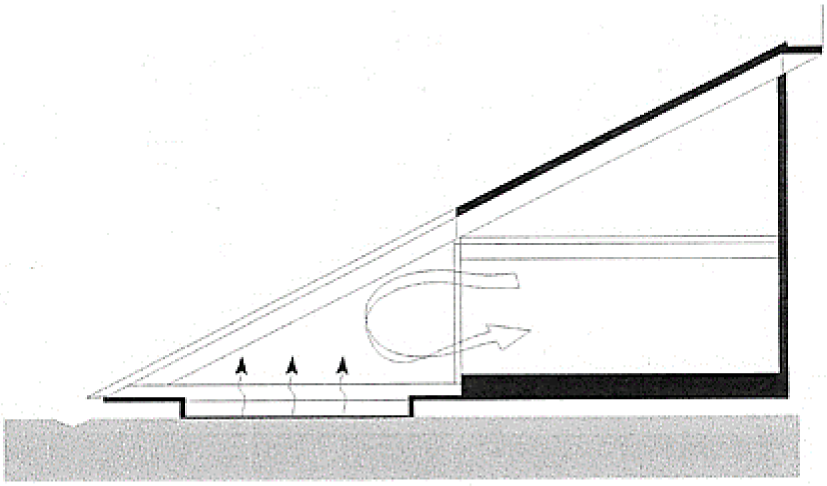

Figure 14: Regensburg House, heat releasing in the evening

To manage temperature at night, the concept of thermal mass is incorporated into the design and informs material selection. Heat is gained and stored in the stone floors throughout the day and released slowly in the evenings to warm the occupied spaces (Figure 14).

Dual pane windows serve to further insulate the space. (This is a strategy used in countless projects, both old and new. Today, we often see concrete utilized to serve this purpose)Herzog designed the House at Regensburg to sit lightly on the earth, with a raised floor system which minimizes any potential environmental disturbance and protects existing drainage patterns, as well as the numerous beech trees on the site. In fact, the design responds to immediate context by removing the sunspace element at a location where an existing beech tree remains.

Figure 15: Regensburg House, minimizing potential environmental disturbances, maintaining the natural tree

Maintaining the natural tree (Figure 15) canopy not only is inherently ecologically responsible, but this practice also provides for shade and natural cooling in the summer months by moderating the microclimate at the site. Lifting the structure off the ground also aids in passive cooling by allowing airflow beneath the building and enabling natural ventilation.

The House at Regensburg has helped us to expand our understanding of sustainable design and to underscore the truth that creativity is not compromised by sustainability. Creativity is, in fact, enhanced by this type of contextual and innovative thinking, and makes for a project that is, as we like to call it, sustainable by design. (Herzog, Kaiser, & Volz, 1996)

However, In 1977 Tomas Herzog in Regensburg materialized a particularly original manufacture. In the substance it is a residence which is incorporated in another nutshell. This as “onion[11]” building functions exploiting one climatic buffer

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[11] The ‘thermal onion’ approach has been developed in France by Jourda and Perraudin, firstly, in their small private house at Lyon (1984) and, subsequently, in major projects including the Training Centre at Herne-Sodingen, Germany (1999), where a large timber framed and glazed structure, with photovoltaic solar panels as sun control devices on the roof, provides enclosure for habitable modules. German practice LOG ID has built projects with ‘buffer zones’ around a ‘building within a building’ featuring solar heating, heat storage, controlled natural ventilation, diathermic heat transfer, and vegetal transpiration. Buildings include a Traumatology Research Laboratory, Ulm (1989); Medium Gmbh Print Works, Lahr (1990); and the Glasshouse Library and

zone (Figure 16). In meets no one a physiologic residence that follows the basic design principals of bioclimatic architecture while from outside it is presented as a high - tech construction (Wines, 2000).Substantially from 1989 and afterwards it begins a big effort for the creation of manufactures that would be autonomous from little as very. This date the International Energy Agency (I.E.A.) it decided it creates one international project in order to they are drawn and manufactured a line from low energy houses with a total consumption for space heating, domestic hot water and electricity for only 25% compared with the typical consumption of new houses in the participating countries. (Sakkas, 2006)

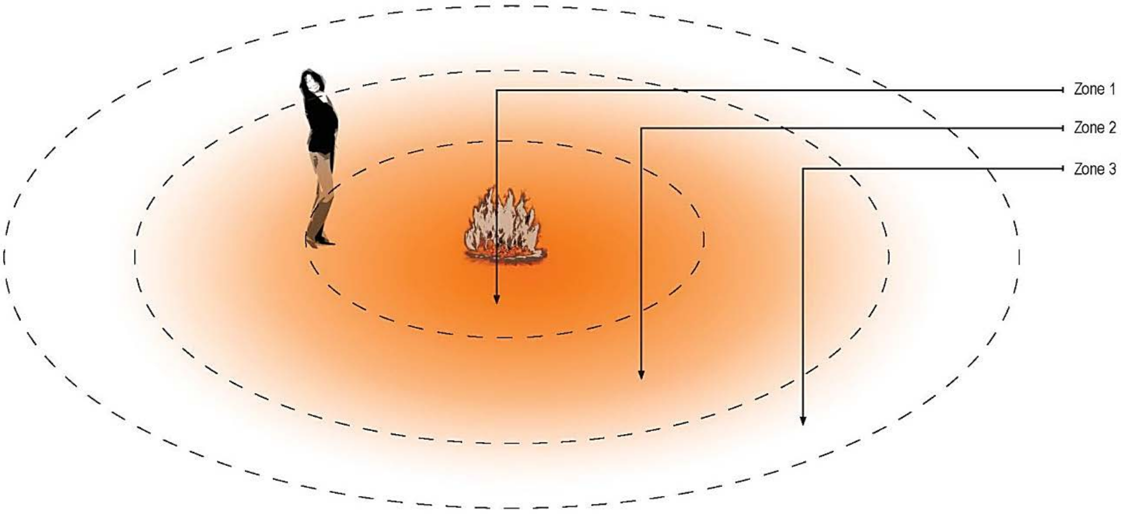

Figure 16: Onion building functions

Traditionally the fire has been the center point of the social life and created the point of focus. Starting with the inner social gathering point and from there through a heating and lighting gradient from the fire defines more private zones for people to use as described by Banham. This can also be seen in the traditional use of the hearth in our houses where they have been the social gathering point. Illustrated in Herschings anecdote about the American family moving from their air-conditioned house to a small village in France and the fireplace becomes the center for them in the winter time, whereas in the summertime the entire house and the streets are a part of their home and life. Here illustrated with the zones around the fire with the first as the social and the third as the more private.

The solar house of Thomas Herzog in Regensburg from 1979 shows an example of an onion principle similar to the different zones from the fire. However here it is strictly

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Cultural Centre, Herten (1994). Other innovative European projects include Future Systems' Green Building (1990) and Project Z (1995) and HPP Hentrich-Petschnigg design for a Corporate Headquarters featuring habitable rooms suspended like cable-cars within a glass enclosure. Many of these examples see architects working in close collaboration at conceptual stage with innovative consulting environmental engineers, such as the London firm Battle McCarthy.

defined zones where the outer zone is a buffer between the outside environment whereas the inside is the warm core of the house defining the environment for the daily life and the central social functions. Here the thermal spaces play a more active role in the design of the building. The buffer creates a zone that during the warm summers functions as a part of the living area whereas it in the cold winters works as a conservatory preheating the air. However it requires the user is aware of these functions and do not see it as an essential part of the living space all year.

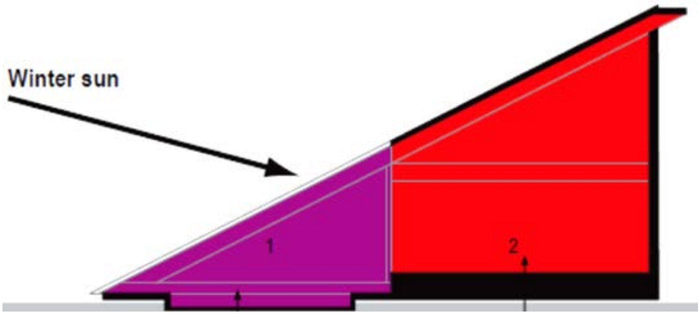

Figure 17: Winter sun, Regensburg House

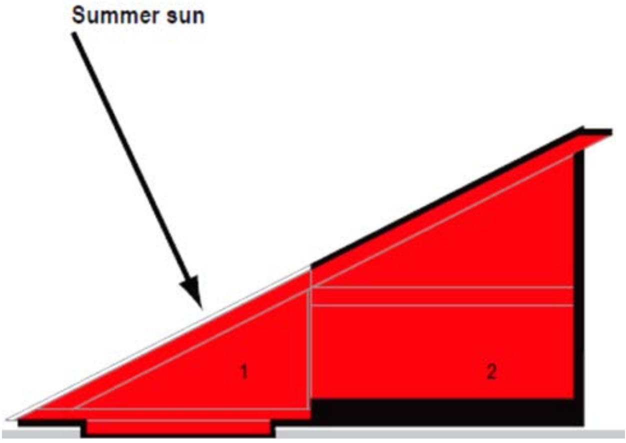

Figure 18: Summer Sun, Regensburg House

1- Zone one as a buffer between the core and heart of the building. In the winter a space that can be used and warmer than the outside, but not a place that is warm and comfortable as the core of the building (Figures 17 & 18).
2- The core of the house is comfortable throughout the year. Naturally ventilated (Figures 17 & 18). (Peterson, 2011)

1-3-1-2 House Waldmohr 1982-84

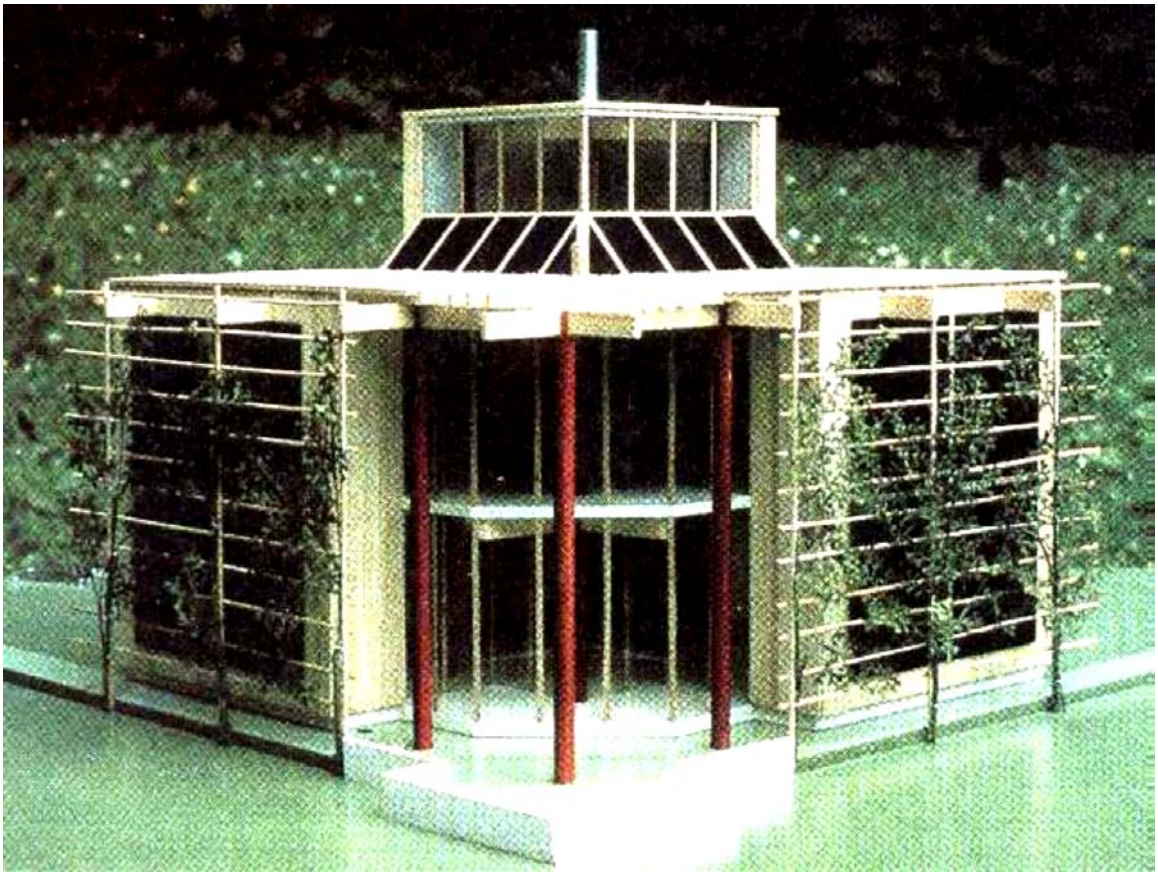

Figure 19: Model of House in Waldmohr, Waldmohr, Germany. Here we see the south facing entrance and the trellis structure shading both east and west elevation.

The second example of Herzog's architecture is a House in Waldmohr (Figure 19). For the plan, Herzog used the "thermal onion" plan, involving another interpretation of the building within a building. The basic principle is to place the rooms requiring the highest indoor temperatures, bathroom, for example, in the center of the house, surrounded by rooms where the temperatures decrease proportionally as they get closer the exterior.

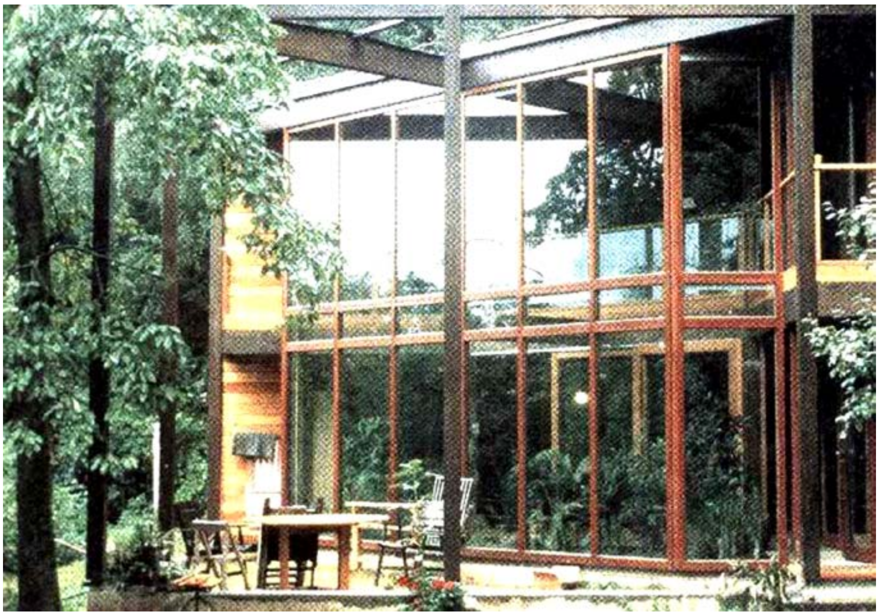

Figure 20: the layering glass membrane walls create a temperature control air space in House in Waldmohr

In Waldmohr, Herzog placed a cube in a square on the diagonal of a south-facing site to create both an external and internal glass facade. A conservatory between these membrane walls (Figure 20) functions as a temperature control buffer zone, and heating comes from hot water under the floors. Each of the environmentally favorable features of the house is clearly visible and part of its aesthetic statement, inclusive of the surrounding trees, laminated timber construction, Mylar foil sun screens on the interior, planted roof, and verdant trellis structure shading the east and west elevations. (Pérez-Gómez, 2002)

His house in Waldmohr is significant in its passive heating technique. Here, the design strategy for the light captivity finds its spatial configuration; rather than the façade arrangement. He located spaces, which require more heat, to the center of the building. He surrounded these spaces with the ones that need less heat, so that they situate near to the façade. Furthermore, on the south axis, he made two separate glass facades to create a thermal buffer zone. Between the facades he located a conservatory that produces hot water to heat the floors. (“Bio Climatic Architecture ,” n.d.)

Traditionally, in houses the location of rooms followed light and warmth: breakfast was in the east, reading along the south, the parlor at the west, etc. Families moved outdoors when it’s hot and indoors when it’s cold. A smart contemporary variation is German architect Thomas Herzog’s House in Waldmohr, in which the warmest spaces, such as bathrooms, occupy the center, with the temperature decreasing gradually toward the perimeter, a “thermal onion.” Conservation and comfort both come with protecting the core first, like the human body, or a tree losing its leaves in winter. Floor planning typically follows space programming, driven by functional and organizational needs (Figures 22-24). ("Blog Entry - Sustainable Floor Planning - Architect Magazine ," n.d.)

Figure 21: North elevation

The concept for a building in timber construction with a square floor plan laid out on the diagonal was implemented for the first time in 1982 as part of a demonstration scheme to build so-called "solar houses". The ratio of surface area to volume of a cube means that this form has certain advantages in respect of thermal losses through transmission. With one corner of the house facing south, the south-east and southwest facades allow an optimum direct exploitation of solar energy, while no side has a purely northern aspect. Conceptual sketches for this building type had been drawn up as early as 1977 as an alternative preliminary design for the house in Regensburg.

In the case of the detached single-family house described here, the south-facing corner of the cube was opened up, and two glazed facade layers were inserted, an external and internal skin. The intermediate conservatory space acts as a thermal buffer zone, as a solar collector and as a draught-excluding lobby. For much of the year, this space can be used as an additional living area. Most of the remaining external surfaces of the building are closed and thermally insulated. The planted roof and the climbing plants along the east and west faces prevent overheating of the house in summer.

The layout of the house, which is a response to spatial and functional constraints, is divided into various temperature zones, based on the principle of a "thermal onion".

Spaces with high temperature levels, such as bathrooms, are situated deep in the interior of the building. The temperature levels of the surrounding rooms decrease towards the outside.

As a means of supplying the building with energy, a new kind of heating system with a heat pump was installed. The requisite thermal energy is drawn from the ground by means of liquid circulating between the walls of coaxial tubes sunk 30 m deep into the earth. In view of the great depth of this installation, no heat is extracted from the upper layers of the earth, so that there are no adverse effects on the vegetation. (Herzog et al., 2001)

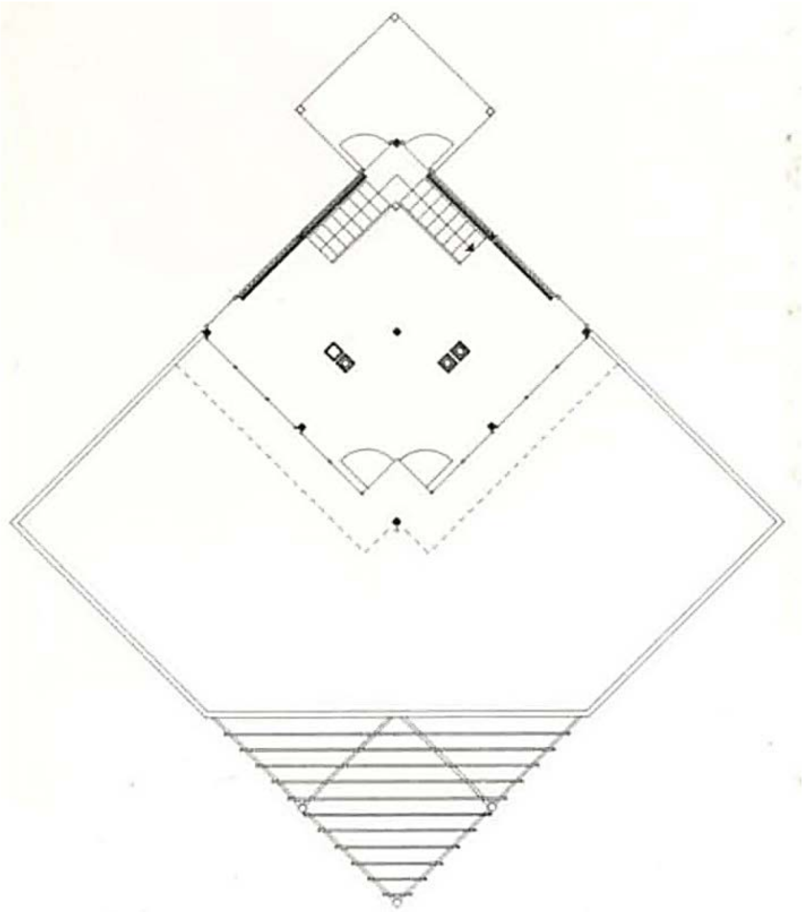

Figure 22: Roof storey plan, Waldmohr House

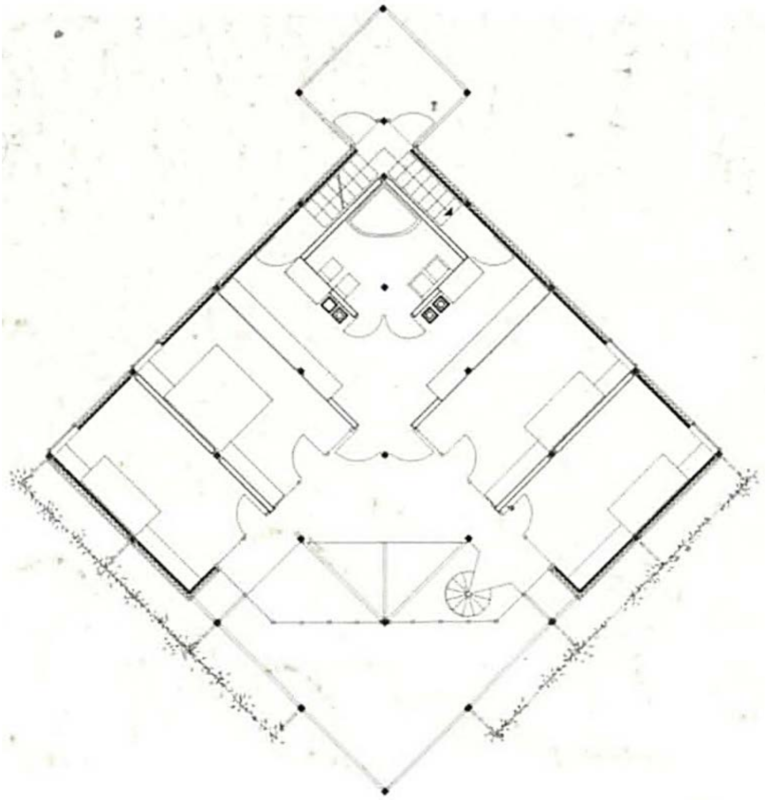

Figure 23: Upper floor plan plan, Waldmohr House

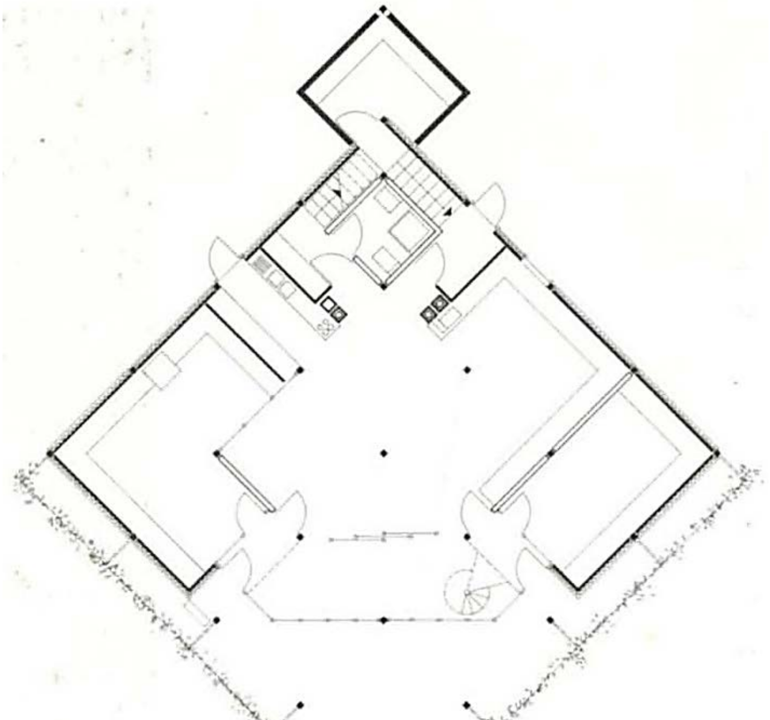

Figure 24: Ground floor plan, Waldmohr House

Figure 25: Sheltered terrace and conservatory at open southern tip of house, Waldmohr House

1-3-1-3 Housing group Kranichstein 1981-83

Beginning in 1978, investigations were made into ways of reducing the costs of housing by incorporating an element of self-help on the part of future occupants. The aim of these investigations was to develop low-cost terraced housing types on a restricted site area. The work enjoyed the support of the Institute for Housing and the Environment in Darmstadt. A solution was proposed in which different forms of construction were to be used for separate sections of the development. The work was divided into so-called" professional" and" non-professional" parts. The former included the technically complex, high-risk sections of the construction that could be executed properly only by professional firms. The non-professional section was planned by the architects in such a way that future occupants would be able to carry out much of the work themselves.

This led to a concept of "two-zone houses". Special importance was attached to the following aspects: low-cost methods of manufacture; and very low operating values for the heating, hot-water and electrical supply. The development was based on a 90 x 90 cm grid.

The zone designed to be executed by specialist firms was built in a solid form of construction and contains the wet areas, including sanitary installations, and the electrical distribution. A prefabricated lightweight, dry form of construction was developed for the living rooms and bedrooms, which could be assembled by the occupants themselves.

Special importance was attached to a varied treatment of the outdoor areas in order to create intimate external spaces despite the high density of the scheme.

The eastern side of the development (Figures 26&27) consists of a terraced-house type with a two-storey-living and sleeping zone for residents who need more space. To the west of the access road are single-storey terraced houses[12] in a high-density form of construction. The internal spaces here receive daylight from what are, in part, extremely small internal courtyards. The zenith light that enters in this way nevertheless provides a high level of illumination in the adjoining rooms. (Herzog et al., 2001)

Figure 26: Housing group Kranichstein, Kitchen gardens being laid out on east side

Figure 27: Housing group Kranichstein, Street front: East face

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[12] In architecture and city planning, a terrace(d) house, terrace, row house, linked house or townhouse (though the last term can also refer to patio houses) is a style of medium-density housing that originated in Europe in the 16th century, where a row of identical or mirror-image houses share side walls. The Place des Vosges in Paris (1605–1612) is one of the early examples of the style. The first and last of these houses is called an *end terrace*, and is often larger than the houses in the middle. Terrace housing can be found throughout the world, though it is in abundance in Europe, and extensive examples can be found in North America and Oceania. Sometimes associated with the working class, historical and reproduction terraces have increasingly become part of the process of gentrification in certain inner-city areas.

Two-zone house
Two stories
East-west orientation

The floor plan (Figures 28-30) of this house type is divided into a two-storey "warm" living room zone and a one storey "cold" zone with secondary rooms. In this design, personal rooms are defined as "warm" rooms and bathrooms as "cold" rooms. While the zoning of the floor plan in this example is not as consistently derived from energy demands (as is the previous example), this house type provides more flexibility in terms of usage. Identically shaped personal rooms are grouped around a central double-height space with a hallway wrapped around it. The principal organization of the internal circulation enables linking this house type to adjoining units on every level. The possibility of externally accessing the upper level via the roof of the secondary room zone opens up additional possibilities for flexible uses. The double-height space could be developed into an "energy garden" with a glass roof to realize heat gains. (Pfeifer & Brauneck, 2008)

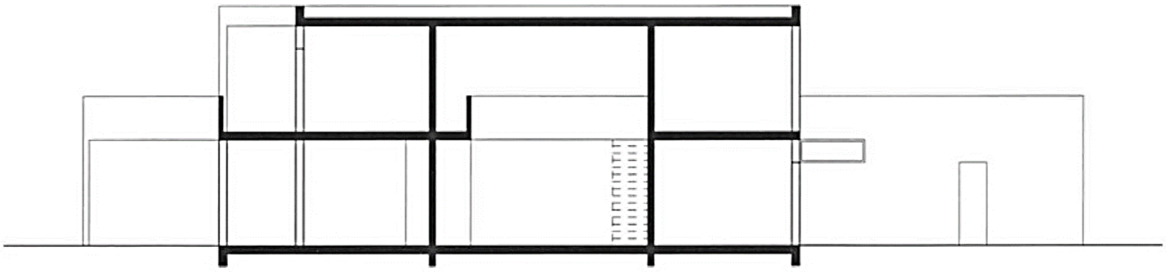

Figure 28: Housing group Kranichstein, longitudinal section, East-west orientation

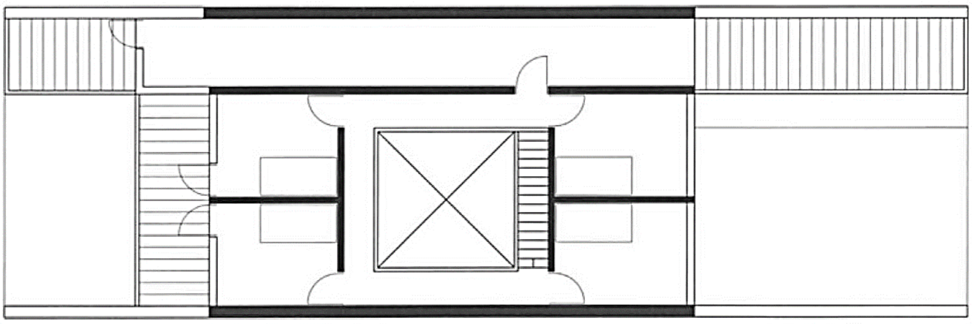

Figure 29: Housing group Kranichstein, upper floor plan, East-west orientation

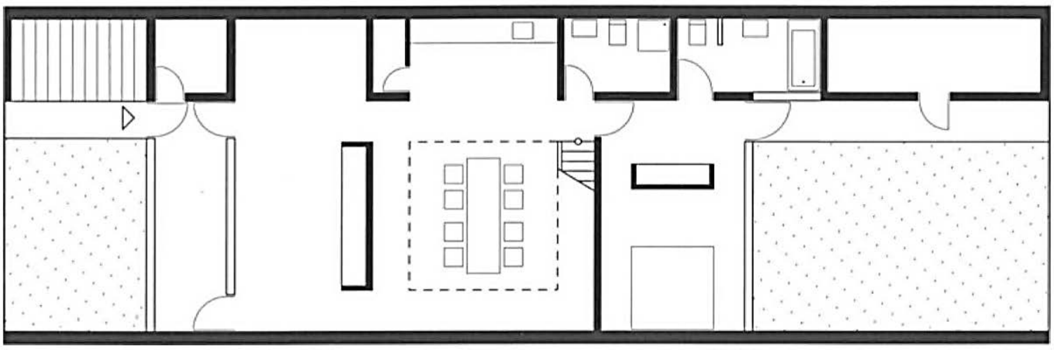

Figure 30: Housing group Kranichstein, Ground floor plan, East-west orientation

1-3-1-4 Two-family House, Pullach 1986-89

Figure 31: Two-family House, Pullach 1

This building's cross section resembles that of a boat (Figure 31-33). In order to "balance" this boat, the architect has linked it to a narrow structure, like the outrigger of a Polynesian canoe. The main framework consists of laminated timber beams with glass cladding suspended around the exterior. Internally a number of cross walls act as structural stiffeners and, along the length of the building, diagonal tubular steel tension members flank a 300 mm service zone. Much wider than the house, the glass roof is insulated at its central section, but cantilevers out supported by plywood ribs. These projections will eventually carry PV cells[13]. Because of its extremely light construction and extensive glazing, the building needs protection against overheating. (“MODERN HISTORY AND SUSTAINABLE ARCHITECTURE IN MUNICH,” 2011)

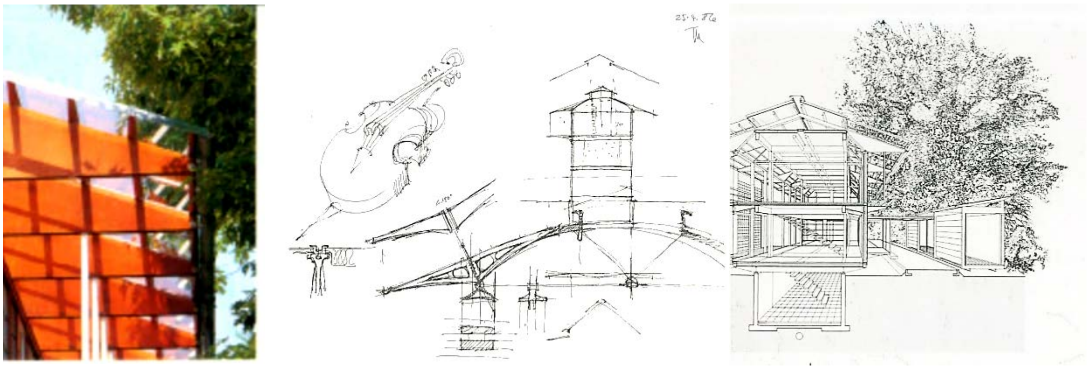

Figure 32: Two-family House, Pullach 2

The house was laid out in such a way that all living rooms *have* a south-facing aspect (Figures 34&35). As a result, when the sun is low in the sky in winter, this long, narrow building is sunlit over its full depth to the rear north wall. This helps to obviate the problem of internal heat transfer from the "warm" to the "cold" side in winter. Another special feature, and an innovation at the time when the house was built, are the elements with translucent thermal insulation set in front of black-painted precast concrete units along the south façade (Figure 38). It was the first occasion on which elements of this kind had been used in a new building development. The 10 cm solid wall slabs absorb heat from insolation during the day and yield the heat in the evening and night to the rooms on the inside face.

The building has a Laminated-timber skeleton-frame structure (Figure 33). In the middle of the house, a 30 cm wide intermediate zone was created in which service installations, chimneys (Figure 38), air ducts and soil-water runs are accommodated. The roof is in an unusual form of construction. In the central area, it is designed as a ventilated (cold) roof type. Along the edges, the slopes are divided into an inner skin with double glazing, which forms the space-enclosing plane, and an external glazed skin consisting of toughened safety glass, which provides protection against the weather for the façade and the timber structure. On the south side, these areas can be covered with Photovoltaic-panels. (Herzog et al., 2001)

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[13] Photovoltaics (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.

Figure 33: Two-family House, Pullach, Building's overview

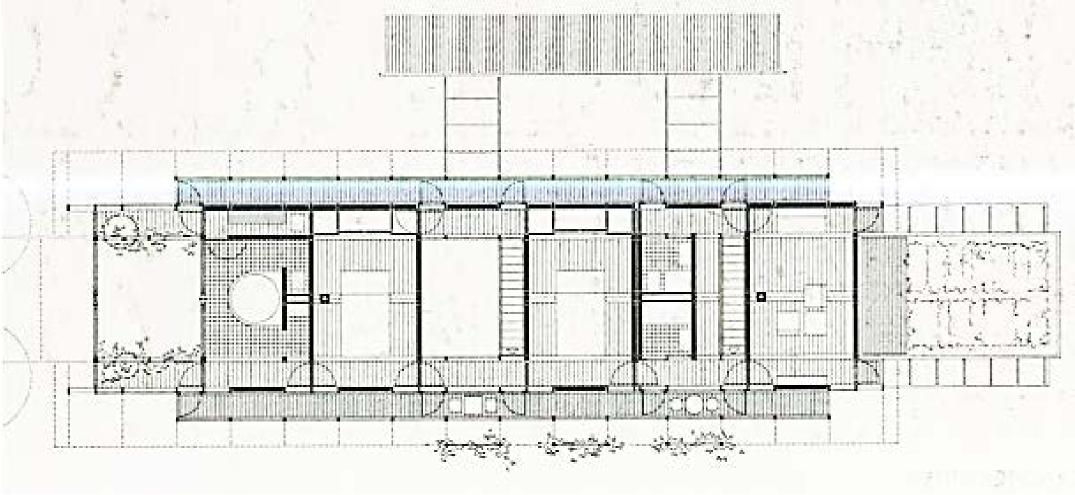

Figure 34: Two-family House, Pullach, Upper floor plan

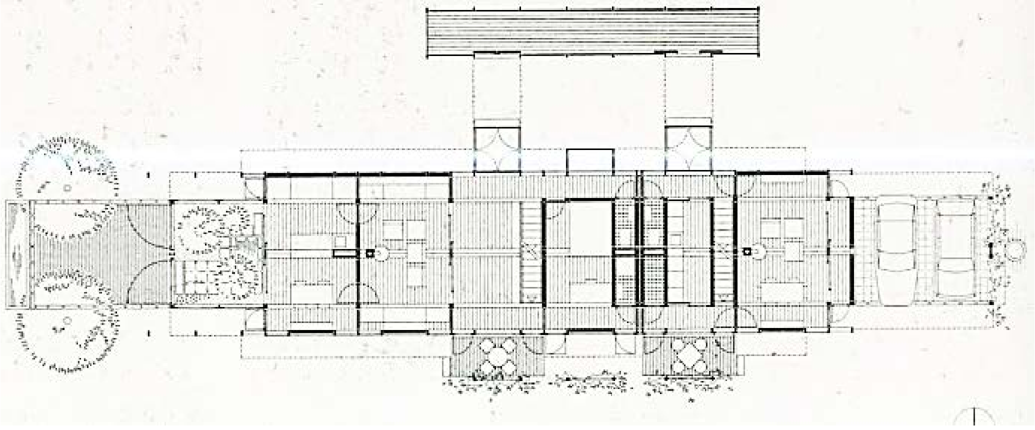

Figure 35: Two-family House, Pullach, Ground floor plan

Figure 36: Two-family House, Pullach, Corridor

Figure 37: Two-family House, Pullach,Two-story conservatory space with wind Bracing

Figure 38: Two-family House, Pullach, South face with translucent thermal insulation elements, Ground-floor

Description

Despite its High-Tech look of glass on laminated wood frame with steel tie cross bracing (Figure 37), this house has its beginnings in the traditional Alpine timber frame barn. Like its vernacular precedent, the Pullach house starts with an elegantly small substructure and cantilevers outward, like Eames House, at each successive upper level. The roof becomes a huge overhanging form in comparison to the thin proportions of its base. A relatively small and well-protected structure rests beneath the sheltering eaves.

The vernacular barn uses this outwardly cascading form defensively to keep its wood frame and rough board cladding dry and covered, structurally. The scheme provides an economy of support and cantilevered spans. Thomas Herzog acknowledges this as a formally appropriate beginning point and then opens up a series of complex interactions with the climate via technical components and Modernist ambitions. Glass is used wherever possible (Figure 33), then solar collector panels are strategically integrated as insulated wall wherever privacy dictates an opaque barrier. There is an exposed industrial wood structure, a galvanized metal screen for climbing summer vines on the south, and a corrugated metal roof that turns to glass beyond the exterior wall line to become a broad and transparent rain canopy.

Herzog's work has been a continuing series of partnerships and collaborations. He approaches each project as a prototype design for state-of-the-art technology, and this research and development requires teamwork. Since +1981 he has worked hand in hand with the Freiburg Institute of Energy Research, because he says, "no architect can ever master all the forces at work on solar buildings. “He believes in the necessity and synergistic effect of multi-disciplinary teams, His partner for the Pullach House was Michael Volz, with assistance from Michael Streib. Structural engineering was provided by Jullus Natterer. Herzog, Volz, and Natterer have also cowritten a book on timber structures.

The emphasis on research and development in Herzog's academic pursuits find Modernist expression in his professional practice. He constantly experiments and seeks to apply the best and most advanced technologies to the service of his buildings. For him, Modernist architecture is still involved in the transition from the 1970s attitude whereby energy efficiency was sacrificed to achieve visual statements of material minimalism. Herzog sees the emerging role of Modern architecture as just the opposite-using new materials and configurations to exploit a building's functional relationship with the environment. This evolution is evident in his own career as well. After following in the footsteps of Frei Otto and publishing his much translated doctoral dissertation Pneumatic Constructions*,* Herzog has essentially abandoned lightweight minimalist envelope solutions in favor of far more proactive and environmentally sophisticated techniques.

Specific statements about design intentions for this project have not been identified, and the architect has been careful to protect his client's privacy. From the philosophical statements and lineage of Herzog's practice and research, however, a few ideas can be identified in the finished building. Primarily, this building was to utilize cutting-edge technology, with provisions for uptake of new technologies as they emerged into practical application. (Bachman, 2003)

Critical technical issues

Inherent

Programmatic challenges for this project seem to have been centered on how to provide glazed solar access and airy ventilated spaces without sacrificing interior privacy. The predominantly glass skin was one antagonizing factor. The need to provide two separate homes within the same see-through building scheme was another.

Contextual

Most of Herzog's residential-scale work has been met with resistance, and often rejection, by conservative-minded building authorities, a problem he shares with Glenn Murcutt. His response is philosophical: He declares no desire to impress with originality and feels no obligation to conform, further saying that our love for new technology has to be made compatible with our love for our old towns and historic cities. Herzog has, along the way, learned to warn his clients about the bureaucratic challenges of designing solar-oriented prototype buildings in tradition-oriented communities.

Intentional

Basing the design scheme on the traditional timber frame barn, Herzog adapted a climatically appropriate form and one that was also suitable for the wood framing suggested by the client. This set the challenge of finding suitable transformations of a romantic form into a high-performance building of modern construction.

Visual

- Structural framing is exposed throughout the house with good effect. Reducing the envelope to skeleton and infill emphasizes the timber qualities of the laminated wood frame. The prevalence of glass also accentuates the wood. It is a plus that all the timber is engineered from plentiful small-dimension lumber.

Performance

- Trombe wall[14] indirect-gain solar collectors with their integral concrete thermal mass make up the opaque wall elements of the south facade.
- Solid north-to-south interior walls give the structure diaphragm strength and partition the separate occupancies.
- Overhanging glass eaves keep the wood structure protected while allowing solar penetration to the interior. The glass canopy can eventually be replaced with photovoltaic panels.
- The cantilevered structure provides overhanging shelter while minimizing loads and member sizes.
- The interior planning strategy allows for flexible use of floor space, especially the shared middle bays that seem to belong to either of the two dwellings.

(Bachman, 2003)

1-3-1-5 Guest Building for the Youth Educational Centre, Windberg 1987-91

Completed in 1991 and situated in the rural Bavarian town of Windberg (Figure 39), this low-energy hostel provides sleeping accommodation and ancillary rooms for 100 guests, in particular youth groups attending the adjacent 12th century monastery and education centre which it serves. A particular requirement of the brief was that spatial divisions in the hostel should be flexible and capable of future change, some recreation and common room facilities having been previously provided in the monastery. The design brief also included the treatment of external spaces around the monastery.

Figure 39: Guest Building for the Youth Educational Centre, Windberg 1987-91

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[14] A Trombe wall is a sun-facing wall separated from the outdoors by glass and an air space, which absorbs solar energy and releases it selectively towards the interior at night. The essential idea was first explored by Edward S. Morse and patented by him in 1881.In the 1960s it was fully developed as an architectural element by French engineer Félix Trombe and architect Jacques Michel.

The design of the building and its energy systems have, from an early stage, been strongly influenced by a thorough analysis of the patterns of use of the various spaces; rooms which are used for several hours at a time are separate from those used for short periods. These differences are evident from an analysis of the space planning, structural systems and materials used in the building. All bedrooms face south giving views of the surrounding countryside and allowing solar radiation to be optimized during the heating season. Used for only a few hours during daytime, but continuously during night time at a relatively low temperature, they benefit from direct solar radiation through the ample, high specification windows, transparent insulation which heats up the massive external walls, and a high level of thermal mass in the internal walls which modulates day-night temperatures in the building. In summer, the bedrooms are protected from excessive solar gain by a large overhanging roof. The intermittently used spaces are located behind the north facade and include circulation, storage, entrance and bathroom areas. The bathrooms need higher temperatures than other spaces, but only for a few hours per day. The external wall facing north is of a thermally lightweight construction, incorporating 140mm of insulation, and features timber cladding reminiscent of local Bavarian barns. Indeed, timber is used extensively for structural roof members, for the frame structure of the northern zone of the building and for internal finishes. Profiled metal decking elements are used for the roof covering.

However, Windberg is a small community on the southern slopes of the Bavarian Forest (Figures 40&41). The monastery complex at the heart of the village comprises a number of buildings for the religious order and an educational center for young people.
To conserve energy, account was taken of the time in use and temperature requirements of certain spaces. Those that are used for several hours at a time, therefore, were separated from those used for only a short period. They were also built with different materials.

Figure 40: Aerial view, Guest Building for the Youth Educational Centre, Windberg

The southern tract of the building contains the rooms in use for longer periods. Its external wall was clad on the outside with a layer of Translucent Thermal insulation. The maximum temperature on the outer face is reached in the early afternoon. During the summer months, a broad roof projection and external blinds protect the rooms against overheating. The northern part of the building houses sanitary facilities, storage and circulation areas (Figure 42). These spaces are used only briefly at certain times of day; e.g. the shower rooms. Hot water is supplied by tubular collectors in the south-facing roof slope, and there is a swift-functioning warm-air heating system. To minimize heat losses due to ventilation, a heat recovery plant was installed in the roof space (Figures 43&44). (Herzog et al., 1996)

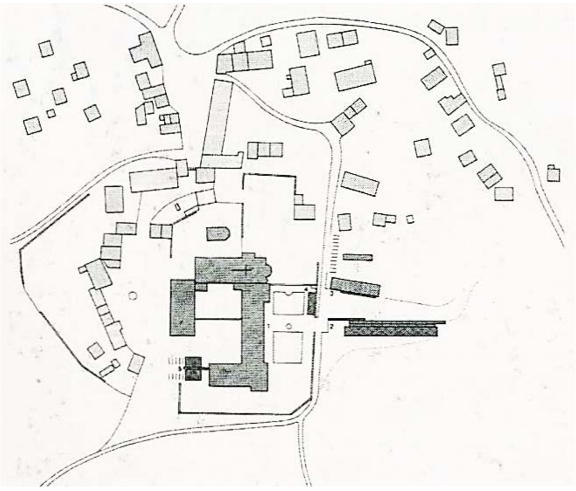

Figure 41: Site plan, Guest Building for the Youth Education Center

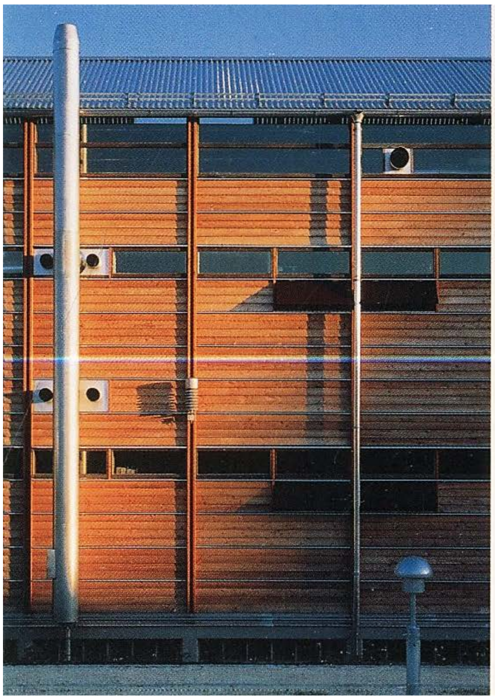

Figure 42: Guest Building, Windberg, Northern facade

Figure 43: Guest Building, Windberg, Southern facade.

1-Translucent insulation and sun protection
5- Heat pipe collectors
8-Mechanical ventilation system with heat recovery

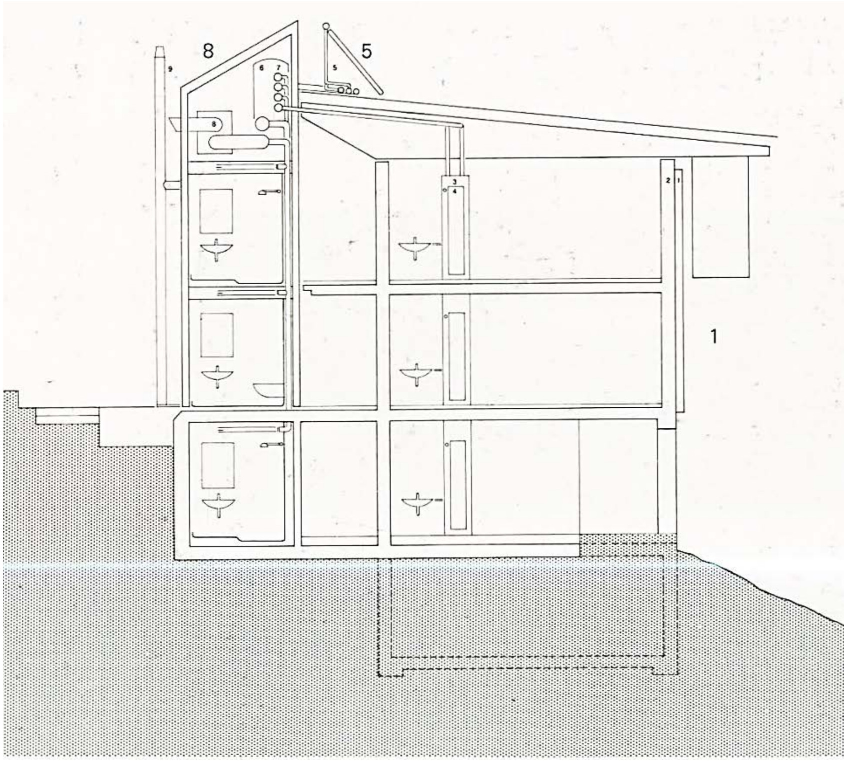

Figure 44: Guest Building, Windberg, Cross section, Utilities

The Premonstratensian monks of Windberg Monastery run a youth education centre for which they commissioned a new dormitory block. The nature and duration of the use of the various groups of rooms (Figure 46-48) played an important role in determining the energy concept for the building. Rooms that are used for longer periods of the day are separated from those that are used only briefly. The two sections of the building were also constructed with different materials (Figures 45&52).

The southern tract houses the lounge areas and the bedrooms, which can be divided in different ways. The rooms on this face enjoy a more attractive aspect, with an open view of the landscape through broad areas of glazing. A direct exploitation of solar energy and daylight was also possible for heating and lighting the spaces on this side, which are used for longer periods. To reduce extremes of temperature and to permit storage of thermal energy, this tract was constructed with heavy, thermally sluggish materials. Opaque areas of the south-facing external walls were also clad with translucent thermal insulation. This allows solar radiation to pass through it, but minimizes thermal losses. The south-facing external wall is thus heated up during the day and passes on the thermal energy to the internal spaces (Figures 50&51) after an interval of five to six hours, beginning in the early evening. In other words, throughout the night, when external temperatures are at their lowest, the outer wall functions as an inward-facing solar heating area. During the summer months, overheating is prevented by the broad roof projection and external louvred blinds.

The northern tract contains the sanitary facilities and storage spaces as well as the circulation route through the building. These spaces are distinguished by the fact that they have a generally lower temperature level, since they are used for only short periods. In the shower rooms, for example, a higher temperature level is required for only two to three hours a day. This tract was, therefore, equipped with a quickly functioning warm-air heating system. To minimize heat losses through ventilation, a heat-recovery unit was installed in the attic space. The hot-water supply is provided largely from solar energy by means of vacuum-tube collectors on the roof.

Part of the teaching program of the youth education center is to make the functioning of the building comprehensible to the young guests by providing them with an insight into the use of environmentally sustainable forms of energy through "passive" and "active" constructional systems and the mechanical installations that play a role in the energy balance. The architectural effect of the newly developed south-facing heating wall is immediately visible in the façade and tangible internally. The service runs, solar storage units and collectors are exposed to view, and a display panel installed in the entrance area shows changes in temperature levels. (Herzog et al., 2001)

Figure 45: Guest Building, Windberg, Timber boarded front facing the village

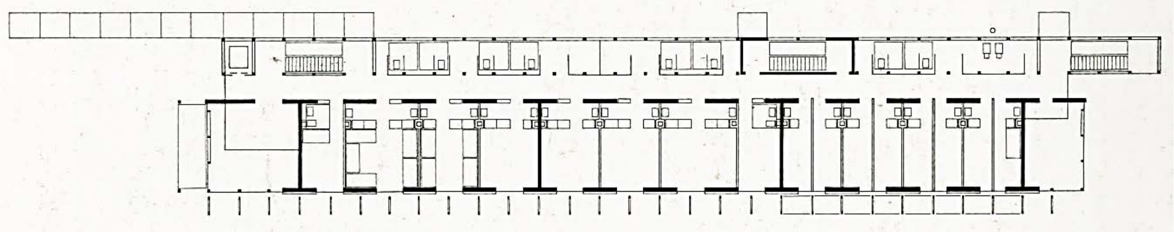

Figure 46: Guest Building, Windberg, Upper floor plan

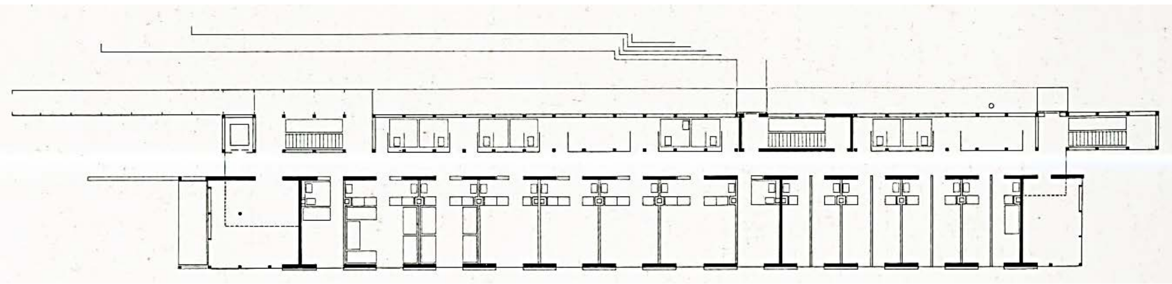

Figure 47: Guest Building, Windberg, Ground floor plan

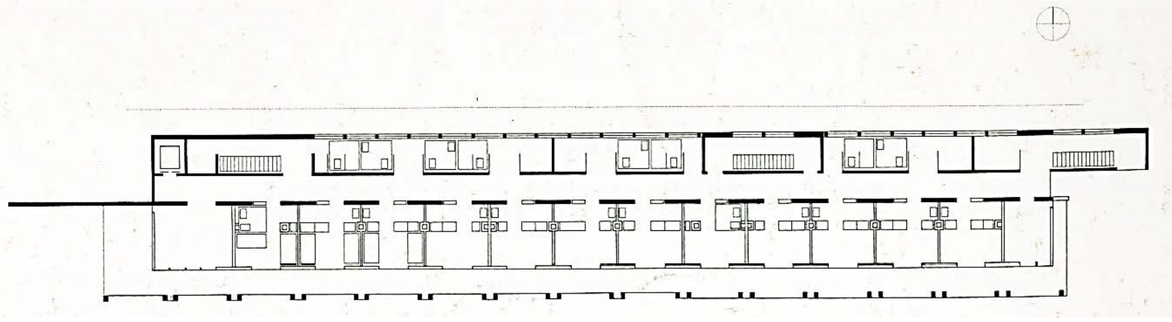

Figure 48: Guest Building, Windberg, Lower Ground floor plan

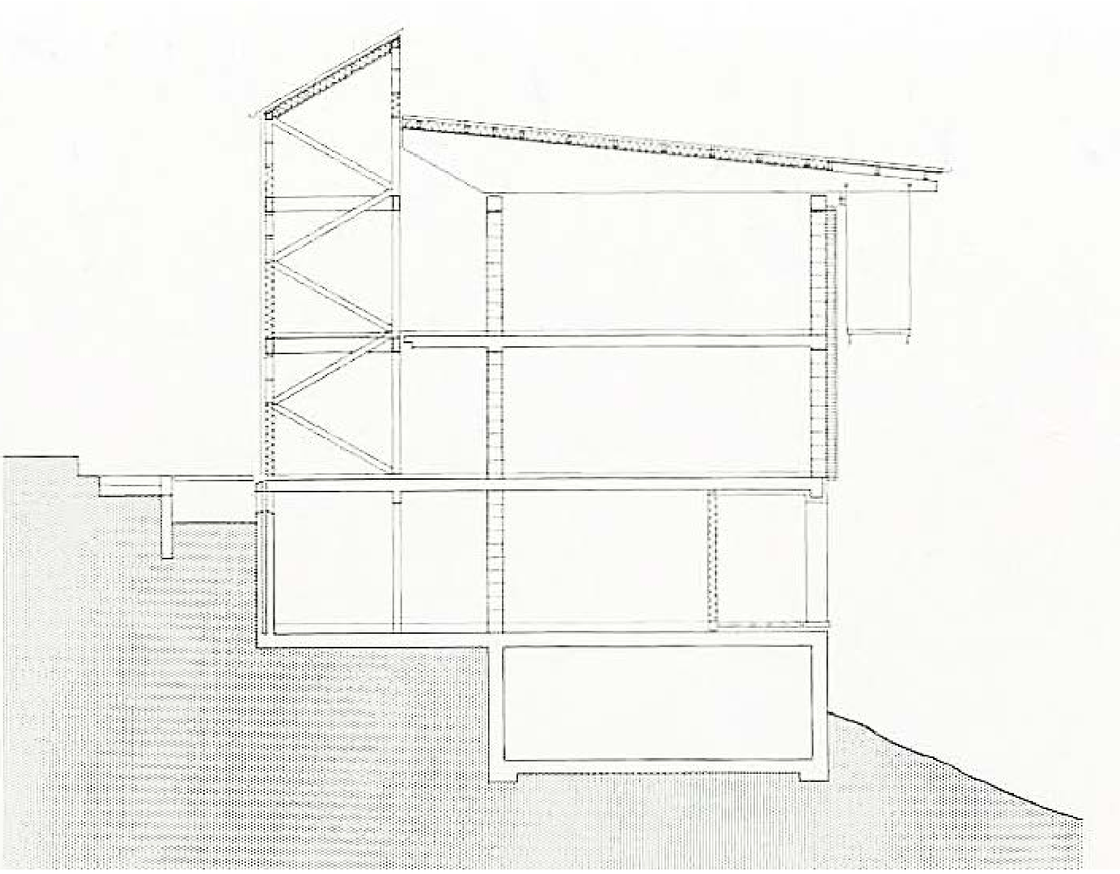

Figure 49: Guest Building, Windberg, cross section.

Figure 50: Guest Building, Windberg, Bedrooms with fitted furnishings

Figure 51: Guest Building, Windberg, Corridor

Figure 52: Guest Building, Windberg ,Eastern facade

1-3-2 Thomas Herzog's Exhibition hall in Linz 1986-1994

The congress and exhibition hall in Linz marks a new interpretation of the concept of early historical examples of large glazed halls. These include the Crystal Palace in London[15] (1851–1936) and the Glaspalast in Munich (1854–1931), which provided effective protection against the elements and a hitherto unknown internal light quality. From the outset, one of the goals in planning the Design Center in Linz, Austria (1989– 93), was to reduce the inner volume of air to a minimum. The internal height of the spaces was limited to 12 m, and since this clear height was not required everywhere in the hall, the roof structure was designed in a flat arched form with a glazed covering (Figures 53&54).

The steel girders forming the load-bearing roof structure span a distance of 76 m and cover an area of 16,800 m2. To ensure maximum flexibility of use, all exhibition and congress spaces (with a capacity of 650 and 1,200 people) adjoin a common foyer (Figures 55&56). The points of access are laid out in such a way that visitors to concurrent events do not interact. Continuous longitudinal access routes along both sides allow the various halls and the gallery space to be combined. The ancillary zones are also laid out in linear form. Since the partitions in these zones can be moved, the spaces remain flexible for the changing uses (Figures 57&58). In developing a natural lighting concept for the building, the challenge was to achieve excellent light quality in exhibition areas without having to make sacrifices in the indoor climate and without giving rise to excessive energy consumption. In collaboration with the Bartenbach LichtLabor, a new kind of building element was developed for the light-transmitting roof (Figure 59). A plastic grid integrated in roof panels with a complex performance allows indirect luminous radiation from the northern hemisphere of the sky to enter the building, while direct sunlight is screened off (Figure 60). In this way, excessive heat gains are avoided in internal spaces in the summer. Just 16 mm deep, the retroreflecting grid, thinly coated with pure aluminum, was inserted into the cavity between the panes of double-glazing over the roof (Figure 60). (Kolarevic & Malkawi, 2005)

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[15] The Crystal Palace was a cast-iron and plate-glass building originally erected in Hyde Park, London, England, to house the Great Exhibition of 1851. More than 14,000 exhibitors from around the world gathered in the Palace's 990,000 square feet (92,000 m^2) of exhibition space to display examples of the latest technology developed in the Industrial Revolution. Designed by Joseph Paxton, the Great Exhibition building was 1,851 feet (564 m) long, with an interior height of 128 feet (39 m). Because of the recent invention of the cast plate glass method in 1848, which allowed for large sheets of cheap but strong glass, it was at the time the largest amount of glass ever seen in a building and astonished visitors with its clear walls and ceilings that did not require interior lights, thus a "Crystal Palace".

Figure 53: Sprawling Design Center, Linz, Austria (1989–93), architect Thomas Herzog with Hanns Jorg Schrade and Heinz Stogmuller

Figure 54: Design Center, model

Figure 55: Design Center: exhibition hall with the ventilation system

Figure 56: Design Center, Congress hall

Figure 57: Design Centers, Steel girders framing the roof structure

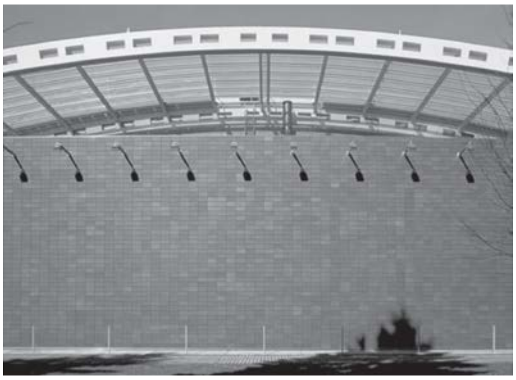

Figure 58: Design Center, end wall with the claytile faca

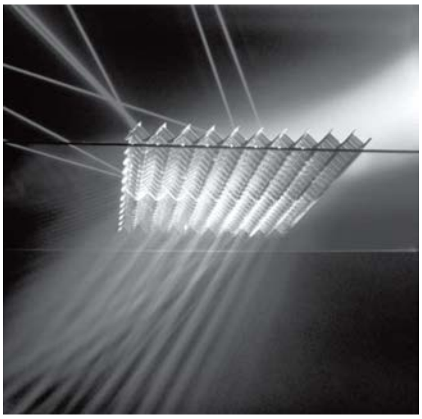

Figure 59: Design Center, simulation of the light-transmitting roof

Figure 60: Design Center, entrance hall

The geometry for cutting the grid was determined by computer programs and had to take account of the following factors: the angle of elevation and the azimuth angle of the sun at various seasons, the exposure and orientation of the building, and the slope of the roof. Thermally separated steel sections help to reduce heat losses through the building envelope.

In addition to thermal and daylighting aspects, a special challenge was posed by the need to guarantee an adequate air change in this flat, deep building. Fresh air enters via floor inlets and ventilation flaps at the sides of the hall. The warmed, used internal air rises to the top of the building as a result of thermal buoyancy. During the heating period, the air is then borne by large ducts to a heat recovery plant. During the rest of the year, the exhaust air escapes from the building at the crest of the roof via a large, continuous opening that is fitted with closable louver flaps. To guarantee the extraction of the vitiated air under unfavorable air pressure conditions, a “spoiler” capping was developed and assembled over the crown of the roof (Figure 61). This 7 m wide element has a convex underside and exploits the “Venturi effect[16]” to support the extraction of air from the building (Figure 66). The final form of this element was determined in wind-tunnel tests (Figures 63&64). In light of these developments, one sees that building envelopes are subject to changes in their technical functioning and construction when, in addition to performing their traditional protective role, they are required to control indoor temperatures and the ingress of daylight. (Kolarevic & Malkawi, 2005)

Figure 61: Design Center, long face of the hall with “Venturi” capping to assist natural ventilation

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[16] When air is channeled into a constricted opening, its speed increases. Then, according to Bernoulli's principle, if a stream of air speeds up, its pressure drops. A cunning designer can use these principles to speed up air flows and/or generate suction. For example, when wind blows towards an open window, some of the air stream enters the opening. If the window is small, the Venturi effect means the air will force through under some pressure and so speed up. On the other hand, if the window is large, the pressure of the air flowing through it will drop, lessening its speed.
The Venturi effect is named after Giovanni Battista Venturi (1746–1822), an Italian physicist.

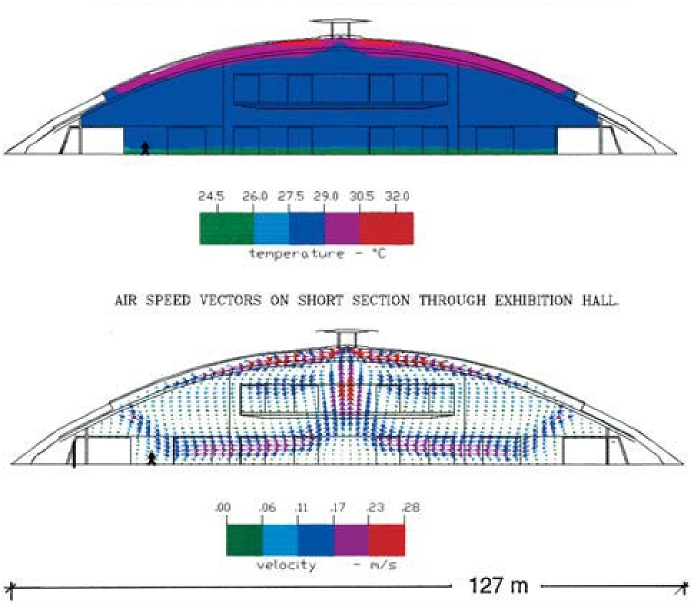

Figure 62: Design Center, simulations of temperature curves and airflow patterns

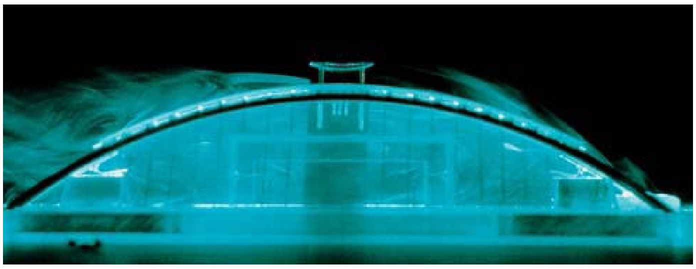

Figure 63: Design Center simulations using the wind tunnel

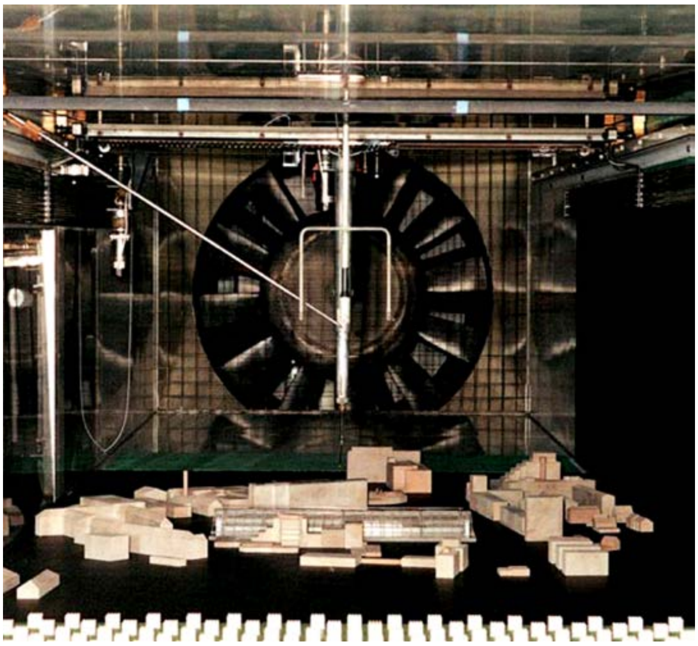

Figure 64: Design Center, simulations using the wind tunnel

1-3-3 Thomas Herzog's Deutsche Messe AG (DMAG) Administration Building

As a building type, high-rise buildings are not usually regarded as compatible with the conservation of resources. This project proved it was possible to design a “sustainable” building that refutes this opinion. This is accomplished through a new interpretation of spatial and functional concepts, by co-ordinating the form of construction with the energy concept, applying sound principles of building physics, and exploiting locally available forms of environmental energy. Taking account of environmentally relevant issues high quality in the workplace and flexibility of use were the main criteria in ensuring that the building could adapt to changing working needs over time (Figures 65-67). (Herzog, Krippner, & Lang, 2004)

Figure 65: Aerial view, Deutsche Messe AG (DMAG)

Figure 66: DMAG

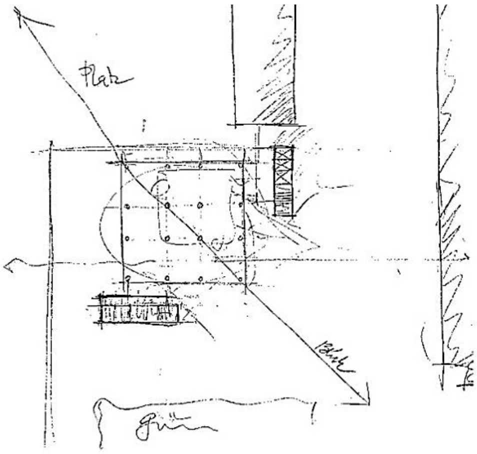

Figure 67: DMAG, Conceptual sketch

The layout is articulated into a central working area of 24 x 24 m in plan and two tower-shaped access cores, containing ancillary spaces, which are offset to the sides. This allows great flexibility in the use of the building, which is twenty stories high. Above the three-story entrance hall are fourteen floors that are used exclusively for offices. At the top of the building are conference and discussion spaces, as well as a story occupied by the company management. The individual floors can be divided into open-plan, combination or single-unit offices as required, whereby a similar quality is guaranteed for every workplace (Figures 68-73). (Kolarevic & Malkawi, 2005)

Figure 68: DMAG, ground floor

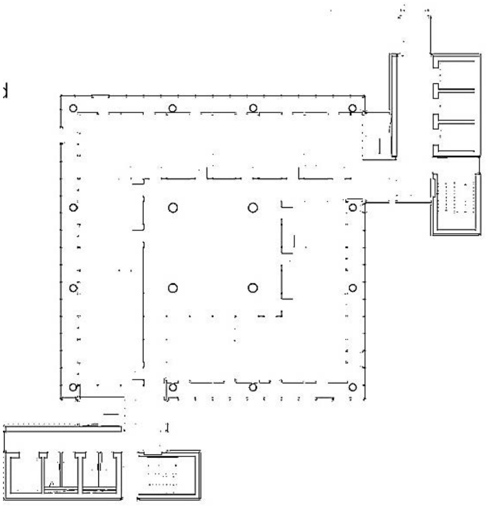

Figure 69: DMAG, standard floor plan

Figure 70: DMAG, Hermes Lounge

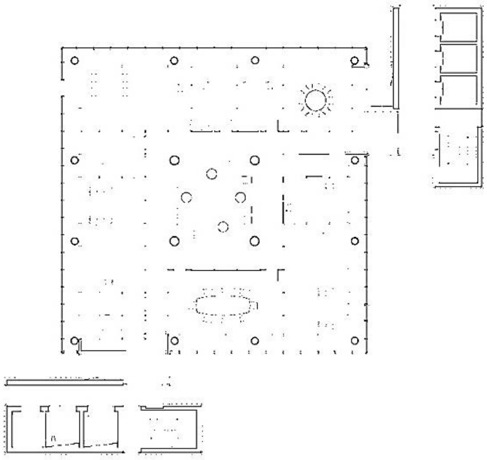

Figure 71: DMAG, board members floor plan

Figure 72: DMAG, glazing

Figure 73: DMAG, terrace

All users can enjoy natural ventilation by opening the sliding casement doors to the intermediate space between the two skins of the facade. When the casements are closed, fresh air is supplied via inlets from the ventilation ducts incorporated in the inner facade skin. Vitiated air is extracted from the offices by means of thermal uplift of the warmed air in the internal spaces and is channeled through a central duct system, with vertical shafts leading up to a rotary heat exchange unit. In winter, this allows 85% of the thermal energy contained in the extracted air to be used for preheating the fresh-air intake. The integration of thermal storage mass into the overall concept was of great importance in ensuring an efficient use of energy and a high degree of internal comfort. The heating and cooling system laid in the monolithic screeds allows the thermal environment to be controlled at a low temperature level. By storing heating or cooling energy in the thermo-active floor slabs, which is released at a later time, it is also possible to reduce temperature extremes, thus ensuring a balanced indoor climate and agreeable surface temperatures on the space-enclosing elements. A distinguishing feature of this structure is the coordination of the various building subsystems within an overall concept. In this way, it was possible to guarantee a high level of comfort with low energy consumption, and to harness sun and wind energy to control the indoor thermal environment and ventilation. (Kolarevic & Malkawi, 2005) A ventilation tower rises by about 30 m above the northern access core. The exploitation of thermal uplift is an important aspect of the natural air-supply and extract system for the entire building (Figures 74&75). (Herzog, 2000)

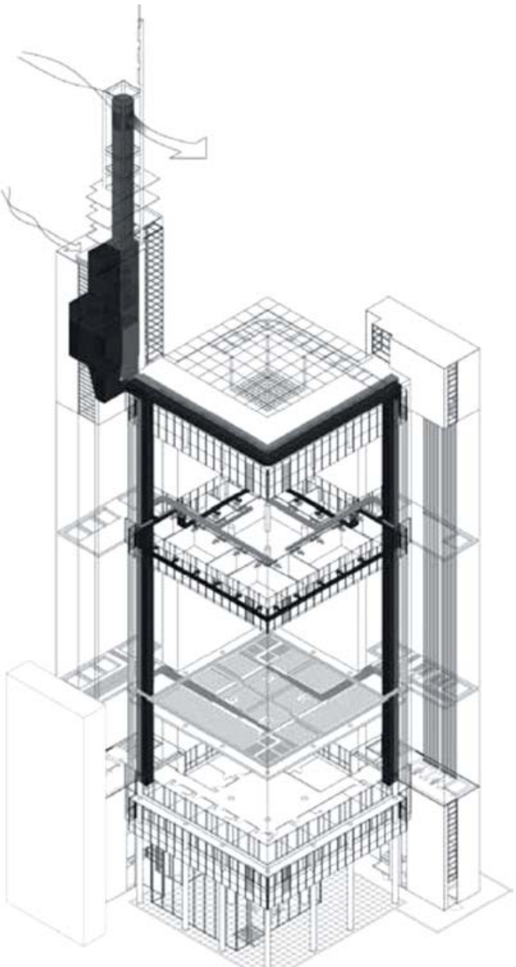

Figure 74: DMAG, the southern and eastern facades

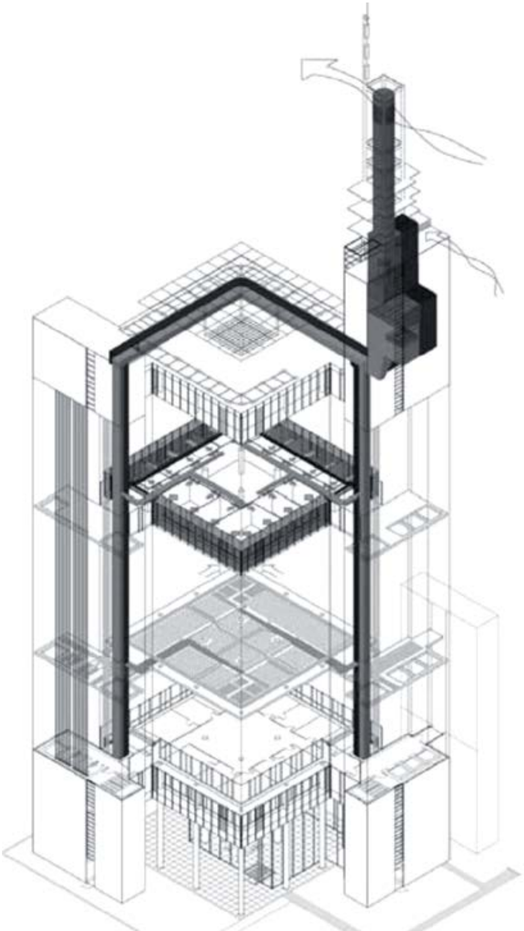

Figure 75: DMAG, the northern and western facades

The load-bearing structure consists of a reinforced concrete skeleton frame with in-situ concrete floors. The building is braced by the two access towers, which, in conjunction with the floor slabs, form a stable structural system. The access towers are clad with the Moeding[17] façade system, a rear-ventilated clay-tile form of construction suspended from the main structure. The double-skin glazed facade to the office areas (Figure 76) offers several advantages. The glazed outer skin acts as a screen against high-speed winds, thereby allowing natural ventilation (Figure 77). Sunshading can be installed in a simple form behind the outer facade layer, where it

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[17] MOEDING is a back-ventilated, thermally insulated terracotta facade. The Moeding system offers a maintenance free, ecological and economical insulative clay product with simple assembly.

MOEDING façade systems offer the following advantages thanks to optimal material characteristics: Resistance to all types of aggressive environmental influences, It patinates beautifully, Long service life and high profitability, Universal application in new buildings and for renovating older buildings, A high level of architectural design quality is protected from the elements and is easily accessible for maintenance and cleaning (Figure 78). (Kolarevic & Malkawi, 2005)

Figure 76: DMAG, double-skin facade with fixed glazing

Figure 77: DMAG, cross-section through the double-skin facade with external ventilation flaps

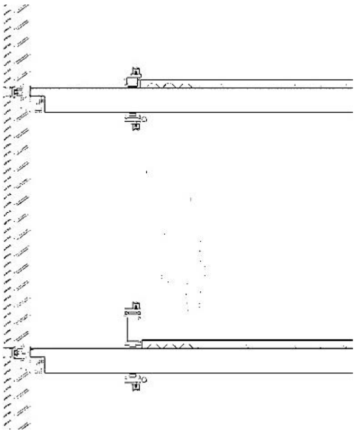
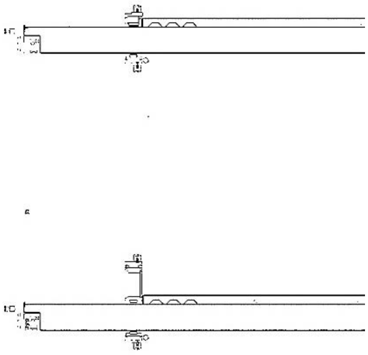


Figure 78: DMAG, cross-section through the double-skin facade with external fixed glazing



The buffer effect created by the corridor space between the two facade skins (Figure 79), and the high resistance to thermal transmission provided by the two layers of glazing, help to reduce the effects of insulation near the surface of the inner facade and increase the sense of comfort in the rooms. The cantilevered reinforced concrete floors and the fire protection they provide allow a form of facade construction with story-high glazed elements. This, in turn, facilitates a maximum exploitation of daylight and creates an ample sense of internal space. The cantilevered section of the floor slab does not have to be thermally separated from the main area as a result of the use of insulating double-glazing in the outer facade skin. In addition, it was possible to locate the load-bearing columns in the façade intermediate space where they do not obstruct the functional floor area. (Kolarevic & Malkawi, 2005)

Figure 79: DMAG, intermediate space between façade skins

1-4 Discussion

House Regensburg:

In accordance to characteristics of this experimental home, we realize that there is emphasize to this fact that environmentally responsive design doesn't mean that a building has to look a certain way. Actually Herzog rejected the widely-held belief during the early 1970's that "energy efficient design had to adhere to a specific aesthetic". In contrast to many designers of the era, who turned into an anti-industrial ideology for helping them to define ecologically responsive form, he celebrated the convergence of modernism, science, and innovation to create a unique solution.

House Waldmohr:

Today Thomas Herzog continues his researches the entire spectrum of climate control within a single building, including air circulation, air quality, lighting, and temperature control. He fundamentally believes that a truly ecologic building also has a corresponding resolution in aesthetic form.

In regards to the design process of the house Waldmohr, It should be mentioned that how does the process of design change when we fully address the needs through strategic connections to the outside, it is specially related to solar orientation? As biophilia[18] becomes more widespread, throughout the world, and informs that how the buildings are shaped, it will be more exciting to see how experiencing the environment affects the process of design.

Housing group Kranichstein:

Actually in this project it was possible to create buildings of great depth with only a small external facade area. To reduce energy consumption and to facilitate a low-cost form of construction for the internal facades, the courtyards were covered with standard greenhouse structures. This created an energy-saving intermediate temperature zone that could be used as an extension of the living areas for much of the year.

Two-family House, Pullach:

The inventiveness of solar design of this project is its principal physical configuration but it is more successful in integration, which is mostly strategic, than physical. The performative characteristics of this project are mostly achieved by design logic rather than system-to-system interfaces. As a result, a plan which is approximately simple, exposes an integration of complex thoughts about solar penetration, interior planning, summer shading, structural spans, privacy, circulation, and view, so actually it has been successful in reconciling different aspects of design. Furthermore its aesthetic quality form is remarkable which is configured by timber framing with a significant transparency by infilling the glass.

Guest Building for the Youth Educational Centre, Windberg:

The aim of Thomas Herzog's architecture is to reach to an ecological self-sufficiency by benefiting from technology, which is applied throughout his works, and actually his main focus is on enhancing passive technologies.
Furthermore, in this project he was successful enough to join the new structure with the existing building (monastery) and actually there is a real harmony between form, material and colors which have used in this building and also he has taken care about outdoor existing scales and its organization of the site, by this work, he made a

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[18] The biophilia hypothesis suggests that there is an instinctive bond between human beings and other living systems. Edward O. Wilson introduced and popularized the hypothesis in his book, *Biophilia* (1984). He defines biophilia as "the urge to affiliate with other forms of life".

Architecture biophilic is a part of a new concept in architecture, that work intensive with human health, ecology and sustainability precepts, such a integrate part of architectural formation which must be in optimal proportion with other buildings material. (Bachman, 2003) The position of green covering and its area depend basically on the category of functions that occur under this area. However, the interpretation and final implementation of biophilic architecture must have a regional dimension with regard to environment and culture.

coordinative approach between “modern architecture” and “historical and cultural references”.

In fact, Herzog’s buildings provide the spaces that really work well for the clients and others who experience the buildings.

One of the aims for designing this building is to educate the habitants or users the solar technologies and energy conservation throughout their living. One of the other things which should be attended is that not only the building organizes a residence hall but also at the same time passive and active design is incorporated in the building’s system while it is visible and incorporated in the interiors and enclosure and also structure of the building.

Exhibition hall in Linz:

The daylight advantages of this building type are evident and the design team developed a system which can be used universally on the building envelope. Between the pains of insulating glass is a retro-reflecting grid coated on one face with a thin layer of pure aluminum. The system allows indirect light to enter via “light shafts”, set next to each other in tight rows, while direct sunlight is excluded.

In fact, the Exhibition Center Linz illustrates integration of the structural form with the daylighting saturation of the envelope –which is joined by the interior function by the same logic for achieving to the final form. Evidently, aspects of the research of project and also an intensive collaboration with the building scientists were indispensable for achieving to this integrated architectural work.

Deutsche Messe AG (DMAG) Administration Building:

This particular sustainable building presents the form of construction with the energy concept, and also incorporation of building physics concept and employing the forms of environmental energy which is locally available for the building.

If we detail more in the work of Thomas Herzog in this project, evidently, we find out that he has applied and developed a worthy career in his innovative approaches toward using materials and rehabilitation of building arts’ which is a complicate task, although it is fruitful. Obviously he represents pure building activities which are significant in architectural profession with a sustainable approach which can be used in our own projects.

1-5 List of figures and tables

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Chapter 2: Energy Efficiency

Chapter 2: Energy Efficiency[1]

2-1 Introduction

2-1-1 Statement of the Problem

Among the most significant environmental challenges of our time are global climate change, excessive fossil fuel dependency and our cities' growing demand for energy – All likely to be major challenges of the twenty-first century and some of the greatest problems facing humanity. Globally, buildings account for around one third of energy use and are responsible for over half of total greenhouse gas emissions. Studies show that the efficiency improvement capacity of buildings is significant: researchers have estimated that the current energy consumption of buildings could be cut by 30 to 35 per cent simply by using energy more efficiently. Another 25 per cent could be gained by transforming the existing building stock through retrofitting it into energy-efficient buildings. Such change would address both energy security and environmental challenges and help to secure social and economic development.

But why are our current buildings so energy hungry? It is worthwhile reflecting on the origins of the dependency of buildings on air conditioning, which evolved with twentieth-century architecture and is related to other developments that affected buildings in the 20th century, such as the emergence of the curtain glass facade, the lack of flexibility and adaptability of most buildings and their relatively short life span. Such reflection shows that many traditional passive design principles have been forgotten or marginalized. We can, however, still find them in heritage buildings from the pre-air conditioning era, and we see that they are based on heat avoidance, the appropriate use of local materials, the use of natural cross-ventilation and the harnessing of natural energies offered by the location.

A move towards better design and building practices would ensure energy efficiency and limitations on emissions of greenhouse gases for decades to come. In fact, buildings are often described as the 'low-hanging fruit' in the challenge of creating a low-carbon future, because the implementation of energy efficiency in the construction sector has been long overdue and has already started to become a worldwide movement. Also, these changes are fairly inexpensive and easy to achieve. (Zalejska-Jonsson, 2011)

However, the concentration of our energy supply on fossil fuels has had a continuous and drastic effect on the balance of nature, ecosystems and the overall environment, on water and soil, biodiversity and climatic stability. The use of fossil energy sources has led to a rapid rise in the emission of carbon dioxide and other greenhouse gases into the atmosphere. The use of energy by urban developments and buildings is of far-reaching importance. Estimates indicate that 'at present urban agglomerations account for up to seventy per cent of all CO2 emissions worldwide, and around forty percent of CO2 emissions can be attributed to housing construction and estate development'. An increase in energy efficiency and a reduction of energy demand in

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[1] Energy efficiency is the use of energy wisely in order to accomplish the same task; sustainable use of energy to ensure that social, environmental and economic aims of sustainable development are supported. The intention is towards energy saving and the reduction of negative impact on the environment.

buildings must, therefore, be a basic condition for any successful climate change policy. (Zalejska-Jonsson, 2011)
Furthermore, the energy sector faces evidently significant challenges that everyday become even more acute. The current energy trends raise great concerns about the ‘‘three Es’’ that are the environment, the energy security and the economic prosperity as defined by the International Energy Agency (IEA). Among the greater energy consumers is the building sector that uses large amounts of energy and releases considerable amounts of CO2. In the European Union (EU), for example, the building sector uses the 40% of the total final energy consumed there in and releases about 40% of the total CO2 emissions. The mean energy dependency of the EU has increased up to 56% in 2006 with an increase rate of 4.5% between 2004 and 2005. As a consequence, the cornerstone of the European energy policy has an explicit orientation to the preservation and rational use of energy in buildings as the Energy Performance of Buildings Directive (EPBD) 2002/91/EC[2] indicates. This is not however a concern of only the EU, since other organizations worldwide put significant efforts towards the same direction. (Diakaki, Grigoroudis, & Kolokotsa, 2008)

In fact, Climate-appropriate and energy-conscious principles were applied in conjunction with the structural and aesthetic aspects of architecture as a matter of course almost until the mid-nineteenth century. The accelerated development of climate technology "liberated" the architect from these constraints and allowed him to focus his attention entirely on structural or formal themes. Architecture thus gradually became divorced from nature. This attitude led to an irresponsible use of energy resources that cannot continue without resulting in grave ecological consequences.

The buildings that are being realized today should continue to be in use thirty to forty years hence, when energy supply will undoubtedly be an even more critical issue than it is today. In order to clarify the close relationships between man, climate and architecture, a wide range of so-called "solar buildings" was created. The energy performance of the buildings and the impact of the various strategies employed to utilize solar energy constituted the principal factors. Simplified calculation methods, developed for PC application, allow for a quantitative evaluation. The principal goal of these efforts should not lie, however, in optimizing the energy performance of these systems, but in establishing architectural applications for energy-conserving strategies and energy generation in the form of specific design components. Special attention should be given to the influence of these solutions on the design of facade and space and the use of the building, but also on the interaction between solar energy concept and the "habit"ation of the users. Ultimately, it is not only a question of conserving energy, specially by integrating the sun into the design, but also of augmenting the living quality in buildings.

Over the years, the foundations for planning a building design that takes the passive use of solar energy into account have grown ever more precise and increased planning stability. At the same time, this development not only served to overcome the

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[2] The directive 2002/91/EC on the energy efficiency of buildings was legislated on 16 December 2002 by Council and Parliament of the European Union and had to be implemented by member states until January 2006 into their national legislation. Germany had already implemented the provisions of the directive for the most part in advance with the Energy Saving Act 2002. After the adoption of the Energy Saving Act 2007, all requirements of this directive were fully implemented in Germany.

arguments and prejudices against energy-saving measures, it also revealed the degree of responsibility residing in the hands of the planner. Energy-efficient architecture- in the context of taking a conscious look at the ecological situation and the constructional and technological possibilities- has become a matter of ethical duty. Another decisive factor in this development was the growing sensitivity among clients with regard to the necessity of energy conservation. Energy-conscious building rose to the top on an international level. Renowned architects gave it prestige by choosing this approach as their leitmotif - with a corresponding multiplying effect. (Gonzalo & Habermann, 2006)

Likewise, in building tasks, energy-conservation begins with the decision to build or not to build, followed firstly by decisions regarding building materials and only then by decisions regarding building methods. For the latter, the standard reference literature already contains planning methods and established rules of thumb as well as a selection of newly evolving technical means with which (nearly) every building task can be mastered. It is the first two decisions that represent the greatest savings potential. Opportunities missed at these preliminary stages can only be compensated for at tremendous economic and ecological expense. “The difficulty does not lie in making things but in creating the conditions under which one can do without those things." Anything that is built or employed for building should be evaluated according to its consumption value and derive its right to exist solely on that basis. Sustainability in a building task is based on necessity. Necessity, in this context, is also understood as the opposite of optional and arbitrary. From this perspective, energy-efficient planning and design cannot stop short at making formal decisions in favor of compact building form or employing specific materials and technologies. On the contrary, it encompasses all stages and areas of the design process. Since priorities must be established at all levels, it is essential to clearly define the goal in advance. (Gonzalo & Habermann, 2006)

Meanwhile, Energy efficiency is now universally recognized as one of the quickest, most cost effective ways to reduce energy related emissions associated with global warming, climate change, acid rain and smog. Improving energy efficiency is a key strategy in making the world's energy system more economically and environmentally sustainable. (DAMPTEY, 2006)

Additionally, a Well-designed energy efficient building maintains the best environment for human habitation while minimizing the cost of energy. The energy efficient buildings are to improve the comfort levels of the occupants and reduce energy use (electricity, natural gas, etc.) for heating, cooling and lighting (Development and Land Use Policy Manual for Australia, 2000 and United Nations, 1991). (Nadzirah Binti Zainordin, 2012)

In fact, Renewable energy is the energy that is generated from natural resources, such as wind, solar, rain, tides, geothermal heat, etc. Due to the shortage of energy supply and wide concern on global warming, renewable energy systems have been receiving wide attention and are being recognized as an important and green strategy to generate a sustainable, environmentally friendly and clean energy. When renewable energy systems are integrated into buildings, they can help reduce the peak electrical and cooling demands and, thus, save the total energy consumption of buildings. (Wang, 2009)

Wither (1999) argues that among the many issues which must be addressed on the road to sustainable development, energy is the “single most important factor”. Building life cycle is counted for 50-100 years and during this time total energy associated with a building may be divided into energy that is directly connected with building itself: energy needed for building’s construction, operation, rehabilitation and demolition, and embodied energy, which is a sum of all energy needed to manufacture and transport goods (all material and technical installations). (Zalejska-Jonsson, 2011)

Holm (1996) suggests that “It seems to be part of our mental make-up that we keep on believing that there must be a single elixir (Medicine) that will be the answer to all problems.” As a result, after more than 30 years of experimentation and research, few ‘successful’ examples of energy efficient buildings exist. The danger is that designers and practitioners in the building industry will continue to look to these few examples of energy efficient building and apply the principles blindly with little consideration to context, resulting in inefficient buildings. (Kut et al., 1985)

Actually, it is important to understand that many design decisions in the building design process is affecting both energy performance and the indoor environment. In practice many building designers do not know the consequences of their initial design decisions in terms of energy performance and indoor environment leaving the task of complying with design goals to expensive sub-optimizations later on in the building design process. If buildings are to contribute to a sustainable development, new methods and tools which integrate energy performance and indoor environment at the earliest state of the building design process is needed. (Steffen Petersen and Svend Svendsen, 2009)

Energy efficiency in buildings is important not only because it represents the lion's share of energy use, but also because of the related social, health and employment impacts. Whilst building standards are the most common policy measure in most countries, there also needs to be training, education and information for all professionals in construction and building maintenance. Information and advice could also be disseminated to self-builders and other non-professional craftsmen. (Koskimäki, 2012)

Meanwhile, Buildings are significant users of energy and materials in a society and energy conservation in buildings plays an important role in urban environmental sustainability. A challenging task of architects and other building professionals today is to design and promote low energy buildings in a cost effective and environmentally responsive way. Passive and low energy architecture has been proposed and investigated in different locations of the world; design guides and handbooks were produced for promoting energy efficient buildings. (Omer, 2002)

Generally, the design of energy-efficient buildings is a complex task for architects and engineers. Truly sustainable design can only be achieved if energy efficiency is combined with material efficiency. It requires a sound understanding of the inter-linkages between various technical, environmental, social and economic criteria. (Lehmann, 2011)

2-1-2 Purpose of the study

This study is aimed at realizing how concepts are brought to construction by exploiting innovative energy efficient design with a professional insight, pursuing energy efficient architecture as a priority in its real dimension, throughout Herzog's projects and to provide building researchers and practitioners with a better understanding of buildings energy saving opportunities and approaches and taking further proper actions to promote energy efficiency and conservation in the buildings.

Further, it attempts to investigate less-focused concepts in establishing guidelines for future energy-efficient building design and administering methods of design that conserve energy and natural resources and to use methods and materials that reduce in a building environmental impact, increase operating efficiency, and increase durability.

2-1-3 Hypotheses

Energy efficient buildings are an integral part of the overarching aim to achieve sustainable development. Sustainable development has been defined as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'. Therefore, energy-efficient buildings have to be designed in such a way that they contribute towards the *larger* vision of building energy-efficient and environmentally sustainable cities. This is achieved by increasing the efficiency of resource (energy) use, but not by increasing resource throughput. This implies that energy is conserved wherever possible and energy supplies, to a large degree, come from renewable and non-polluting (non-fossil fuels) sources.

Importantly, energy-efficient buildings do not have to conform to a particular 'building style'; they can be existing buildings adapted for reuse. They are buildings that effectively manage natural resources by taking all possible measures to ensure that the need for energy is minimal during their operation (applying passive and active systems to harvest renewable energy sources). In these buildings, cooling, heating, ventilating and lighting systems use methods, technologies and products that conserve non-renewable energy or eliminate energy use. Cutting energy demand requires the use of design solutions, materials and equipment that are more energy efficient.

Sustainable building design, also known as green or energy-efficient building design, is therefore the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life cycle, from concept to design, construction, operation, maintenance, renovation and demolition. Although new technologies are constantly being developed, the common objective is for energy efficient buildings to be designed to reduce the overall impact of the built environment on human health and the natural environment by efficiently using energy as well as water, materials and other resources and reducing waste and pollution. (Lehmann, 2011)

Moreover, energy efficient design does not necessarily have to result in increased construction costs. Indeed, one of the key approaches to energy efficient design is to invest in the building's form and enclosure (e.g., windows, walls) so that the heating, cooling, and lighting loads are reduced, and in turn, smaller, less costly heating, ventilating, and air conditioning systems are needed.

Well-designed energy efficient buildings maintain the best environment for human habitation while minimizing the cost of energy. The energy efficient buildings are to improve the comfort levels of the occupants and reduce energy use (electricity, natural gas, etc.) for heating, cooling and lighting.

Furthermore, one of the fundamental principles is to design buildings 'low tech', where passive strategies are employed before active ones and Traditional buildings are a great educational source as they frequently achieve 'more with less': high comfort for building occupants, good indoor air quality combined with surprisingly low energy requirements.

Likewise, 'We need solutions for buildings that can do more with less technology', argues engineer Gerhard Hausladen, adding: 'The optimization of the building layout and detailing of the facade system are essential for an integrated approach to the design of low-energy consuming buildings and cities'. (Nadzirah Binti Zainordin, 2012)

2-1-4 Methods

This study is performed based on reviewing and interpreting the most current resources in green architecture focusing on all gathered information linked to Thomas Herzog in the form of case studies. Further, his techniques and strategies will be evaluated based on his designs in different spots.

2-2 Literature review

"To improve sustainability of building main contribution is of increased energy efficiency."(Herzog et al., 2001) ***In the future "... architects will have to exert a greater influence in the conception and planning of urban environments, design of buildings, material use, construction and components. Thus, they will contribute to the reduction of energy consumption."*** (Usón Guardiola, 2007)

According to the Final declaration of the UIA / AIA[3] conference held In Chicago in 1993 "Buildings and the built environment play a major role in the human impact on the natural environment and on the quality of life; a sustainable design integrates consideration of resource and energy efficiency, Healthy building materials, ecologically and socially sensitive, and use, and an aesthetic sensitivity that Inspires, affirms, and ennobles; a sustainable design can significantly reduce adverse human impacts on the natural environment while simultaneously improving quality of life and economic well-being." (Usón Guardiola, 2007)

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[3] International Union of Architects (UIA) and the American Institute of Architects (AIA)

In fact, Climate change due to greenhouse gas emissions from anthropogenic and natural activities has been a major concern of all people across the globe. Fast urbanization, continuous industrialization and improved living standards have boosted up energy consumption in recent years. All human activities essentially need energy as driving force. Since long time fossil fuels have been the basic source of generation of energy. Combustion of fossil fuel for the generation of energy results into emission of greenhouse gases predominantly carbon dioxide. With increasing concern to greenhouse gas emission form anthropogenic activity concept of energy efficient building has been evolved.

Buildings are essential part of civilized society. Buildings account for one sixth of world's fresh water withdrawals, one quarter of its wood harvest and two fifths of its material and energy flows. Construction of building is energy intensive process which consumes energy in each stage right from site clearance up to operation and maintenance throughout its life cycle. Improvement in energy efficiency of building results in reducing energy demand, saving of scarce natural resource and reduction in carbon emission. This improves overall environmental performance of the building. Construction of buildings includes various activities, viz. planning, design, execution, operation and maintenance. Each stage of building construction uses energy in one or the other form. Sources of energy used in the development of building include coal in manufacturing of construction materials, oil and fuel in transportation and running equipments and electricity for operating appliances. Improving environmental performance of the building through its improved energy efficiency can be divided into five stages; policy formulation on global and national levels, planning and designing energy efficient building, making construction process energy efficient and using energy efficient appliances. (Vaidehi A. Dakwale Sachin Mandavgane, 2011)

Scientists have observed a warming of the climate system. The average global air and ocean temperatures have increased which has prompted extreme polar ice melting and rising of average sea levels. Additionally ecosystems and hydrological systems are being affected by the earlier arrival of spring. The frequency and intensity of tropical cyclones in North America have also increased. The rise in global temperatures is likely due to the increase in anthropogenic greenhouse gas (GHG) concentrations. Scientific modeling shows that the past 50 years would have experienced cooling when considering the solar and volcanic forces, but with the inclusion of anthropogenic forces the Earth has experienced warming patterns. The modeling and research concludes that the actions of humans are producing drastic effects on the global environment.

Human activity is causing excessive GHG to be emitted into the atmosphere. These GHG's are altering the atmospheric composition of the Earth which impacts the climate system negatively. Carbon Dioxide (CO2) is a major GHG that is impacting the global environment. Hansen et al states that due to the high amounts of CO2 currently in the atmosphere the climate requires that the reduction in emissions be reduced to almost zero. The 2030 Challenge, initiated by 2030 Inc. /Architecture 2030 director Edward Mazria, recommends that the building industry adopt emission reduction targets through energy efficiency investments and measures.

The production of electricity for buildings from coal is a major contributor of CO2 emissions into the atmosphere. Coal is responsible for 81% of the emissions, and 76% of all electricity generated by the power plants in the United States is for building operations. Developing a strategy to decrease these emissions is difficult. This reduction requires the replacement of the coal power plants and/or the elimination of the demand. An effective strategy is to invest in building energy efficiency. Mazria & Kershner states that an investment of $21.6 billion into building energy efficiency would significantly reduce dependency on electricity generated from coal. The reduction in electrical demand from coal would be equivalent to the production of 22.3 conventional 500 MW coal fired power plants. It would reduce CO2 emissions by 86.7 million metric tons, save users $8.46 billion annually in energy bills and create 216,000 jobs. Additionally the authors provide a comparative example of the cost of energy production to produce one Quadrillion Btu[4] (QBtu) of delivered energy. Coal costs about $256 billion, and nuclear power is about $222 billion to produce and deliver the energy. The investment of $42.1 billion applied to energy efficiency measures for residential and commercial buildings could result in the reduction of one QBtu of produced and delivered energy. The 2030 challenge presented by Mazria & Kershner provides steps to achieve a goal of being carbon neutral by the year 2030. The challenge requires that an equal number of existing buildings be renovated to achieve a 50% reduction of energy.

The impacts that humans have on the natural environment is a critical issue. The built environment, which includes existing buildings, affects natural resources and its surroundings. These effects highlight the need for existing buildings to take on new strategies and technologies to reduce environmental damage. This includes the minimization of natural resource consumption, the emissions of air pollutants, the discharge of solid waste and other effluents, and also the maximization of the indoor air quality. ASHRAE states that energy efficiency must be driven by the desire to do the right thing, conformance to regulations, lowering ownership costs, increasing productivity, and educating all who are involved. (JONES, 2009)

2-2-1 Evolution

The comfort provided by house technology has evolved mostly during the last three centuries. Increased life expectancy is directly linked to this evolution. However, the constantly rising energy demand that goes hand in hand with technological development and the plundering of available resources were ignored for a very long time. It was only gradually and under pressure –reflected in political milestones such as the Charter of Athens, the oil crisis, the accident at the reactor in Chernobyl, the Rio Conference and finally the ratification of the Kyoto Protocol– that public awareness of ecological issues began to develop.

Generally, the recent history of architecture abounds with forerunners of ecological housing, for example the garden cities or the housing initiatives during the Industrial Revolution. Energy consumption in the context of building was not the

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[4] A British Thermal Unit (BTU) is the amount of heat energy needed to raise the temperature of one pound of water by one degree F. This is the standard measurement used to state the amount of energy that a fuel has as well as the amount of output of any heat generating device.

primary concern in these historic examples, however. The focus was on creating a social environment rather than reacting to the profound impact of industrialization. At that time, attitudes toward energy consumption were characterized by an optimism that was still free of thoughts of relinquishing services or accepting restrictions.

Energy-conscious attitudes and the concept of utilizing solar radiation to reduce the heating requirements in housing came to the fore in so-called solar architecture. It would take until the 1970s, however, before the breakthrough from purely experimental and isolated projects to a broader consideration of the linkages between architecture and energy took place.

However, Energy-efficient building was finally able to establish itself in architecture and to leave its "alternative" character behind. The prejudices that were a legacy of the era of development and experimentation, namely that any sensible application of these principles would always be restricted to isolated objects and small developments, were overcome. (Gonzalo & Habermann, 2006)

In the mid-1970s, when the so-called energy crisis first made us aware of the finite nature of fossil fuels, architects and urban planners –who are in part responsible for a field that accounts for more than half our energy consumption– were unable to find an immediate answer to this problem. For far too long, energy had been available in unlimited quantities and at a reasonable price; and there had seemed to be no vital need to reduce its consumption. Although there was a great sense of insecurity at the time, the challenge that this new situation presented was at least recognized: the primary function of buildings –the provision of shelter and comfort for man and his belongings– had to be reinterpreted. The careful husbanding of energy and its more effective use in ecologically sustainable forms (in particular solar energy) came to assume a central role in the work of our profession. This new approach was a pragmatic response to the situation and was not based just on fashionable trends. Now, one can point to a number of outstanding structures that reveal an ambitious architectural concept as well as completely new interpretations and intense applications of environmental energy –for heating, cooling, natural ventilation, lighting and the generation of electricity. The buildings in which solar energy has become a factor of the design and has been used in an aesthetically effective form include schools, universities, housing schemes of all kinds and sizes, offices, museums, galleries and many other structures.

In addition, a large number of new products and systems have been developed for the outer skins of buildings, including translucent thermal insulation, improved shading and daylight-deflection systems, new types of glass and new forms of facade construction, the correct application of which can achieve exceptionally good values in the energy household of a building. "Grey" energy[5] and the life cycles of materials are two other aspects that are being increasingly taken into account. Regenerable, renewable raw materials are coming to assume a much greater importance than in

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[5] Energy is necessary for the construction and disassembly of a building. This energy is called grey energy, and contains energies for the manufacturing and processing of the building materials, their transport and disposal. Together with the energy for covering the heating energy demand during the lifetime of the building, this results in the cumulative energy. Only this measure is suitable, to make an evaluation of the sustainability. The grey energy of a residential building, distributed over the lifetime of its different components, is roughly 30 kWh/ ($m^2 \cdot a$). This is a significant part of the energy, which is used for heating during the usage of the building. The higher the constructional and technical effort of a building, the higher is this fraction.

the past in decisions concerning the choice of building materials and the form of construction. The use of recyclable products and minimal quantities of materials for structural membranes is another area where the scope for conserving resources has been recognized. (Novikova, 2010)

2-2-2 European orientation

Likewise, the European Union in its energy and climate change policy has decided to set up binding target of 20% renewables in gross final energy demand, to reduce greenhouse gases emissions by 20% and to increase the energy efficiency by 20% by 2020. It is in the process of deciding to decarbonize its power sector by 2050. A significant technology shift will be necessary to fulfill such goals, but it is already clear that technologies that will be used are available, mainly in the area of renewable electricity and heat generation, biofuels and electricity for transport, energy efficiency, *especially in buildings and transportation*, cogeneration, nuclear energy in those countries in which it is politically acceptable. (Guzovic, 2011)

2-2-3 Background

Until 1970 energy was abundant and inexpensive. During this period building technology is said to have soared. Architects and developers embraced the artificial with regards to thermal comfort and lighting and thus, gradually moved away from the traditional, more energy efficient building.

Slessor states that “Since the Industrial Revolution, but more particularly in the present century, the twin phenomena of more widely diffused wealth and cheaper energy have resulted in a greater prevalence of energy usage.” (Phil Jones Jo Patterson, Chris Tweed, 2009)

Slessor continues; “Until the oil crisis of the 1970’s shocked the developed world out of its apathy, it had seemed unnecessary and irrelevant to make connections between design and energy use, as the cost of making and maintaining buildings was relatively low.” (Slessor, 2000)

“Looking at the global economy today, one has to be increasingly aware of energy as a scarce resource; the need for architects to design for a sustainable future becomes a self-evident imperative”. (Yeang, 2004)

According to Yeang, “design is only part of a greater gestalt in environmental design. Regarded independently, there are essentially three routes to low energy consumption in architecture: through material and component selection; through supplier economics (i.e. a life-cycle approach from 'source' to 'sink'); or through basic design.”

“Many environmental problems result directly or indirectly from inefficient use of resources, particularly energy (bio-climatic principles). Careful design of the building envelope, lighting systems, and heating, ventilation, and air-conditioning (HVAC) systems are important, as all of these elements affect the energy use of the building”. (Alex Wilson, Jenifer L. Uncapher, Lisa McManigal, L. Hunter Lovins, Maureen Cureton, 1997)

The most effective building designs with respect to energy efficiency emerge through careful attention to the following elements; (Alex Wilson, Jenifer L. Uncapher, Lisa McManigal, L. Hunter Lovins, Maureen Cureton, 1997)

1. Design to fit the site. (Orientation)
2. Design for resource efficiency. (Control heat gain and heat loss)
3. Design for a healthy indoor (and outdoor) environment.
4. Design for adaptability.
5. Design for durability and easy maintenance.

"Until a few hundred years ago the relationship between human beings and their environment was characterized by their willingness to adapt to the environment and to live in harmony with it". (Daniels, 1997)

Most researchers are in agreement with Daniels with regard to the extent and complexity of skills, measures and elements used to obtain energy efficiency. "The measures employed in ecological building are complex and derive from several specialized disciplines – from urban planning, architecture, construction, and façade design to active technical building services and their applications. Planted surfaces, indoor and outdoor, fresh air, soil, water, and rainwater all contribute to an integrated design, as does the management of building services and utilities that use the abundant resource of the environment". (Holm, 1996)

Holm, however, suggests that many of the aforementioned applications and elements are used carelessly and therefore often have the adverse effect of rendering a building unsustainable or inefficient.

Furthermore, Population growth through the years has played the major role in rendering the earth and its resources unsustainable. "Small populations (in the past) and modest requirements for energy utilization meant low emissions, mainly related to combustion processes (open fires). The waste products of past centuries were readily recyclable and bio-degradable and posed no threat to the environment. All waste could be returned to the natural cycle". (Daniels, 1997)

Small windows characterized buildings in the past, demonstrating "building masses with high storage capacities, and low standards for heating and sanitary systems. The small window units allowed little daylight to penetrate into rooms. Small windows also resulted in minimal heat gains from the outside to the inside and therefore also in minimal cooling loads. Compensating for thermal loads never presented itself". (Daniels, 1997)

Daniels explains that in winter, the small window did not allow for significant heat losses "and the heating requirements for rooms in these buildings were generally no higher than they are in modern, well-insulated buildings."

The 'thermal storage masses' of older buildings were large in proportion to the square meterage – (high storage capacity is the current term) and were usually constructed of unfinished thick, natural stone walls, so that thermal energy coming from the outside or released in the room was almost completely absorbed by the building mass(Figure 1).

Figure 1: Thermal massing

“ Due to the minimal loads and the high storage capacity such buildings remained cool even on hot summer days and tended to be uncomfortably cold in winter…unacceptable to modern comfort requirements”. (Daniels, 1997)

Holm agrees and explains that lots of mass reduces the temperature range towards the average temperature which may be either too high or too low for comfort. The designer should therefore be aware that thermal massing is not always desirable. Thermal mass may be useful in hot dry climates such as Botswana, but not in hot humid areas. Therefore mass must be considered together with night cooling or solar heating.

“As the use of building materials continued to evolve together with demands for comfort and better hygiene, the form of buildings changed; they became more open”. (Daniels, 1997)

In fact, a building is a climate moderator with the fundamental role of modifying the external environment through its building envelope, and creating a hospitable climate for human dwelling. The measure of degree of control of the indoor thermal climate is known as the thermal performance of the building.

The building envelope is often described as the skin of the building as it is this layer that is in direct contact with the environment. As skin protects and regulates the temperature of a living being, the building envelope needs to perform a similar function.

Many designers support the opinion that energy efficient systems can easily be added to a building after construction, similarly to how air-conditioning is added.

On the contrary, it has been proven that it is substantially more expensive to add alternate energy systems to buildings after construction. So much so that it becomes prohibitive in most cases. (Leban, 2001)

Envelope design needs to be well thought out from the inception of the building design. “Getting the building envelope right the first time is particularly important, because future modifications will be difficult, expensive and environmentally costly”. (Alex Wilson, Jenifer L. Uncapher, Lisa McManigal, L. Hunter Lovins, Maureen Cureton, 1997)

It therefore becomes important to consider building envelope design systematically and holistically, in conjunction with all the other elements of energy efficient design and resource management.

In cool climates, indoor temperatures are maintained significantly higher than outdoor temperatures. Here, heat gains and losses through the building envelope elements can be determined by the general resistance to the flow of heat through these elements. As an example, the color and texture of a wall surface can affect the wall’s thermal resistance as well as its insulation and heat storage capacities.

In areas of large diurnal temperature ranges and intense solar radiation, thermal massing is required. Thus materials with good heat storage capacity are desirable.

Cooler climates or even warm humid climates with low diurnal temperature ranges may require lightweight materials with a high resistance to heat transfer.

Yeang suggests that “external walls should be regarded as permeable, ‘environmentally interactive membranes’ with adjustable openings (rather than as a sealed skin). In temperate climates the external wall has to serve very cold winters and hot summers. In this case, the external wall should be filter-like, with variable parts that provide good insulation but are openable in warm periods. In the tropics the external wall should have moveable parts that control and enable good cross ventilation for internal comfort, provide solar protection, regulate wind-driven rain, besides facilitating rapid discharge of heavy rainfall”. (Yeang, 2004)

If the building membrane does not serve the aforementioned functions effectively, active energy intensive systems have to be introduced to moderate the interior climate.

It therefore stands to reason that the “envelope decisions will likely determine the energy consumption of the building for decades to come…” (Alex Wilson, Jenifer L. Uncapher, Lisa McManigal, L. Hunter Lovins, Maureen Cureton, 1997)

The Glucksberg (Figure 2), a castle with a moat, displays a much larger window, allowing more daylight to penetrate the room, improving lighting conditions and ventilation. At the same time, thermal gains from the outside increased in summer as did heat losses in winter. Nonetheless, high storage buildings were still constructed of massed local stone thus the “greater heat gains in summer did not create over heated rooms but merely improved the comfort level”. (Daniels, 1997)

Figure 2: The Glucksberg Castle Daniels

Replacing open fires, heating shafts were introduced in order to heat individual rooms more efficiently in multistory buildings during the cold winter months. Thus the first forms of climate control occurred. “Tile stoves came into use between the 15th and 18th centuries; they could heat not only one, but several rooms through shafts. This system improved comfort overall and satisfied the increased heat requirements created by the larger windows”. (Daniels, 1997)

The moat around the castle Glucksburg was created for safety reasons. However, the moat held secondary benefits to the inhabitants of the building. Light conditions within the building were improved as the water reflected additional light towards the windows. Most Practitioners agree that water is also a powerful thermal control element. Thus general comfort was improved. Through evaporation occurring at the water’s surface, the surrounding air is cooled in summer, and “at night, the water mass cools less slowly than the surrounding air, improving the climate near the building”. (Daniels, 1997)

However, Holm disagrees with Daniels with regard to water as a cooling device. Holm suggests that context must be taken into account as solar reflection from nearby buildings, roads and water sources can have a serious effect on the heating of a building.

A fundamental mistake with regard to the practical application of energy efficient design principles is, according to Holm, the fact that most designers dismiss diffuse solar radiation with regards to heat gain. Holm explains that a significant amount of solar radiation is diffuse. Commonly, designers assume that solar radiation consists of direct rays only. Holm suggests that “For example, the average diffuse radiation is near half the total solar radiation (46%) in Durban.”

Holm continues; “If the radiation reflected from the ground, (water) and neighboring buildings is added to the average diffuse radiation, the total diffuse radiation easily surpasses the direct component during a period of maximum negative impact.

Meanwhile, In hot desert climates, the tendency was to locate living spaces beneath ground level to take advantage of the insulating properties of sand and stone as well as to “utilize the coolness of the earth and to create ventilation through buoyancy, thus improving thermal comfort” . (Daniels, 1997)

However, at the beginning of the 19th century, the dawn of the Industrial age, rapid advances in technology increased the demands for energy created at this time through the burning of coals and natural gas. “The sharp increase in emissions was generally ignored and no effort undertaken to act against the environmental threat posed by dust soot and other polluting materials”. (Daniels, 1997)

2-2-4 Energy efficiency from Herzog’s perspective

“I am convinced that architects have a key role to play in the extremely complex field of the world-wide ecological crisis, because this impacts directly on their professional responsibility. When all is said and done about 40% of primary energy is used for building and running buildings, at least in Central Europe. Then additional quantities of fossil energy are used as a result of town planning measures.” (Herzog, 2000) *“In the future, the aim of our work must be to plan buildings and urban spaces in a way to make possible the safeguarding of Nature’s reserves and the regular use of renewable forms of energy, thus avoiding lots of the current undesirable urban developments. Architects and engineers will have to design their projects on the basis of a knowledge of the local conditions, the existing resources and the main criteria that regulate the use of the several renewable energy sources and the ecological components and techniques.”* (Usón Guardiola, 2007)
Thomas Herzog

According to Thomas Herzog, a German architect considered one of the founding fathers of Bioclimatic Architecture who, in his speech, presented an introspective of the work carried out by the German firm Herzog+Partner, the aim of his profession should be based on designing buildings and urban spaces that protect natural resources and use renewable energies - in particular solar energy - as extensively as possible. “The shape of the future environment we build must be based on a social approach to the environment and the use of the inexhaustible energy potential of the sun”, he said. As he explained in his speech, approximately half the energy consumed in the whole world is used to power buildings and a further 25% is consumed by traffic. To generate this energy, enormous amounts of non-renewable fossil fuels are used and the processes required to turn these fuels into energy also have a long-lasting negative effect on the environment, represented by the emissions they produce. Herzog highlighted that this situation necessitates a major shift in our way of thinking and soon, particularly from the perspective of urban planners and the institutions that are part of the construction process. According to the German architect, who has won some major international awards, the role of architecture as a responsible profession becomes extremely important in this regard. “In the future, architects must have a much more decisive influence when it comes to conceiving and designing urban structures and buildings, in the use of building materials and elements and, therefore, in the use of energy, in comparison with the role they played in the past”, he commented. However, he also pointed out that in order to achieve these goals, existing training and qualifications must be changed, along with energy supply systems, models of finance and distribution, and standards, legal regulations and legislation in accordance with the new objectives. (CENER, 2010)

“…The amount of radiation this earth receives from the sun is many times higher than mankind's energy needs will ever be. The question is how to exploit this potential. It is a fact that the amount of energy consumed to meet buildings' thermal needs is already a quarter or a fifth of what was achieved only a few years ago. Today we should make these results affective across the board, instead of flirting with so-called "zero energy buildings." Ultimately it is not about an Olympic discipline, but about looking at the matter as a whole and saving energy dramatically, or using solar energy.” (Contal, Revedin, & Herzog, 2009)
Thomas Herzog

At the time Herzog was a student, the oil crisis of the early 1970s provided the incentive to pull together the strands of previous work in the area of solar architecture, and redouble efforts to develop new solar architectural solutions. The architecture of this period was experimental and driven solely by energy performance criteria. The early buildings were considered by many architectural critics to be without merit. Criticism ranged from addressing the ugliness or ungainliness of form to the difficulty of fitting these buildings into an urban architectural context. In fact, many of the early buildings did not perform well either. Not coincidentally, it was at this time that Thomas Herzog began his professional career. His work breaks the early stereotype, fitting within the framework of early Modernist principles, yet responsive to the directives of the Solar Energy Charter. Herzog eschews labels; however in a 1993 interview, he reluctantly agreed upon the name “ecological architect”. He did not wish to be called a “solar architect” in view of the negative image associated with that term and the early experimental work of the 1970s. In fact he stated, “The problem with solar architecture is solar architects”. (Pérez-Gómez, 2002)

He asserted that: “In 1974, for the first time, we focused our attention on the subject of renewable forms of energy. We noticed that something was going on in this area in the United States. Looking at this field of studies today, it is interesting to see how far the Americans have dropped back, compared with what has happened in Europe in the meantime, and especially in central Europe. In the US, oil is still too cheap, and that obscures the view for what is necessary. After it became clear what the continuous consumption of fossil fuel was causing, I soon became aware that the use of renewable forms of energy –especially solar energy– and the integration of this theme into architecture would be a central objective for the future”. He stressed that his new working premise was a direct reaction of the first energy crisis. Moreover he argued that:

“The energy crisis was felt by everyone, and for the first time, we architects gave serious consideration to the implications of simply burning this valuable raw material oil on a gigantic scale and damaging the environment into the bargain through the emission of pollutants. It also became clear that it was not enough just to screw collectors on to the roofs of buildings. More fundamental questions were investigated, such as: "What will be the appearance of buildings that need less energy?" (It wasn't simply a matter of making the thermal insulation thicker.) Or: "How great are the energy gains resulting from a coordinated direct exploitation of solar energy by means of temporary thermal insulation?" In those days, we didn't have the good quality glass with lower U-values that is on the market today.” (Herzog et al., 2001)

Like the modernists, Herzog is concerned with developing a strong architectural vocabulary based on the premise that the construction materials and elements be efficient in form and production method. Herzog is known for working with representatives of academia and industry to develop new “high tech” construction materials and systems, as well as re-engineering older systems. (Pérez-Gómez, 2002)

Meanwhile, In the United States the 1980s and early 1990s saw significant efforts by sustainability proponents such as Robert Berkebile, and Sandra Mendler. Internationally, designers such as Germany’s Thomas Herzog, Malaysia’s Kenneth Yeang, and England’s Norman Foster and Richard Rogers were experimenting with prefabricated energy efficient wall systems, water-reclamation systems, and modular construction units that were designed to minimize construction waste. At this time Scandinavian governments set minimum standards for access to daylight and operable windows in workspaces. (Kubba, 2010)

However, an early demonstration project done by Herzog in collaboration with the Fraunhofer Energy Institute in Freiburg and SET of Luxembourg provides an example of a highly efficient house and studio, and utilizes technologies pioneered by Herzog. In this project, Herzog and his collaborators developed, over a period of time, a translucent, insulating panel. The aerogel panel system provides insulation while admitting light through the wall. This highly energy efficient cladding system resulted in a rationally designed house that was solar without looking solar. Another of the cladding systems developed by Herzog is a lightweight, ventilated tile wall panel system that works well in both warm and cold climates. The air plenum behind the mass-produced cladding system provides a rainshield, and the tiles can be manufactured in various colors and finishes. The size and range of color and texture make for a potentially highly articulated system that could work well in the urban context of many cities.

Herzog also continues to explore the possibilities of working with highly efficient steel structural systems in combination with wood, which is a renewable resource. We see this in the development of his larger scale work in Hannover, from the Production Halls and Central Energy Plant for Wilkahn, to Hall 26 and the Deutsche Messe AG Administration Building. Herzog also continues to explore the possibilities of working with highly efficient steel structural systems in combination with wood, which is a renewable resource. We see this in the development of his larger scale work in Hannover, from the Production Halls and Central Energy Plant for Wilkahn, to Hall 26 and the Deutsche Messe AG Administration Building. (Pérez-Gómez, 2002)

The premise that the building works as an ecosystem is a reinterpretation of the idea of the building as machine for living. In most of his projects, the machine becomes an expressive element as well as providing the underlying order of the building. Herzog is also concerned about the human occupants of his buildings. Unlike many of his predecessors, the answer is not in creating a strictly technological response, but also to address the wider range of site, social and cultural issues. In this way, he shares some characteristics with Aalto.

“What we are working on is a new material culture that must be fitted into an old material culture. We love new technology and new materials but we also love our old towns and cities. In no way am I prepared to abandon our whole cultural heritage just to pick up a few watts of free energy from the outside world”. (Pérez-Gómez, 2002)

Furthermore, In Thomas Herzog's buildings, in contrast, the lessons of the energy crisis have been learned, and the ecological awareness we have acquired since then has been applied. Instead of closed systems that are independent of their location, he develops buildings related to specific places and contexts. Their outer skins can react flexibly to changing conditions, and the energy balance can be regulated like an open system in accordance with dissipative climatic structures. The most important element of a building is no longer the load-bearing structure, but the envelope, which is conceived as an energy-exchange medium that reacts to specific local conditions. Since this relationship between the building and *its* environment is assessed inductively by means of measurements taken in the actual surroundings, there are no repeatable types or monolithic structures. The buildings are complex entities attuned to the characteristics of a particular region and constructed as a series of distinct energy zones. Herzog has developed a number of different architectural concepts for this principle of climatic zoning. These range from the "thermal onion", in which the functional spaces are arranged within each other in a series of layers, according to their energy needs, to "zoned buildings" and structures with various forms of wall construction, the different energy functions of which are related to their orientation. Construction and function thus become variable factors that reflect the location and environment. The building is not imposed on a particular climatic region; it is conceived in such a way that it can respond interactively. (Herzog et al., 2001)

In general, Herzog’s earliest buildings looked ‘solar’. The long, angled south-facing glazed walls in the carefully designed and crafted structures also relied on strong geometric forms and efficient structural systems. As his work developed the building form seems to have become more expressive of the materials and techniques of construction. This is a strategy that may help make solar buildings much more acceptable to the mass consumer - typically someone who does not want to be too different than his or her neighbor. (Pérez-Gómez, 2002)

The WCRE’s general framework emerged from the investigation of a number of initiatives and ideas, including a new generation of international, multi-actor research, development and dissemination initiatives. EUROSOLAR launched the “European Charter Solar Energy in Architecture and Urban Planning”, elaborated by Thomas Herzog. The World Council for Renewable Energy (WCRE) adopted at its First World Renewable Energy Forum in 2002 the Guideline “Renewable Energy and the City”. International Energy Agency (IEA) auspiced research and development work advanced a method to pursue city-wide applications as integral to the main planning agenda. These initiatives are now being integrated in the broader ‘Solar Habitat’ approach by the World Council for Renewable Energy, as a basic policy and planning framework that can apply to all cities and towns. (“Solar Habitat in Cities and Villages,” n.d.)

Meanwhile, The European Solar Charter – drawn up by 30 of the most influential architects worldwide such as Thomas Herzog, Norman Foster, and Renzo Piano – puts it in a nutshell: “The form of our future built environment must be based on a responsible approach to nature and the inexhaustible energy of the sun.” Yet even low-energy buildings consume too much energy, and even Passive Houses still emit CO2 into the atmosphere. Passive building is not enough – we need a “solar activation” of our houses! To this end, we set three goals for the Plus Energy House: 100 percent renewable energy supply, emission-free operation, and a positive energy footprint. On top of which, building materials for healthy living are chosen – and all is to be achieved at a marketable price. With regard to new buildings this is the decisive breakthrough. For cities and communities as overall energy-using entities, the Plus Energy House can be a symbol, a stimulus to introduce further measures, a component in a holistic concept of sustainability that embraces modernization, transportation and other infrastructure, green areas, and water systems. (Disch, n.d.)

Early proponents of more energy-efficient architecture included William McDonough, Bruce Fowle and Robert Fox in America, Thomas Herzog in Germany, and Norman Foster and Richard Rogers in Britain.

These forward-thinking architects began to explore designs that focused on the long-term environmental impact of maintaining and operating a building, looking beyond the so-called “first costs” of getting it built in the first place. This approach has since been formalized in a number of assessment and rating systems, such as the BREEAM standard introduced in Britain in 1990, and the LEED[6] (Leadership in Energy and Environmental Design) standards developed by the United States Green Building Council (USGBC) starting in 2000.

Rating buildings in this way reveals how inefficient traditional buildings and building processes are. “We can sometimes waste up to 30 cents on the dollar,” says Phillip Bernstein, an architect and professor at Yale University. “It's not just the consumption of energy, it's the use of materials, the waste of water, the incredibly inefficient strategies we use for choosing the subsystems of our buildings. It's a scary thing.” In part, he says, this is because the construction industry is so fragmented. Designers, architects, engineers, developers and builders each make decisions that serve their own interests, but create huge inefficiencies overall. (“REPORTS: The rise of the green building | The Economist ,” n.d.)

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[6] The LEED standards are intended to produce “the world's greenest and best buildings” by giving developers a straightforward checklist of criteria by which the greenness of a building can be judged. Points are awarded in various categories, from energy use (up to 17 points) to water efficiency (up to five points) to indoor environment quality (up to 15 points); the total then determines the building's LEED rating. Extra points can be earned by installing particular features, such as renewable-energy generators or carbon-dioxide monitoring systems. A building that achieves a score of 39 points earns a “gold” rating; 52 points earns a “platinum” rating. A gold-rated building is estimated to have reduced its environmental impact by 50% compared with an equivalent conventional building, and a platinum-rated building by over 70 %.

2-3 Manifestation of energy efficiency in Herzog's works

2-3-1 Two-family House, Pullach 1986-89

Actually, the cross section of this building resembles that of a bout. The architect elaborately has linked it into a narrow structure to "balance" this boat, Like the Polynesian canoe's outrigger. The main framework contains of laminated timber beams with the glass cladding suspended around the exterior of the building. At the inside of the building a number of cross walls work as stiffeners for the structure and along the length of this building, diagonal tubular members-which are made from steel- act as tension members which are flanked by the service zone. One of the significant actions which has done for this building is that the glass roof is insulated at its medial sections and cantilevers out have supported by several plywood ribs. In fact, these projections will finally carry PV cells. Because of the building has extremely light construction and also has extensive glazing, the overheating is one of the major issues for this building which should be protected against that. However, It will be explain that how the architect has incorporated the suitable protection against overheating. (Figure 3&4)

Figure 3: Two-family House, Pullach 1

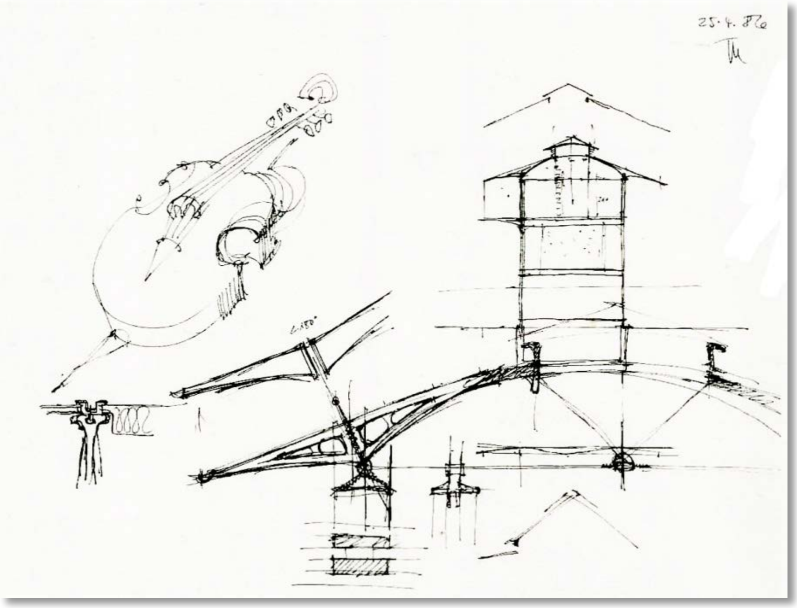

Figure 4: **Two-family House, Pullach, conceptual sketches**

The open *site* is bordered on both sides by tree-lined fences. This allowed Herzog to press the house against the north property line for protection from the most bitter northerly winter winds and leave it exposed to low angles of winter sun from the south. The form of the house, a thin pavilion, is worked into the site by indoor/outdoor buffers on all four sides. To the north and south are overhanging balconies and shaded decks. On the east side is a carport whose roof is a terrace accessed from the second floor. Finally, on the west, there is a conservatory greenhouse opening to a tree-covered deck at grade level (Figure 5-7). (Bachman, 2003)

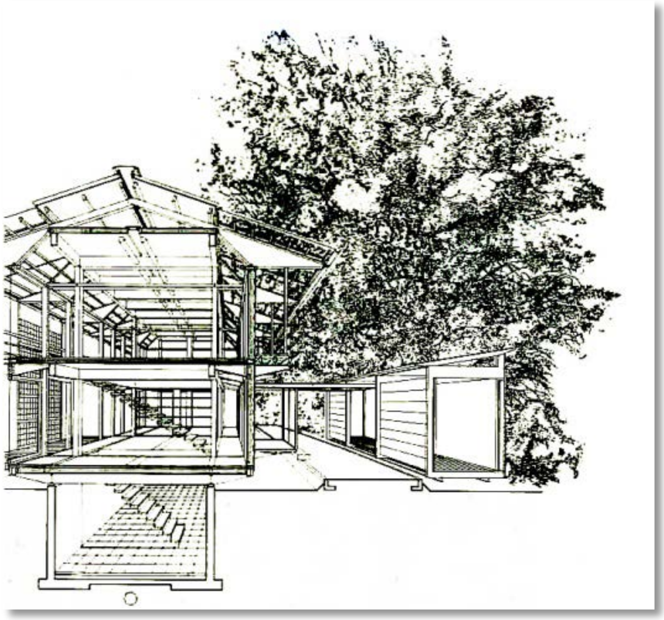

Figure 5: **Two-family House, Pullach 2**

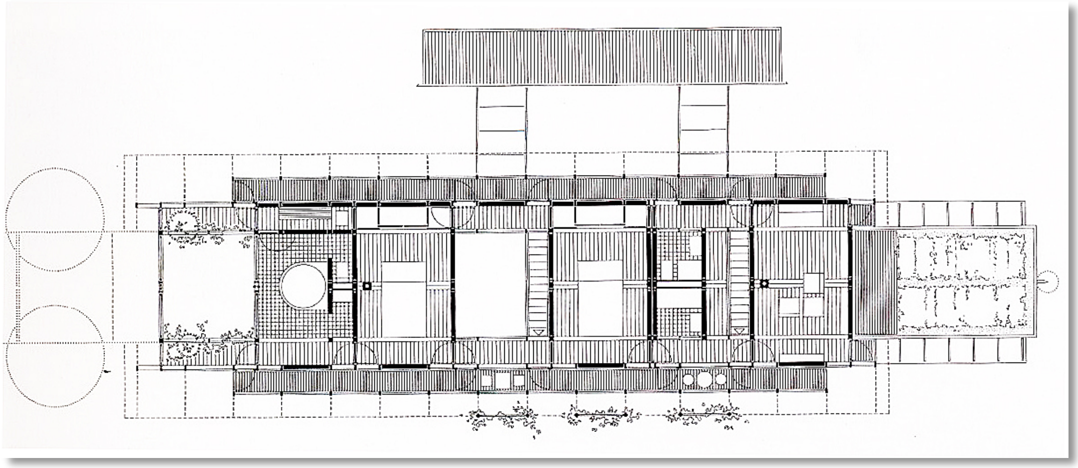

Figure 6: **Two-family House, Pullach, Upper floor plan**

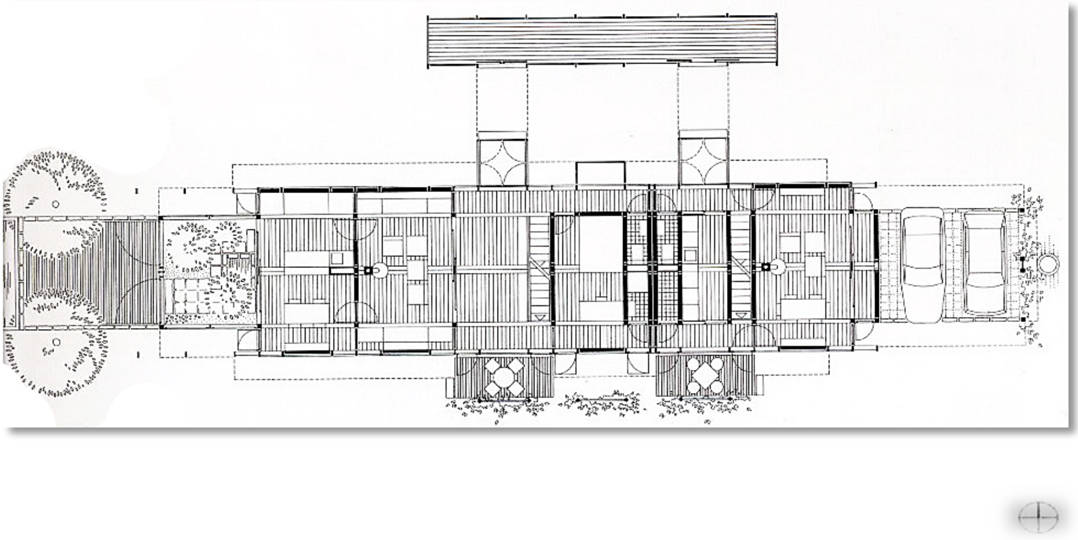

Figure 7: **Two-family House, Pullach, Ground floor plan**

The house was laid out in such a way that all living rooms have a south-facing aspect (Figure 8). As a result, when the sun is Low in the sky in winter, this Long, narrow building is sunlit over its full depth to the rear north wall. This helps to obviate the problem of internal heat transfer from the "warm" to the "cold" side in winter. (Herzog et al., 2001)

Figure 8: Two-family House, Pullach, South face

Surrounding walkways at the upper levels flank the central rooms, providing insulating buffer zones, and these are used for storage of hay, onions, or other goods less susceptible to frost (Figure 9). A steep and broad roof overhangs the building on all four sides, resisting the accumulation of snow and shedding moisture away from the foundation. (Bachman, 2003)

Figure 9: Two-family House, Pullach, Surrounding walkways at the upper levels

Other special features, and an innovation at the time when the house was built, are the elements with translucent thermal insulation set in front of black-painted precast concrete units along the south facade. It was the first occasion on which elements of this kind had been used in a new building development. The 10 cm solid wall slabs absorb heat from insolation during the day and yield the heat in the evening and night to the rooms on the inside face.

To minimize energy needs for heating the air intake in winter, thermal energy is extracted from the vitiated air from the rooms via heat-exchange units and used to preheat the fresh-air intake. The temperature of the preheated fresh-air supply is raised to room temperature by means of small heat pumps. Peak needs in extremely cold periods are met by a number of small radiators. In summer, when the sun is high in the sky, a trellis with climbing plants and a cantilevered balcony provide shading for the facade, thereby avoiding *overheating* of the rooms.

The building has a Laminated-timber skeleton-frame structure. In the middle of the house, a 30 cm wide intermediate zone was created in which service installations, chimneys, air ducts and soil-water runs are accommodated (Figure 10). The roof is in an unusual form of construction. In the central area, it is designed as a ventilated (cold) roof type. Along the edges, the slopes are divided into an inner skin with double glazing, which forms the space-enclosing plane, and an external glazed skin consisting of toughened safety glass, which provides protection against the weather for the façade and the timber structure. On the south side, these areas can be covered with photovoltaic[7] panels. (Herzog et al., 2001)

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[7] Photovoltaics (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.

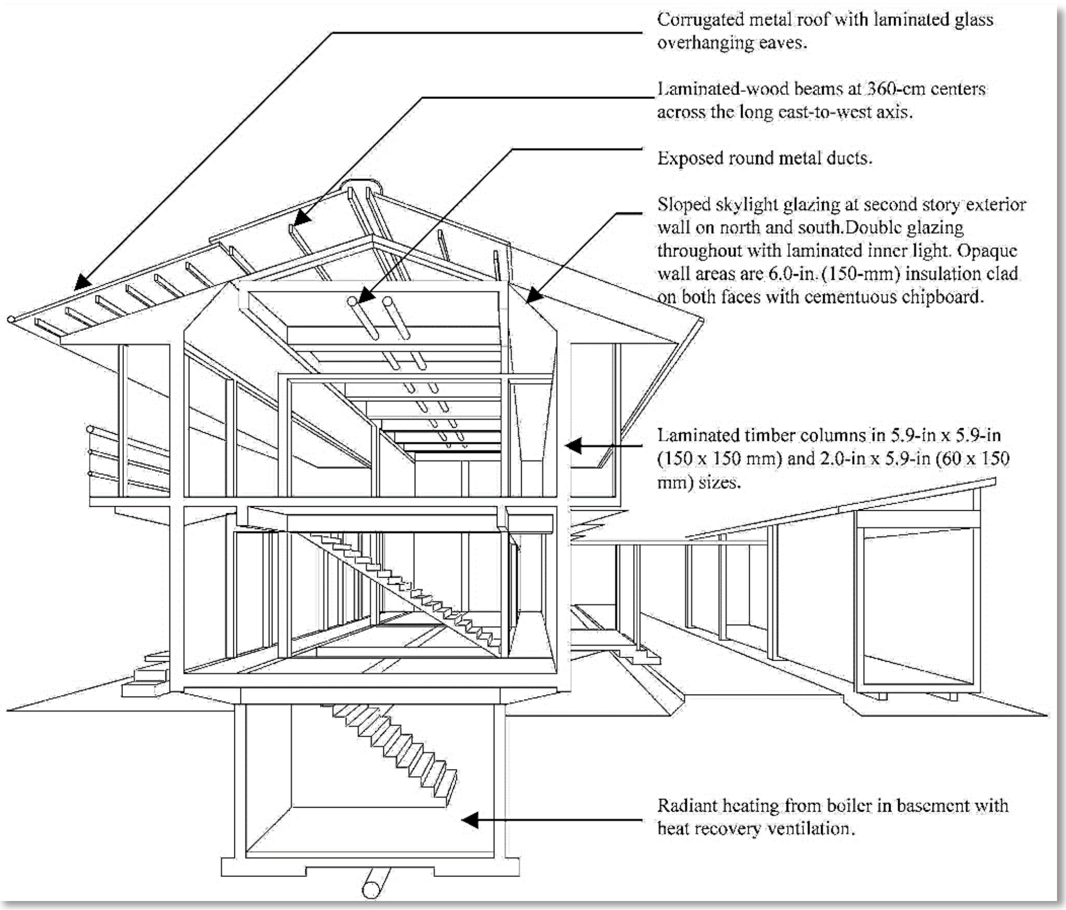

Figure 10: Two-family House, Pullach, Anatomic section

Façade design

External cladding of the house (Figure 11) is typical of passive heating schemes, with extensive glass to the south and opaque insulated construction to the north. Herzog uses 5.9 in. (150 mm) insulation blankets in all the opaque walls with cement-bound chipboard on both sides. The primary vertical glazing is insulated with clear glass, and the skylights are insulated with a laminated inner light. The glazed portion of the roof is tempered single pane.

An experimental solar collector was built into four of the 5.8 ft. (1.8 m) bays of the south wall. These resemble unvented Trombe wall[8] construction, except that they are filled with translucent insulation fibers inspired by the light transmitting hairs of the well-insulated polar bear. Glass is used as the panel's outside covering, and a 4.0 in. (100 mm) thick precast concrete slab with a black painted surface is placed behind the insulation to absorb sunlight and store heat. The collectors total only 194 ft2 (18m2) but succeed in providing 10 percent of the annual heating requirement.

In the summer, shade from the high sun is provided at the ground floor by the

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[8] A Trombe wall is a sun-facing wall separated from the outdoors by glass and an air space, which absorbs solar energy and releases it selectively towards the interior at night. The essential idea was first explored by Edward S. Morse and patented by him in 1881.In the 1960s it was fully developed as an architectural element by French engineer Félix Trombe and architect Jacques Michel.

overhanging balconies, and sunlight at the upper floor is screened by the roof purlins below the glass canopy. Two-story-high trellises are planted in front of three bays of the south wall. The plants grow from wood decks outside the middle bays to the bottom of the eave line. For air, a great number of exterior doors on the house accommodate the separate occupancies, and these can also be used for natural ventilation in warmer weather. No less than 27 doors open to decks and balconies, and the end wall of the conservatory has an additional pair of sliding doors. The attic space above the center bay width is ventilated at both ends by louvers sheltered beneath the projecting roof gable. A continuous roof ridge vent provides ample exhaust for hot air from the attic. (Bachman, 2003)

Figure 11: Two-family House, Pullach, South façade longitudinal view and close view

Mechanical design

Backup *mechanical* heating is a necessity in the 6701 annual degree-day heating climate of Munich. The winter dry-bulb design temperature is a frigid 10ºF (–12.5ºC), and the summer design conditions are a mild 78ºF dry-bulb and a 63ºF wet-bulb temperature (25.5/17.4ºC).Supplemental heat is provided by a conventional boiler in the basement and distributed by radiators. In addition, there is a wood-burning stove in each dwelling.

While the house is closed tight in winter, indoor air quality is maintained by an air-to-air heat exchanger that reclaims warmth from exhausted indoor air and passes it to incoming outside makeup air. These simple devices pass the two air streams by each other with lots of high-conduction surface area separating them. Usually some 90 percent of the heat can be reclaimed from kitchen, toilet, room, and other exhaust air streams. Ideally, slightly more outdoor air is brought in than indoor air is exhausted to keep the house positively pressurized relative to the outdoors and thereby reduce infiltration of cold air. (Bachman, 2003)

In fact, concerning *performance* integration of the project, firstly, the exterior storage building promotes openness of the house by removing potentially interrupting interior storage closets and other elements. It also acts as a free standing buffer against winter winds. Secondly, the one-room depth of the pavilion plan allows shorter spans and facilitates natural cross ventilation. Thirdly, the interior storage provides extra thermal insulation to the opaque areas of the envelope.

Additionally, concerning the *visual* integration of the project, the pavilion plan (Figure 12) opens communication from interior rooms to the open site, and the shading strategies manage to protect against glare and overheating. (Bachman, 2003)

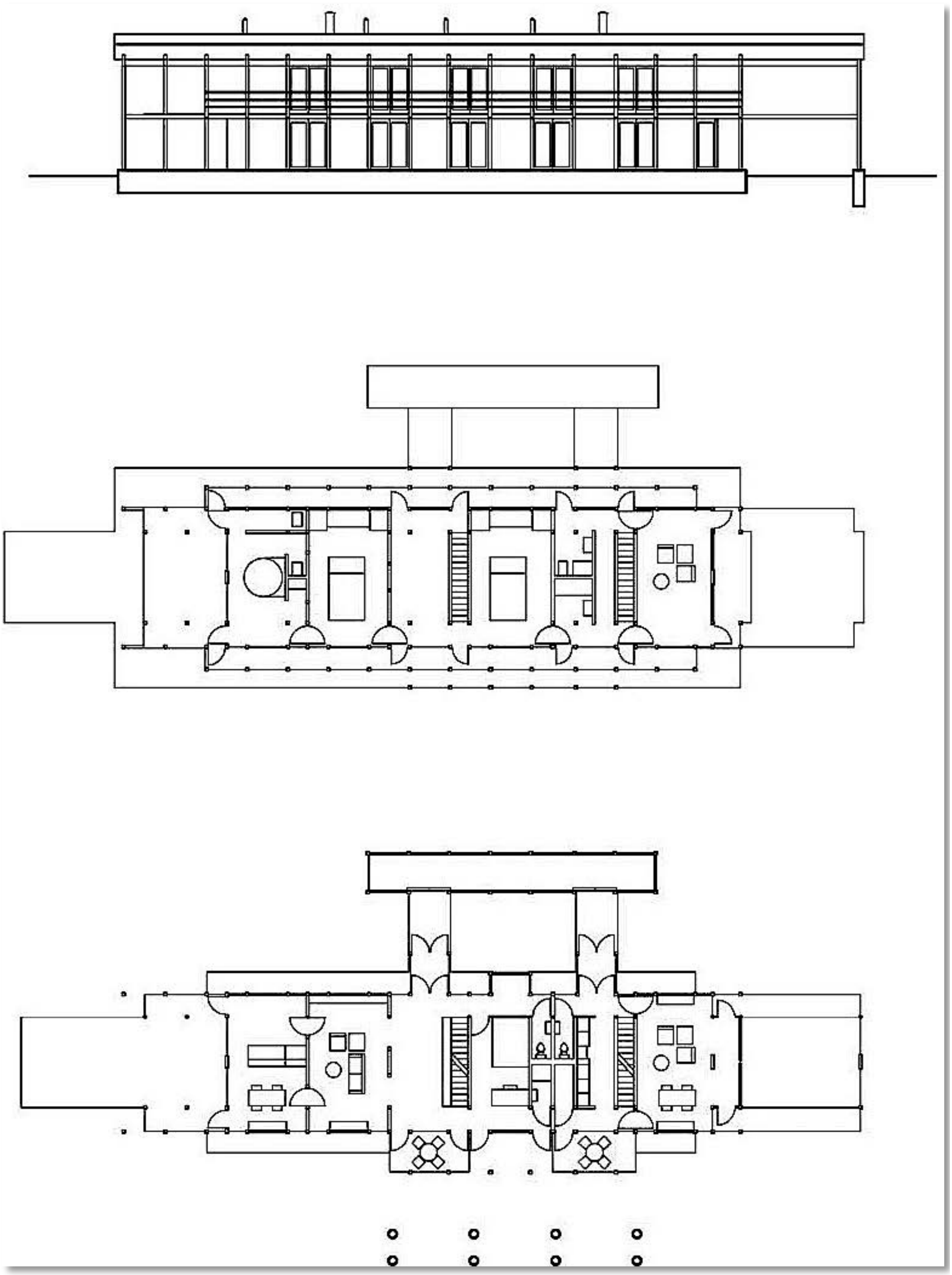


Figure 12: Two-family House, Pullach, South elevation with corresponding plans

2-3-2 Guest Building for Youth Educational Center, Windberg 1987-91

Windberg is a small community on the southern slopes of the Bavarian Forest (Figure 13). The monastery complex at the heart of the village comprises a number of buildings for the religious order and an educational center for young people. (Herzog, Kaiser, & Volz, 1996)

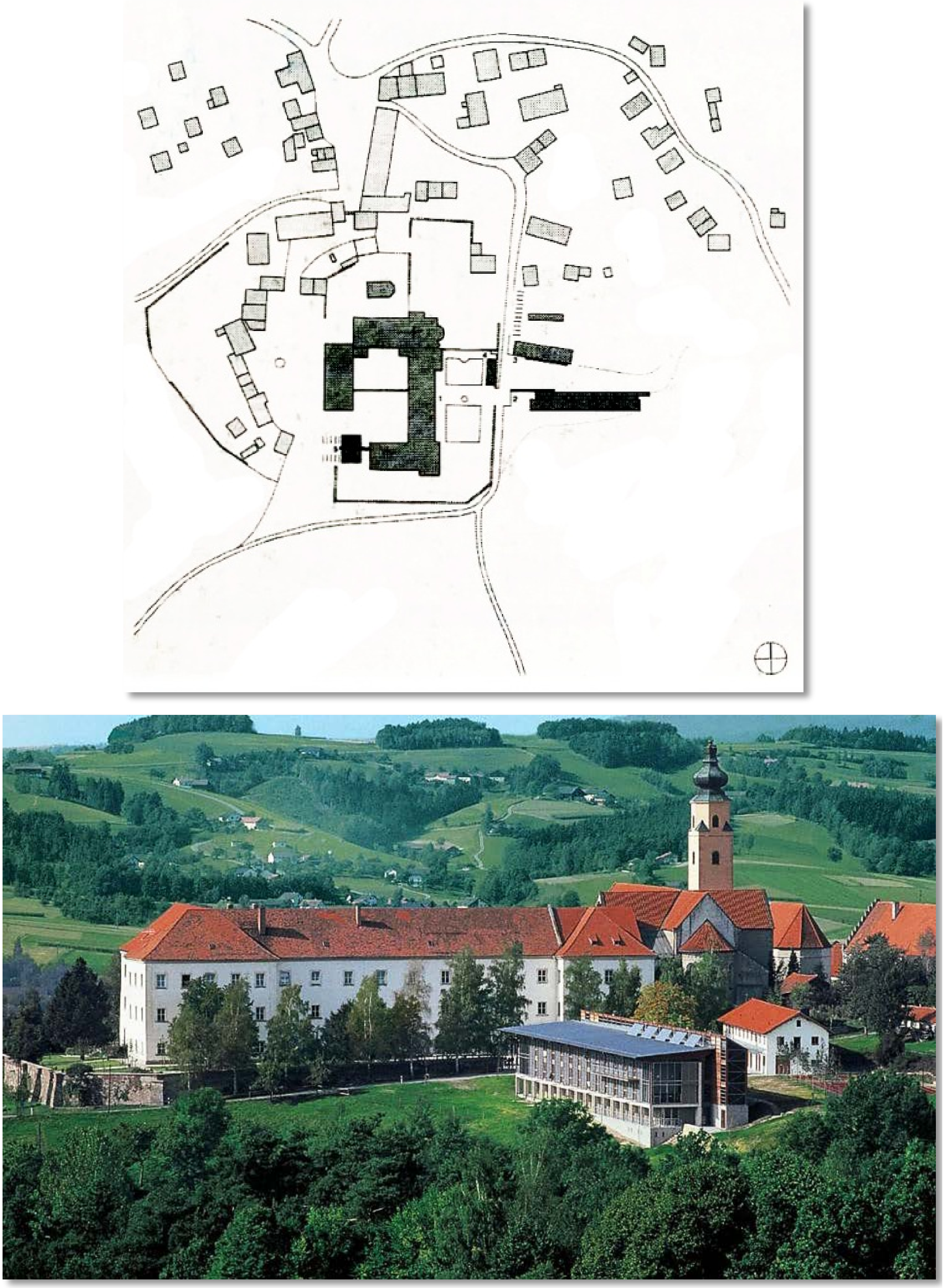


Figure 13: Guest Building, Windberg, Site plan & Aerial view

The Premonstratensian monks of Windberg Monastery run a youth education centre for which they commissioned a new dormitory block. The nature and duration of the use of the various groups of rooms played an important role in determining the energy concept for the building. Rooms that are used for longer periods of the day are separated from those that are used only briefly. The two sections of the building were also constructed with different materials (Figure 14-16). (Herzog et al., 2001)

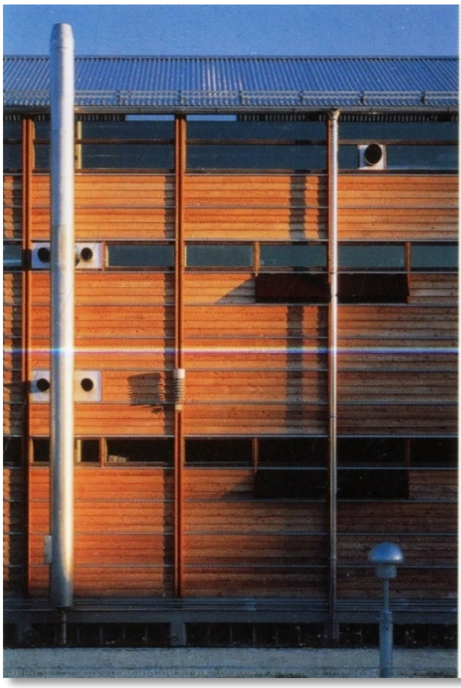


Figure 14: Guest Building, Windberg, Northern façade. **Figure 15: Guest Building, Windberg, Southern façade.**

Figure 16: Guest Building, Windberg, View of timber-boarded front facing the village

The southern tract houses the lounge areas, and the bedrooms, which can be divided in different ways. The rooms on this face enjoy a more attractive aspect, with an open view of the landscape through broad areas of glazing (Figure 17-19). A direct exploitation of solar energy and daylight was also possible for heating and lighting the spaces on this side, which are used for longer periods. To reduce extremes of temperature and to permit storage of thermal energy, this tract was constructed with heavy, thermally sluggish materials. Opaque areas of the south-facing external walls were also clad with translucent thermal insulation (Figure 20). This allows solar radiation to pass through it, but minimizes thermal losses. (Herzog et al., 2001)It should be mentioned that the opaque elements are an assembly of sand-lime brick with an exterior layer of translucent insulation. This assembly allows for the gain of solar energy and the mass of the wall creates a time lag into the evening hours when the heat is needed inside the living spaces on the interior (Figure 21). (Kienzl, 1999)The south-facing external wall is thus heated up during the day (The maximum temperature on the outer face is reached in the early afternoon) and passes on the thermal energy to the internal spaces after an interval of five to six hours - beginning in the early evening. In other words, throughout the night, when external temperatures are at their lowest, the outer wall functions as an inward-facing solar heating area. During the summer months, overheating is prevented by the broad roof projection and external louvered blinds. (Herzog et al., 2001)

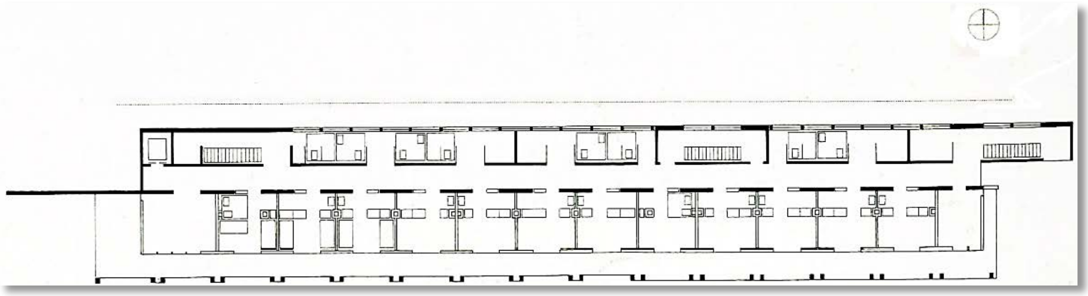


Figure 17: Guest Building, Windberg, Lower Ground floor plan

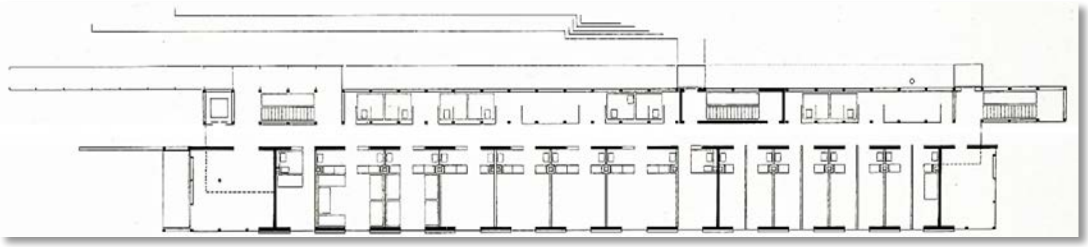


Figure 18: Guest Building, Windberg, Ground floor plan

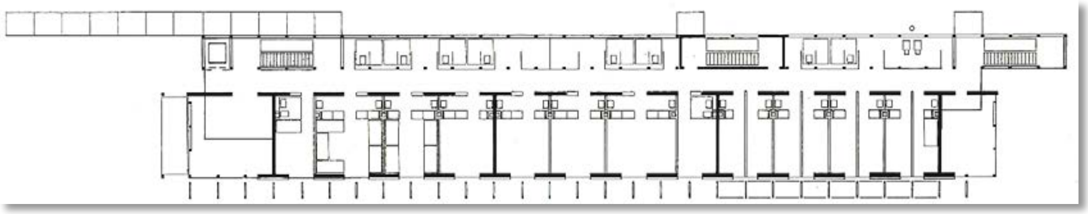


Figure 19: Guest Building, Windberg, Upper floor plan

Figure 20: Guest Building, Windberg, south elevation with TIM elements in front of opaque wall element on upper two floors

Figure 21: **Guest Building, Windberg, Internal spaces & Eastern view of the building**

The northern tract contains the sanitary facilities and storage spaces as well as the circulation route through the building (Figure 22). These spaces are distinguished by the fact that they have a generally lower temperature level, since they are used for only short periods. In the shower rooms, for example, a higher temperature level is required for only two to three hours a day. This tract was, therefore, equipped with a quickly functioning warm-air heating system (swift-functioning warm-air heating system). To minimize heat losses through ventilation, a heat-recovery unit was installed in the attic space. The hot-water supply is provided largely from solar energy by means of vacuum-tube collectors on the roof, in the south-facing roof slope (Figure 23). (Herzog et al., 2001)

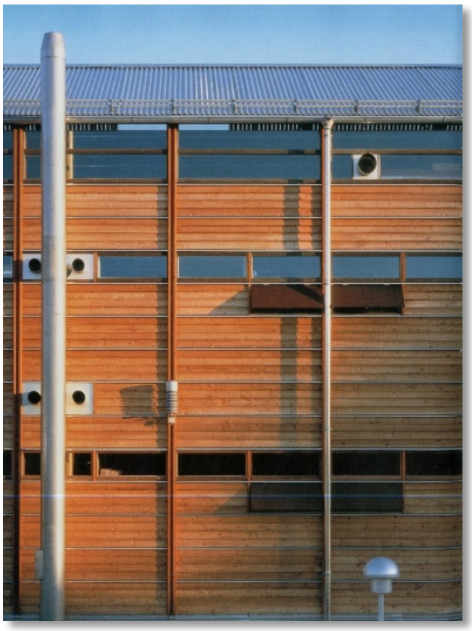


Figure 22: Guest Building, Windberg, North Side with installed utilities

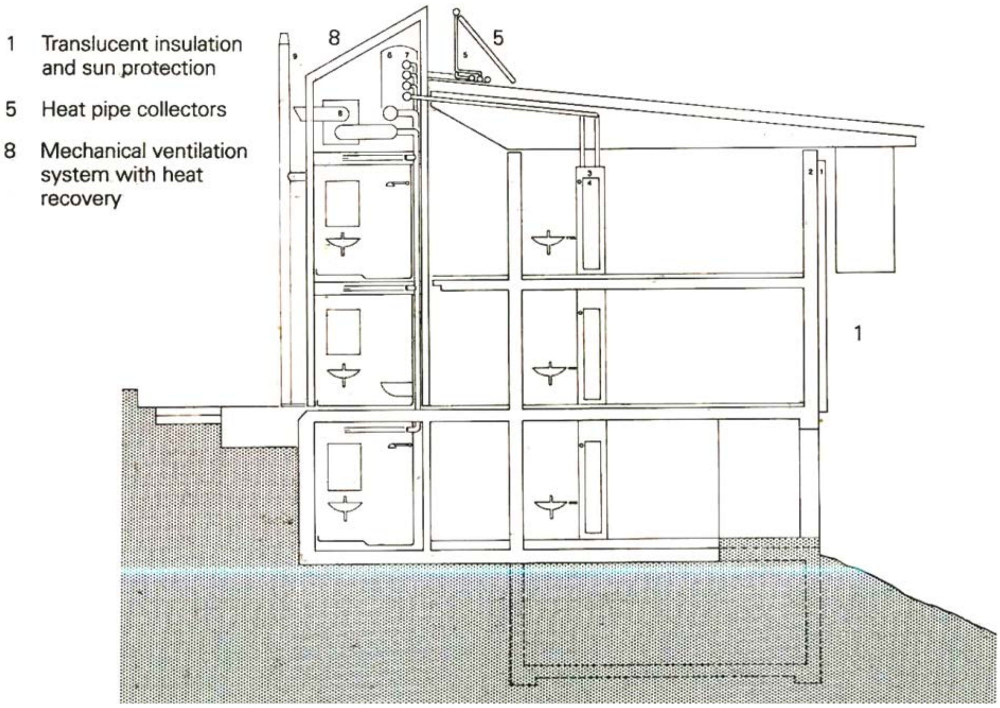
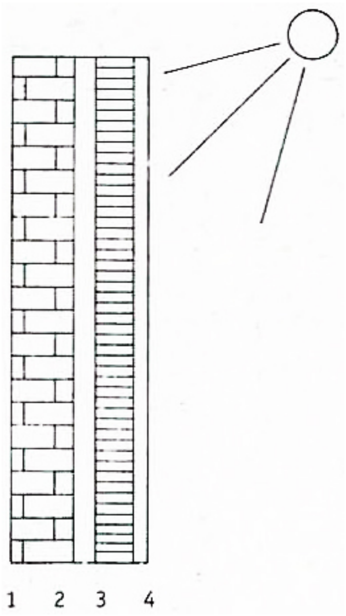


Figure 23: Guest Building, Windberg, Cross section with Installed utilities

Meanwhile, Water for showers and other domestic purposes is heated by evacuated-tube solar collectors[9] located in the south-facing roof and stored in six large tanks situated internally. When required, two gas-fired boilers with a total capacity of 92 kW provide auxiliary domestic hot water and also space heating via small radiators in the southern part of the building and a warm-air ducted heating system in the northern part. The latter can respond quickly to provide both heating and the requisite air changes to the shower rooms located in the thermally lightweight northern zone. To minimize heat losses due to ventilation, a non-recirculating heat recovery unit is fitted in the roof space.

The overall heating energy used by the building is only 45kWh/m²y. Lighting energy is also low, and no energy is used for HVAC other than a few small fans in bathrooms and similar areas.

Actually, part of the teaching program of the youth education center is to make the functioning (if the building comprehensible to the young guests by providing them with an insight into the use of environmentally sustainable forms of energy through "passive" and "active" constructional systems and the mechanical installations that Play a role in the energy balance. The architectural effect of the newly developed south-facing heating wall (Figure 24&25) is immediately visible in the facade - and tangible internally. The service runs, solar storage units and collectors are exposed to view, and a display panel installed in the entrance area shows changes in temperature levels.



1- Solid wall with black surface
2- cavity
3- Translucent thermal insulation
4- glass

Figure 24: South-facing external wall construction

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[9] Evacuated-tube solar collectors are used to collect heat for space heating, domestic hot water or cooling with an absorption chiller.

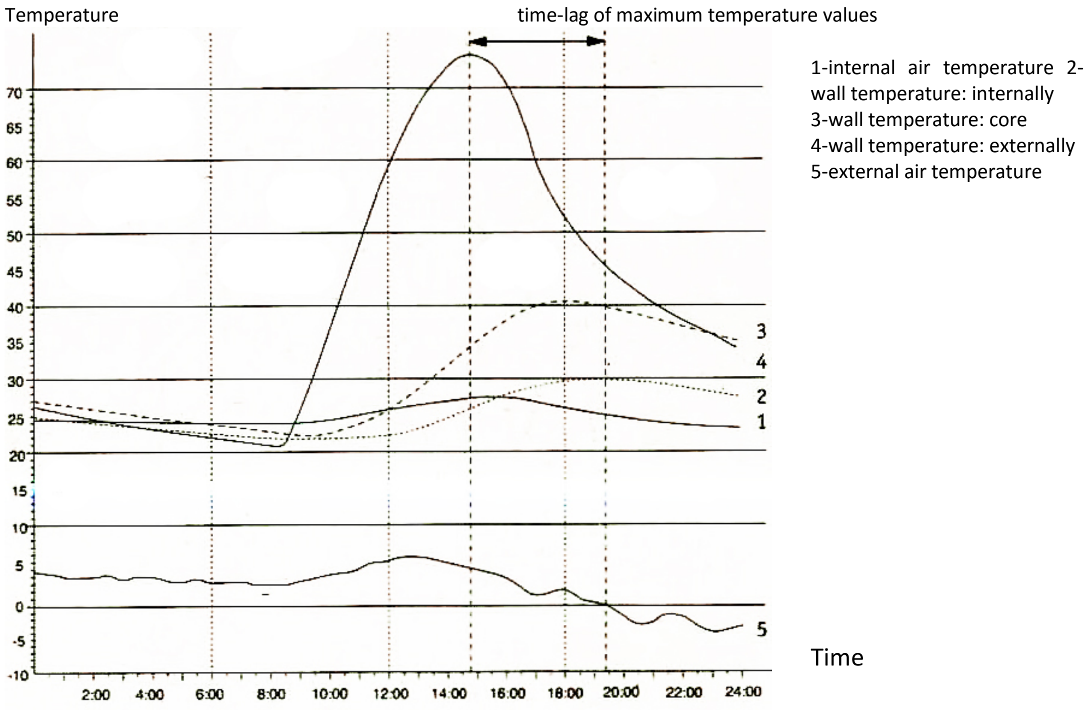

Figure 25: Guest Building, Windberg, temperature curves in south-facing external wall on a clear January day.

2-3-3 Exhibition hall in Linz 1988-1993

Shifting from cathedrals to pavilions, the prototype of large exhibition pavilions was established by the Crystal Palace[10], the legendary world exhibition building in London which was built by Paxton in 1851 (Hinte, 2003). Constant reference to its influence is unavoidable. Creative reinterpretation of Paxton's 1851 masterpiece is an inherent goal in the architecture of many pavilions since. The objective of "adapting principles to modern needs" has inspired a number of Brunelleschi[11]-scale innovations in pavilion design, but none quite so dramatic perhaps as Thomas Herzog's development of the Linz Design Center. (Bachman, 2003)

As a continuously top lit building, the Linz Design Center is a direct technical descendent of the Crystal Palace. Adapting the wonder of a clear span and fully glazed pavilion to the needs and capabilities of modern science was clearly the founding architectural intention. In keeping with Herzog's philosophy, this would involve a great

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[10] The Crystal Palace was a cast-iron and plate-glass building originally erected in Hyde Park, London, England, to house the Great Exhibition of 1851. More than 14,000 exhibitors from around the world gathered in the Palace's 990,000 square feet (92,000 m^2) of exhibition space to display examples of the latest technology developed in the Industrial Revolution. Designed by Joseph Paxton, the Great Exhibition building was 1,851 feet (564 m) long, with an interior height of 128 feet (39 m). Because of the recent invention of the cast plate glass method in 1848, which allowed for large sheets of cheap but strong glass, it was at the time the largest amount of glass ever seen in a building and astonished visitors with its clear walls and ceilings that did not require interior lights, thus a "Crystal Palace".

[11] In 1420, the Italian Renaissance architect, goldsmith, and craftsman Filippo Brunelleschi found it necessary to invent the building technology and equipment of construction necessary to win a competition. His design and construction of the 138.5 ft. (42.2 m) diameter dome and its spire over the existing base of the Florence Cathedral was prototypically Renaissance. Peter Murray, in *The Architecture of the Italian Renaissance,* says that Brunelleschi was the first to "begin to comprehend the structural system of classical architecture and to adapt its principles to modern needs."

deal of research and development and the participation of several experts. (Bachman, 2003)

Actually, after the winning the competition Herzog (Figure 26) knew that one could construct the building as a linear-and point-supported glass or membrane construction with a translucent roof, so that light would penetrate into the depths of the internal spaces. He always thought about daylighting from above and possibilities of designing the roof by extending of the technical history of glazed forms of construction -Paxton's Crystal Palace, built for the Great Exhibition in London in 1851, and the glass palace built in 1853-54 in Munich which were considerably larger than the hall in Linz- and finally to take a *further step*. (Herzog et al., 2001)

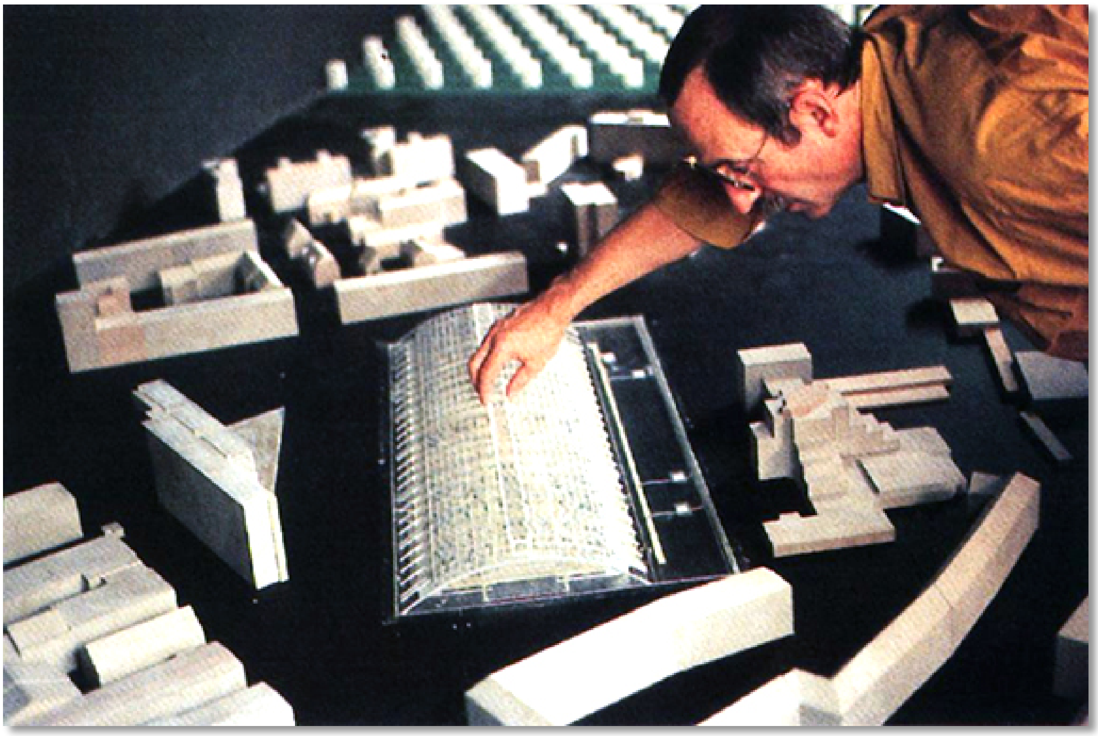

Figure 26: Exhibition hall in Linz, Model

The crowning glory of the Linz pavilion was not a dome, but a free span, glass-skinned barrel vault. Like Brunelleschi, Herzog and his team were required to include a detailed structural engineering study with their competition submission. This was an unusual requirement in modern times, one that might have stymied more speculative projects like the Sydney Opera House. The real innovation at Linz, however, was the glass skin across the vault. Herzog recognized that the Crystal Palace scheme failed to satisfy the thermal insulation, glare control, and solar shading requirements of modern buildings. At the same time, he intended to capture the airy lightness of a daylight-saturated space. To resolve his interpretation, Herzog would oversee the deployment of radically new glazing technologies and the means of their manufacture. (Bachman, 2003)

The congress and exhibition hall in Linz marks a new interpretation and representation of the concept of the "glass palace". Early historical examples of glazed exhibition halls, such as the Crystal Palace in London 1851-1936 and the GLaspalast[12] in Munich 1854 -1931 provided effective protection against the elements and a hitherto unknown internal light quality. From the very outset, one of the goals in planning the Design Centre in Linz (Figure 27&28) was to reduce the volume of air to a minimum. (Herzog et al., 2001)

Figure 27: Exhibition hall in Linz, Conceptual sketch and Aerial view

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[12] The *Glaspalast* (Glass Palace) was a glass and iron exhibition building in Munich modeled after The Crystal Palace in London. The Glaspalast opened for the *Erste Allgemeine Deutsche Industrieausstellung* (First General German Industrial Exhibition) on July 15, 1854. The *Glaspalast* was ordered by Maximilian II, King of Bavaria, built by MAN AG and designed by August von Voit, and hosted many large art exhibitions and international trade fairs. The two-storied building was 234 meters (768 ft.) long and 67 meters (220 ft.) wide. The building's height measured 25 meters (82 ft.). Construction was a mere six months, beginning December 31, 1853 and ending June 7, 1854, during which time 37,000 windows were installed. The total cost of construction was 800,000 guldens.

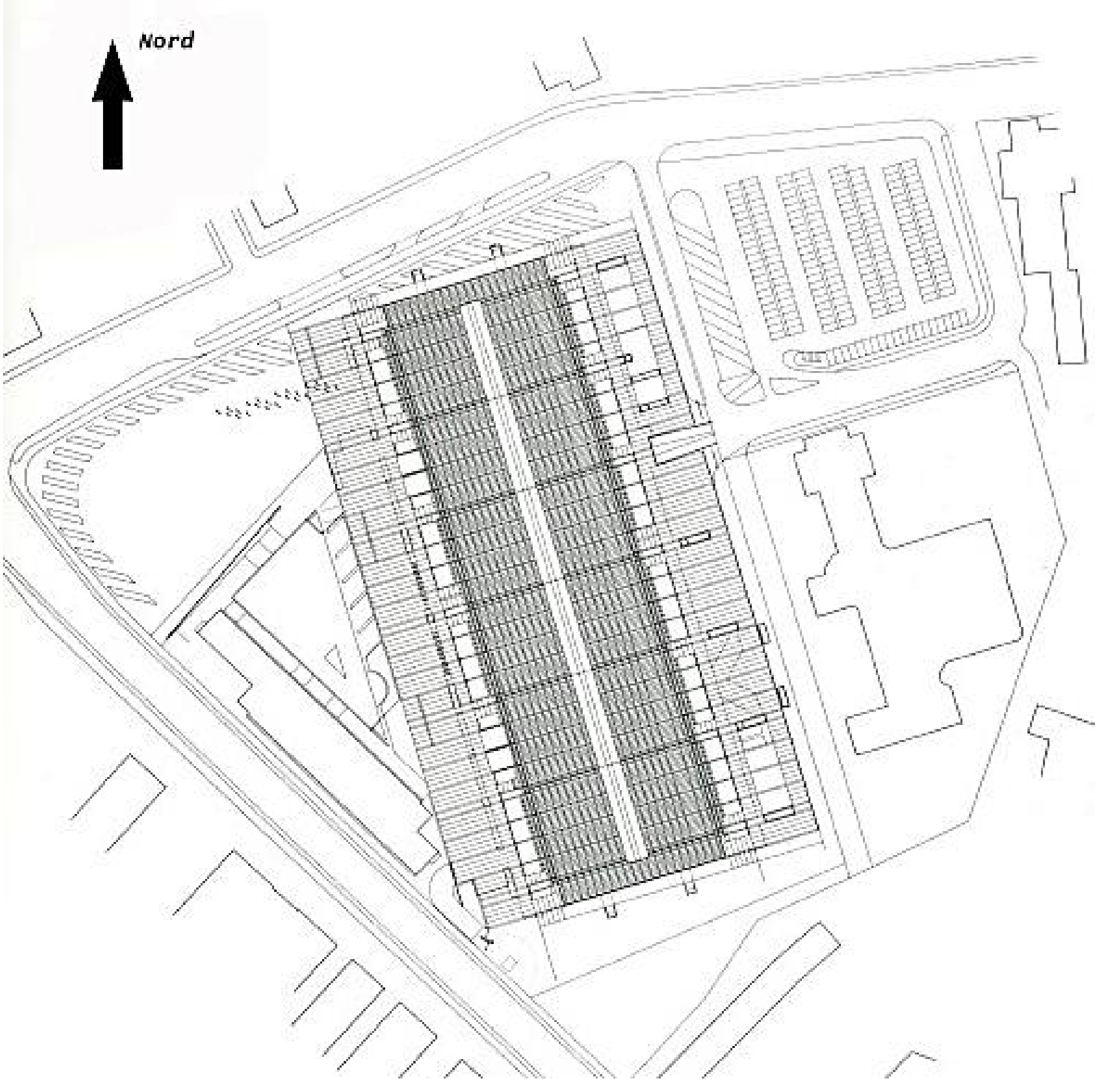
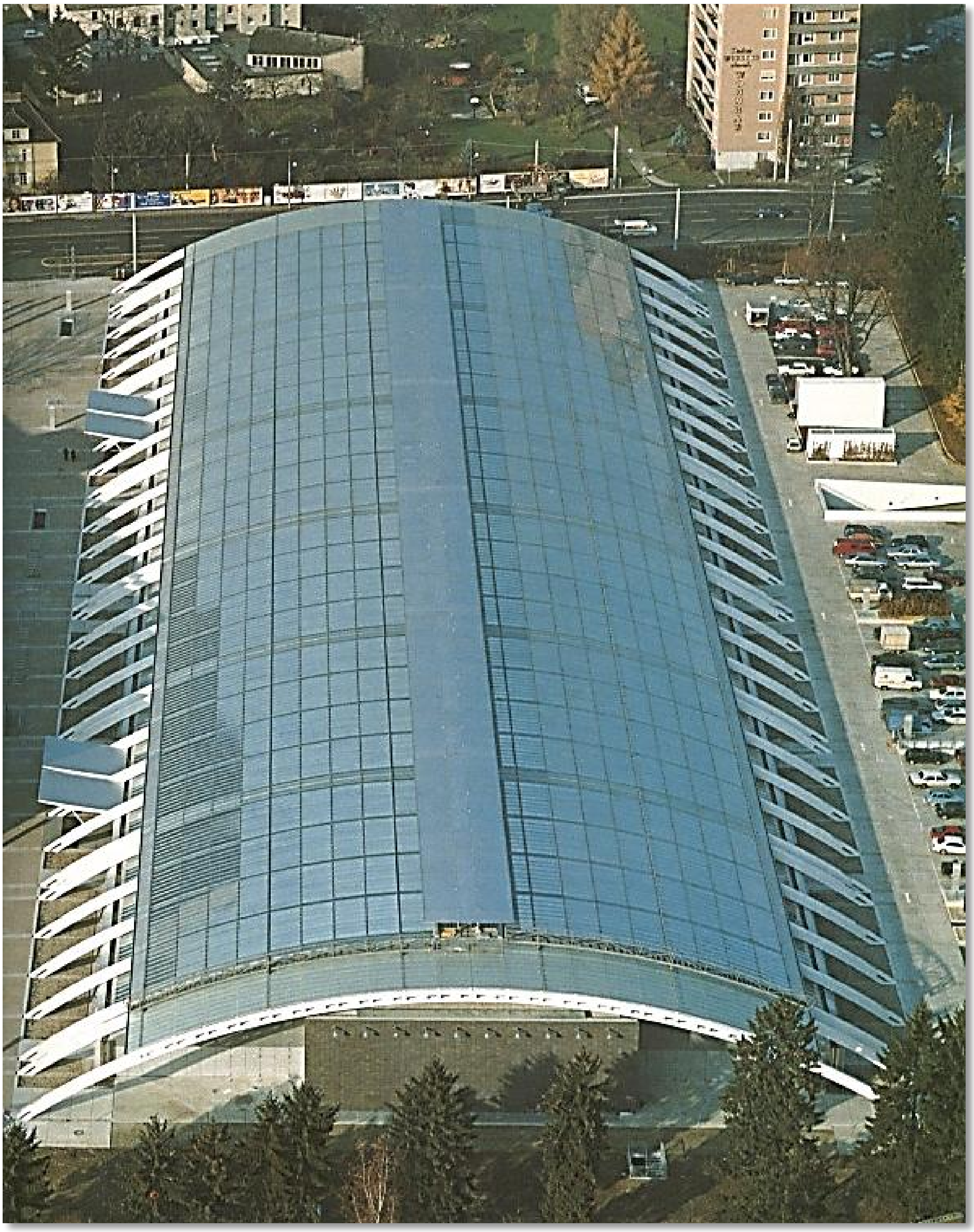


Figure 28: Exhibition hall in Linz, Site plan

The internal height of the spaces was limited to 12 m, to minimize the air volume to be heated, and since this clear height was not required everywhere in the hall, the roof structure was designed in a flat arched form with a glazed covering (Figure 29). The steel girders forming the Load-bearing roof structure span a distance of 76 m and cover an area 204x80 m in extent (Figure 30&31). To ensure maximum flexibility of use, all exhibition and congress spaces (with accommodation for 650 and 1,200 persons) adjoin a common foyer. The points of access are laid out in such a way that visitors to concurrent events do not mingle. Continuous longitudinal access routes along both sides allow the various halls and the gallery space to be combined. The ancillary zones are also laid out in linear form. Since the partitions in these zones can be moved, the spaces remain flexible for changing uses (Figure 32-34). (Herzog et al., 2001)



igure 29: Exhibition hall in Linz, with a Glazed covering

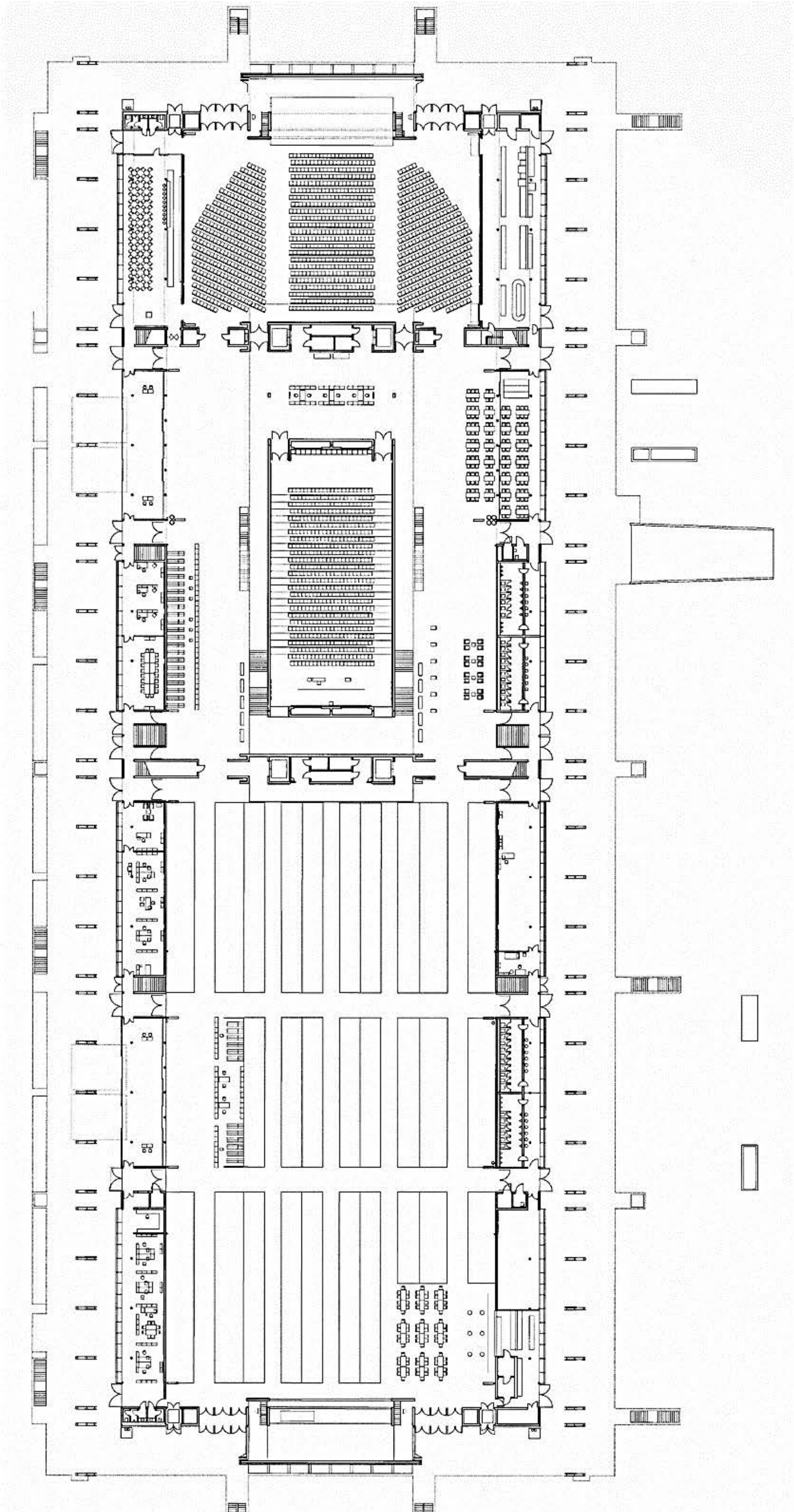


Figure 30: Exhibition hall in Linz, Ground floor plan

Figure 31: Exhibition hall in Linz, First floor

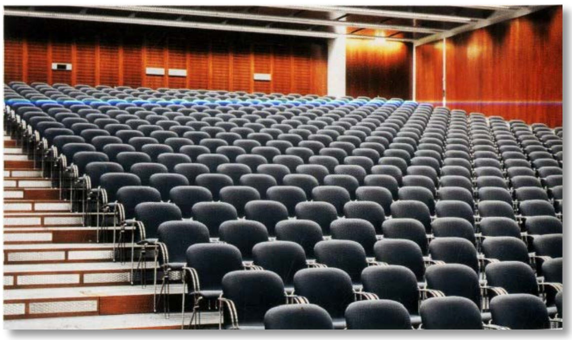


Figure 32: Exhibition hall in Linz, interiors 1, Congress hall

Figure 33: Exhibition hall in Linz, interiors 2

Figure 34: Exhibition hall in Linz, interiors 3

To prevent overheating in summer it has been invented a new kind of envelope. Actually, a central aspect of the new glass roof over the exhibition and congress center in Linz is that it prevents excessive heat gains from insolation during the summer months, even though the incidence of the sun changes in the course of the day and the year and the curved roof has different angles of slope. At the same time, large quantities of daylight can enter the building from the northern hemisphere of the sky to create brilliant lighting conditions internally. A maximum exploitation of daylight and an ideal lighting quality were required. Glare from direct sunlight had to be avoided, however (Figure 35-37).

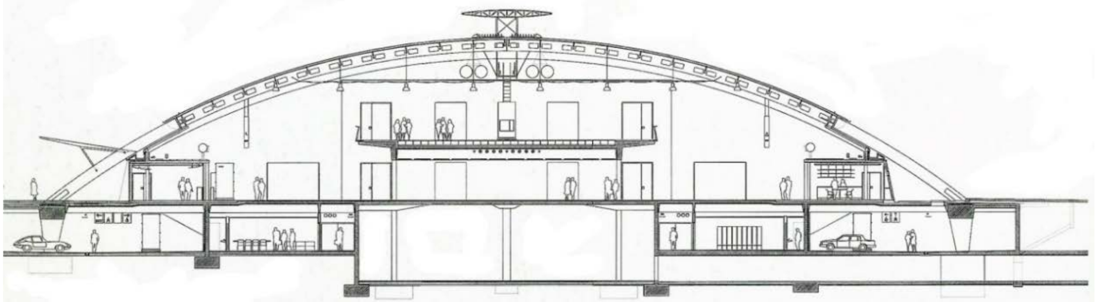


Figure 35: Exhibition hall in Linz, Cross-section through entrance zone

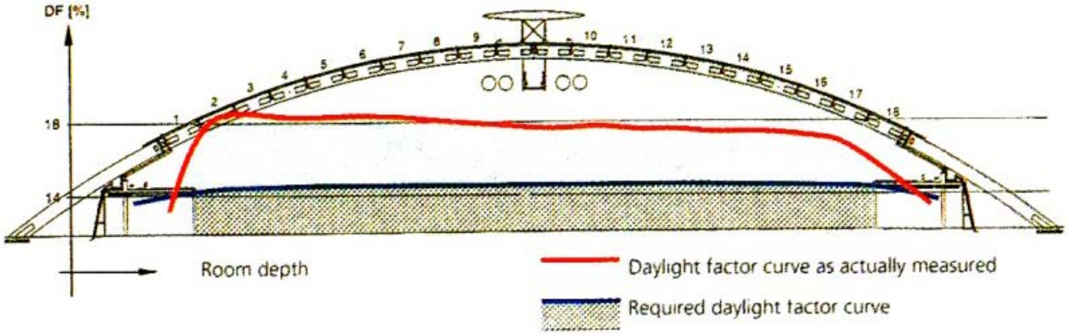


Figure 36: Exhibition hall in Linz, Cross-section with daylight factor curve (DF)

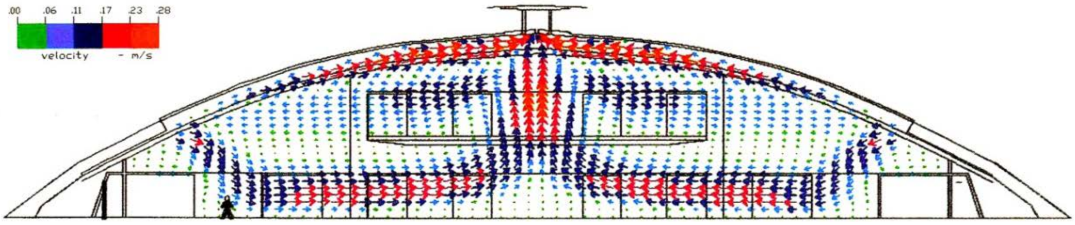


Figure 37: Exhibition hall in Linz, Air speed vectors in cross-section through exhibition hall

One of the primary considerations was to provide an outdoor quality of daylight for the interior of the building. Likewise, in developing a natural lighting concept for the building, the challenge lay in achieving a brilliant light quality for the exhibition areas without having to make sacrifices in the indoor climate and without giving rise to excessive energy consumption. In collaboration with the Bartenbach[13] office, a new kind of building element was developed for the light transmitting roof. A plastic grid integrated in roof panels with a complex performance allows indirect luminous radiation from the northern hemisphere of the sky to enter the building, while direct sunlight is screened off. In this way, excessive heat gains are avoided in the internal spaces in summer. Just 16 mm deep, the retroreflecting grid screen (micro mirror screen), which transforms the light from unidirectional into diffuses, thinly coated with pure aluminum which was inserted into the cavity between the panes of double glazing over the roof (Figure 38 &39). (Herzog et al., 2001)

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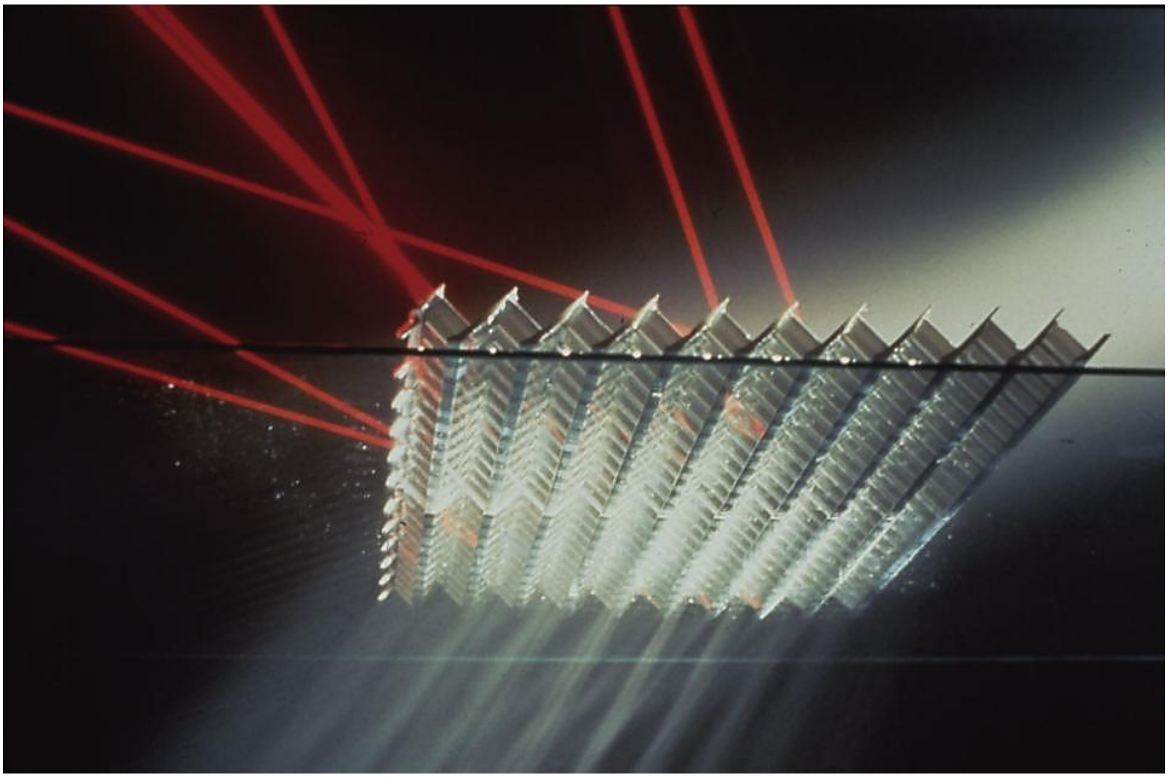
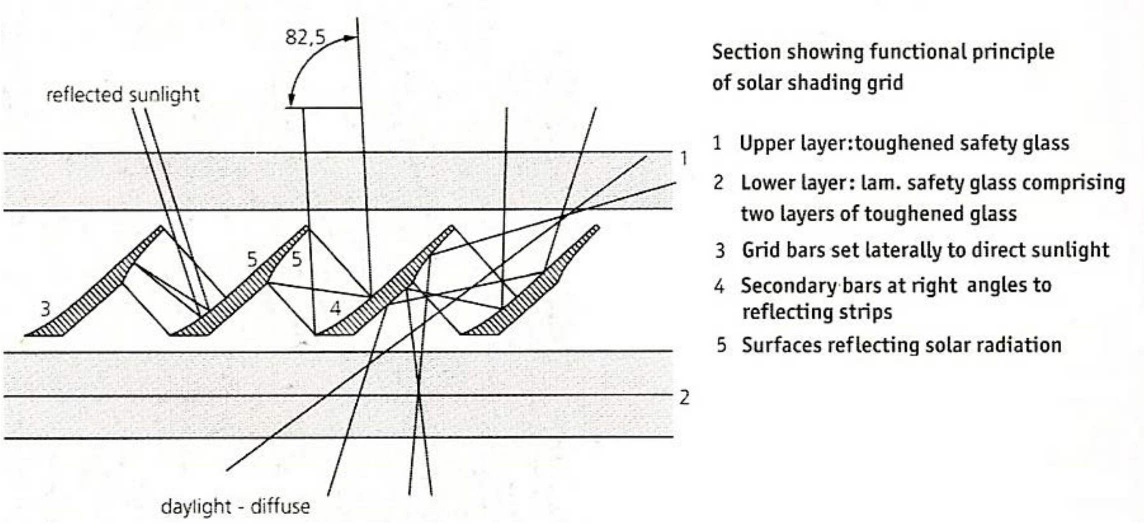
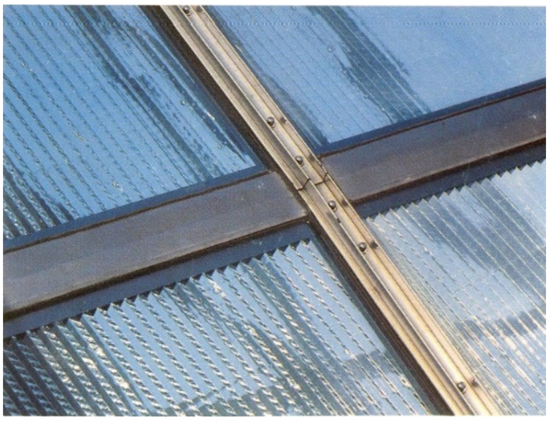
[13] Herzog worked with Austrian daylighting scientist Christian Bartenbach on the development of a glazing system for the Design Center. Bartenbach also worked on the Lloyd's of London Headquarters (1984) with Richard Rogers and the Hong Kong and Shanghai Bank (1985) with Norman Foster, as well as many other daylighting projects across Europe.





Reflected sunlight

Figure 38: Exhibition hall in Linz, Grid screens



Insertion of grid elements between layers of double glazing

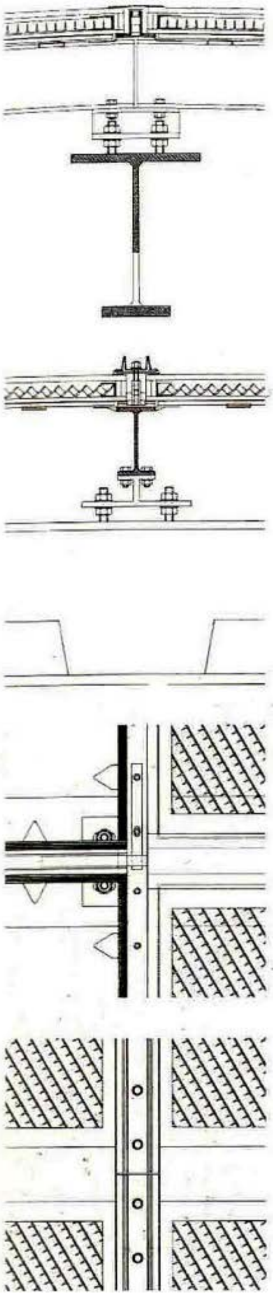


Figure 39: Exhibition hall in Linz, Glass roof construction with inserted grid screens

It allows Light to enter the building indirectly via a large number of small openings that are like minute light shafts. The aluminum coating and the special cross-sectional geometry of the grid permit a very high degree of Light reflection (approx. 90 per cent).

The geometry for cutting the grid was determined by computer programs and had to take account of the following factors: the angle of elevation and the azimuth angle of the sun at various seasons; the exposure and orientation of the building; and the slope of the roof. Thermally divided steel sections help to reduce heat losses through the building envelope.

The development of the appropriate high-precision equipment for cutting the grid posed a special challenge. The equipment consists of a number of parts. It had to be extremely robust and capable of cutting this kind of relief structure with parabolic curves on both sides and with an absolutely smooth surface.

The cross section of the roof is consist of twenty double glazing panels. Each of the twenty 8.9 ft. × 2.6 to 2.9 ft. (2.7 m by 0.80 to 0.90 m) double glazing panels in the cross section of the roof had to be considered separately. Not only was each panel oriented differently along the roof slope, their solar exposure changed with the seasonally changing path of the sun (Figure 40). (Bachman, 2003)

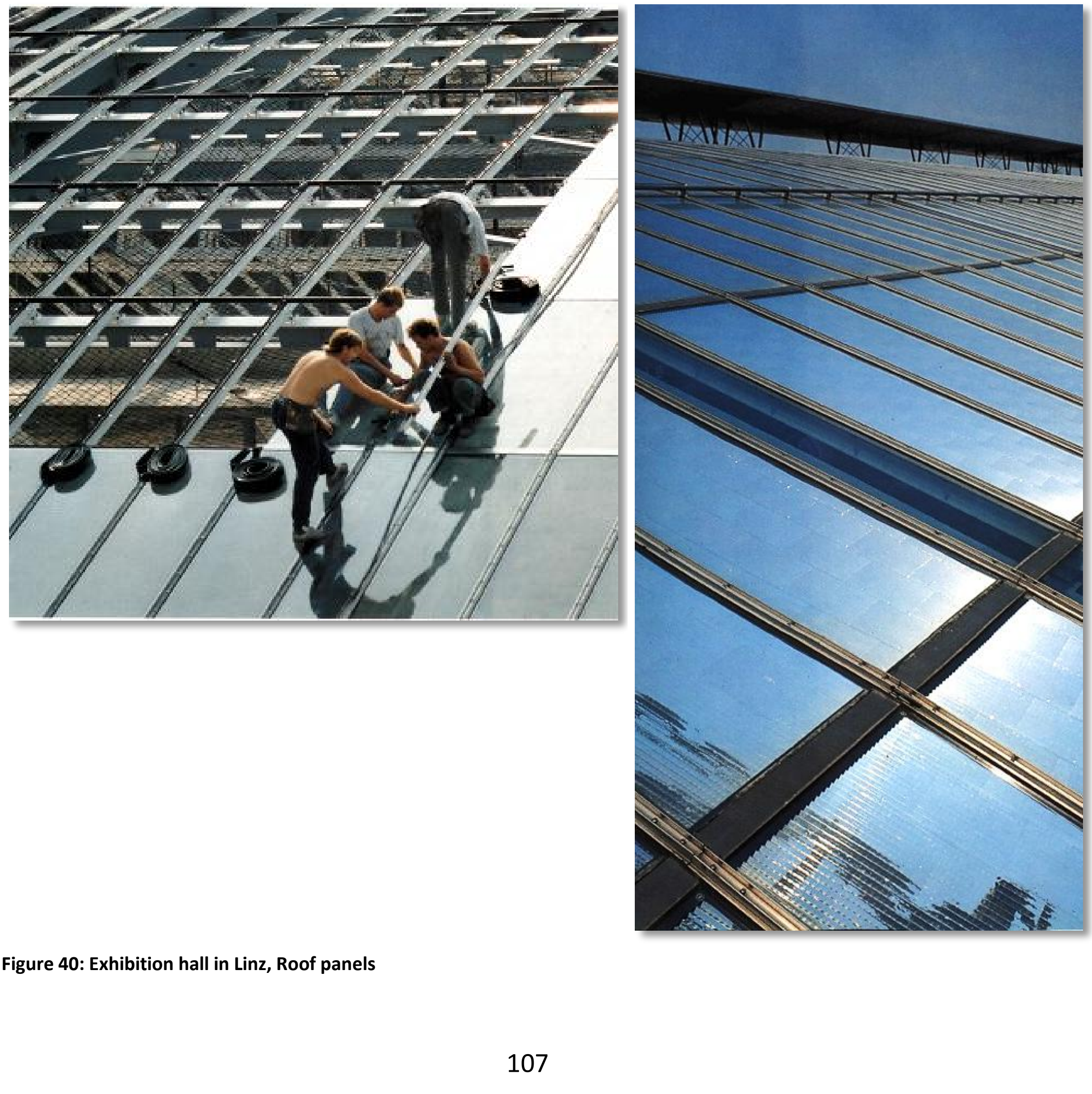


Figure 40: Exhibition hall in Linz, Roof panels

The accompanying measurements to determine the thermal transmission (U-value), the total energy transmission factor (g-value) and the transmission in relation to the different angles of incidence of the solar radiation were carried out at the Institute for Solar Energy Systems (ISE) of the Fraunhofer Society in Freiburg[14].

The overall transmission value of the grid is roughly 42 per cent. The overall daylight transmission value measured for the finished panels, with the grid inserted between the two Layers of glazing, is 33 per cent. Roughly 220,000 of these elements were manufactured for the hall in Linz. Today, the system is marketed worldwide. (Herzog et al., 2001)

The screens inside the glass panels have a different direction, depending on the position the panel takes. As a result, visually, the grid screen produces two effects. When the viewer is standing in the hall looking south, reflections of the floor are pixilated on the tiny reflective surfaces of the roof and they give an impression of shimmering. Looking north, however, gives a view of the sky through the fine network of the roof grids. An exhibition, even with large objects, looks as though it is in the open air but there are no sharp contrasts. (Hinte, 2003)

These grids can be enclosed in the depth of conventional double glazing and are highly effective in the reduction of cooling loads. Meanwhile, it was the first time to use this kind of technology, as composite elements, for covering this whole curved roof structure of an extensive conference and exhibition center.

Concerning thermal and daylighting aspects, a special challenge was posed by the need to guarantee an adequate air change in this very flat, deep building. Fresh air enters via floor inlets and ventilation flaps (window strips) at the sides of the hall which occur at the point where the plane of the roof changes. The warmed, used internal air rises as a result of thermal buoyancy to the top of the building. During the heating period, the air is then borne by large ducts to a heat recovery plant. During the rest of the year- during summer, the exhaust air escapes from the building at the crest of the roof via a large, continuous opening fitted with closable louver flaps to regulate the extraction of air. It allows stack effect[15] along the entire length of the building. (J. W. Lee, 2001) To guarantee the extraction of the vitiated air under

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[14] The Fraunhofer Institute for Solar Energy Systems ISE (or Fraunhofer ISE) is an institute of the Fraunhofer-Gesellschaft. Located in Freiburg, Germany, The Institute performs applied scientific and engineering research and development for all areas of solar energy. Fraunhofer ISE has three external branches in Germany which carry out work on solar cell and semiconductor material development: the Laboratory and Service Center (LSC) in Gelsenkirchen, the Technology Center of Semiconductor Materials (THM) in Freiberg, and the Fraunhofer Center for Silicon Photovoltaics (CSP) in Halle. Since 2006, Prof. Dr. Eicke R. Weber is the director of Fraunhofer ISE. With over 1,100 employees, Fraunhofer ISE is the largest institute for applied solar energy research in Europe. The 2012 Operational Budget including investments is 74.3 million euro.

[15] The stack effect of air moving through buildings, flues or chimneys is governed by buoyancy. When indoor and outdoor air densities differ because their temperature and moisture content differ, a positive or negative buoyancy force is created. This causes hot air to move in a direction that will neutralize the differences in buoyancy; a natural convection that can reduce the need for mechanical air handling.

This means that the warm air inside your building moves upwards in the winter and draws cold air in through the bottom of the structure and, in the summer, cooler air inside the home sinks and draws warmer outside air in through the top of the building. The warmer outside air is sucked down. This may sound counterintuitive, but it follows the second law of thermodynamics that states that warm air will move from a high pressure to a low pressure i.e. it will flow from warm areas to cooler areas, regardless of the direction it must take to do so.

In most homes, the stack effect can be seen as an undesirable phenomenon because all homes leak. This means that, in the winter, your expensive heated indoor air leaks out while undesirable air from outside is sucked inside. Modern green buildings are more airtight, but this can have its own design considerations as the more tightly sealed building envelopes of modern high rise buildings create massive air pressure differences. The stack effect is more pronounced in the winter; when it’s cold outside, the stack effect creates about 4 pascals of pressure for every floor the building. In the summer, this drops to 1.5 pascals per floor.

unfavorable air-pressure conditions, a "spoiler" capping was developed and assembled over the crown of the roof. This 7-metre-wide element has a convex underside and exploits the "Venturi effect[16]" to support the extraction of air from the building -a wing with 7 meters width and 200 meters long, which, is like a jet's case and when it gets too hot it opens and whooshes -cause of the air flow. And when the rain starts, it automatically closes (Figure 41&42). ("Thomas Herzog lecture," 2009)

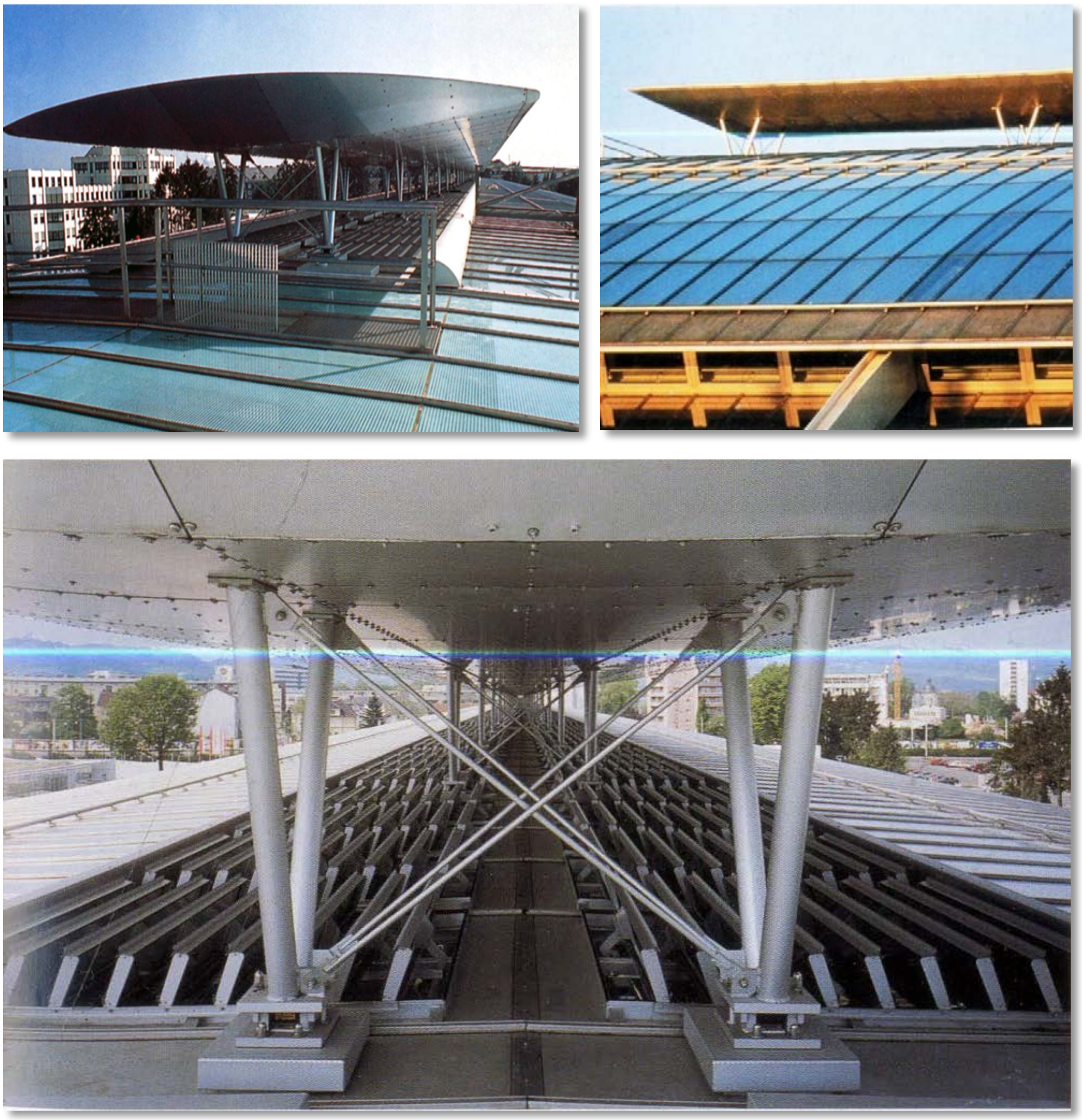

Figure 41: Exhibition hall in Linz, Ventilation elements with "Venturi" capping to assist natural ventilation

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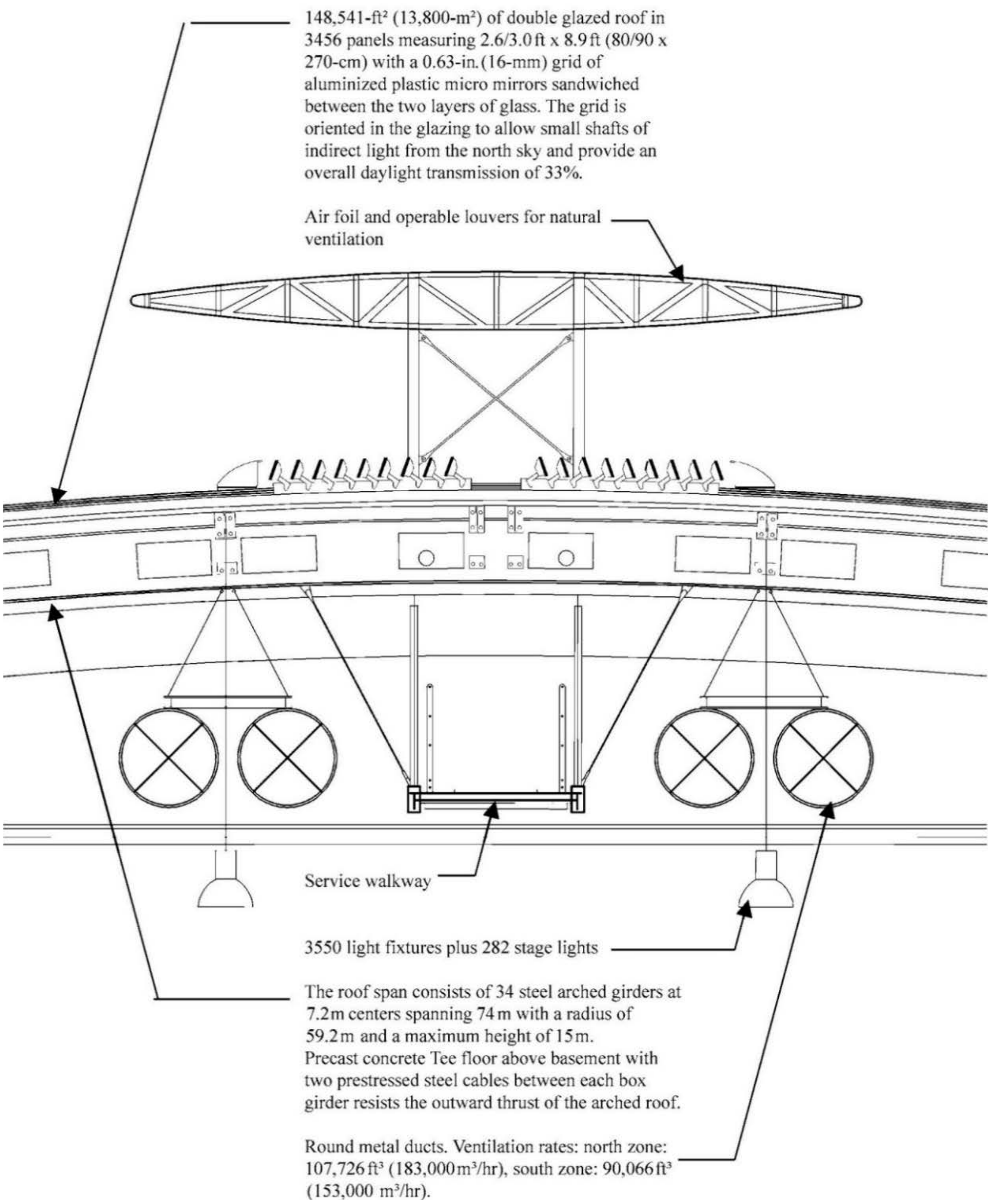
[16] The Venturi effect is the phenomenon that occurs when a fluid that is flowing through a pipe is forced through a narrow section, resulting in a pressure decrease and a velocity increase. The effect is mathematically described through the Bernoulli equation and can be observed in both nature and industry. Many industry applications rely on this effect as they need to be able to predict a fluid's reaction when flowing through constricted piping.



148,541-ft^2 (13,800-m^2) of double glazed roof in 3456 panels measuring 2.6/3.0 ft x 8.9 ft (80/90 x 270-cm) with a 0.63-in. (16-mm) grid of aluminized plastic micro mirrors sandwiched between the two layers of glass. The grid is oriented in the glazing to allow small shafts of indirect light from the north sky and provide an overall daylight transmission of 33%.

Air foil and operable louvers for natural ventilation

Service walkway

3550 light fixtures plus 282 stage lights

The roof span consists of 34 steel arched girders at 7.2 m centers spanning 74 m with a radius of 59.2 m and a maximum height of 15 m.
Precast concrete Tee floor above basement with two prestressed steel cables between each box girder resists the outward thrust of the arched roof.

Round metal ducts. Ventilation rates: north zone: 107,726 ft^3 (183,000 m^3/hr), south zone: 90,066 ft^3 (153,000 m^3/hr).

Figure 42: Exhibition hall in Linz, Anatomical section of the roof with Ventilation elements and "Venturi" capping

The final form of this element was determined in wind-tunnel tests. In the light of these developments, one sees that building envelopes are subject to changes in their technical functioning and construction when, in addition to performing their traditional protective role, they are required to control indoor temperatures and the ingress of daylight. (Herzog et al., 2001)

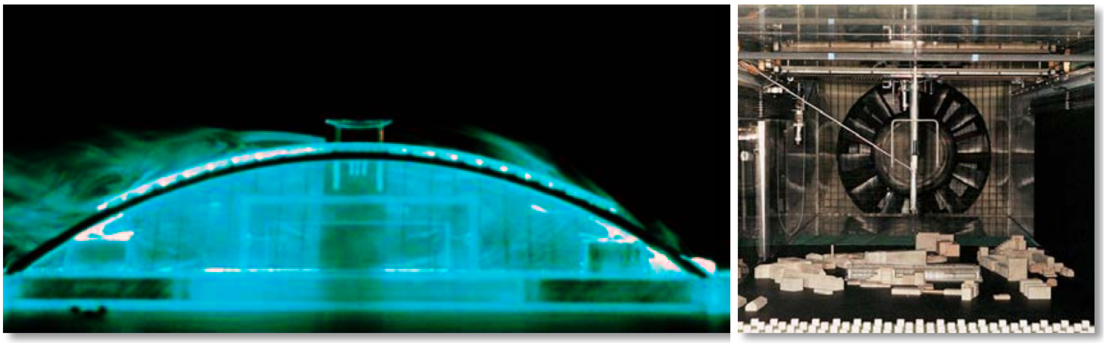


Figure 43: Exhibition hall in Linz, Simulations using wind tunnel.

Additionally, as in mentioned before, one of the major envelope feature was a continuous vent along the ridge of the roof that opened under an airfoil wing. Carefully contrived as a *passive ventilation strategy*, this system was tested in wind tunnels at the Technical University in Munich with 1:250 scale models that included a 1312 ft. (400 m) diameter of the Design Center surroundings.

The building's orientation worked into this configuration as well. Because the prevailing winds in Linz are from the west all year, the long axis of the building would produce a large wind shadow of negative pressure on the east side of the roof. The airfoil cover protected the operable louvers from rain and enhanced the ventilation by directing air across its curved profile.

Wind tunnel tests suggested a natural ventilation strategy utilizing outside air intakes at the floor level and exhaust at the roof ridge. Inlets are placed across the floor, and additional louvers were placed in the roof eaves for complete washing of the space with air movement and to provide flexible use of the floor space that might cover the floor louvers. Supplemental fan-powered ventilation on the order of 212,000 cfm (360,000 m^3/hr.) takes hot air from the top of the hall. In colder months this extracted air is fed through a heat exchanger to preheat outside air before it is used to ventilate the building. (Bachman, 2003)

Meanwhile, the ventilation valves are controlled by an elaborate learning computer system that gets its information from almost 2500 sensors providing feedback to any action that takes place. (Hinte, 2003)

Concerning mechanical aspects, thermally, the hall was divided into several zones to tailor operation to occupied spaces only and minimize the amount of energy being used at any one time. Calculations indicated that the maximum cooling load in the building was 42.5 Btu/ft^2 (134 W/m^2). Solar heat gain and temperature difference through the glazed roof accounted for 60 percent of this, 26.0 Btu/ft^2 (82 W/m^2). The total connected cooling load for the building was 1,530 kW which, assuming an EER of 12.0 Btu/W, equates to the same number of tons in cooling capacity, 1530 tons. The cooling load contribution of the roof has to be discounted against the reduction in total cooling load provided by daylighting. An opaque roof with the same level of light provided by artificial sources would have resulted in a need for much greater cooling capacity.

Four distribution ducts for fan-powered ventilation and return air to the mechanical plants are placed under the center of the roof. Supply air ducts are run along the lower edge of the roof above the perimeter cabins that occupy the low ceiling curve of the roof vault (Figure 44). (Bachman, 2003)

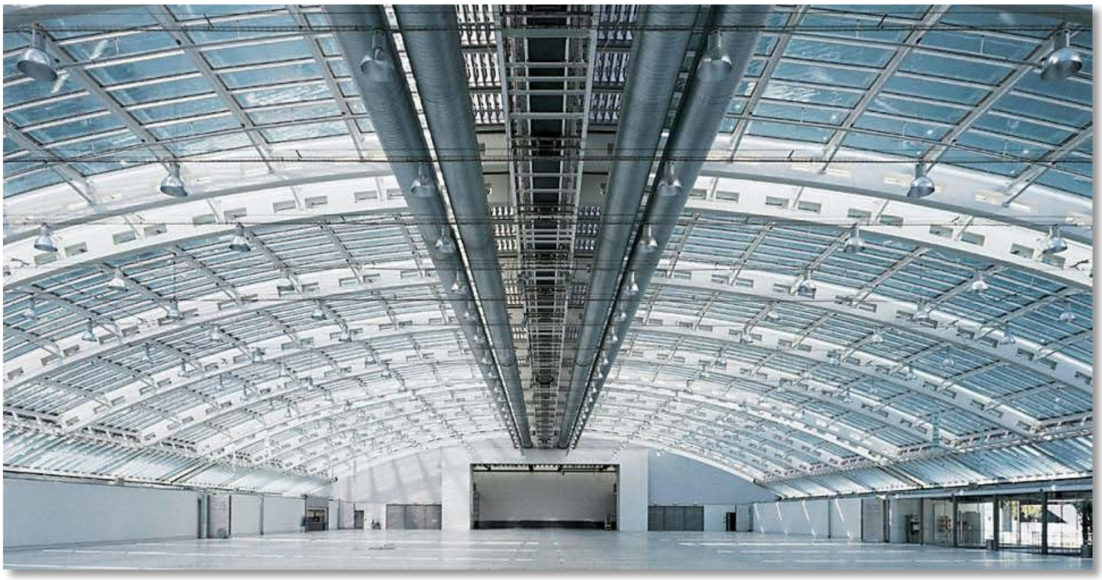


Figure 44: Exhibition hall in Linz, Distribution ducts installed under the center of the roof.

Concerning performance aspects, Roof glazing incorporates daylight distribution and solar shading. Additionally, acoustical sails can be used to diffuse and soften daylight on bright days. Furthermore, the natural ventilation scheme is meshed with the aerodynamics of the envelope. Moreover, natural ventilation works with mechanical ventilation on warmer days when fan power is needed. (Bachman, 2003)

Generally, in this project, significant considerations have been done to minimize the height of the exhibition hall in order to reduce the volume of space for conditioning. Additionally, thermally insulated glass with infrared-reflective coatings has been used to minimize heat gain while maximizing light. Furthermore, an “active spatial environment” has been achieved through daylight saturation without the presence of uncomfortable glare. This dictated that skylight has been admitted but direct-beam sunlight has been shielded from the interior. (Bachman, 2003)

In overall view, the additional temperature control and daylight systems have influenced the outer skin of the building not only its technical functioning but also its construction and the aesthetic effects (Herzog et al., 1996).Meanwhile, the energy efficiency and also industrial-quality construction were from cultural expectations. Actually, architects need to special services during their courses of design development such as graphics, lighting, etc. Likewise, Herzog who is realized as co-inventor of the Lightmetrics, had special attentions to design services, which was not merely based on the constructional costs, and many specialists[17] were engaged with

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[17] For the Linz Design Center, Herzog worked closely with Hanns Jörg Schrade and a team of six assistants. Daylighting for the project involved the participation of Christian Bartenbach, whose office in Innsbruck includes a staff of 60 and provides lighting expertise internationally. Energy simulation was performed at the Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany. Wind tunnel experiments were directed by Dr. Rudolf Frimberger at the Technical University of Munich. Internal airflow modeling was performed by Design Flow Solutions in Cardiff, United Kingdom

special technical supports for this project consisting energy studies, lighting, acoustics, etc.

In Herzog's case, architectural problems are analyzed by the research team at the start of the planning. They are investigated experimentally and resolved in a process of optimization, whereby it is important that the problems are seen not in isolation, but in relation to the specific building assignment, the individual client, and the climatic and environmental characteristics of the site. For example, the entire urban situation around the Design Centre in Linz was reconstructed in the form of a model, which was then used in a wind tunnel simulation to determine the air currents over the roof of the building resulting from the specific contours of the surrounding urban fabric and the climatic conditions. The roof construction (Figure 45) with its specially shaped "spoiler" is, therefore, the direct outcome of a contextual analysis of the climate. (Herzog et al., 2001)

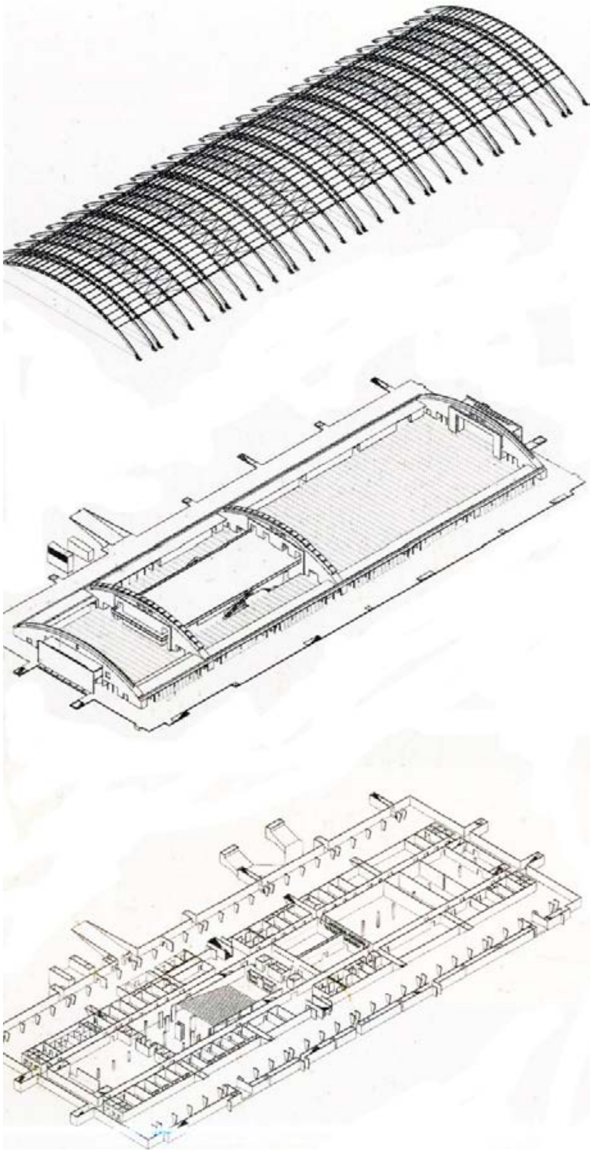

Figure 45: Exhibition hall in Linz, Diagram of constructional layers

2-3-4 Solar city, Linz 1995-2004

The idea for the solar City[18] Linz[19] (Figure 46) project arose in 1990 following the decision of the City of Linz to put low energy construction methods into practice in the field of public housing. At the same time the construction and operation of buildings involved a high consumption of fossil energy which was a major contributor to the greenhouse effect. Both factors were decisive arguments in favor of a plan for a sustainable ecological urban district and so the idea for building a "solar City" was born. ("Sustainable Utopia," 2003)

Figure 46: Solar city, Linz

After an energy study in 1993, Linz City signaled that it was willing to partly finance the planning and development of a solar city at Pitchling (Figure 46), to create a model estate of low energy flats. World class architects Norman Foster, Richard Rogers and Professor Thomas Herzog then agreed to design the first 750 flats, working closely with German energy engineers Norbert Kaiser under the Renewable Energies in Architecture and Design (READ[20]) grouping. By 1996 the commitment to solar and low

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[18] The name "solarCity" stands for the all-encompassing use of the energy of the sun. This concept ranges from the direct use of the sun to improve individual comfort and plant growth to the use of the sun as a source of energy. A compact construction method largely oriented towards the south, highly insulated facades, natural ventilation and lighting and the optimum storage of heat are characteristics of this solar construction.

[19] Linz, a city in northern Austria and capital of the province of Upper Austria, has a population of 185.000 inhabitants. Linz is a green city that has the largest port on the Austrian Danube. Historically the world's premier market for trading salt, today it is better known as a center for trade, industry and education

[20] The READ Group (Renewable Energies in Architecture and Design) is a special task force which began collaboration in 1991. In April 1994 leading architects Sir Norman Foster, Renzo Piano, Sir Richard Rogers, and Professor Thomas Herzog met together with Norbert Kaiser and representatives of the European Commission to establish a new core group for READ. The meeting was hosted by Renzo Piano in his EC/UNESCO workshop in Genoa, and it agreed to develop in common the concept of the Solar City and to identify a suitable neighborhood or town where a new urban development would be designed and built following the principles of sustainable energy and environment utilization and social integration. The concept is being applied in the first phase of a new urban area for 30,000 people in Pichling/Linz, Austria. READ has also drafted technical guidelines and compiled a charter,

energy construction for residential and public buildings in the plans for Pitchling had won support from the European Union's DG XII to the tune of 600,000 ECU for research and development. By this stage some 9 different contractors had also joined the project. The scheme had also expanded to include 1500 flats on an area of around 34 hectares with Viennese architect Martin Treberspurg, a specialist in solar architecture for social housing, designing the second set of 750 flats. (DEVİREN, 2010)

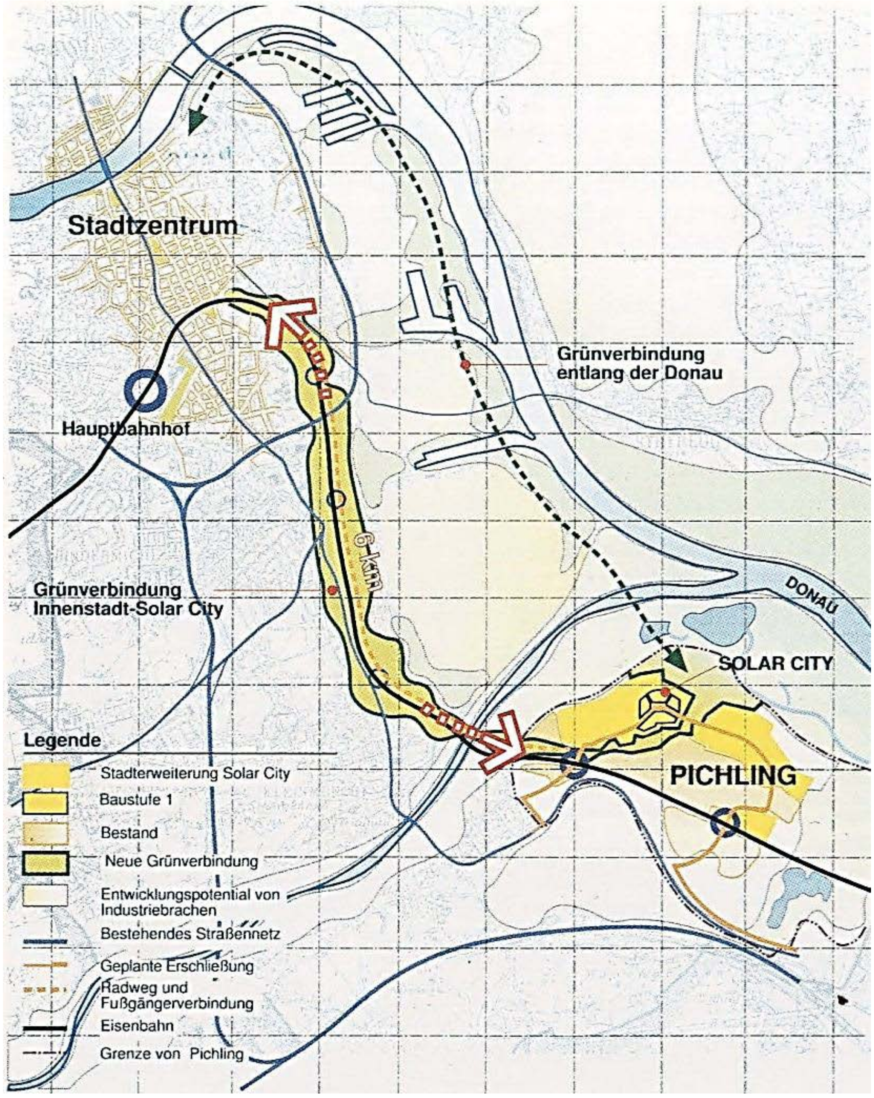

Figure 47: Solar city, Linz, Integrated Urban Plan, new connection to the city center by a green zone

Linz, the chief provincial city of northern Austria, is about to realize an ambitious plan for a new urban settlement for approximately 25,000 inhabitants, made possible also thanks to the financial contributions provided by the EEC given the highly experimental significance of this project: an actual Neue Stadt called ''Solar City

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and prepared a publication illustrating both modern and historical urban and architectural spaces and structures in which solar energy has played an important role (Behling and Behling, 1996).

Linz" (Figure 48), characterized by intensive use of solar energy[21] and in general by the application of principles, methods and instrumentation that will make this new city the biggest event in ecological settlement experimentation in Europe. (Battisti, Tucci, Herzog, & Dierna, 2000)

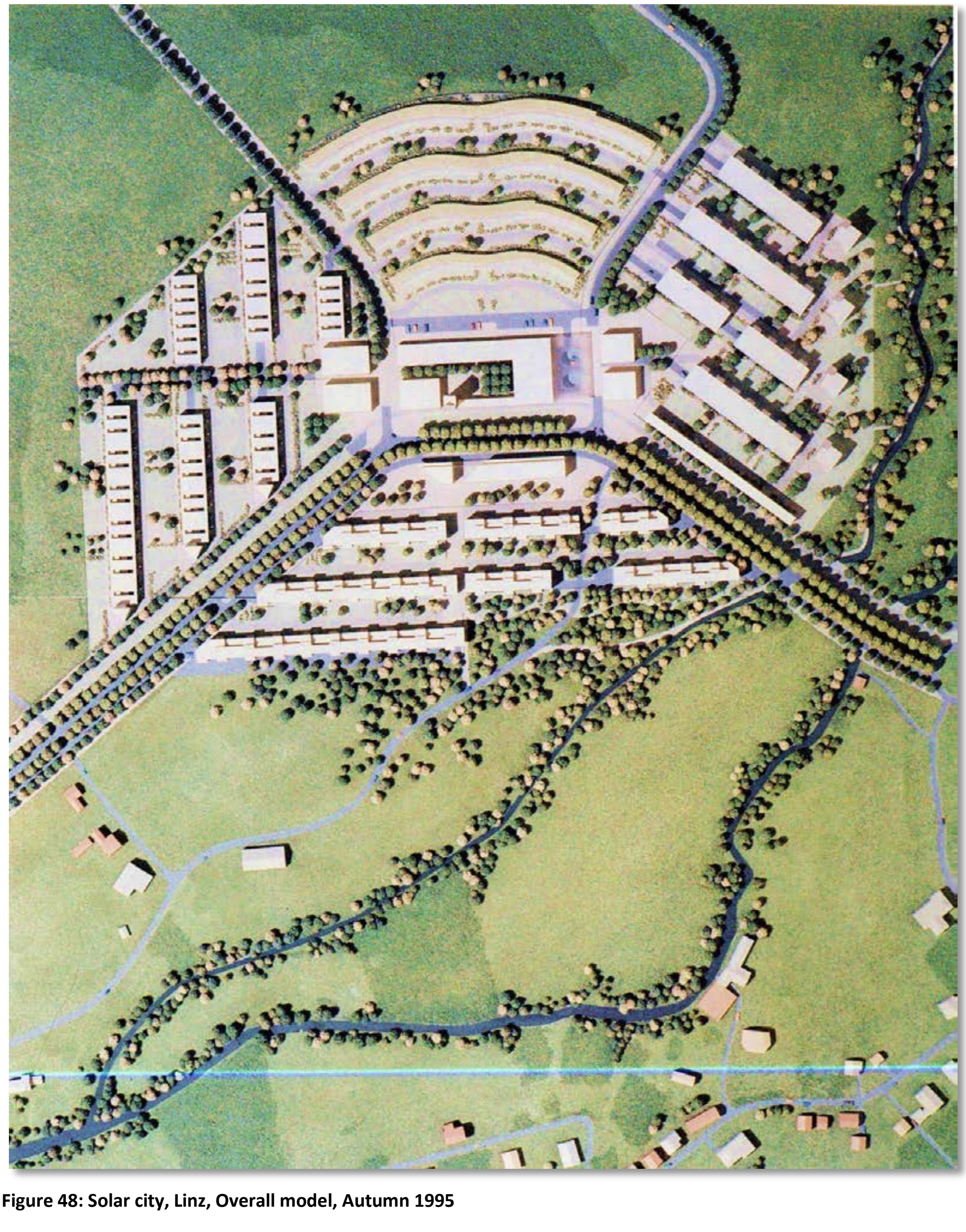

Figure 48: Solar city, Linz, Overall model, Autumn 1995

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[21] The name originates from the European Charta for solar energy in architecture and urban planning from 1996. This includes the basic orientation of buildings and its height, the quality of the building envelope as well as the use of active and passive use of solar energy. The concept of low energy was introduced by combination of technical details, good ration of volume to square meters and orientation of building blocks.

The general outline criteria by Thomas Herzog, Norman Foster and Richard Rogers have selected urban ecological parameters consolidated in central European culture such as the reaching of the maximum density possible and the conferring of maximum typological flexibility in order to offer a great variety of options in relation to the principle of mixed use and the existence of housing grants for those with rather low budgets (Figure 49). The intervention is structured in a series of compact urban sectors for mixed use. A system of public transport has been organized reachable on foot setting out from the center of each sector with the objective of definitely favoring its use rather than that of private cars. (Battisti et al., 2000)

Figure 49: Solar city, Linz. Norman Foster, Richard Rogers and Professor Thomas Herzog, working closely with German energy engineers Norbert Kaiser under the READ grouping.

"Solar City Linz" is also a laboratory of technical and typological experimentation in which the attempt will be made to invert that way of conceiving the making of architecture which Thomas Herzog has been talking about since the end of the 1970s. The aim is to reach an equilibrium between morphological characteristics of human artifice and "Umweltfreundlickeit", environmental sustainability in its fullest sense. (Battisti et al., 2000)

The project is a realistic approach towards the thorough integration of solar energy on an urban level, based on the conditions of local policies and economy, with all the accompanying constraints regarding political, legal and economic decisions, (such as land-ownership, acceptance of the design by neighborhood inhabitants, dependence on local politicians and changes due to elections and political force). (Herzog et al., 1996)

In order to create a variety of new situations, or otherwise to respond to the different existing conditions a diversified range of building types has been developed, which broadens the scope of currently accepted architectural solutions to the use of solar energy.

The separate building plots within the open spaces (Figure 50) are highly individuated and broken up into small areas by allotments, quiet zones, children's play areas and places for communal activities. (Herzog et al., 1996)

Figure 50: Solar city, Linz, Open spaces

The fact that transport networks and energy-supply can be defined from the outset gives the development an economic advantage. Surplus electricity produced locally by means of co-generation, can be supplied to the urban grid (Figure 51). (Herzog et al., 1996)

Figure 51: Solar city, Linz. Urban structure: Roadways, public transport and pedestrian paths

The building phase lasted from 1999 up to 2008, and the first apartments were finished in 2003. The area is situated along the river Danube and is ecological sensible (Figure 52). Therefore the new settlement was considered to cover the aspect of recreational facilities and recultivation of a small river and a lake. It also has a concept for grey water use. (Phil Jones Jo Patterson, Chris Tweed, 2009)

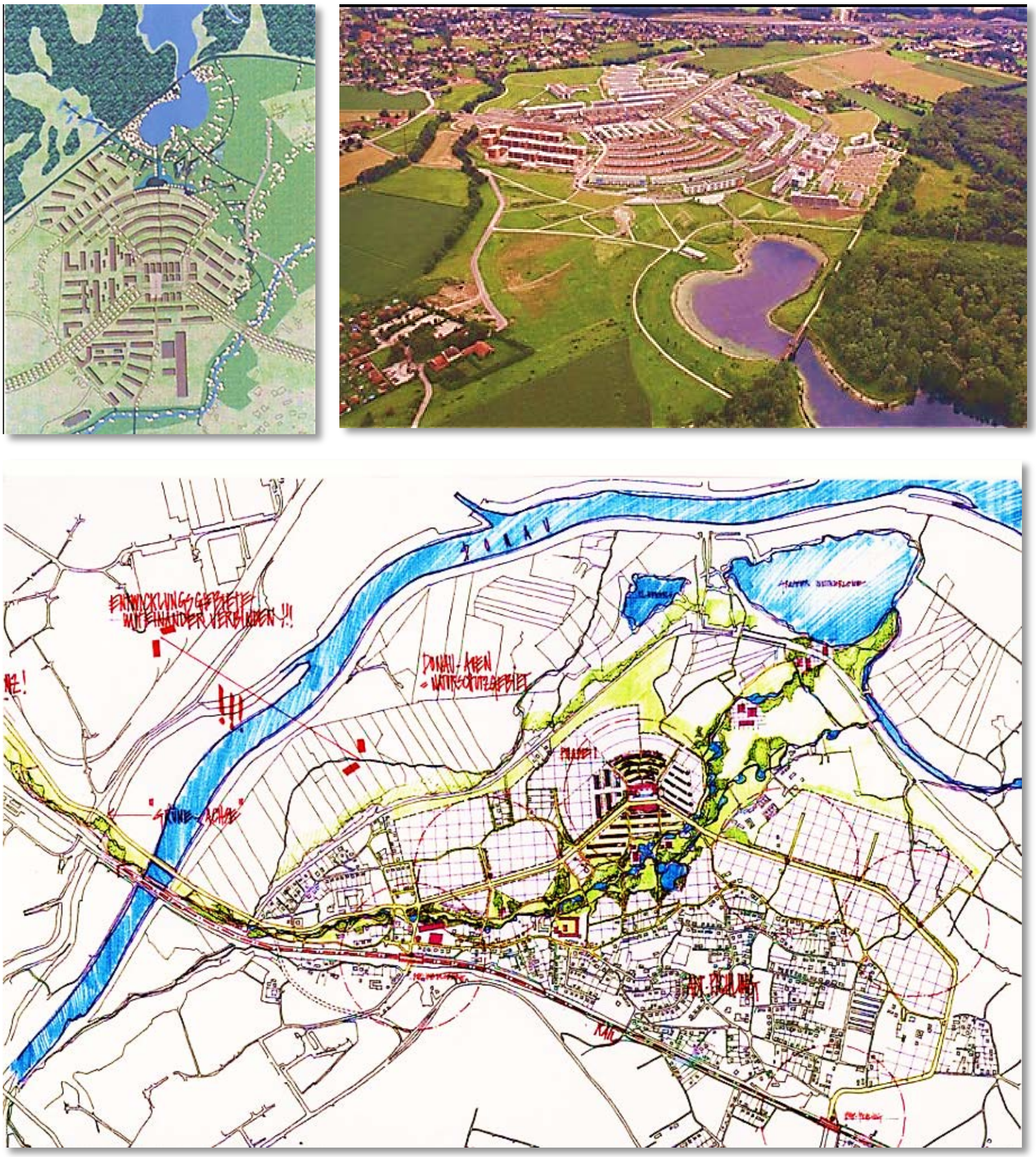

Figure 52: Solar city, Linz, Master Plan

In the Solar City a wide variation of typology was used (Figure 53). It ranges from east-west oriented rather wide building blocks including large scale windows to south oriented houses with 6m high winter glass houses to passive house standard buildings in different variations. It is meant to create a mix of various attitudes in the spirit of solar building concepts. (Phil Jones Jo Patterson, Chris Tweed, 2009)

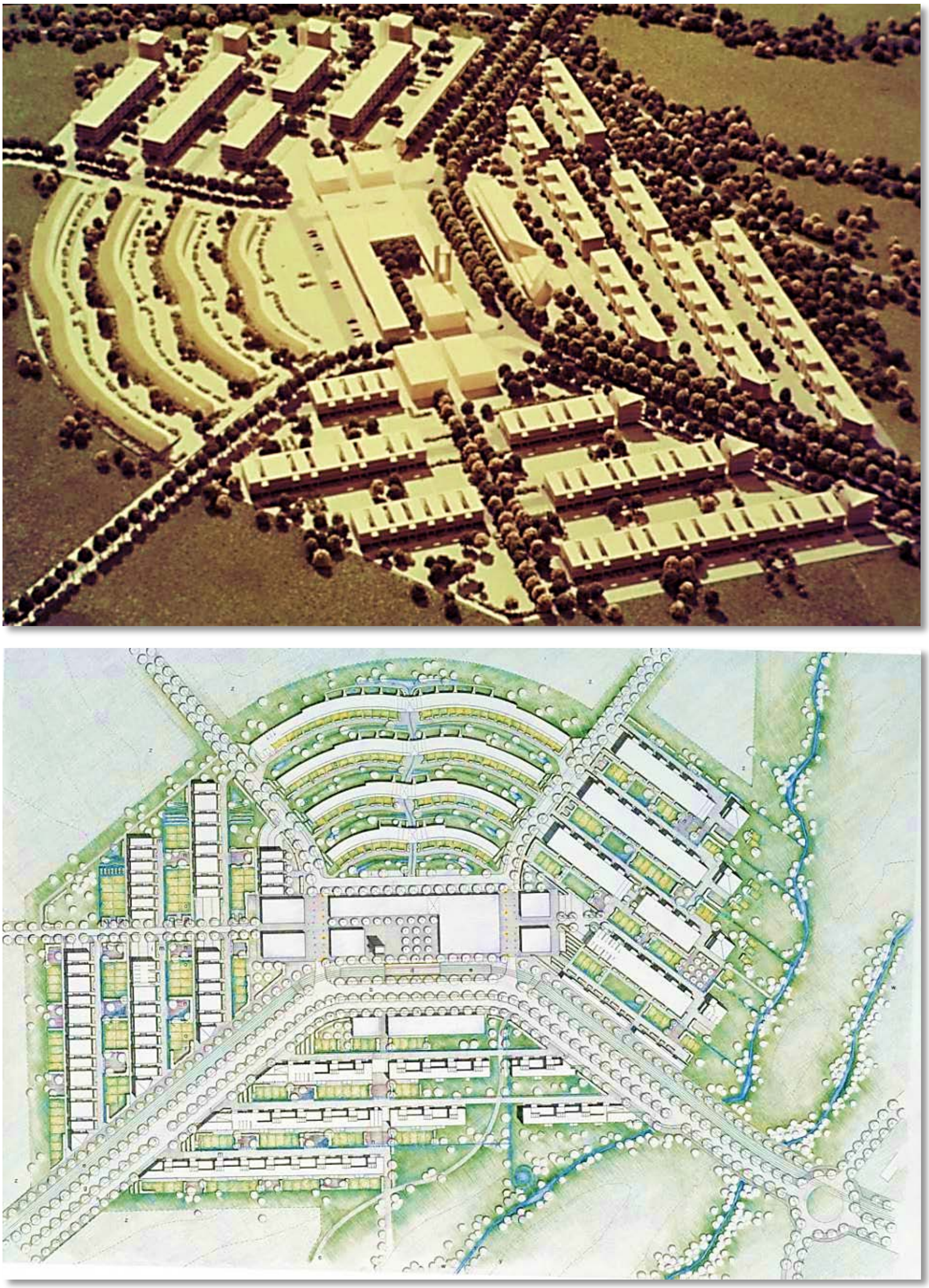

Figure 53: Solar city, Linz, Typology variations

The initial plan was to have a European-wide showcase of district planning including alternative use of energy. The start for realization was also based on an agreement of the 12 social housing companies involved to have common standards in energy figures such as hot water solar panels and prime energy figure of below 44 kWh/m²a. This was also applied to public buildings such as schools, kindergartens and similar facilities. The basic idea was to provide at least 34% of hot water by solar panels. Reality shows a figure almost close to 50 % and the average figure of energy/building below 36 kWh/m²a. The goal was also supported by subsidies by the municipality of Linz and resulted in a total of 3500 m² of solar panels mounted on roofs. The problem of overheating in summer was already considered in the planning phase and every social housing company involved had to prove by calculation to stay below the problematic temperature.

Additionally, Energy supply for all buildings is done by a district heating[22] supply system. It contains pipes of 150 mm in diameter and is linked to the overall district heating system of Linz. The transport pipes of steel are specially insulated with polyurethane foam resulting in a loss of only 8% from heat generation to end-user.

Furthermore, the district heating system was completed in 2004 with a 65m high storage-tower for a total of 35,000 m3. The system was also combined with a biomass-heating/energy plant. This results in an efficiency of heating material of 85 % by the use of a so called “Kraft-Warme-Kopplung”. It provides a total of 17 % of the energy needed in the district heating system being also a relevant factor for CO_2 reduction. (Phil Jones Jo Patterson, Chris Tweed, 2009)

In fact, the area was originally planned for 25.000 inhabitants. The Roland Rainer’s master plan (Figure 52) was modified during the development stages for the priorities given to buildings and open spaces for the extensive use of solar energy. A radial concentric plan is applied for the settlement layout and the entire development was restricted in height to prevent the need for the use of elevators.

Comprehensive use of solar power and compact design mean the buildings largely face to the south (Figure 54), have intelligent facades, natural ventilation and large amounts of natural lighting as well as optimal heat storage and an overall heating requirement of less than 40kwh/m² per year. Different possible ways of utilizing solar energy were applied-1. individual use: to increase the a feeling of well-being and comfort that relate to the quality of daylight, the view, and the integration of sunny areas; 2. technical use: the physical or biological utilization of sunlight to produce energy and to relieve strain on the environment; 3. social use: outdoor areas are created that receive plenty of sunlight, thus making them more pleasant to use and plant growth is stimulated. (DEVİREN, 2010)

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[22] District Heating and Cooling is a technological concept comprising infrastructure for delivering heating and cooling services to customers throughout Europe and other parts of the world.

District Heating systems provide space heating and hot tap water to residential, commercial, public and industrial customers.

District Heating and cooling is based on the ‘fundamental idea’ of using local heat, cold and fuel sources that under normal circumstances would be lost or remain unused. Another essential feature is that it provides a flexible infrastructure able to integrate a wide range of (renewable) energy sources. At present, with approximately 86% of heat deriving from a combination of recovered heat, renewable energy and waste resources, modern District Heating and Cooling comes very close to fulfilling its fundamental idea in practice.

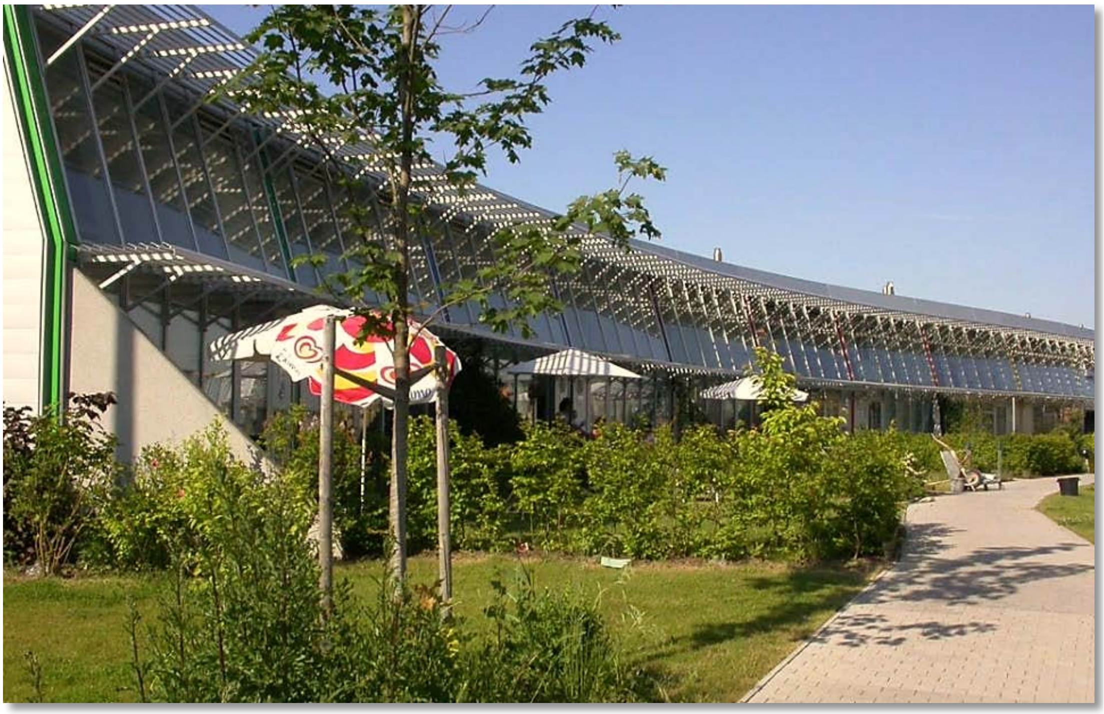


Figure 54: Solar city, Linz, South facing large facades

The goals were to achieve maximum permissible density, variety, possibilities of mixed use and subsidized social housing at a low overall cost. The technical, functional and social effects of solar energy were also be implemented.

The main task of the planning of the Solar City is social housing with the goal of solar urban planning and the method was to build sustainable buildings that allow innovation. The main focus of the urban development project: low-energy construction, a future oriented approach to energy supply and waste disposal, the issues of building biology, local recreation and leisure time, the creation of a modern socio-cultural, family oriented infrastructure, as well as joint, group specific marketing campaign, all formulated in a project agreement. Each building in the settlement context has an urban planning concept, building design concept and energy concept (Figure 55). (DEVİREN, 2010)

Figure 55: : Solar city, Linz, social housing with the goal of solar urban planning

In fact, the natural topography was to be respected in laying out the homes, making most of building orientation and the local climatic conditions. An attractive town center with kindergartens, schools and a multi-function center are planned in the center of the new quarter, not only serving the new district, but also older communities nearby.

Additionally, in general the buildings would primary have a linear framework and have a height of two and three stories. The town center would be primarily north south oriented, with passive environmental measures effected through atriums and compact layout; active measures include controlled building ventilation and hear recovery systems, underground air pre-heating or cooling depending on the seasons and PV collectors integrated with the roof or façade systems. Excess heat in summer is lessened via covered passages and light deflecting mirrors. Meanwhile, a catalogue of building materials based on eco-building principles and criteria is compiled by the builders, who would have to work on the basis of such agreements. This ensures that the building materials used minimize both the harm to the environment and the noxious effects on the persons living in the buildings. (Hee, 2008)

Figure 56: Solar city, Linz, PV collectors applied

Snapshot of Herzog's focus on Solar city, Linz (Figure 57)

1 center by Auer+Weber
2 Residential building by Richard Rogers
3 Residential building by Thomas Herzog
4 Residential building by Norman Foster

Figure 57: Solar city, Linz, Aerial view

East-west oriented linear block housing (Figure 58&59) are characterized as three-story double-span flats of compact construction with minimal surface area; 16m deep two- and four-room flats. In the buffer zone between each unit is a naturally lit interior space, with covered balconies on the west side, and lobbies and staircases on the east. Parking and access roads are beneath the housing, so as to maximize use of green space (allotments, play areas, quiet zones, sun traps and shaded places ...) centralized servicing, in vertical cores, with integrated heat recovery.
Optimal alignment of open space to the sun because of the north-south alignment of the blocks. Effective wind protection for the exterior space from west and east wind. (Herzog et al., 1996)

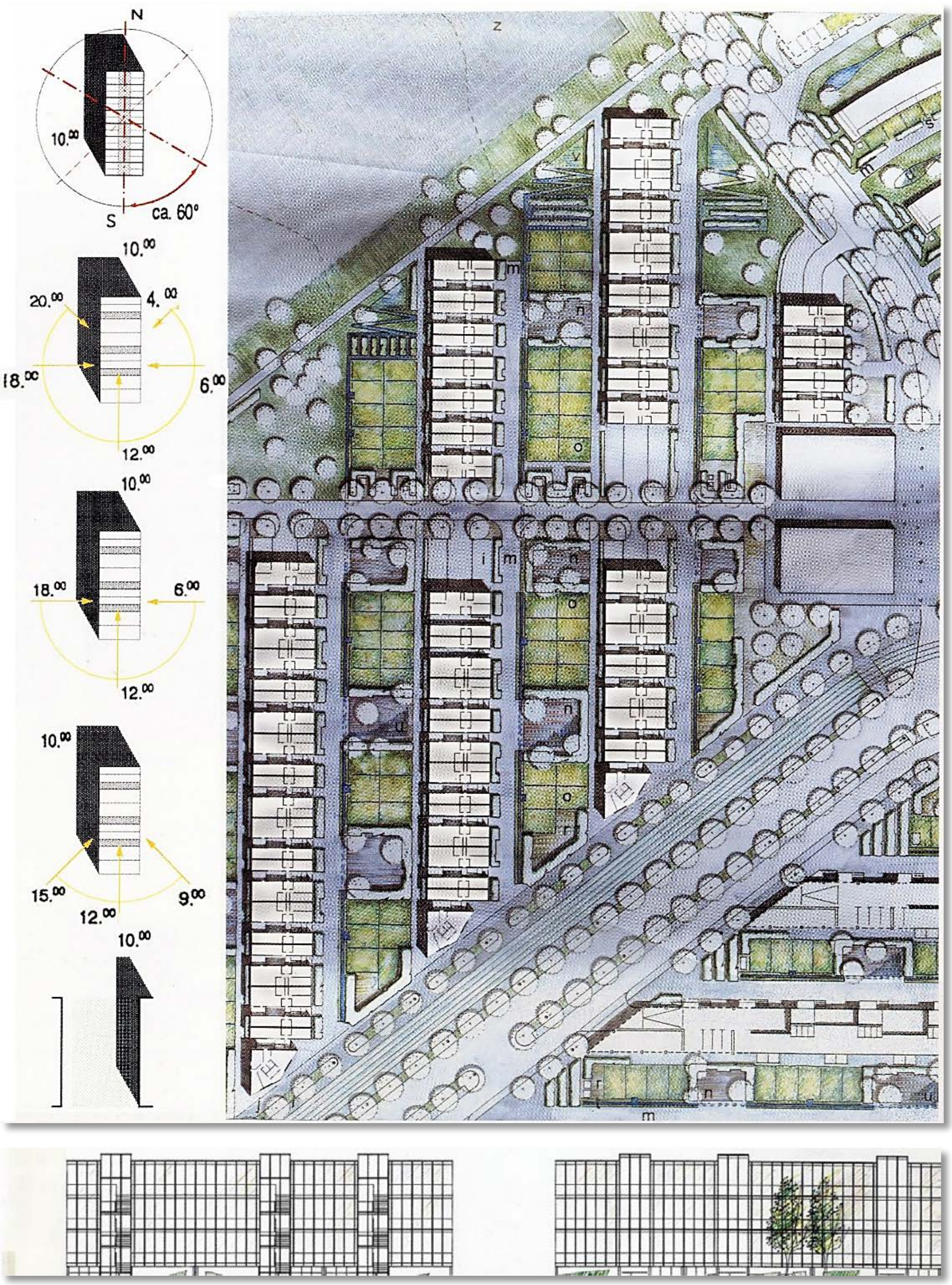


Figure 58: Solar city, Linz. East-west oriented linear blocks, Site plan & Elevations

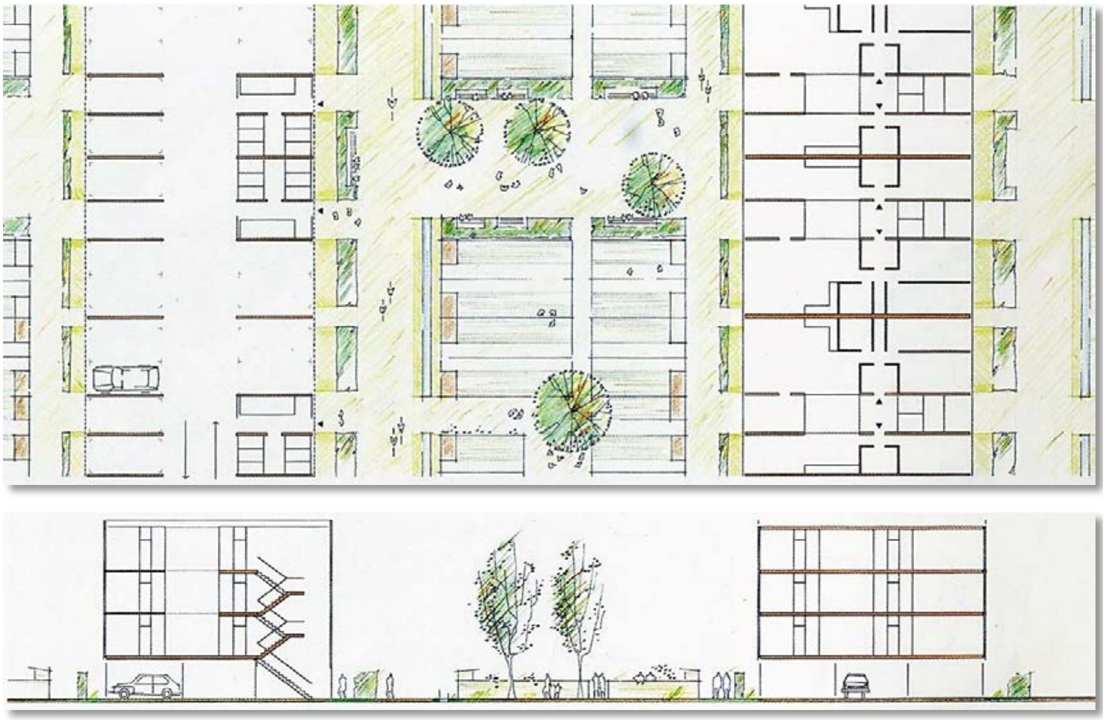


Figure 59: Solar city, Linz. East-west oriented linear blocks, Plans & Cross sections

Natural Lighting: The deep plan receives light from the East and West through the extensively glazed facade. All apartments look out on both sides. In the central area are the kitchens and dining areas naturally lit from the bufferzone (Figure 60). (Herzog et al., 1996)

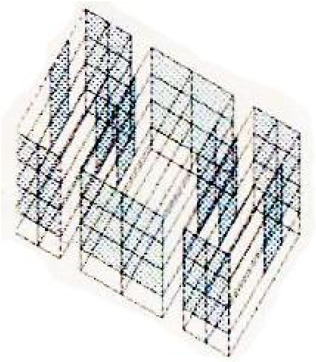


Figure 60: Solar city, Linz, Naturally lit kitchen and dining areas by bufferzone

Thermal Buffer Zone: Glazed atria that act as thermal bufferzones between the housing units (Figure 61) are used for: 1. staircases and lobbies to the flats; 2. protected green courtyards and play areas for small children; 3. hanging balconies. (Herzog et al., 1996)

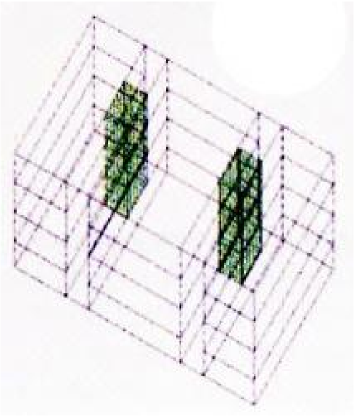


Figure 61: Solar city, Linz, Glazed atria act as thermal bufferzone

Sanitary core with central shaft: It caters for servicing. Heat from waste water and exhaust air should be processed by heat exchange and heat pump for heating and domestic water preheating. To put short, extensive prefabrication and preinstallation possible: short cabling, good access for maintenance (Figure 62). (Herzog et al., 1996)

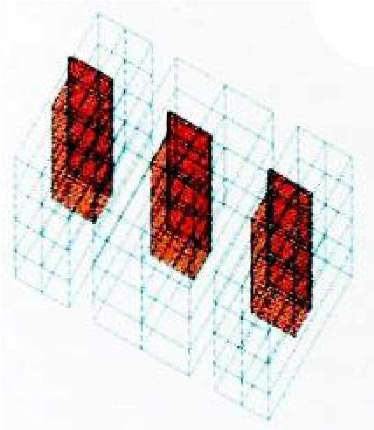


Figure 62: Solar city, Linz, Sanitary core with central shaft

Northwest-southeast oriented linear blocks (Figure 63&64) are characterized as three-story double-span flats of compact construction with minimal surface area; 15m deep three-room flats with conservatories or covered balconies at the front. The facades have mobile blinds to protect against solar gain and heat loss. Parking is under the building.

Moreover, they have centralized servicing, in vertical cores, with integrated heat recovery.

Additionally, it has achieved to a favorable sun-aspect of open spaces as a result of the northwest-southeast alignment of the buildings. (Herzog et al., 1996)

Slender block on the street (Figure 63&64) which are realized as small apartments, of which the focus is a central glazed hall to the south-west. The front elevations enjoy an optimal level of sunshine. (Herzog et al., 1996)

Point blocks (Figure 63&64) are characterized as four-story, double span apartments, facing south-east and south-west; parking below; south-facing conservatories. They have compact building form with favorable orientation for absorbing solar energy during the heating period.

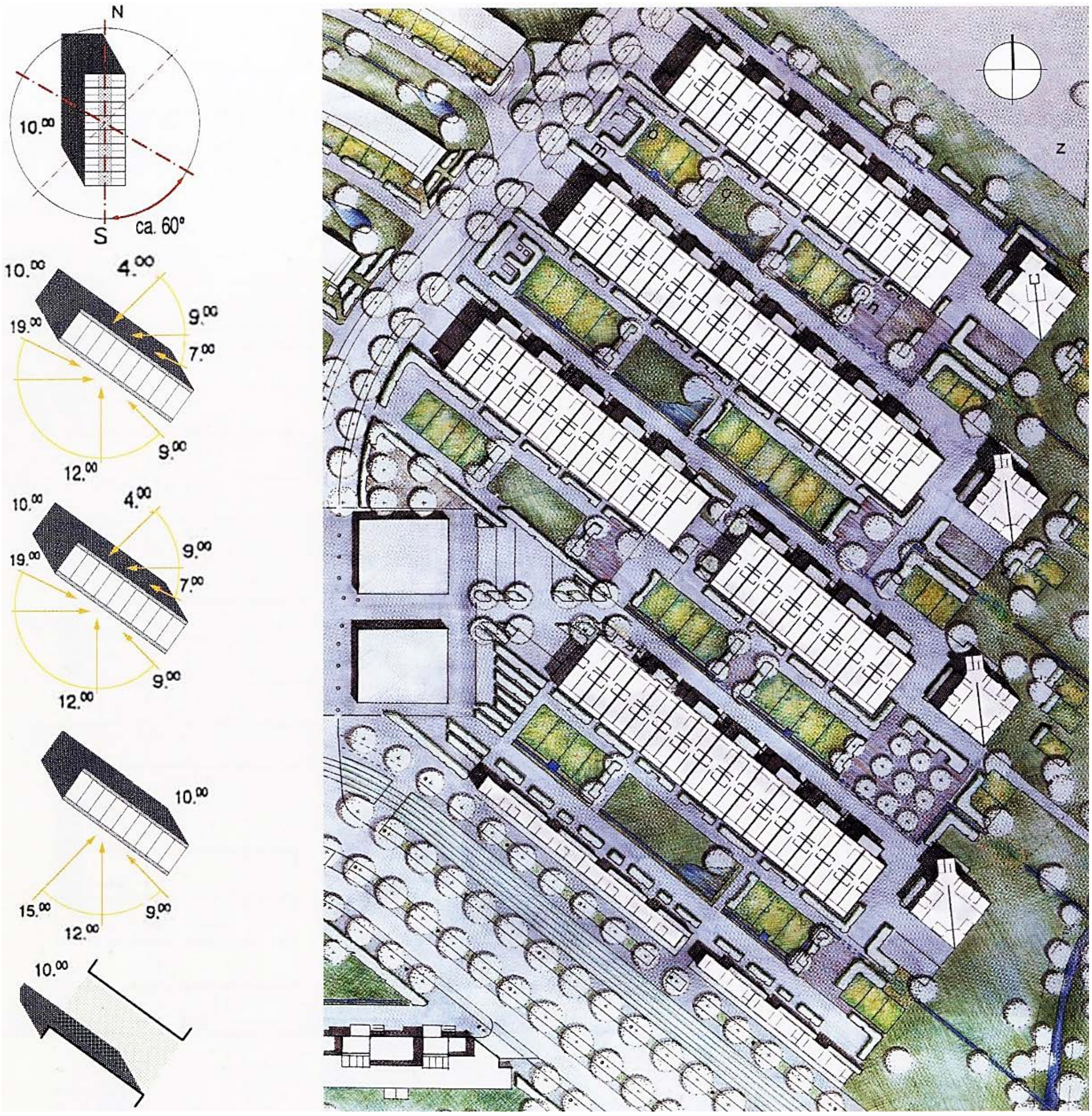
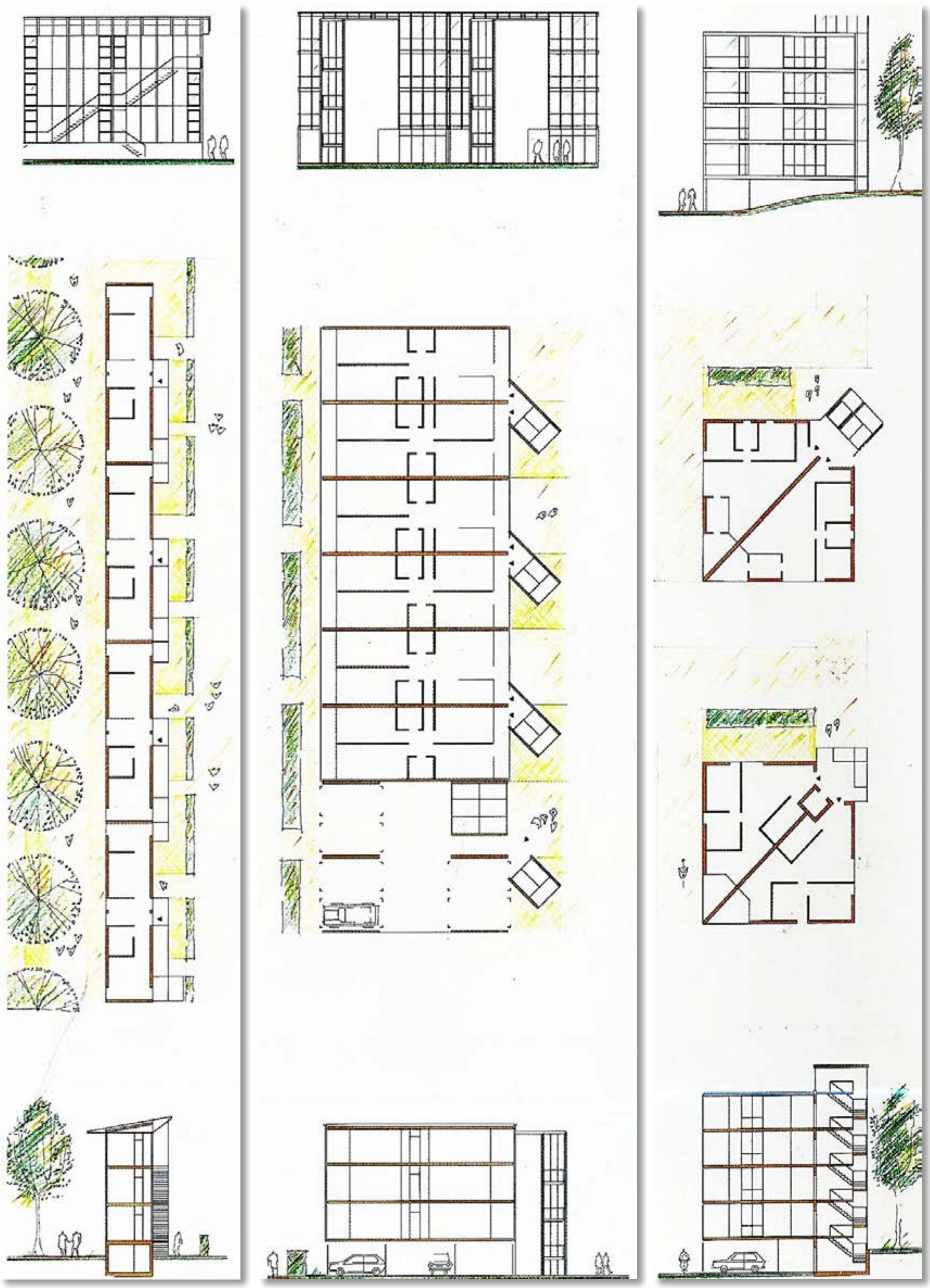


Figure 63: Solar city, Linz. Slender & Linear block and Point blocks, Site Plan



Slender block along the street

Linear block

Point blocks

Figure 64: Solar city, Linz. Elevation, plan and section of the Slender & Linear block and Point blocks

Solar City Linz is two of the first passive social housing units in whole Europe. The energy concept is to exploit all possibilities of using energy in a careful and conscious way. Low energy building systems is a standard; housing units are either passive houses or almost passive houses (energy demand of the units should not exceed 44kWh (m2a) (the actual average is 36 kWh).Furthermore, At least 34 % of the

hot water to be obtained from solar energy was planned and 50% was gained. (DEVİREN, 2010)
Furthermore, energy would be not be supplied by the city grid but would come from the widespread use of solar panels and installations that would make the whole city self-sufficient and even return energy surplus to the city grid. A compact layout was favored with buildings largely oriented towards the south, with highly insulating facades, natural ventilation and lighting and optimum storage of heat. (Hee, 2008)

In an overall view, the architecture of Thomas Herzog is based to reach to a self -sufficiency in ecology while the application of technology is his main concern. Additionally, his main focus is to enhance the passive technology in the buildings. Moreover, in this project the most important issue is the solar gain system of dwellings while the neighborhood development has seen and was not ignored as one of his notable design strategies. Therefore, undoubtedly, the architecture of Thomas Herzog is an example of “technicist development” in the contemporary architecture.

2-3-5 Hall 26, Hannover 1994-1996

Trade fairs mean communication. The Deutsche Messe AG (Figure 65) provides the environment for a dialogue between exhibitors and visitors. In view of the limited time available and the resulting stress of fairs, discussions between producers and clients should take place in congenial surroundings. This is a target the Deutsche Messe AG has set itself for many years now and has consistently pursued.

A striking feature for exhibitors and visitors alike is the special quality of the individual buildings and the extent of the park-like, landscaped grounds. This positive image is no coincidence. It is the product of strategic planning conducted over a long period. (Herzog & Heckmann, 1996)

Figure 65: The Deutsche Messe AG, Hannover, Aerial view

In fact, in addition to its concern for the urban design aspects, the Deutsche Messe AG also collaborated with experts in future-oriented workshops and in study groups to examine themes such as " industrial building and ecology" and" design and art", to develop a framework for future buildings and infrastructure measures on the world's largest trade fairs site.

This work led to the formulation of a number of criteria for the improvement of the overall situation, including

. The development of a striking architectural design for the halls to facilitate better orientation on site;

. The creation of bold entrance situations; improvement of orientation on the site for visitors;
. The realization of realms of experience - spaces with new events and perceptions;
. The creation of a sense of urban flair. Relation to the exhibition halls, this implies:
. The construction of large-scale enclosing structures with a controlled indoor climate;
. The opening up, structuring and articulation of the hall facades;
. The creation of glazed arcades and links between halls;
. Increased use of daylighting;
. The design of striking entrance situations to the halls;
. The provision of zones for recreation and relaxation;
. Improvements to circulation and routing;
. Exploitation of scope for natural ventilation;
. The use of raw materials in a way that would conserve resources;
. The use of regenerable raw materials. (Herzog & Heckmann, 1996)

The office of Prof. Herzog + Partner, Munich, was commissioned to prepare a feasibility study of the Masterplan EXPO 2000 on this basis and to develop an overall concept for the site (Figure 66). The joint solutions were to be implemented in the design of the new Hall 26, which was scheduled for immediate construction, was to serve as a model for future hall construction.

From the point of view of the Deutsche Messe AG, these objectives have been achieved with remarkable success.

Within the space of only nine months, an impressive structure has been realized on the western side of the fairs site in an architectural form that points the way to the future. The new hall has resulted in an upgrading of the entire area and lent it a striking new appearance. An innovative building has been created that is not merely an exhibition hall; the theme of the World Exposition 2000[23], "man, nature, technology", has assumed concrete form. The scheme can be regarded as the first contribution to the EXPO development. (Herzog & Heckmann, 1996)

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[23] Expodach is a large-scale roof structure located in Hanover, Germany designed by architect Thomas Herzog. Hanover's Expo-Dach (Expo-Roof) symbolizes, a partnership between man, nature and technology.
EXPO 2000 is the first World Exposition in the close to one-and-a-half centuries' history of world exhibitions to take place in Germany. It presents at the same time two new features. This World Exposition is not just taking place in Hanover, but all over the world where people are developing ideas for the future and putting them into practice: the concept of global projects is joining together model ideas from all over the world in the presentation, and in this way is taking this World Exposition out into the wider world. Also new is the EXPO 2000 idea of the Thematic Area.
Whereas earlier world expositions concentrated on presenting advances in technology, EXPO 2000 will be concentrating on solutions for the future: solutions for current problems in the environment and development. Under the motto "Humankind-Nature-Technology – a new world arising", EXPO 2000 demonstrates in an attractive, factual and entertaining manner, how the major challenges of the 21st century can be met and mastered.

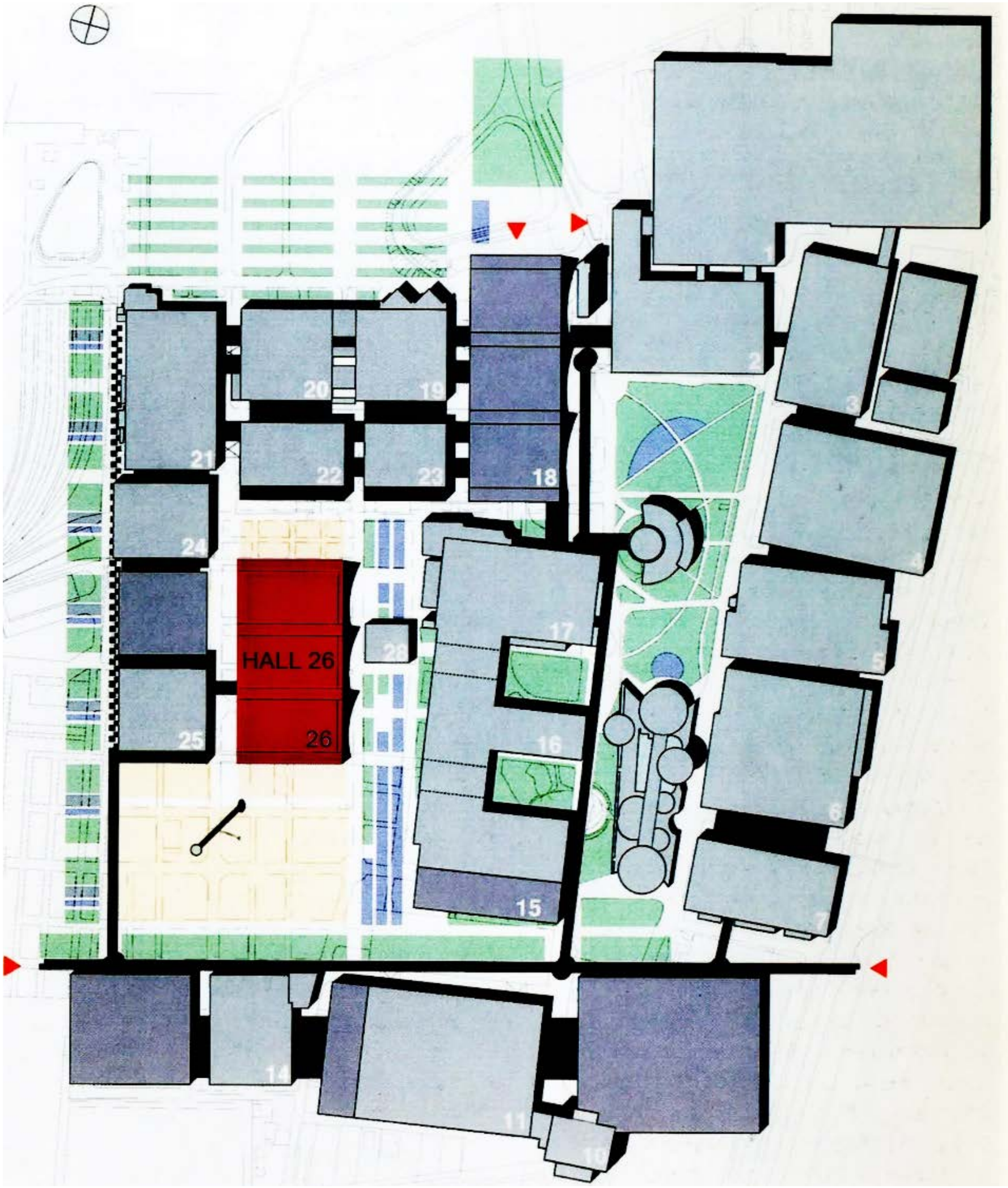


Figure 66: The Deutsche Messe AG, Hannover, Site Plan

At the same time, the hall is evidence of the way in which clients and architects can work in a close and constructive collaboration to create a building of outstanding quality and of optimum function and design. (Herzog & Heckmann, 1996)

Undoubtedly, Hall 26 (Figure 67) proved to be an impressive structure with forward-looking architecture. It is an innovative building that not only represents a new model form for a trade fair hall; it can also be seen to anticipate other developments for the EXPO 2000. The design of Hall 26 was expected to fulfill special conditions. A hall type with a new cross-sectional geometry was to be created, the outline of which would respond to the dynamics of the internal climate and the needs of natural lighting. (EXPO, 2000)

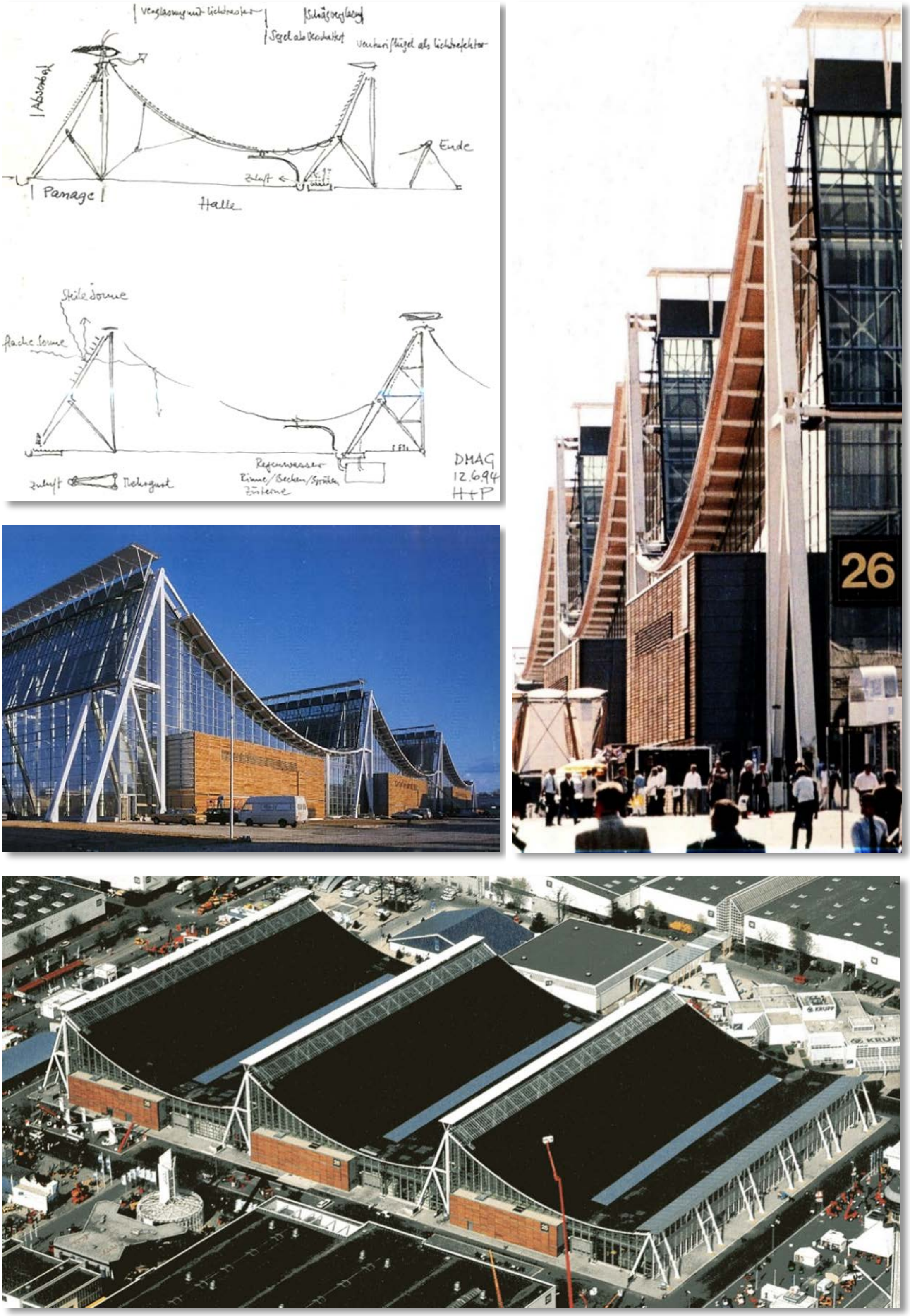


Figure 67: Hall 26, Hannover,Different views & Conceptual sketches

In fact, concerning overall concept of the building, Future construction measures were to facilitate a maximum use of renewable forms of energy and regenerable raw materials, as far as this was compatible with existing constraints and building regulations. New architectural qualities were to be created, oriented to the leitmotifs of the EXPO 2000: man, nature, technology. In terms of objectives for future design plans, this implied:

. A simple, clearly legible basic zoning of halls and open spaces;
. A geometrically clear ordering structure to achieve a major improvement in the orientation for visitors;
. an improved approach from the north by means of a generous redesign of the entrance situation in particular and the entire front in general with a projecting canopy roof; and in the interior of the site, the creation of a comprehensible circulation system to the adjoining hall areas, which could be used independently of each other;
. The construction of new halls in the form of light enclosures with a controlled indoor climate and with varied sequences of spaces;
. The creation of green, landscaped areas as recreational zones for visitors;
. Partial covering of open areas to provide protection against the elements;
. The use of daylight in the exhibition areas as the dominant factor in terms of spatial quality and brilliant, glare free lighting conditions;
. the use of timber as a regrowable raw material in all appropriate situations; the refurbishment of existing halls; the implementation of technical and design measures to improve lighting quality in internal spaces and thus achieve a considerable saving of electricity for lighting. (Herzog & Heckmann, 1996)

A special provision of the brief relating to Hall 26 - with an area of 25,000 to 30,000 m²- was to develop a type with a cross-sectional geometry that would combine the following features:
. A form of load-bearing structure (Figure 68) suited to large spans; this led to the choice of a suspended roof construction;

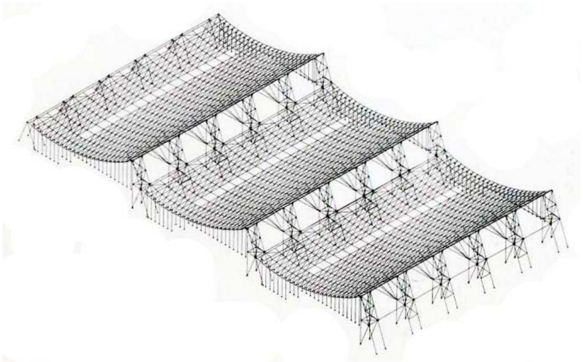


Figure 68: Hall 26, Hannover, Principle of load-bearing structure

. The provision of a functionally determined minimum room height over large areas of the hall and at the same time, the creation of high points, in attention to the upward curving forms of the roof and the articulation of the crests, that would facilitate natural ventilation, exploiting the effect of thermal upcurrents(thermal uplift);
. The creation of large areas through which daylight could enter the building, whilst at the same time restricting direct solar insolation. Brilliant, glare-free lighting was seen as crucial to the spatial quality of the hall.
- Renewable raw materials were to be used in appropriate parts of the construction The roof has an area of roughly 20,000 m', and timber was used for the roof panels to

demonstrate not only the advantages of this material in terms of its low primary energy content, but its constructional efficiency as well (Figure 69). (Herzog et al., 2001)

Figure 69: Hall 26, Hannover, Using timber as a renewable material

The layout of the newly developed hall type, in which environmentally-friendly sustainable forms of energy are used to great effect, comprises two different zones:
. Spacious, freely divisible exhibition areas without intermediate columns, column-free exhibition areas that allow a flexible layout, beneath a light, tensile, steel suspension roof structure with a timber covering;. Narrow zones (strips) between the exhibition areas, at the edges of the hall, flanked by rows of steel masts (steel load-

bearing pylons and trestle-like steel masts), which support the loads from the suspension roof as well as the horizontal loads.
These zones, which serve as access routes and accommodate leisure facilities, should be planted. (Herzog & Heckmann, 1996)

The huge exhibition hall, 220 m long x 116 m wide, was laid out in three bays (Figure 71-76). Its appearance is an expression of the state-of-the-art technology used in its construction and the optimized exploitation of environmentally sustainable forms of energy. It is regarded as one of the finest trade fair halls in the world. With the development of an air supply concept that allows a combination of natural and mechanical forms of ventilation, it was possible to reduce the investment for air conditioning by 50 per cent. The hall receives natural light through large, north-facing areas of glazing (Figure 70). In addition, mirrored areas in the soffit of the roof act as large-scale reflectors for natural and artificial light. (Herzog et al., 2001)

Figure 70: Hall 26, Hannover, North face

Other special facilities (Figure 71&72), such as the three catering units (dining and refreshment centers), the toilets and the spaces for technical supply and waste disposal services, including air-conditioning and waste disposal, are situated along the sides of the building in six independent, cubic structures. The external cladding to these structures, in the form of bold timber louvers, allows ventilation openings, doors and sliding elements to be integrated in a single design. (Herzog & Heckmann, 1996)

1	exhibition area	8	kitchen	15 WC
2	entrances	9	cooling plant	
3	vehicular access and emergency exits	10	telecommunications	
4	escape tunnel entrances	11	hall supervisor	
5	restaurant	12	telecommunications	
6	snack bar	13	electrical plant	
7	bistro	14	reserve areas	

Figure 71: Hall 26, Hannover, Plan description

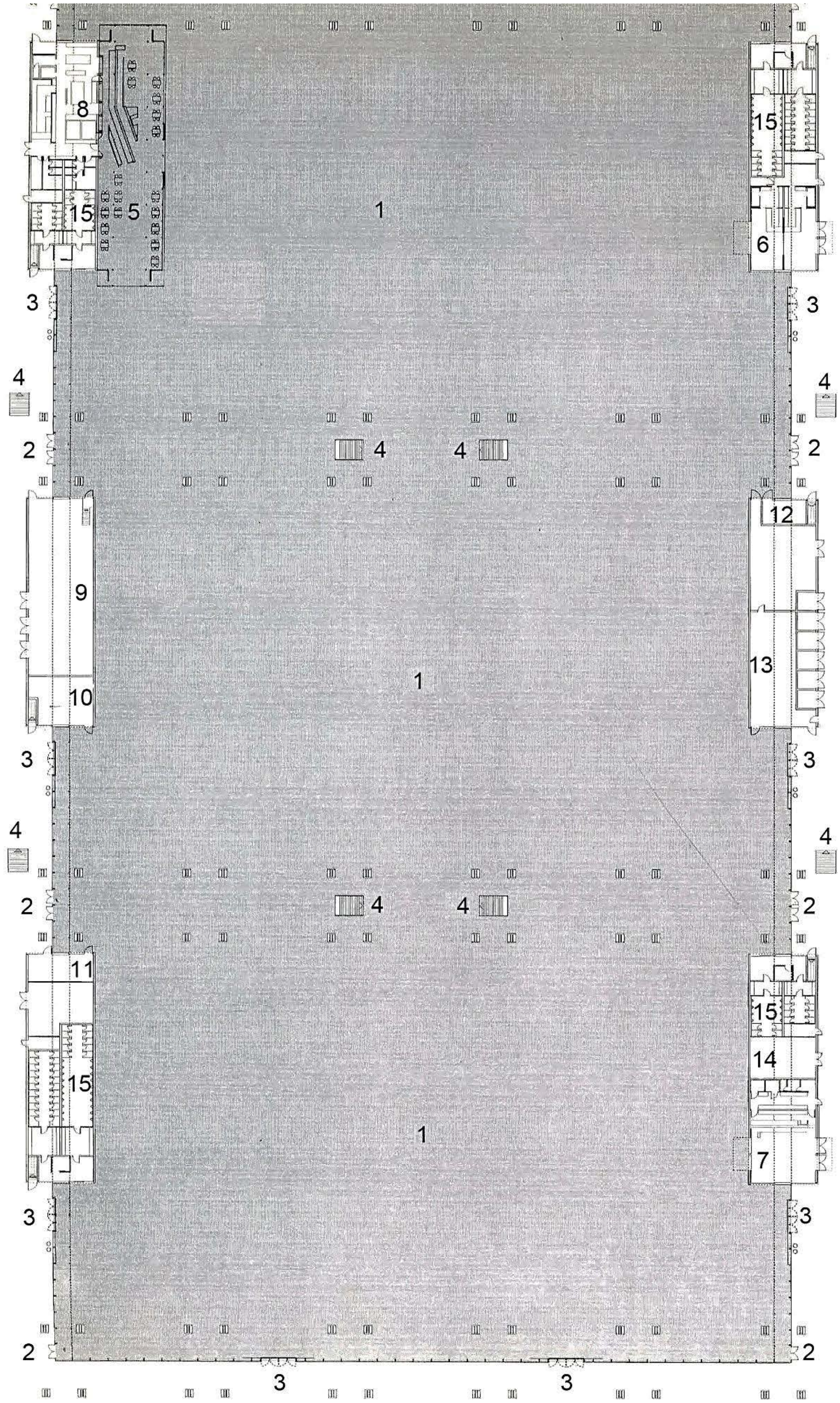
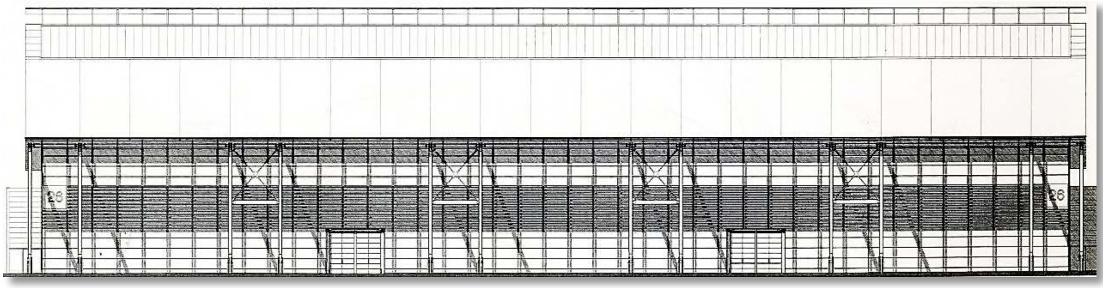
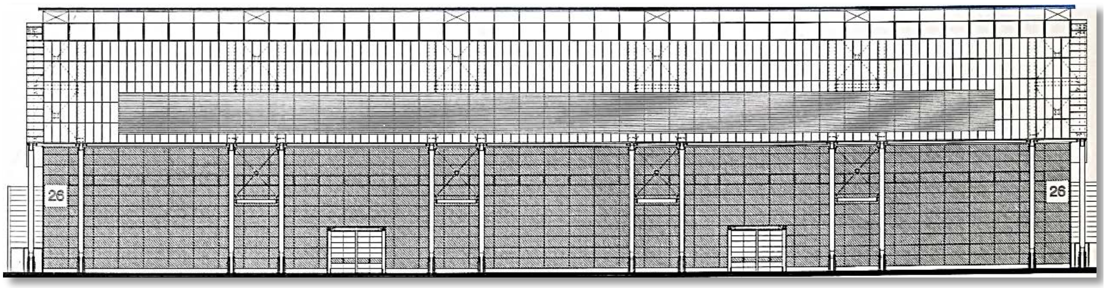


Figure 72: Hall 26, Hannover, plan view



South elevation

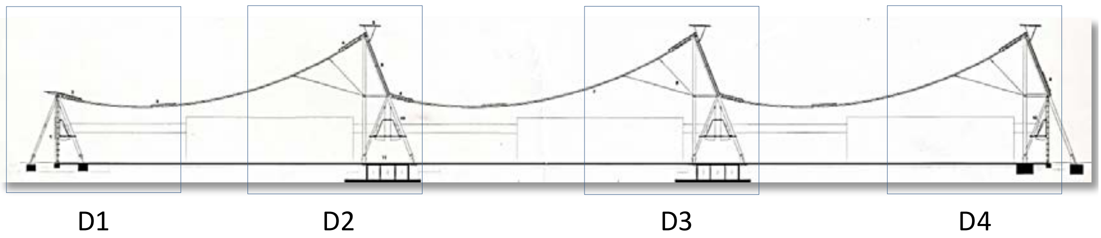


North elevation

Figure 73: Hall 26, Hannover, South & North elevations.

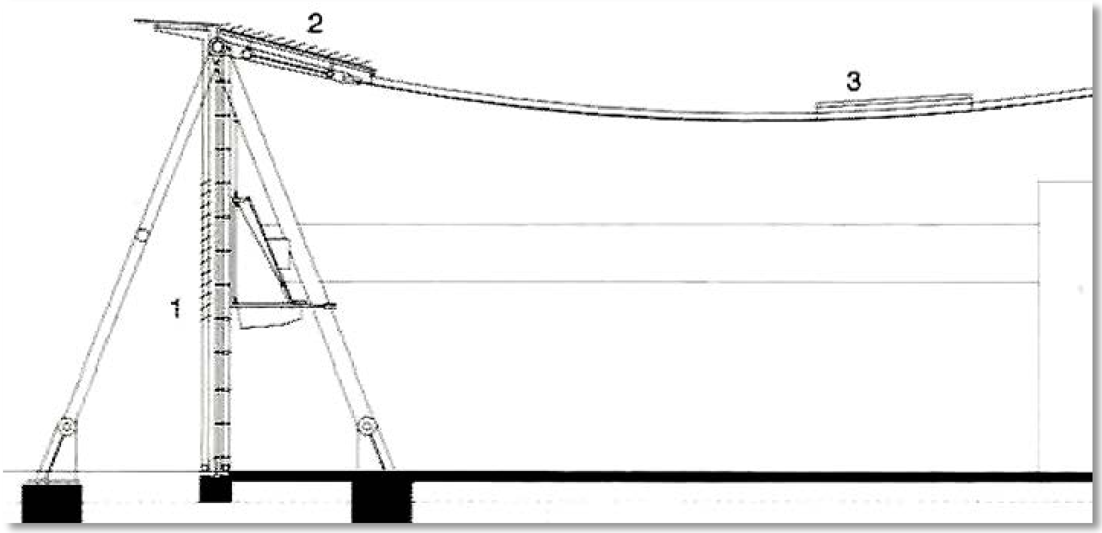
East elevation

1 external sunscreening (fixed louvers)
2 skylight with external sunscreening (Fixed louvers)
3 skylight with daylight grids
4 trussed girders with skylight
5 capping over smoke and heat exhaust flaps
6 large-area north-light glazing
7 suspension roof structure: timber panels on steel tie members; polished metal sheets to part of soffit, forming mirror surface for diffusion of light 8 anchor cables to stabilize roof against dynamic forces
9 light-deflecting elements
10 glass ventilation ducts
11 walkway
12 escape tunnel (below ground level)
13 service tunnel (below ground level)

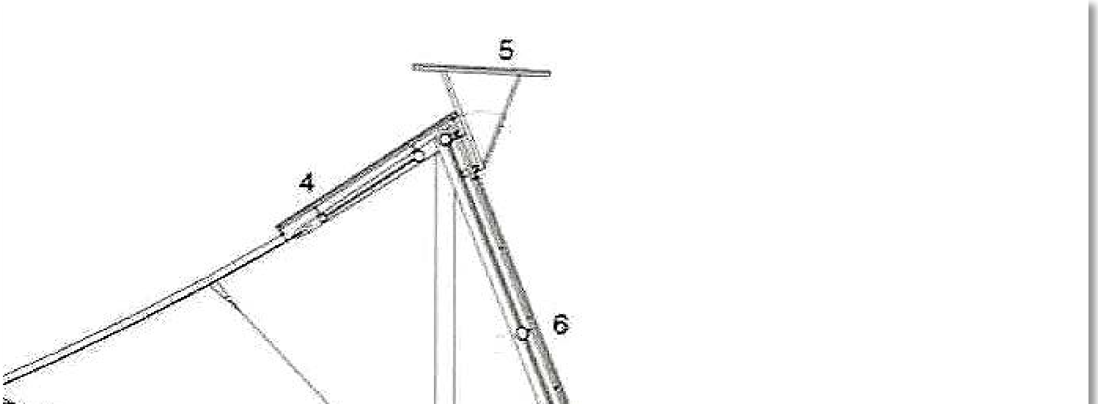


Longitudinal section

Figure 74: Hall 26, Hannover. East elevation, its Longitudinal section & Detail descriptions

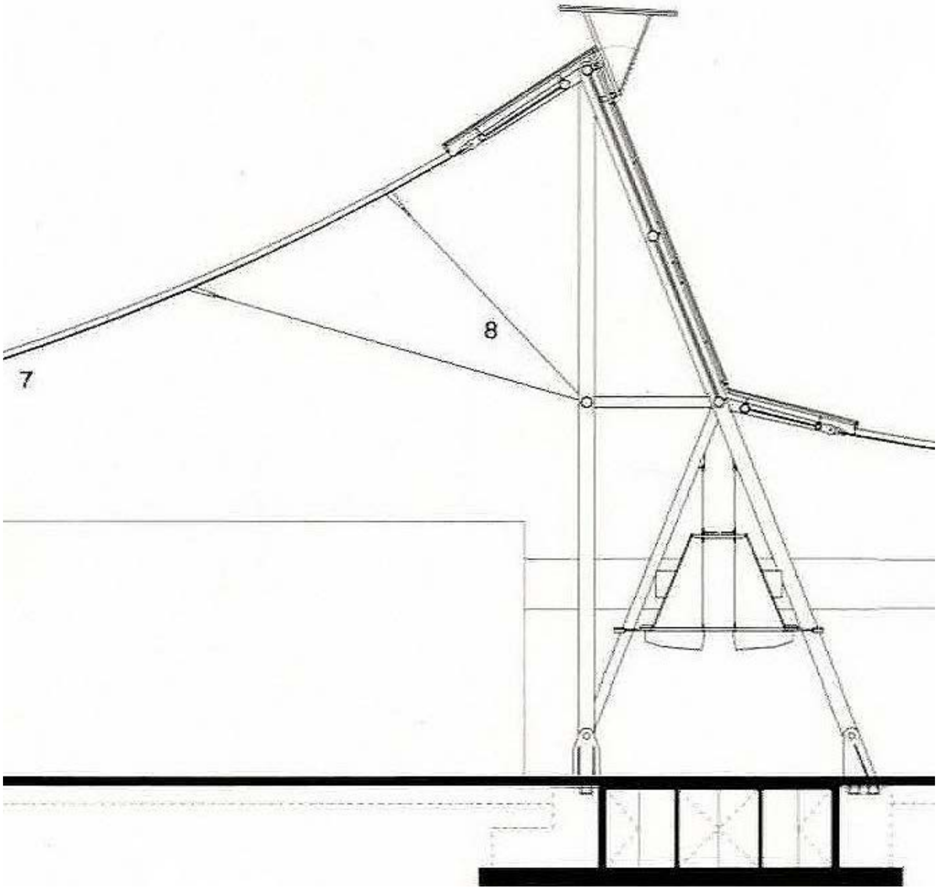


Detail Num. 1



Detail Num. 2

Figure 75: Hall 26, Hannover, Longitudinal section,Details 1 & 2



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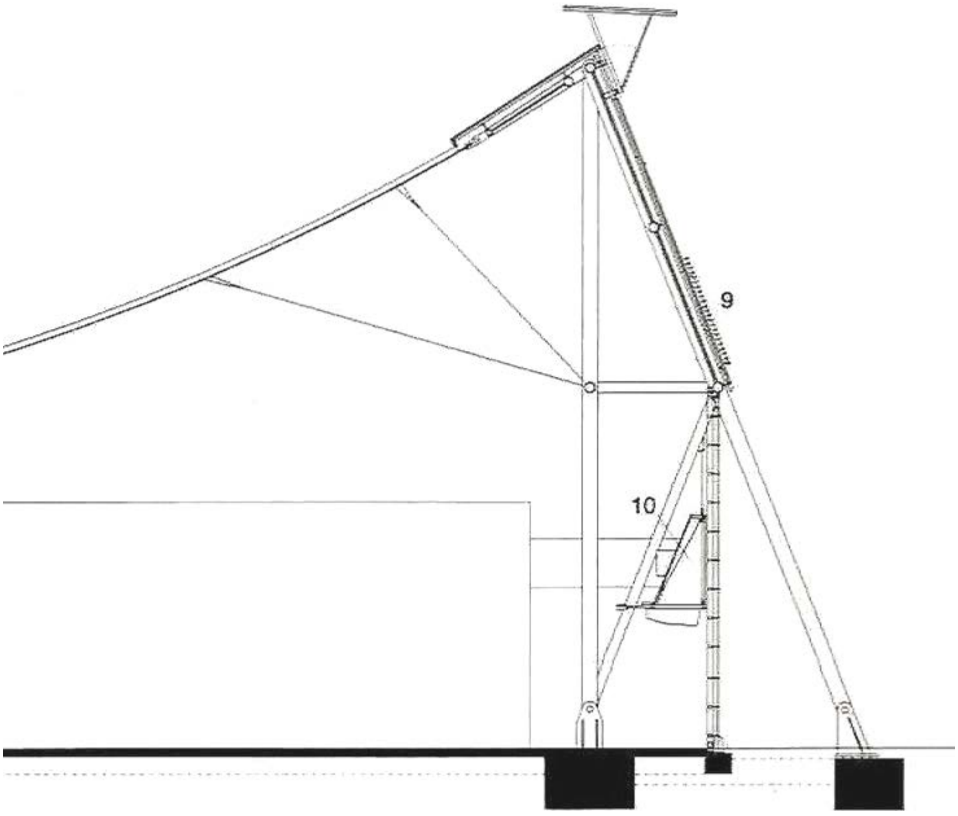

Details Num. 4

Figure 76: Hall 26, Hannover, Longitudinal section,Details 3 & 4

Actually, concerning concept for indoor climate, the silhouette or cross-section of the building is largely determined by two aspects: the formal laws governing the tensile structural roof system; and requirements for the natural control of the indoor climate and the exploitation of daylight.

Air circulation in most trade fair halls is from top to top and takes the form of a combined system. Here, in contrast, the cooling system functions from bottom to top. With a maximum floor loading of 10 tones/m², however, and with the need for major construction measures on occasion to create new temporary foundations for exhibits, an air-inlet system at floor level would not have been possible at a reasonable cost. A method was, therefore, designed by which air is introduced through special overhead canopies with large-area inlets. Fresh air is fed in at a height of 4.70 m and flows downwards, distributing itself evenly over the floor and penetrating to all areas of the hall. The air supply is via large glass ducts routed along the main lines of access (Figure 77&78). The transparent sides of these ducts help to retain the continuity of the internal space. In a similar manner to a fresh-air floor-inlet system, THE air is then borne slowly upwards by the heat generated within the space itself (by human beings, machines, equipment, computers, light fittings, etc.). (Herzog & Heckmann, 1996)

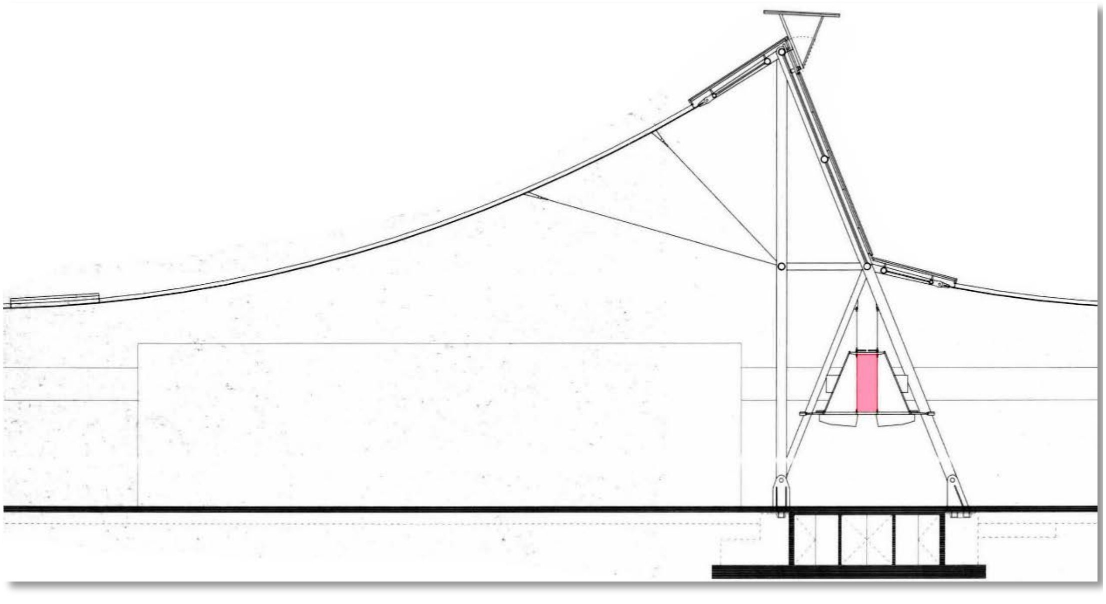

Figure 77: Hall 26, Hannover, Glass air duct: part cross-section

Figure 78: Hall 26, Hannover, Glass ventilation ducts

The evident advantages of this system lie in the better air quality and the greater degree of comfort experienced by those within the hall. Following the principle of thermal rising currents, used air leaves the building in the ridge zone. The system adopted for this scheme reduces the expenditure for mechanical ventilation by approximately 50 per cent.

For heating purposes, the installation can be switched to a system by which pre-heated air is injected horizontally via adjustable long-range nozzles.

The air circulation system was developed and tested on the basis of a 1: 5 model. The effectiveness of the natural ventilation and the superimposition of mechanical ventilation (Figure 81) were demonstrated both in wind-tunnel trials and through computer-aided simulations.
The continuous openings in the ridge zone can be opened or closed by a system of adjustable flaps. The flaps can be individually controlled, depending to the direction of wind currents, so that only suction forces are active at any one time. This system is supported by a horizontal capping over the crest of the roof, creating a kind of Venturi effect (Figure 79). (Herzog & Heckmann, 1996)

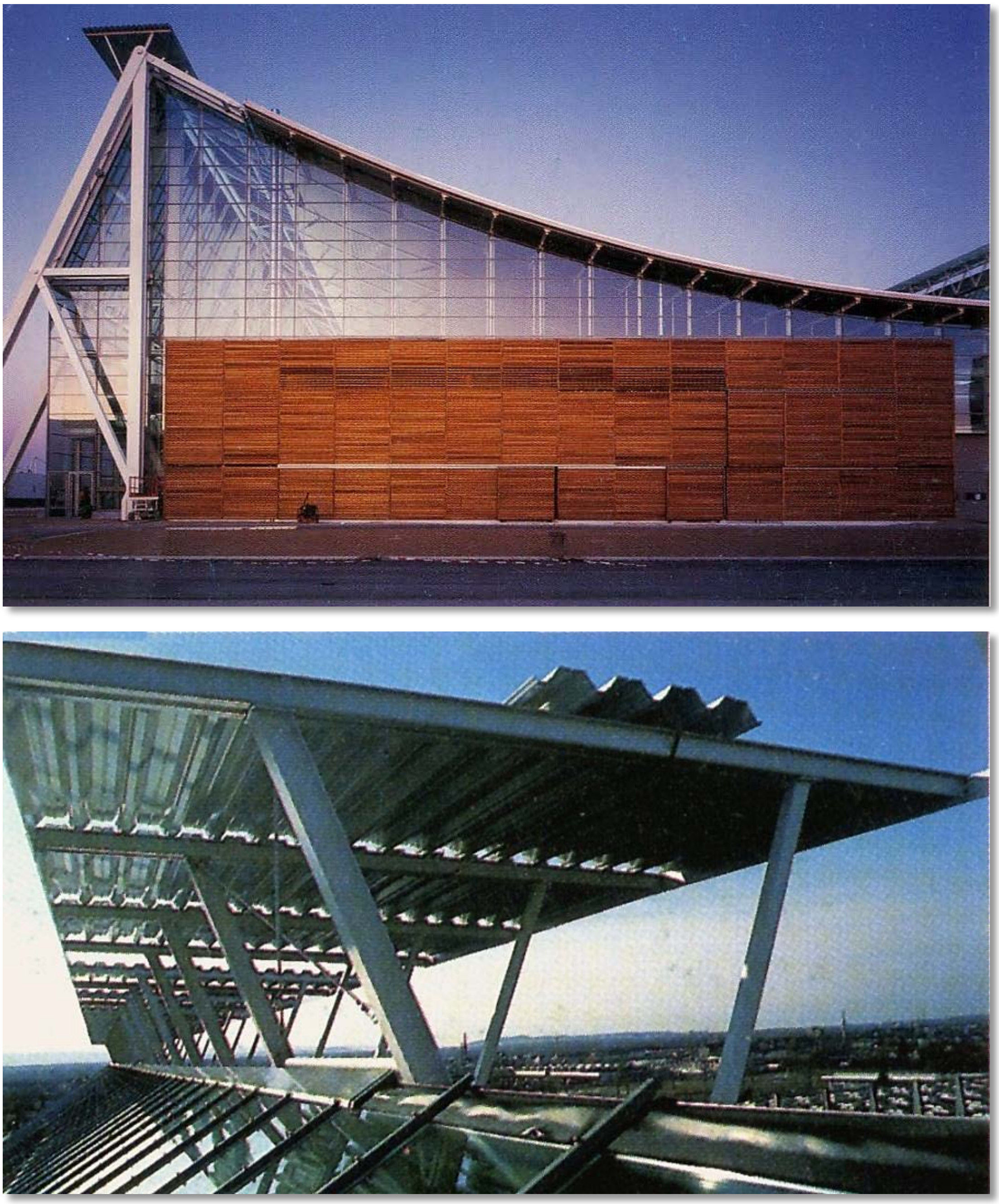

Figure 79: Hall 26, Hannover, "Venturi" capping over crest of roof

Additionally, if a building is unable to use cross-ventilation effectively, ventilation can be enhanced by utilizing the physical principle that cold air, which is denser than hot air, will sink towards the ground, pushing hot air up towards the ceiling. This is called the stack effect [24](Figure 80).

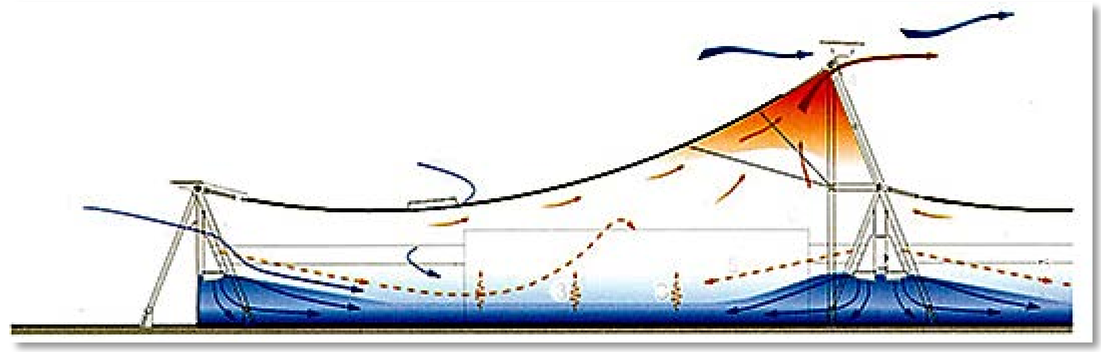

Figure 80: Hall 26, Hannover, Application of stack effect to draw heat out of a large volume space

The technique eliminates the need for a narrow building because heat can escape at predetermined intervals in the roof and does not require external differentials like cross-ventilation. By venting hot air through a small aperture in the ceiling, a pressure differential will be created which will increase the velocity of the air as it exits the building, creating an updraft which will further improve airflow. (Meredith, 2009)

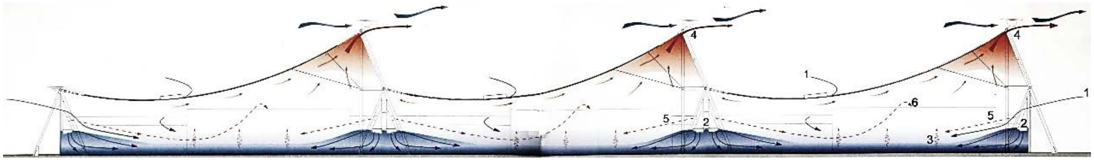

Diagram of Mechanical and natural ventilation (as installed), longitudinal-section

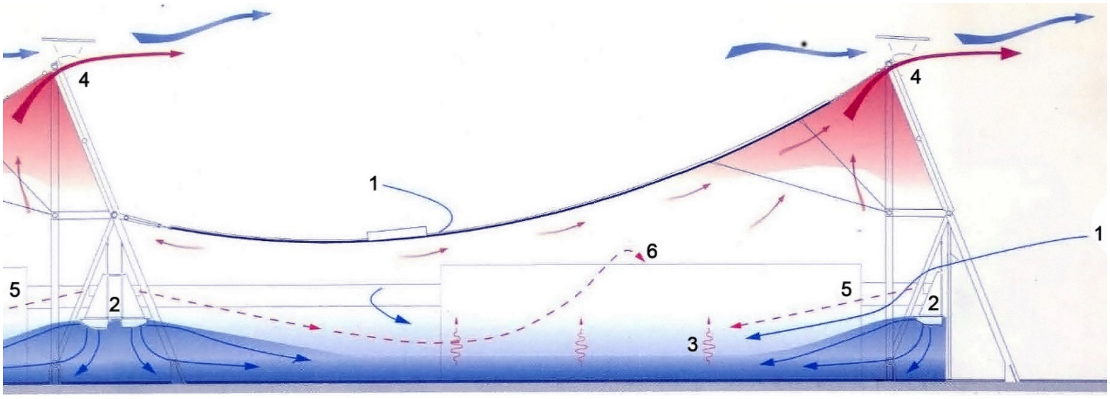

Diagram of Mechanical and natural ventilation (as installed),part longitudinal-section, close view

Cooling operation:
1 natural air supply via flaps in facade
2 glass ventilation duct with cool-air outlets in floor of duct
3 thermal up-currents(Thermal uplift) from Internal heat sources
4 natural ventilation(Natural air extract) via ridge flaps

Heating operation:
5 mechanical distribution of heated, intake, air via long-range nozzles
6 air extract via ventilation plant at sides

Figure 81: Hall 26, Hannover, Mechanical and natural ventilation diagram

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[24] [Stack ventilation] may occur via purposefully built vertical ducts or via an internal atrium or other type of vertical spacial continuity within the building. Stack ventilation is buoyancy driven and relies on density differences to draw cooler, denser outdoor air into a building via low level vents and to exhaust warmer, less dense indoor air via high level vents

Actually, concerning daylighting and artificial lighting (Figure 83&84), Natural lighting (Figure 82) within the hall occurs via large north lights along the main steel structural supports and via light grids in the roof at the lowest points of the suspension bays. Light-deflecting elements channel daylight through the large “reflector" roof of the hall into the public areas. The supplementary lighting and the artificial lighting systems follow the same principle, whereby the convex surfaces of the soffit are used to diffuse light. (Herzog & Heckmann, 1996)

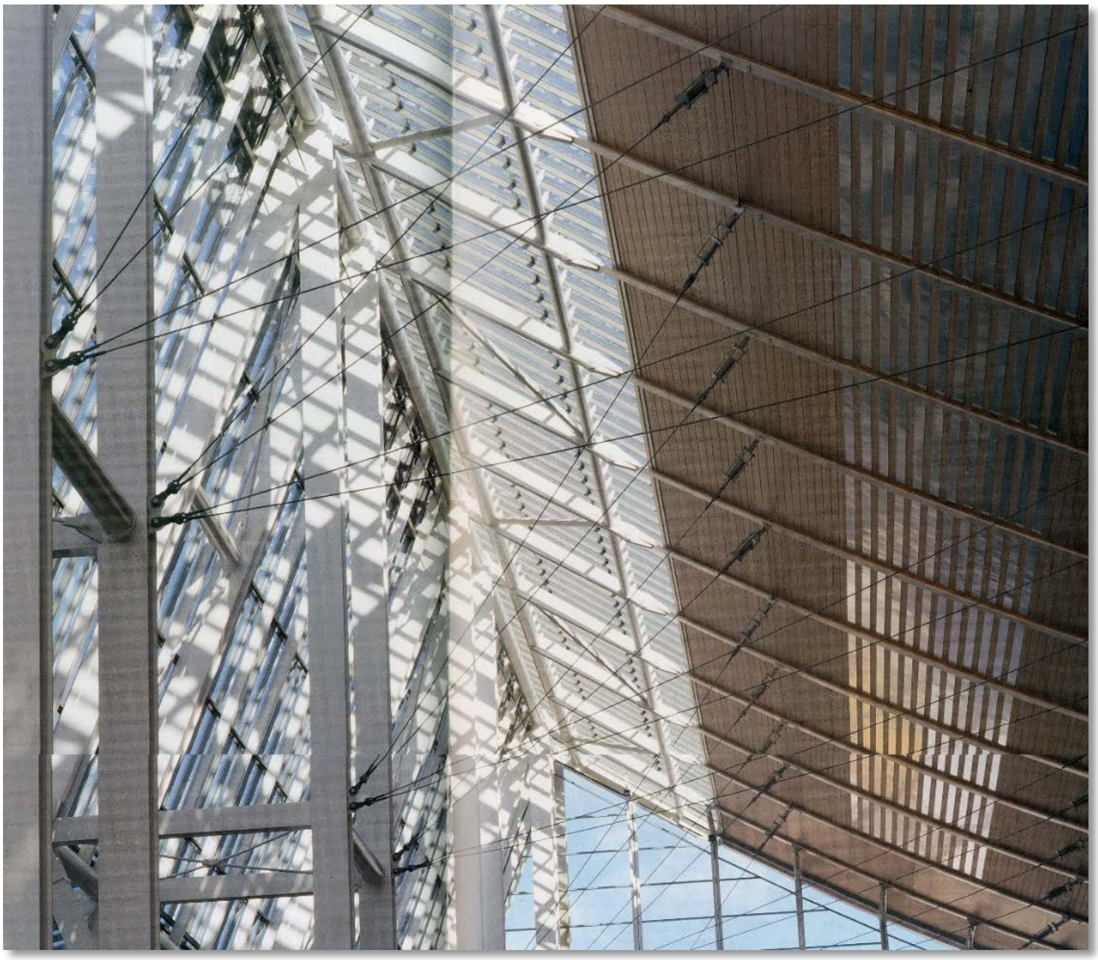


Figure 82: Hall 26, Hannover, Daylight deflection via reflectors

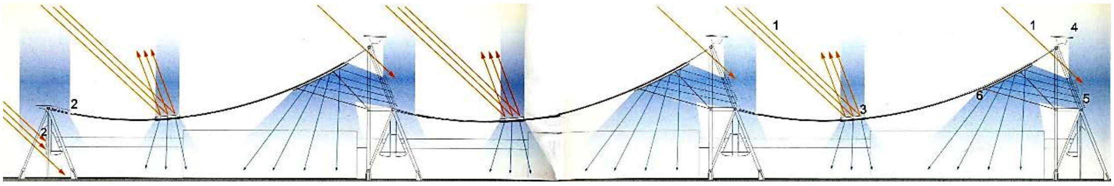
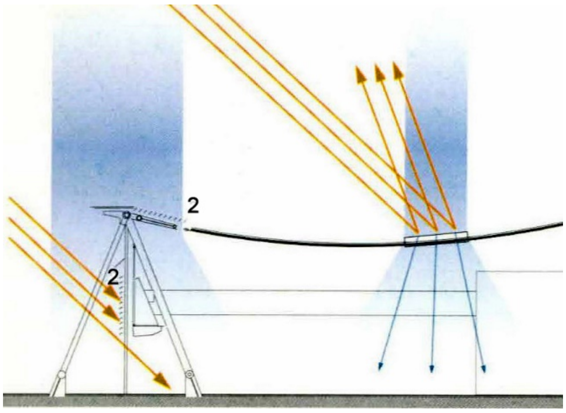


Diagram of Daylighting system: longitudinal-section

Diagram of Daylighting system: part longitudinal-section, close view

1 direct sunlight
2 external sunscreening (sunshading) on south façade and roof
3 triple glazing with daylight grids; reflected sunlight
4 diffused daylight
5 louvers for light deflection
6 mirror soffit



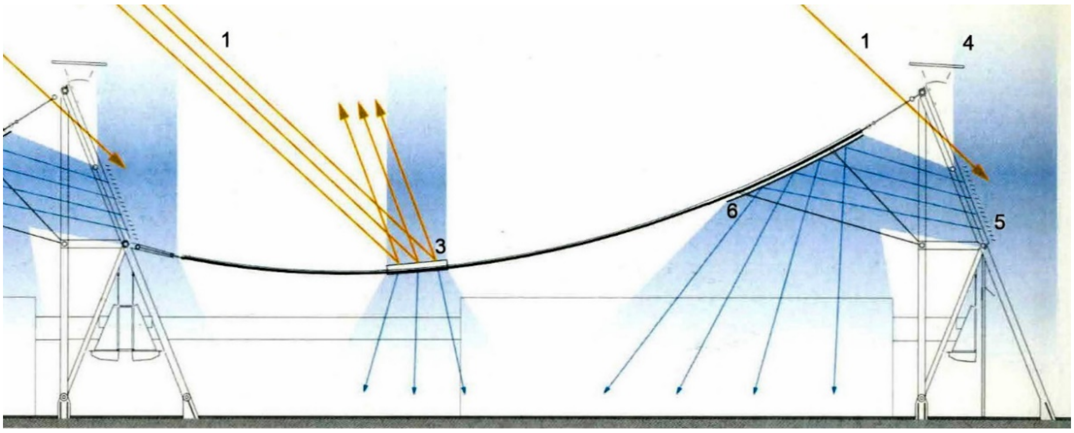


Figure 83: Hall 26, Hannover, Daylighting system diagram

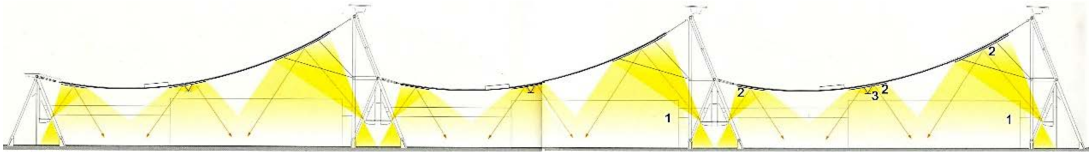


Diagram of Artificial lighting system: longitudinal-section

Diagram of Artificial lighting system: part longitudinal-section, close view
1 glass duct with light fittings at sides
2 indirect lighting via mirror soffit
3 suspended lighting strip

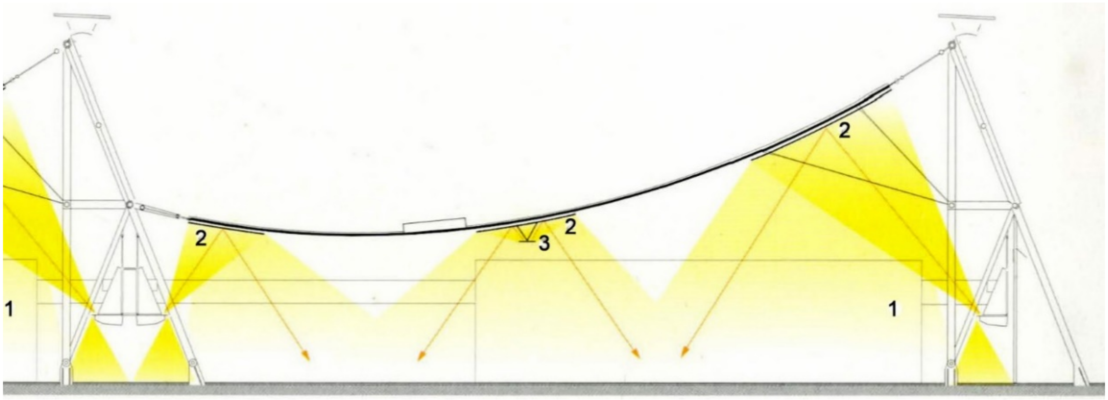


Figure 84: Hall 26, Hannover, Artificial lighting system diagram

Rainwater runs off via the convex counter-curvature of the roof to the eastern and western outer edges. (This secondary curvature also greatly enhances the quality of the internal space (Figure 85)). The design measures described above meant that the huge roof areas and the exhibition spaces could be kept free of mechanical services. These are concentrated at a single point: along the glazed ventilation duct and air inlet canopy.

As a result, it was possible to create a bright, high, generous space - and an efficient architectural form - the specific characteristics of which are communicated in an aesthetically direct manner.

Light deflection and diffusion systems, as well as the layout of the artificial lighting, were also optimized by means of simulation trials. (Herzog & Heckmann, 1996)

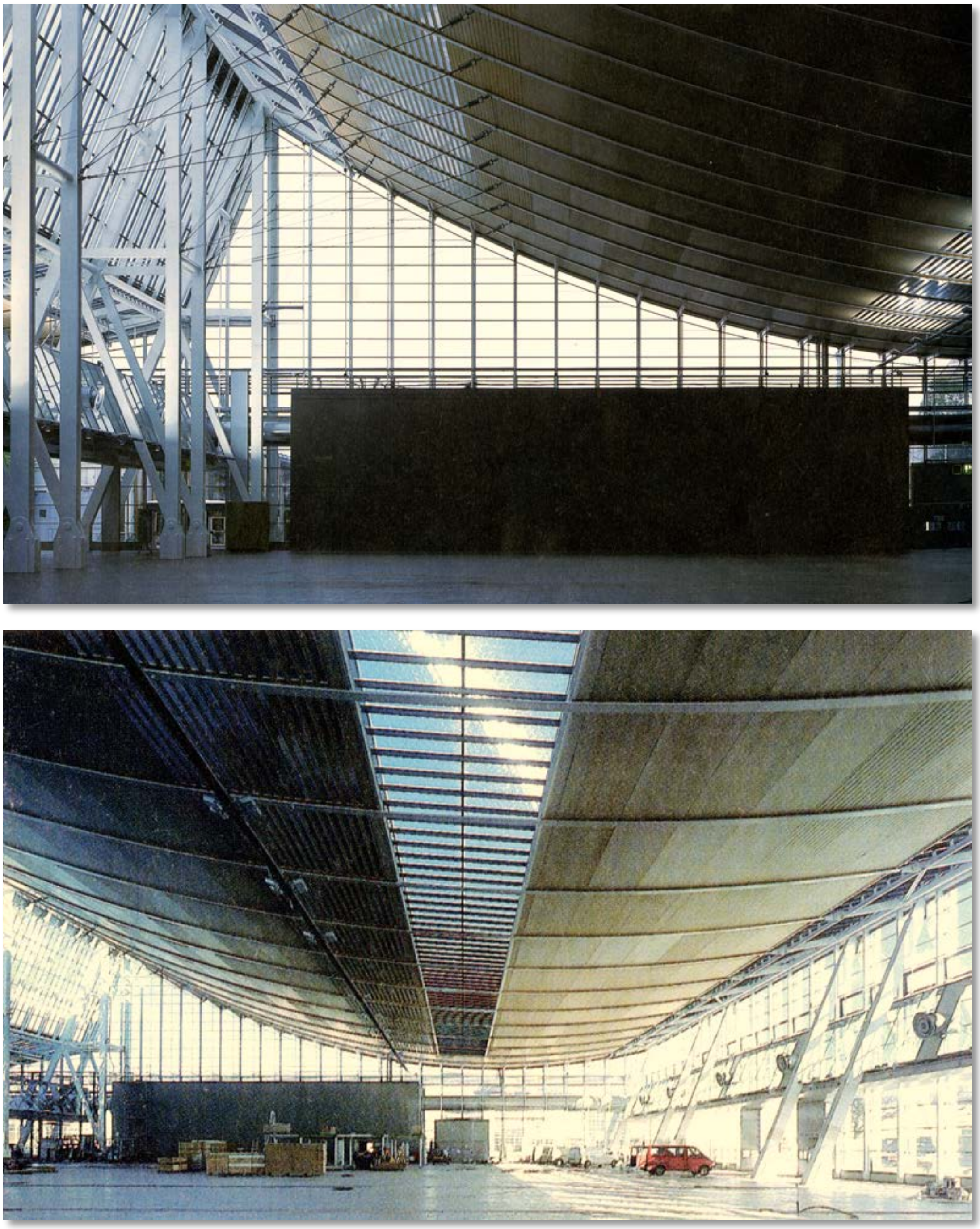


Figure 85: Hall 26, Hannover, The curvaceous roof

In fact, concerning facades, large areas of the facades and the roof were designed to allow the ingress of daylight while reducing insolation.
The glazed facades were executed in a post and rail form of construction with slender hollow sections (Figure 86&87). Wind pressure and suction forces occurring over the great height of the facades are absorbed via a separate internal system, consisting of pairs of channels 220 mm deep, to which the filigree façade rails are fixed with

adjustable connections. The transmission of horizontal loads to the structure occurs at the top via a hinged connection to two suspension members at the edge of the roof. Potential deformation is avoided by prestressing the vertical elements. (Herzog & Heckmann, 1996)

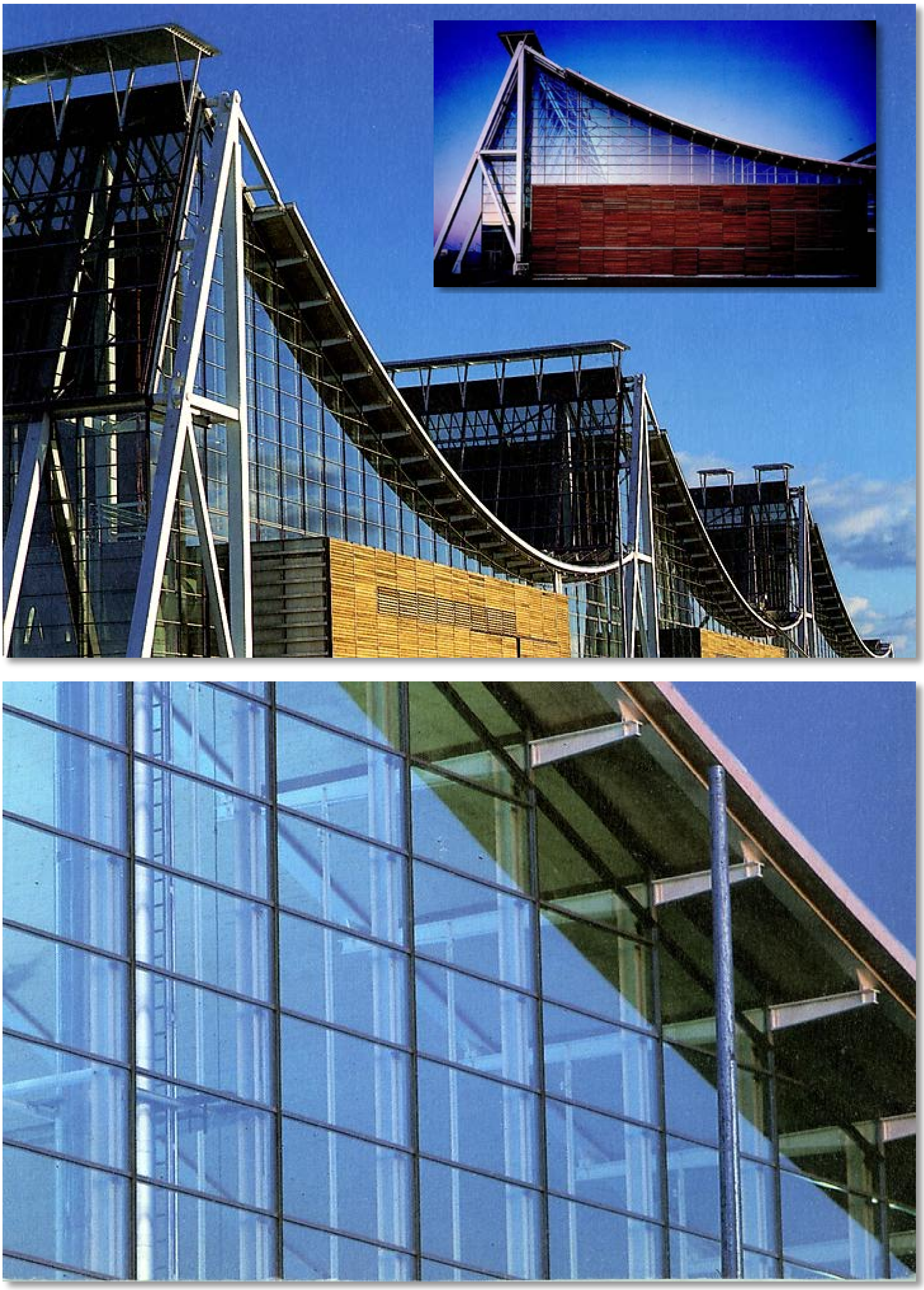
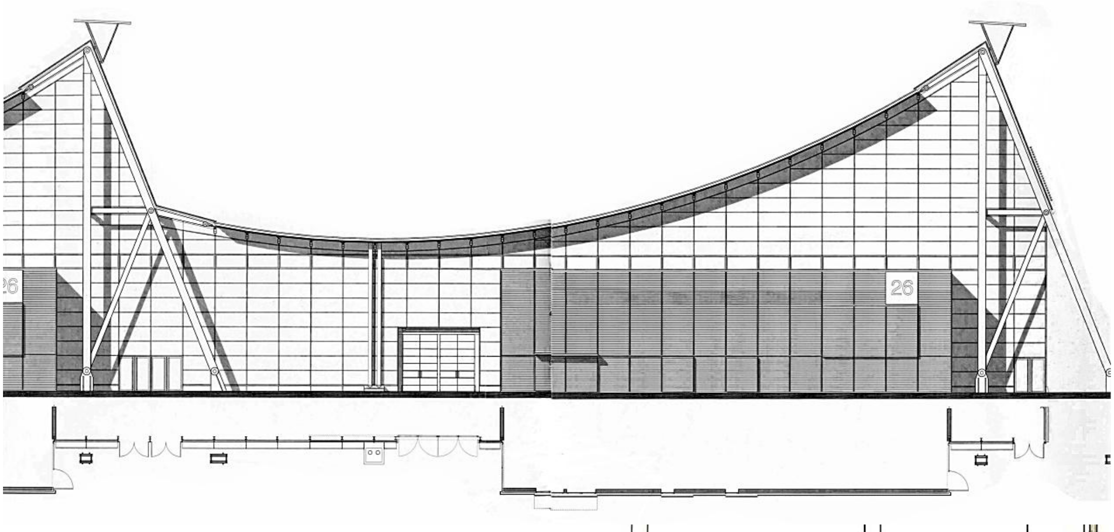
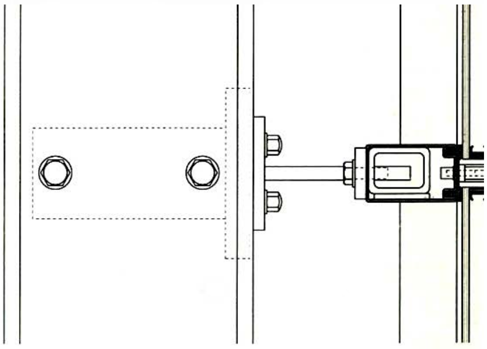


Figure 86: Hall 26, Hannover, glazed facades



Vertical section through facade



Horizontal section through façade

1 Channel 220 mm deep
2 170/80/40 mm sheet steel with 16 mm dia. Threaded borings
2 Halfen fixing channel 150mm long Rail fixing piece (with scope of adjustment to accommodate vertical and horizontal tolerances)
3 Façade rail: 80/50 mm steel hollow section
4 Façade post: 50/50 mm steel hollow section
5 Sunscreen glazing
6 Cover strip

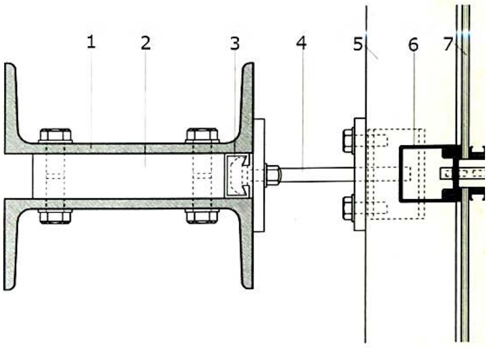


Figure 87: Hall 26, Hannover, Façade horizontal & vertical sections

One of the outstanding features of the major trade fairs held on this vast site in Hanover has always been the well-organized yet unobtrusive sequence of arrival, visiting the exhibition and departure (Figure 88&89). (Herzog & Heckmann, 1996)

Figure 88: Hall 26, Hannover, Hall 26 during trade fair

Figure 89: Hall 26, Hannover, Restaurant with soffit light-deflectors

In an overall view, the existing building on the Hanover Trade Fair site illustrates the tradition of the fair as a location for impressive buildings and future-looking architecture. One important phenomenon in this respect is a clearly recognizable trend in the use of resources. It manifests itself in a step by step progression from the economic use of basic resources to the restrained use of energy and a deliberate shift to the exploitation of environmentally friendly forms of energy. This has ultimately led to a new approach, in which environmentally sustainable forms of energy has been intensively exploited for heat gains, cooling, natural ventilation, lighting and finally for new forms of power generation. In this respect, solar energy becomes a key factor in terms of design and aesthetics while representing advanced forms of construction in terms of technological developments. This leads to open up more and more perspectives for durability and sustainability in buildings.

Additionally, the programmatic and structural ideas implemented in Hall 26 go far beyond those of traditional hall types. The logic of the new concept underlying the brief, a changed understanding of technology, and the sculptural gesture of the form-plus the sense of innovative inquiry informing the structural design - communicate themselves through the outline of the hall. In its functionally motivated longitudinal section, the structure acquires a new independent status: as a space of climatic dynamics; as a space of natural light, and as a space for reflection.

Furthermore, Hall 26 exhibits a strikingly new dynamic expression in the relationship between structure and outward appearance. Changes that have occurred in the energy and indoor climate concepts of buildings in the course of time are reflected in the modified longitudinal section. The dynamic correspondence between the structure and the three-dimensional volume of the hall is sensuously legible. For the observer, it is an experience in itself. The structural form, designed to articulate the conceptual principles, was not concealed during the fitting out stage beneath masking layers and cladding. It remains clearly and attractively visible. The design principles underlying the structural engineering are evident: characterized by its polyvalency, complexity and yet great clarity, the building is an example of reflexive modernism[25]. (EXPO, 2000)

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[25] A concept of design that takes account of the breadth of technological developments and respects the reflexive idea of sustainability in its present form belongs to the more complex definitions of construction. The theory of reflexive modernization provides the occasion for a “volte-face of modernism” (Scott Lash), which would put an end to the increasingly relentless destruction of our “habit” by the “system”.

2-3-6 Administration building, Deutsche Messe AG (DMAG), Hannover 1996-99

Thomas Herzog is one of the very few true (constructional) scientists among German architects - and indeed among university teachers of architecture. He comprehends building in its entirety. His sphere of activity is the academy and the workshop. He attaches great importance to the culture of doing things.

"From the very beginning, Herzog has addressed himself in his research work to the efficiency of highly developed, innovative forms of construction." He describes his goal as "efficient form, convincingly designed". A good example of the tenacity and perseverance of this “researcher of materials" may be found in the façade cladding to the two core structures flanking the central glazed office tower in Hanover. The facings are based on studies of lightweight, non-load-bearing forms of external wall construction, which Herzog has pursued since 1978. The cladding to the tower in Hanover represents an optimized development of a system first used in Lohhof near Munich in 1984. It consists of a form of construction using clay tiles fixed to a supporting structure and with a ventilated cavity to the rear. The system provides weather protection for existing and new buildings and is erected over an external layer of thermal insulation. Architecture does not have to be reinvented every Monday.

Hanover's architecture may not be particularly spectacular. It is, however, distinguished by a quality of clarity and moderation. (Herzog, 2000)

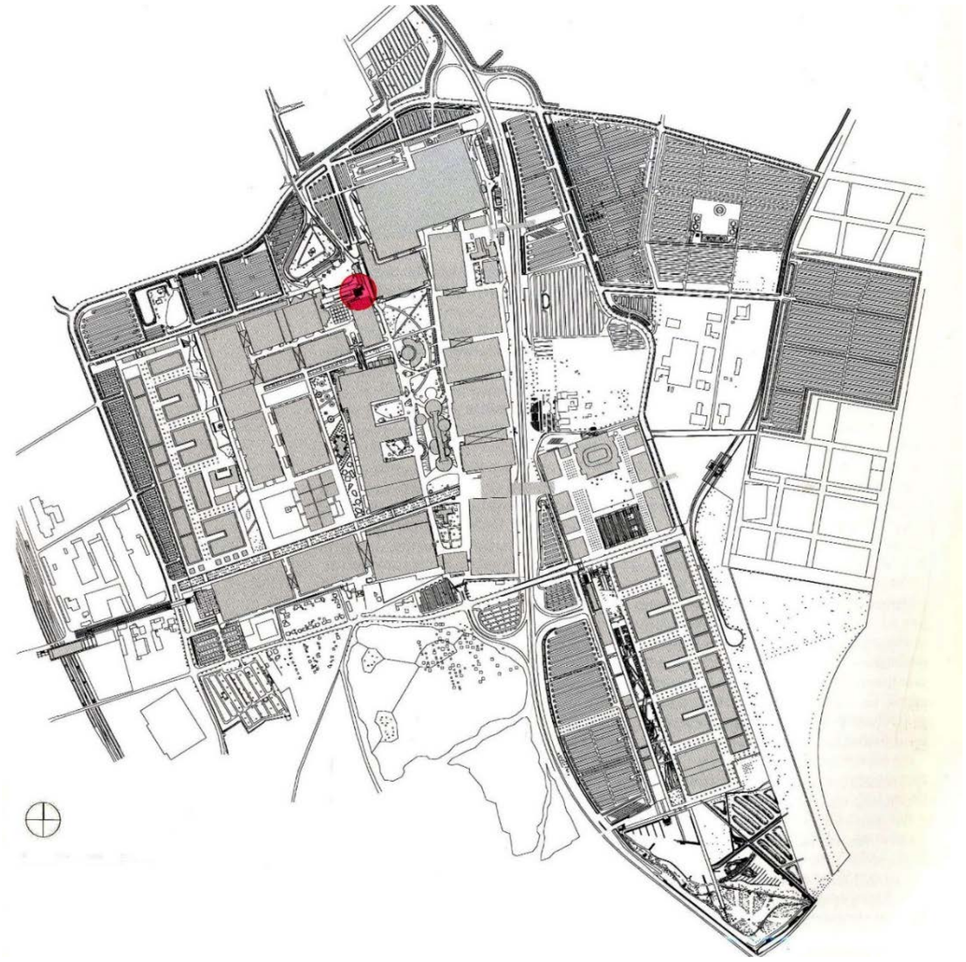
The project was for the extension of the existing administration building. After a series of alternative investigations and the considerations of a number of different sites, the conclusion was reached that only one location was really suitable for the purposes of the trade fair organization. But the site was of limited size, so that the building had to be developed vertically.

Since the clients were prepared to support that proposal, they (Herzog and his design team) were able to demonstrate that one could build a modern administration building to low construction costs, a building that would nevertheless require a minimum of operating energy – all without sacrificing comfort and other amenities, such as telecommunications, workplace and lighting quality, visual links, scope for communication, high-quality equipment and finishings, and good artificial lighting. Thomas Herzog mentioned that, if one was prepared to accept solutions that use state-of-the-art technology for which no technical standards was existed - like the special form of double-skin facade or the thermal activitation of building components (heating and cooling) - a level of energy consumption for the regulation of the indoor climate could be achieved that is lower (by at least a factor of 10) for a high-rise administration block than the average for existing office buildings in Germany. (Herzog et al., 2001)

In fact, as a building type, high-rise structures are not usually regarded as compatible with the conservation of resources. In the present case, it proved possible to design a "sustainable" building that refutes this opinion - through a new interpretation of spatial functional concepts, by coordinating the form of construction

with the energy concept, by applying sound principles of building physics and exploiting locally available forms of environmental energy.
As well as taking account of environmentally relevant issues, high quality in the workplace and flexibility of use were the main criteria in ensuring that the building could adapt to changing working needs over a long period. (Herzog et al., 2001)

Administration tower for the trade fair organization. Located near the northern entrance to the site and visible from afar, this singular free-standing structure is an extension of an existing office block and is the tallest building in Hanover (Figure 90). Designed by Thomas Herzog, Hanns Jorg Schrade and their team, it reflects the conditions of the brief, which required high-quality workplaces and an innovative exploitation of environmentally friendly forms of energy. In other words, the design parameters were working comfort and low energy consumption. The great height of the building was determined by the tight site conditions. Architecturally and in terms of the urban planning, the tower is oriented on the diagonal: the recessed, three-story entrance hall is fully glazed and thus creates a link between the (public) forecourt at the northern point of access and the (semipublic) landscaped area of the trade fair site. In other words, the structure connects the city with its trade fair. (Herzog, 2000)



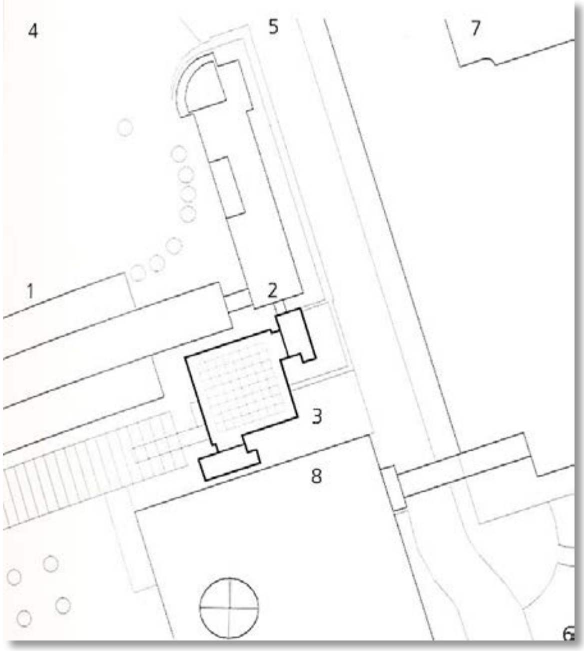
the administration building near the northern entrance is at the top in the red circle, with the trade fair site and the pavilions for the World Exposition laid out around it; right: Brusseler Strasse urban railway station; extreme left: the intercity-express rail route with Hanover-Laatzen Station

Figure 90: Deutsche Messe AG (DMAG), Overall EXPO site plan

In fact, concerning building volume and form of construction, the decision in favor of a high-rise building was the outcome of the tight site conditions. The layout is articulated into a square office tower roughly 24 x 24 meters on plan and two "core" or access structures to the northeast and south-west (Figure 91). This resulted in single-story functional units of not more than about 400 square meters in area, which in turn meant that it was possible to avoid more stringent building regulations for this type of building. By setting the staircases diagonally opposite each other, ideal fire-safety conditions were created for users in terms of escape routes. (Herzog, 2000)

Site plan of administration building at northern entrance(winter *1999/2000)*

1 Northern entrance to trade fair
2 Existing administration building
3 New administration building
4 Rapid suburban railway station
5 Northern approach to trade fair
6 Landscaped areas
7 Hall 1
8 Hall 18



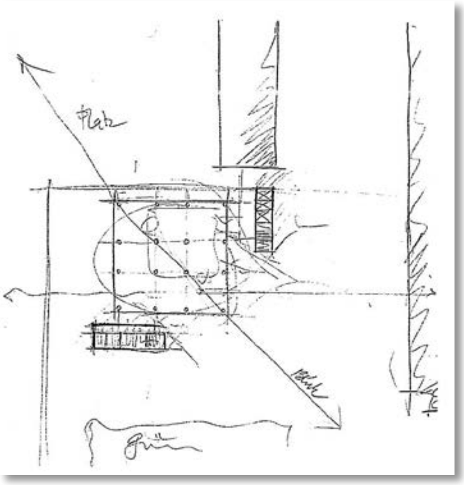


Figure 91: Administration building, Hannover, Site plan & conceptual sketch

Of central importance to the architectural design is the transparent volume of the building and its spatial orientation on the diagonal from the northern site entrance to the large landscaped open space to the south-east. The southern access area, which is protected against the weather by setting back the facade, serves as the vehicle approach route.

The building has 20 full stories (Figure 98-105), comprising

- A recessed entrance hall three stories high
- 14 office stories (standard floors)
- An executive floor with board rooms
- The "Hermes Lounge"
- A mechanical services story.

The individual floors can be divided up in different ways. Depending on requirements, between 15 and 20 office workplaces can be located next to the facade on each floor. The offices can be in the form of open-plan, combination or individual unit spaces. It was possible to achieve virtually the same level of quality for all workplaces especially in terms of comfort, but also in respect of organization and the technical infrastructure. The central zone of each office story is used for communal purposes.

The fully glazed new entrance hall – accessible from the west and south - is foreseen as the main point of access to the trade fair administration in the event of a redesign of the northern entrance to the site.

Beneath the entrance level is a basement with spaces for mechanical services. A linking tract connects the individual floors of the existing administration building to the new structure. The central office tower has a maximum height of 67 meters up to roof level. The floor level of the uppermost occupied space is just below the 60-metre limit. The two outer core structures are laid out and dimensioned in such a way that they reduce or shade the areas of glazing to the south and east faces of the building. In view of the fully glazed office facades, this is an important factor in terms of overheating and glare.

The north-east core serves principally as a means of vertical circulation, containing passenger lifts and a staircase. The south-west core houses the sanitary facilities as well as a further staircase and a firefighting/goods lift.

Both staircases lead up to roof level (+ 66.5 m). The north-east staircase also provides access to the basement. The passenger lifts in the north-east core serve the topmost level in which there are occupied spaces (Hermes Lounge, + 58.3 m). The firefighting lift goes up to the services story (+ 62.3 m). The north-east core has an overall height of 85 meters, excluding roof structures such as the ventilation tower, aerials, etc. In this core, the stories above the tower roof level used exclusively for services are reached via an internal spiral staircase (Figure 92). The southwest core has an overall height of 70 meters. (Herzog, 2000)

Figure 92: Administration building, Hannover, Roof level

A reinforced concrete skeleton frame system was used for the load-bearing structure of the new administration building. The insitu concrete slabs are supported by 16 columns at 6.30 and 7.80 m centers. The reinforced concrete walls to the stiffening cores are 40 centimeters thick. The northern core is surmounted by a steel tower structure. (Herzog, 2000)

Actually, concerning facades and thermal and ventilation Concepts**,** The core towers are clad externally with a clay-tile curtain wall construction based on the Moding Argeton system (Figure 111). The cladding is fixed to an aluminum supporting structure and is ventilated by a cavity to the rear. The pale pearl-grey color of the tiles, which was specially developed for the trade fair tower, is the natural color of the ceramic material. In other words, it is not a surface pigment. Facing slabs with horizontal grooves were used here for the first time. The grooves have the advantage that they retard the flow of rainwater over the facade and thus prevent the water being driven upwards by high winds at the top of the building. The grooves also reduce extreme stresses in the tiles during the manufacturing process. The visual emphasis placed on the horizontal lines is accentuated by the especially narrow vertical joints.

Both skins of the two-layer facade around the offices are in double glazing. Flint glass was used in the outer skin to ensure a greater degree of transparency and to minimize color distortion in the view out from the interior. The inner skin of the double façade (Figure 93&94) is a wood-and-glass construction, with service ducts integrated into the apron panels beneath the windows. The outer skin is in a steel post-and-rail form of construction. (Herzog, 2000)

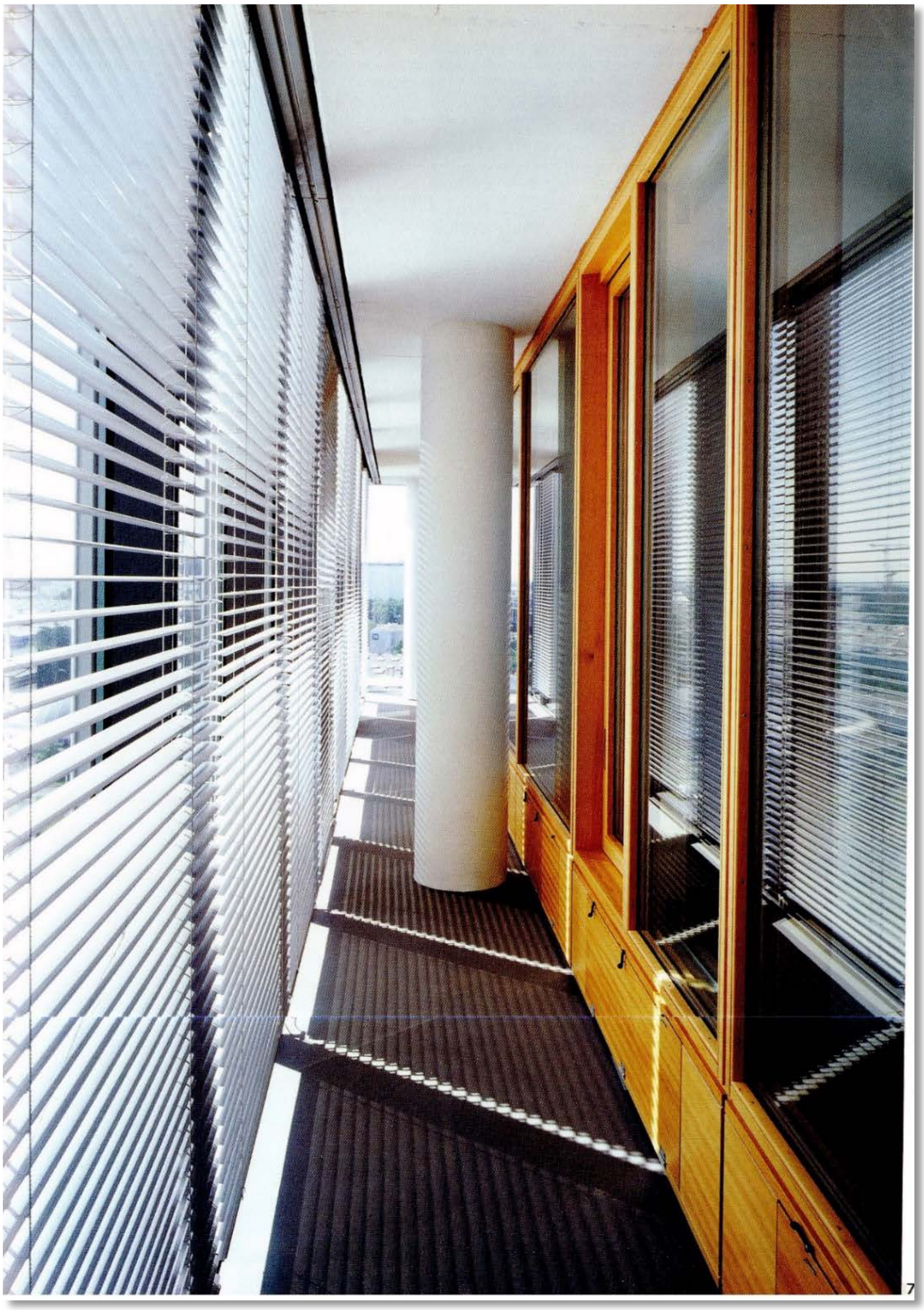
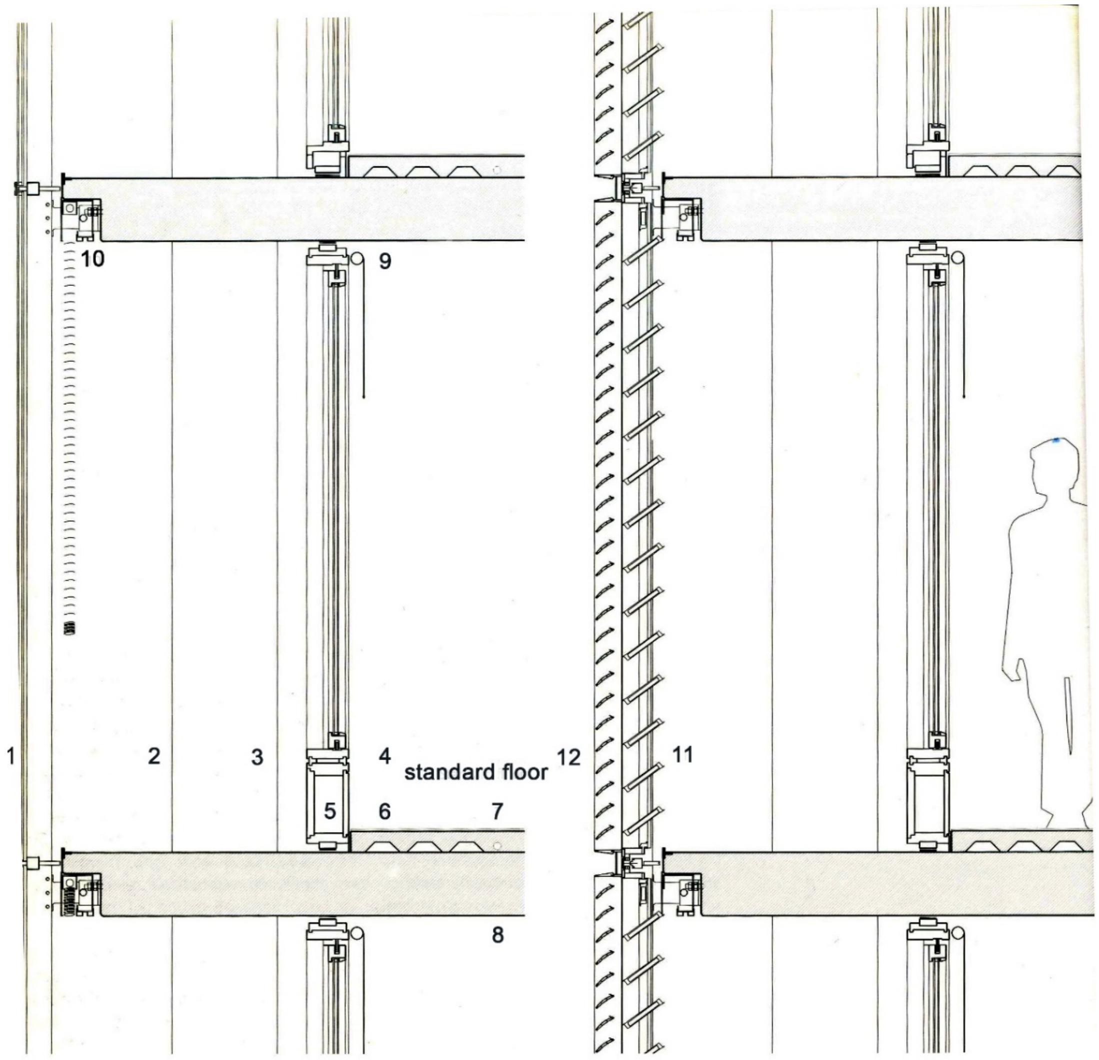


Figure 93: Administration building, Hannover, Intermediate space between façade skins



1 Metal and glass facade: hollow steel section posts and rails with aluminum cover strips low-E glazing – flint glass
2 Intermediate space in two-layer facade - air corridor
3 Rein forced concrete column
4 Wood and glass facade with sliding doors for natural ventilation; low-E glass
5 Air-supply duct for mechanical ventilation
6 Subfloor conduit for electrical and communications technology
7 Heating and cooling runs in 10 cm screed
8 Reinforced concrete floor slab
9 Anti-glare blind
10 Sunblind
11 Adjustable glass louvers with automatic setting (Figure 95): low-E glass
12 Protective louvers construction

Figure 94: Administration building, Hannover, Sections through two-layer façade; Left: fixed glazing; right: louver strip

Figure 95: Administration building, Hannover, Adjustable glass louvers with automatic setting

The use of this special double-facade construction - or horizontally continuous “corridor facade“- offers a number of important advantages.

- Since the external skin has the sole function of providing protection against the weather and is of a geometrically simple design with a construction reduced to only a few very resistant elements, it can be assembled step by step following the erection of the load-bearing structure. As a result, the inner facade layer, which is technically and functionally far more elaborate, can be installed independently of weather conditions and under much more favorable circumstances as part of the fitting out of the interior.
- The peripheral corridor functions as a large-volume ventilation duct. Depending on pressure conditions, automatically controlled louvers in the outer layer of the facade admit external air into this space. From here, the air enters the offices via openable windows. The location of the bays of louvers was determined on the basis of elaborate wind-tunnel tests and simulations.
- The office stories used by the staff are enclosed within a thermal buffer zone. This form of construction helps to cut energy consumption and also ensures a pleasant working environment by reducing insolation and providing users with a high degree of indoor thermal comfort.
- Adjustable sunshading can be installed in a simple form in the space behind the outer layer of glazing, where it is accessible for maintenance and protected against the weather.
- The glazing (Figure 97) to the various stories can extend down to the floor. This guarantees a good level of daylight internally and also creates a sense of ample space (Figure 96). The cantilevered floor slabs ensure that users do not

experience any sense of vertigo as a result of the great height of the tower. (Herzog, 2000)

Figure 96: Administration building, Hannover, Interiors

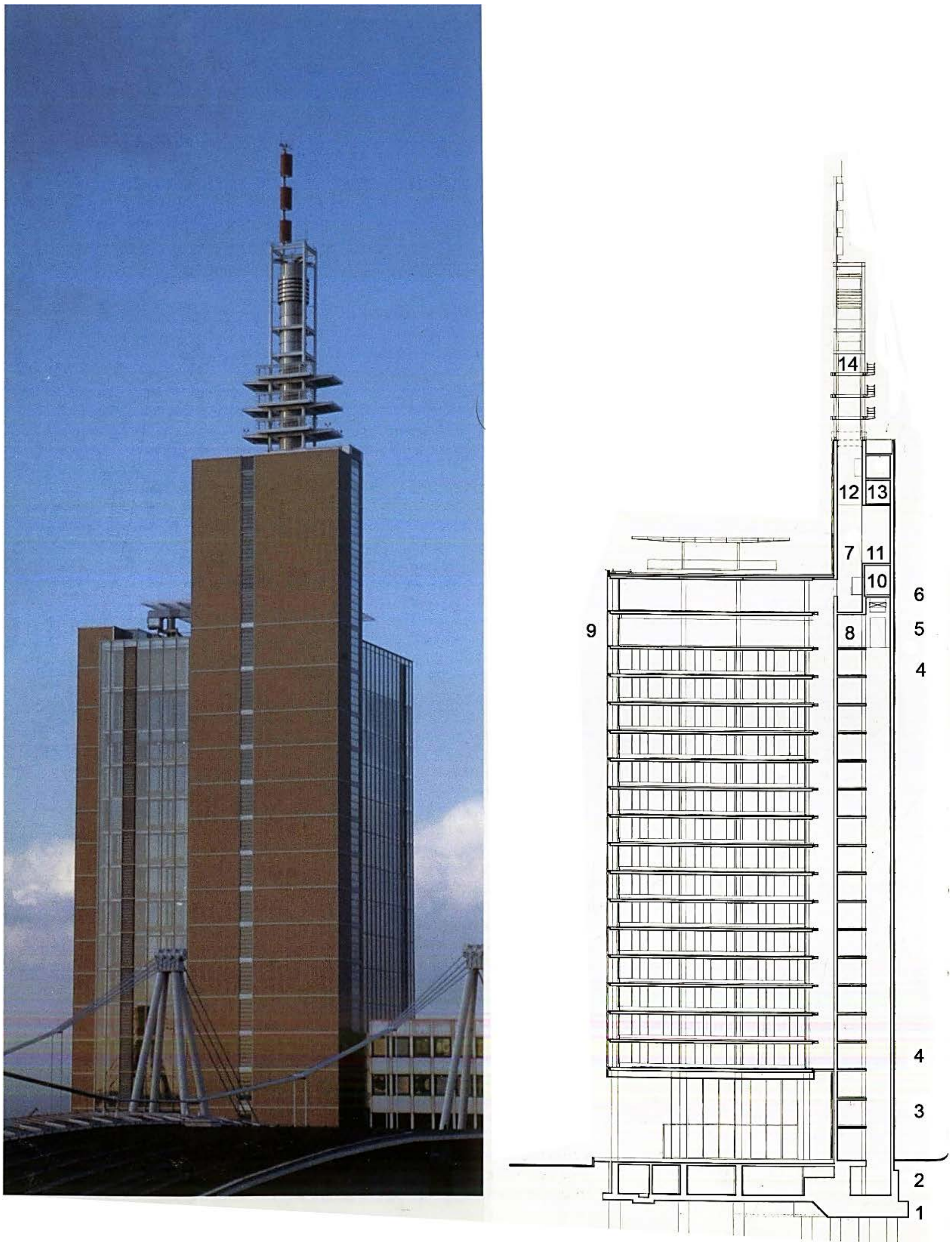
- The cantilevered sections of the floor slabs can be constructed as fire-breaks without the thermal separation that would normally be required.
- The columns in the intermediate corridor space do not obstruct the actual office areas.

Figure 97: Administration building, Hannover, Extended glazing

Heating and cooling are based primarily on the thermal activation of the solid volumes of the building. The unclad floor slabs with monolithic screeds function as thermal storage elements for the heating and cooling systems laid in the screeds. In other words, the structural members themselves are subject to heating and cooling (also known as a "thermoactive slab" system). In conjunction with the ventilation installation, these thermal systems ensure an ideal indoor climate with scope for individual control. Internal heat sources (people, equipment, lamps, etc.) are more or less adequate to heat the building during the hours it is in use.

Unwanted heat, resulting from insolation in summer, is removed directly – without entering the offices - by the large volume of air flowing between the inner and outer facade layers. At the same time, the double-facade construction acts as a "protective shield", balancing out wind forces of varying intensity that hit the building. This buffer zone also forms a means of naturally ventilating the office spaces in conjunction with sliding windows.

As part of the ventilation concept, for each workplace a window is foreseen that opens on to the intermediate space in the facade. In every office, there is at least one 1.80-metre-wide, room-height sliding casement that can be opened for ventilation purposes. Depending on the size and position of the space, there can be more than one opening. In addition, a small air duct is incorporated in the apron panels of the timber casement construction. The outlets to these ducts, located in the facade modules, admit air when the windows are closed. In order to avoid heat losses through ventilation via open windows, the outlets are closed by a mechanical device when the sliding casements are opened. In this way, natural and mechanical forms of ventilation complement each other. Users can individually determine the amount and the temperature of the air supply according to personal requirements. (Herzog, 2000)

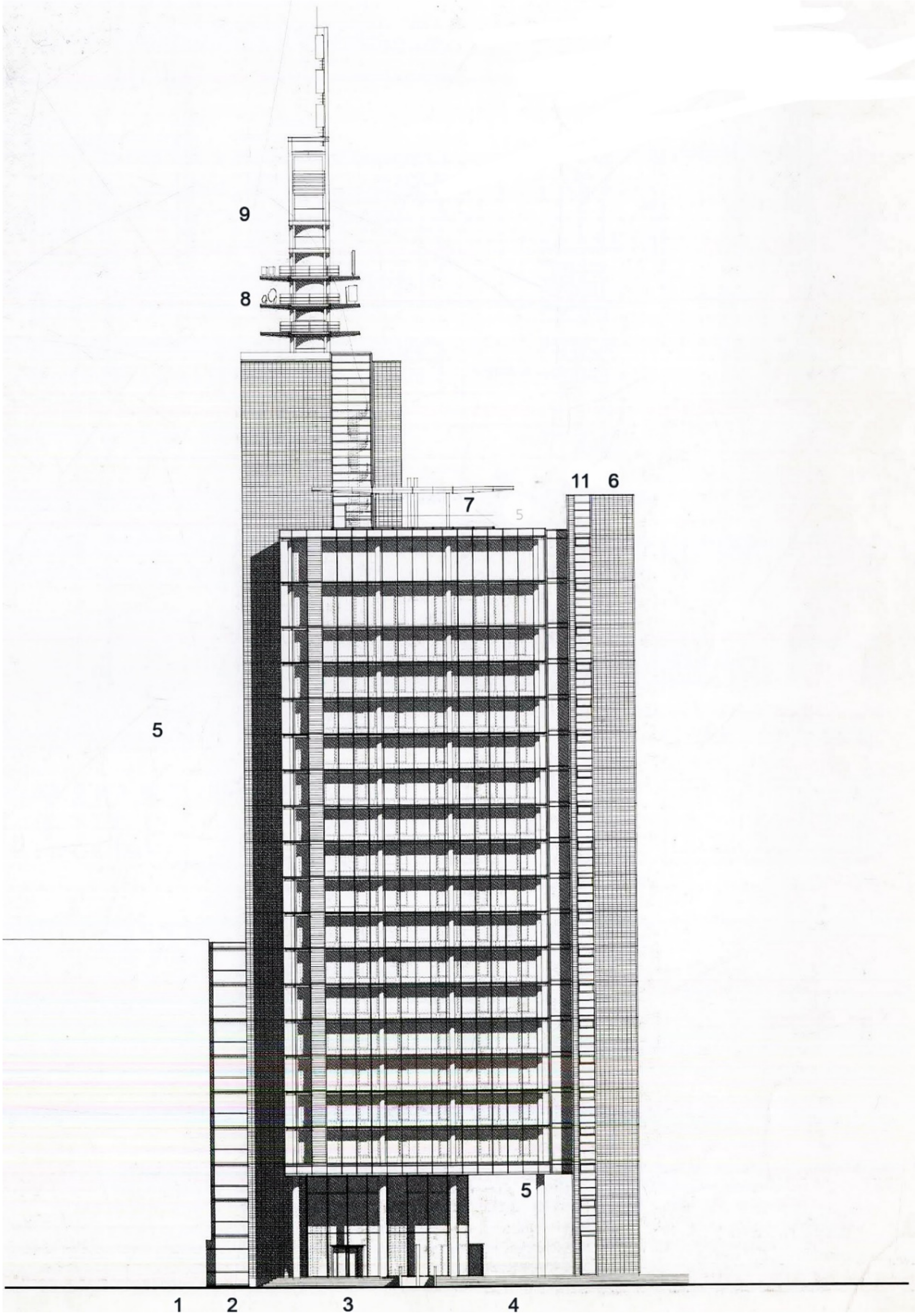


Section aa (for position see Figure 102)

1 Foundations
2 Basement
3 Entrance hall
4 Office stories
5 Hermes Lounge
6 Mechanical services story
7 Air shaft
8 Access corridor; lifts
9 Two-layer facade
10 Lift machine room
11 Rotary fan heat-exchange unit
12 Ventilation technology
13 Mechanical services
14 Ventilation tower

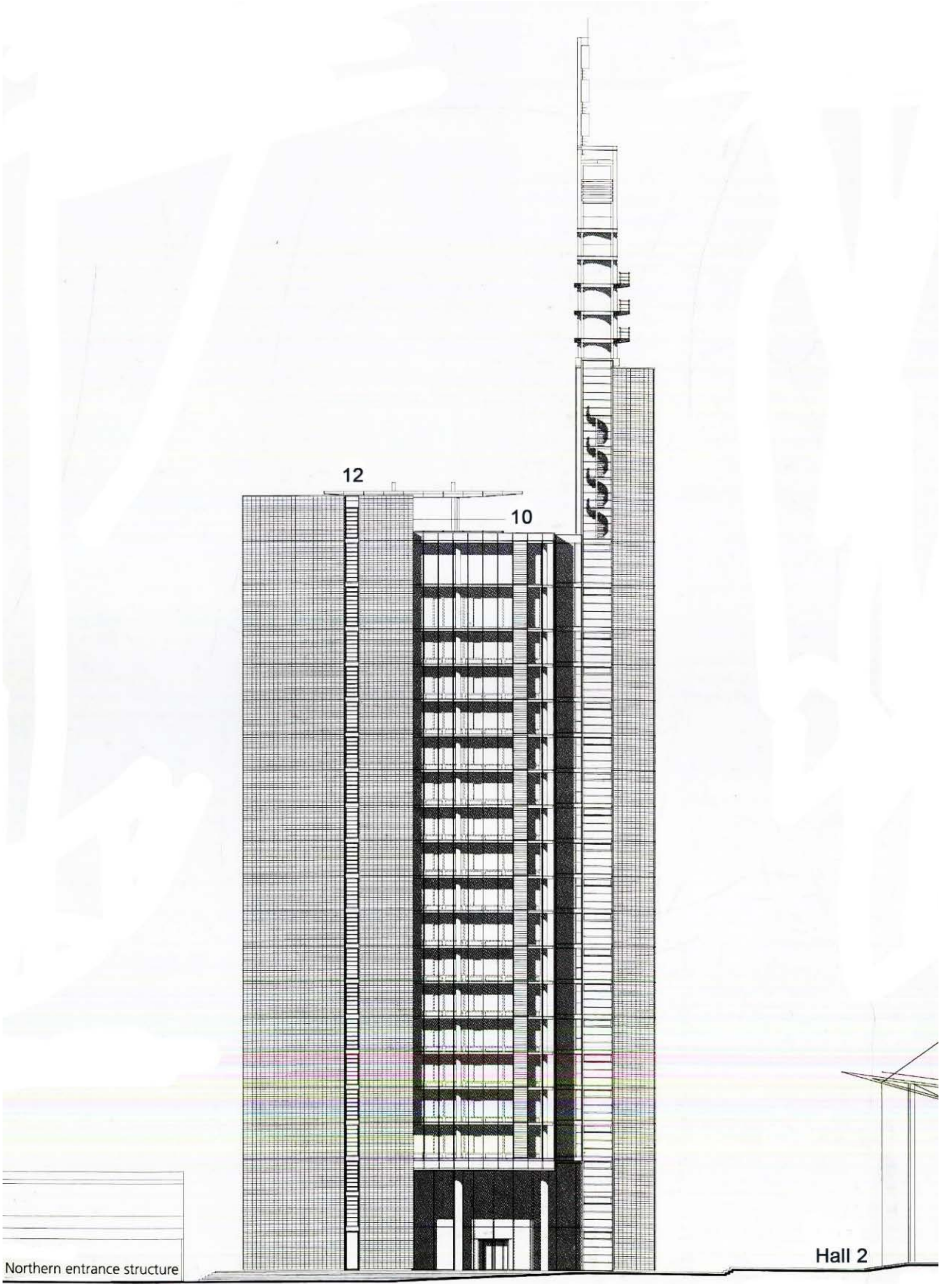
Figure 98: Administration building, Hannover, Section a-a

Exhaust air is collected story by story via a central system of conduits beneath the floor slabs in the inner zone of the office areas and drawn up through continuous vertical shafts to the top of the building, where it is emitted (Figure 106&107). Air circulation in the building is supported by thermal up-currents. In this way, a ventilation system was implemented that is activated largely by natural forces, exploiting the great uplift created by the height of the building and the strong winds at the top - which induce a powerful suction effect. The complementary mechanical installation operates with a minimum use of primary energy. In winter, vitiated air is drawn through a rotary heat-exchange unit at the top of the air-extract shaft before being discharged from the building. Up to 85 per cent of the thermal energy content of the exhaust air is recovered in the process and is used to preheat the intake of external air (fresh air). [4-4] In fact, the integration of thermal storage mass into the overall concept was of great importance in ensuring an efficient use of energy and a high degree of internal comfort. (Herzog et al., 2001)



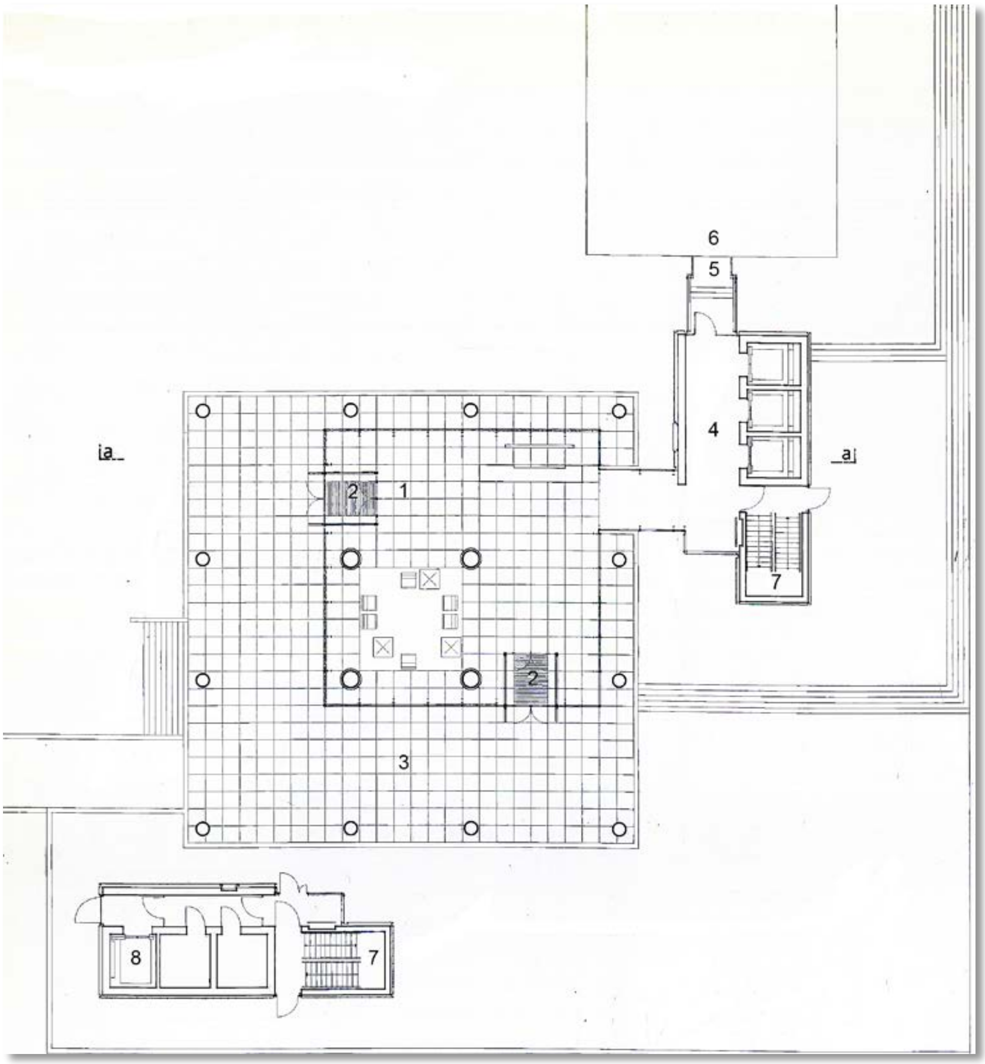
1 Existing administration building	6 Moding Argeton facade
2 link to new building	7 Roof garden
3 Entrance hall	8 Platform for cellular radio/telephone aerials
4 Vehicle approach	9 Ventilation tower
5 Two-layer facade to office tower	11 Corridor facade with ventilation louvers

Figure 99: Administration building, Hannover, West elevation



10 Elements In two-layer façade for natural ventilation
12 Louvered windows in staircase

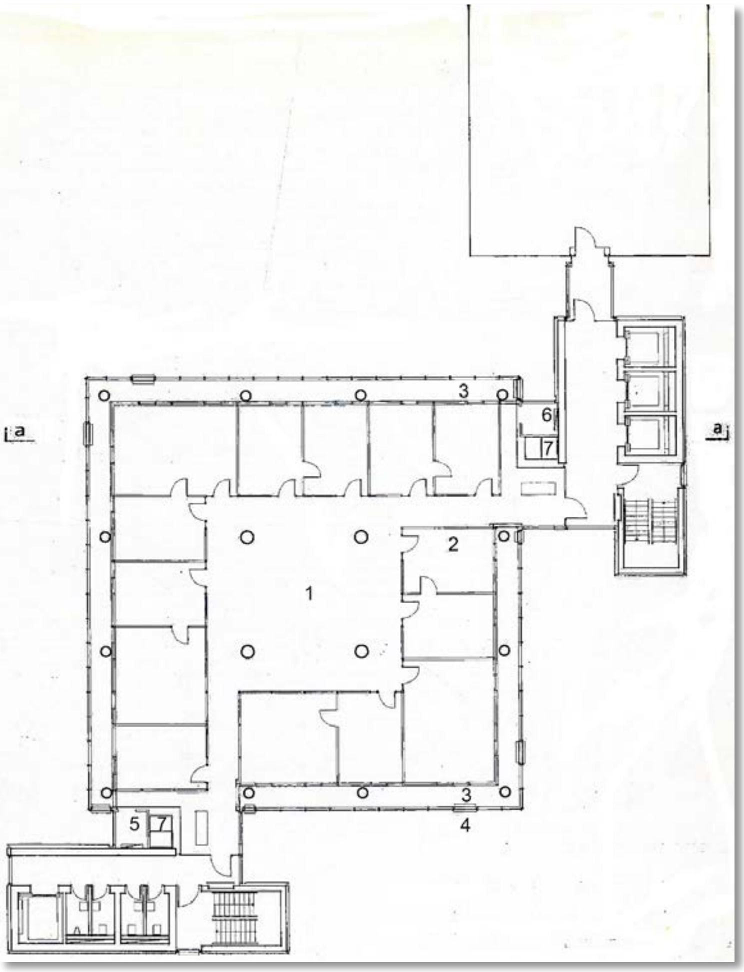
Figure 100: Administration building, Hannover, South elevation



Ground floor plan with entrance hall

1 Entrance hall
2 Wind lobbies
3 Vehicle access
4 Access corridor, Lifts
5 Link to existing administration building
6 Existing administration building
7 Escape staircase (with emergency exit)
8 Firefighting and goods lift

Figure 101: **Administration building, Hannover, Ground floor plan**

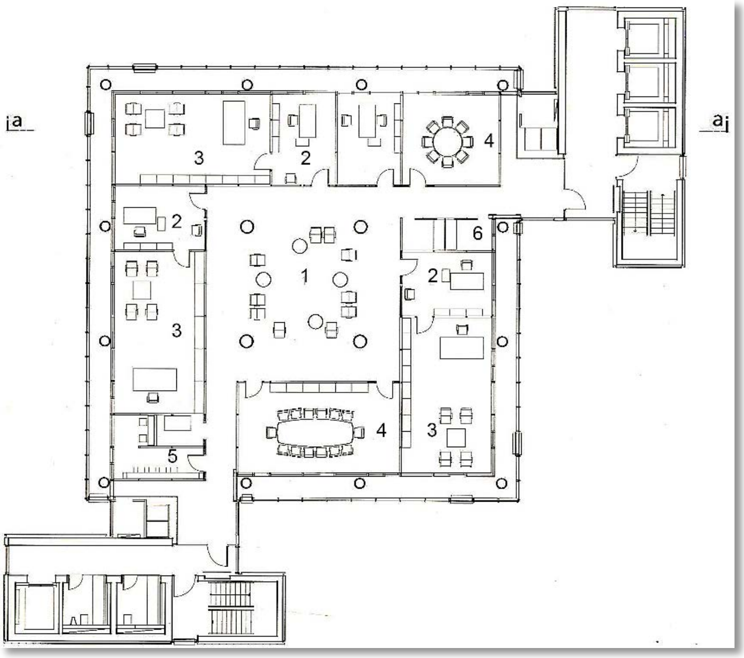


Standard floor plan: can be flexibly divided

The grid axes of the inner and outer skins of the two-layer facade are offset to each other. Both grids are centered on the central axis of the building.

1 Communal area
2 Office
3 Two-layer facades - intermediate space
4 Ventilation elements
5 Subdistribution room for communications technology
6 Subdistribution room for electrical installation
7 Air-supply and extract shafts

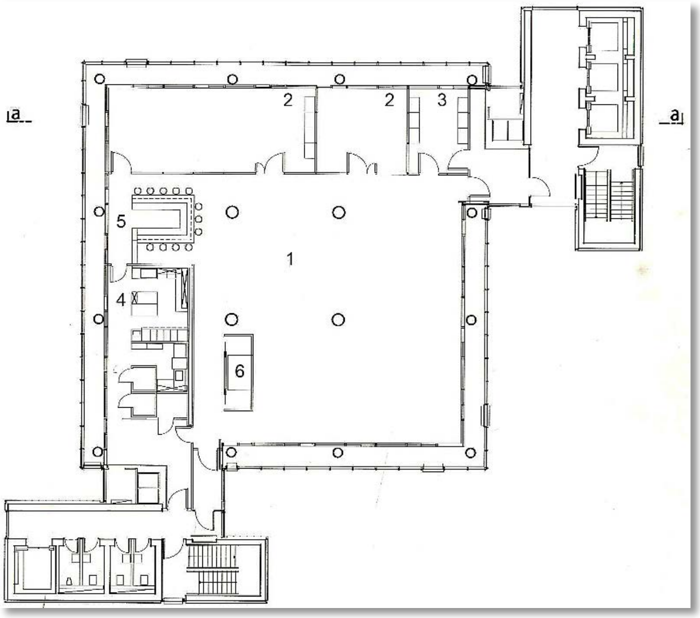
Figure 102: Administration building, Hannover, Standard floor plan



Plan of executive floor with board rooms

1 Visitors
2 Secretarial office
3 Office
4 Discussion
5 Kitchenette
6 Cloakroom

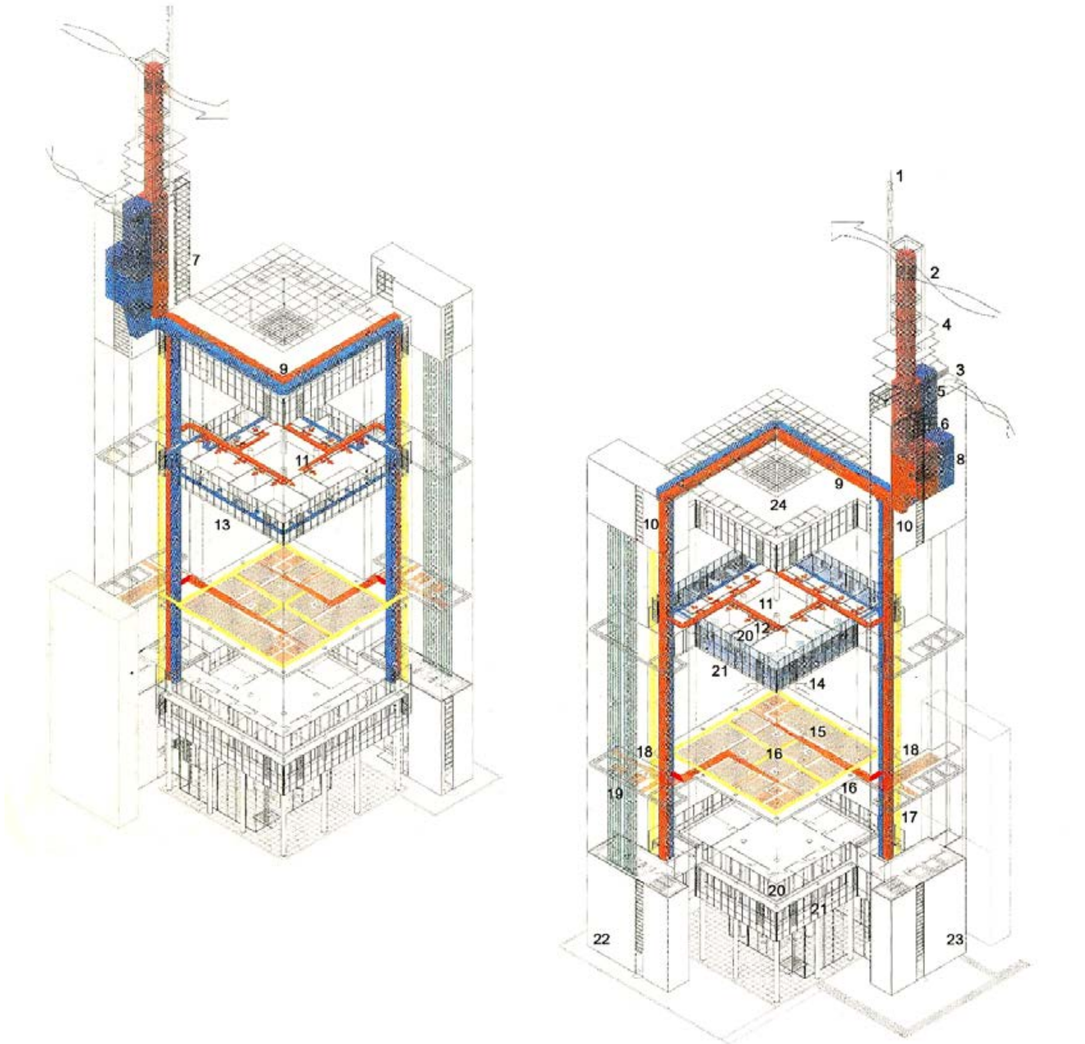
Figure 103: Administration building, Hannover, Plan of executive floor with board rooms



Plan of Hermes Lounge (18th floor) oriented to landscaped external space

1 Lounge
2 Conference rooms
3 Cloakroom
4 Kitchen
5 Bar
6 Multimedia projections

Figure 104: Administration building, Hannover, Plan of Hermes Lounge (18th floor)



Right, the south and east faces; left, the north and west faces in one case, the principle of natural ventilation via the corridor facade is shown; in the other case, the principle of mechanical air supply via ducts in the plinth zone of the inner façade

1 Weather station
2 Extract air
3 Air supply
4 Platform for aerials
5 Fans
6 Sound dampers
7 Louvre flaps
8 Rotary heat-exchange unit
9 Air ducts in mechanical services story
10 Air-supply ducts in office stories
11 Air-extract ducts in hall area
12 Air-extract opening in partition
13 Air-supply ducts in plinth
14 Ventilation element consisting of glass louvers with metal protective louvers
15 Thermoactive floor slab
16 Subfloor ducts
17 Vertical runs: electrical distribution
18 Vertical runs for communications technology
19 Ventilation and sanitary runs
20 Wood and glass facade
21 Metal and glass facade
22 Southern access tower
23 Northern access tower
24 light well with hybrid cooler

Figure 105: Administration building, Hannover, Isometric Diagrams of Technical Systems

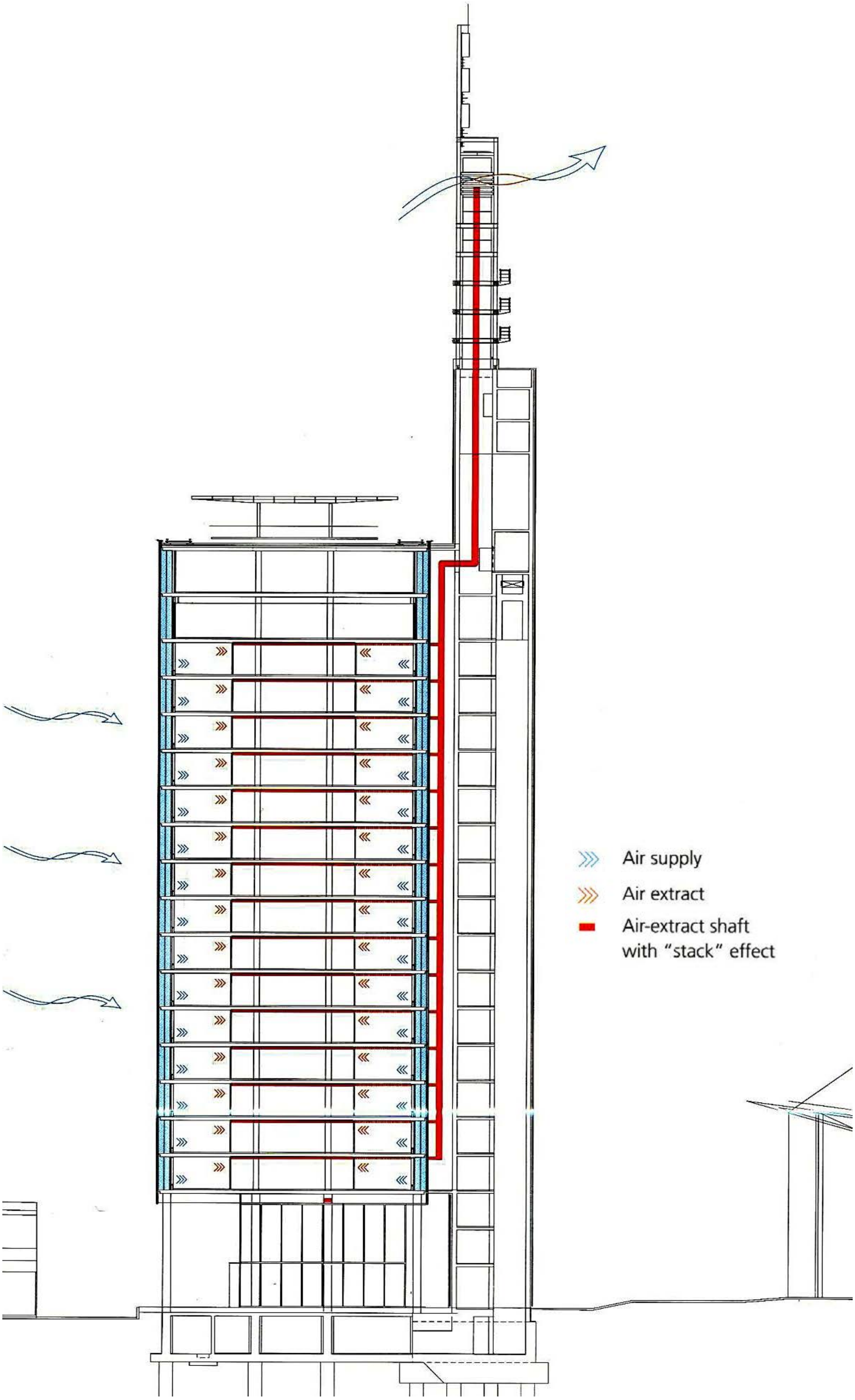


Figure 106: Administration building, Hannover. Diagram of natural airflow from outside to inside, Vertical section (transitional period)

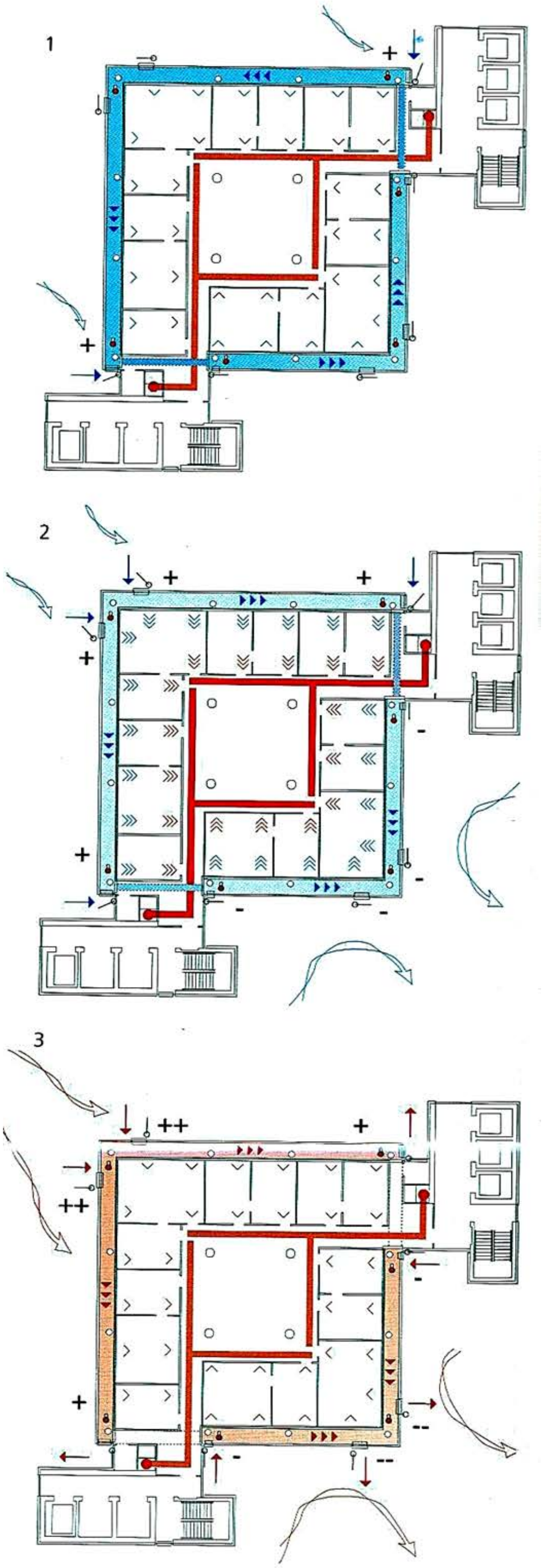
+ ... +++	Wind pressure
- ... ---	Wind suction
—○	Facade opening
●	Temperature sensor
→	External air, exhaust air
▸▸▸	Airflow through corridor facade
> ≫	Air supply, air extract
⬚	Bypass
▬●▭	Air-extract shaft

The DMAG Tower has a two-layer façade (Figure 108-112) that forms an environmental buffer around the building.

This buffer provides the opportunity for environmental control in various ways.

- It forms a zone around the offices in which the effects of winds at high level can be reduced.
- Office users can control their working environment and open windows at high level.
- The natural ventilation strategy supplements and supports the mechanical heating and cooling system used in the offices.
- In addition, the buffer zone provides the architects with structural, fire-engineering and constructional advantages.

A 300 mm diameter duct links the buffer zones to the north and west with those to the south and east. The intermediate space between the facade layers is divided into story-height segments, thereby creating a series of horizontal air ducts around the building. The top and bottom of the Buffer spaces are formed by the concrete floor slabs, which cantilever out one meter beyond the office facades. This means that each floor of



1 Two-layer facade (corridor facade) winter
2 Two-layer facade (corridor facade) transitional period
3 Two-layer facade (corridor facade) high summer

Figure 107: Administration building, Hannover. Diagram of natural airflow, from outside to inside (Horizontal sections)

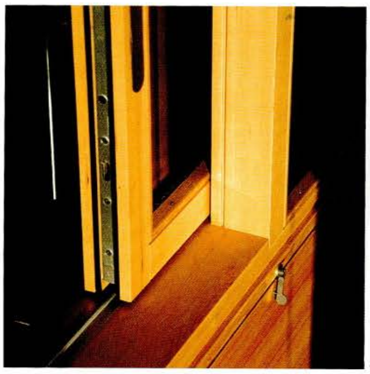
the building represents a self-contained fire zone.

In the outer skin of the facade are eight 3-metre-high strips with ventilation louvers that allow the passage of air into and out of the intermediate corridors. The louvers can be set in six different positions, which allow 720 permutations per story or some 14,000 for the entire building. The adjustment of the louvers is controlled by real-time computerized input, using system data. This includes information from weather stations, wind-Tunnel tests and analytical values. Six temperature measurement points were installed to control the minimum, maximum and estimated mean temperature values in the intermediate corridor. (Herzog, 2000)

Different opening strategies are applied for the following situations. (Herzog, 2000)

- The different seasons of the year. In this case, the strategy was determined according to relevant external temperatures and not according to the date. This strategy was adopted because it is the external temperature - and not the date and time of day – that is of importance to the environmental conditions within the buffer zone. In broad terms, the temperature ranges selected correspond to spring, summer, high summer, autumn, winter and deep winter.
- The time of day.
- The amount of solar energy impacting the facades.
- The external wind speed and direction


4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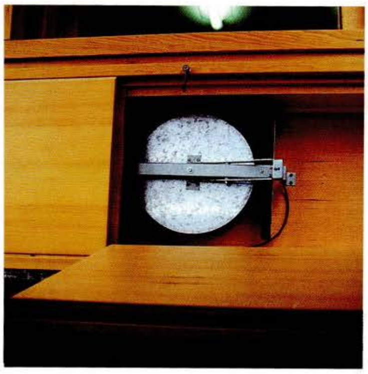
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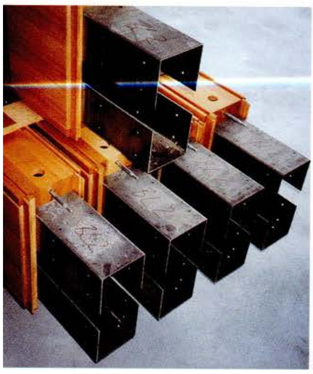
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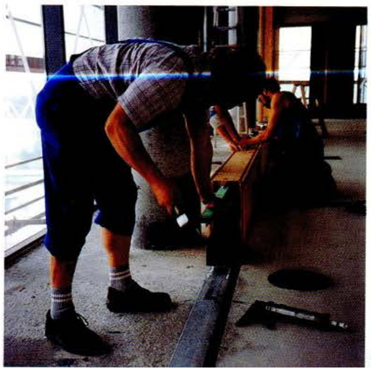
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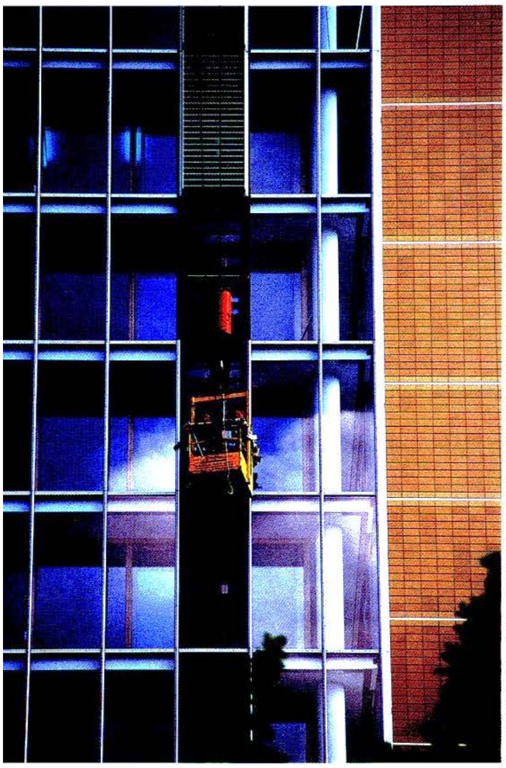
1 Apron wall with ventilation element beneath sliding casement
2 Ventilation ducts in prefabricated facade elements
3 Assembly of internal facade
4 View from outside through metal and glass façade to inner wood and glass facade protected against the weather
5 Sliding French window in open position
6 Open ventilation element in corridor
7(see Figure 93) View along intermediate temperature zone between two skins of double facade. By locating the columns in the corridor, the offices remain column-free (see Figure 93 & Figure 101-104)

Figure 108: Administration building, Hannover. Inner Skin of Two-Layer Facade: Wood and Glass


3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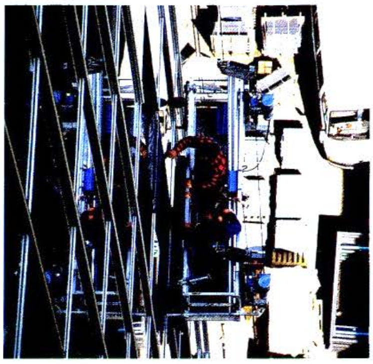
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1 Assembly of ventilation louvers
2 Inner view of glass louvers
3 Window division: part of slenderly dimensioned metal and glass facade construction. The specially developed aluminum cover strip also serves as a guide track for the facade cleaning equipment
4 View of facade assembly cradle from above

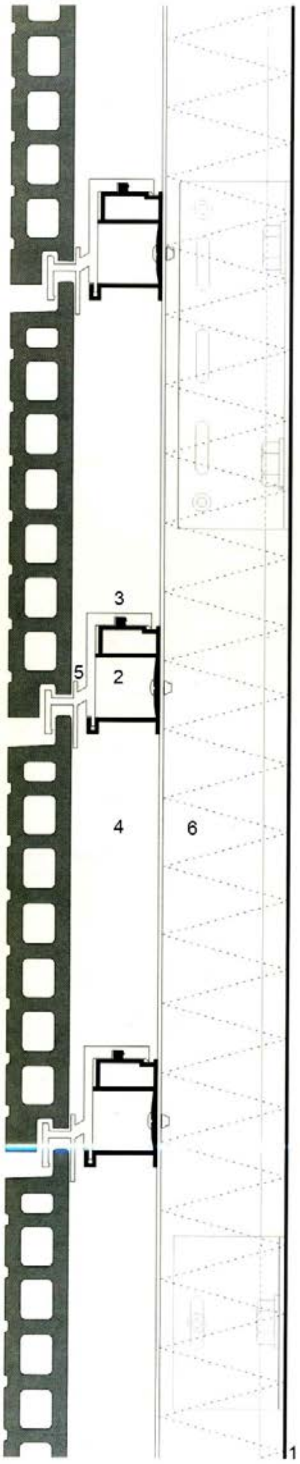
Figure 109: Administration building, Hannover. Outer Skin of Two-Layer Facade: Metal and Glass (1)

6

7

5 Window mullions awaiting assembly
6 and 7 Corner detail of building

Figure 110: Administration building, Hannover, Outer Skin of Two-Layer Facade: Metal and Glass (2)



1

2

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4

5

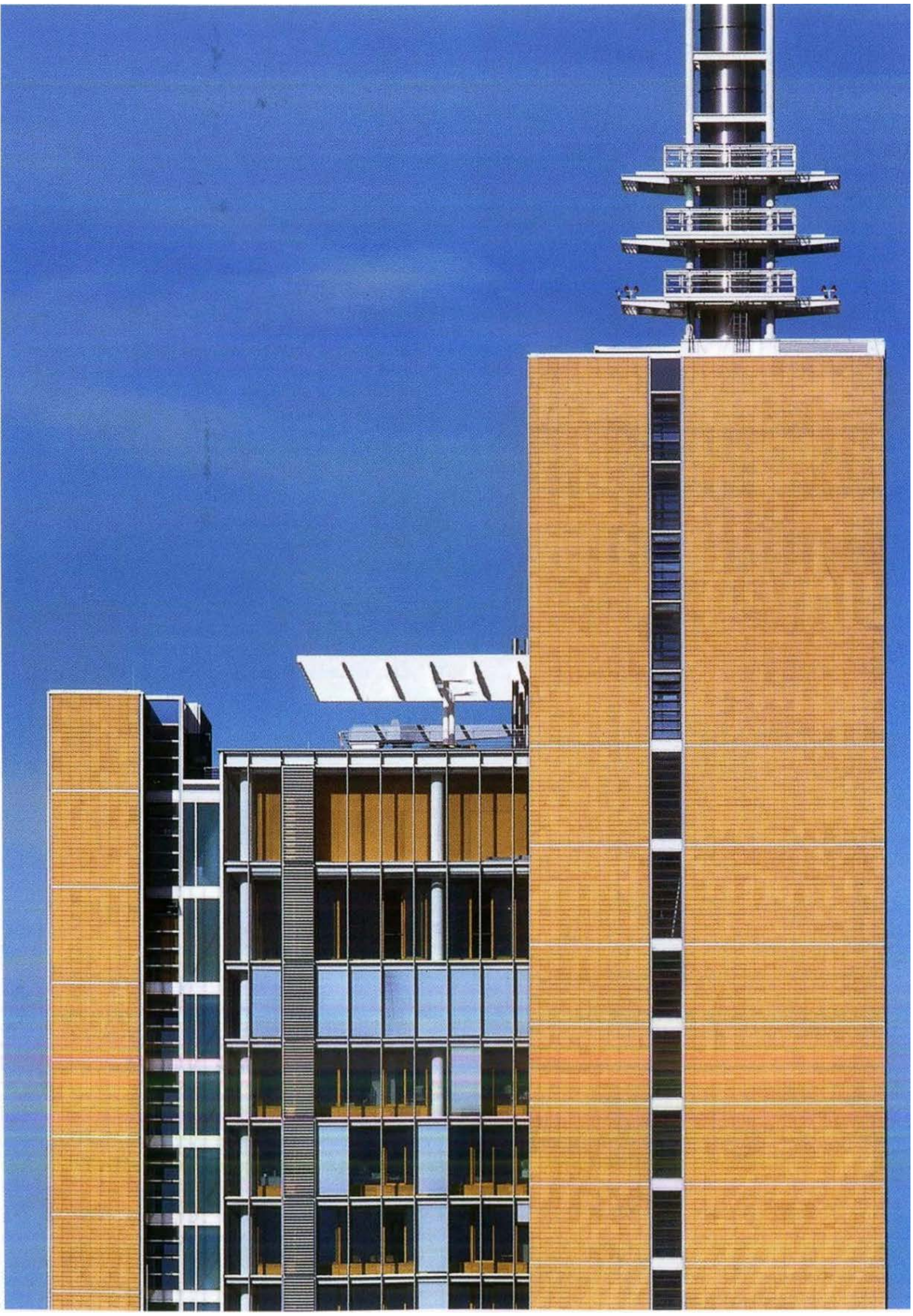
1 Vertical section through Moding Argeton facade (patented):

- 1 30 mm Argeton clay tiles with horizontal grooves
- 2 aluminum bearer
- 3 aluminum fixing clip
- 4 cavity
- 5 anti-capillary gap
- 6 thermal insulation between vertical fixing elements

2 and 4 Sample facade panels for color trials: new facing tiles in pale pearl-grey
3 Facade assembly with aluminum bearers
5 Clay-tile facade with ventilating window strip

Figure 111: Administration building, Hannover, Clay-Tile Façade to Access Towers (1)

6



6 View from east with main tower flanked by access towers: clay-tile facade cladding

Figure 112: Administration building, Hannover, Clay-Tile Façade to Access Towers (2)

In fact, concerning thermal and Ventilation Concepts, The concept for the heating, cooling and ventilation systems as implemented is new in respect of the low energy-consumption values achieved.

Concerning heating and cooling management, thermal requirements for offices are set out in the German code of practice for workplaces. But defining the quality of thermal comfort solely in terms of achieving and maintaining a predetermined room temperature is not sufficient in itself. In addition to the requirements contained in the code of practice, the following factors are important for a sense of well-being:

- The perceived room temperature
- The symmetry of surface temperatures
- The individual influence exerted by the user
- Balancing out load fluctuations.
-

Concerning Forms of energy and load behavior, the form of energy (heating/cooling) required in a building can be established after determining the dynamic load patterns in a simulation. Buildings with a good level of insulation in the outer skins have low heating needs. In new buildings that comply with modern insulation standards, internal heat gains (from people, appliances, artificial lighting, etc.) are often adequate to heat the building for much of the time it is in use. With external temperatures of 0 °C and above, rooms with large internal heat gains will actually require cooling. The decisive form of energy in that case will be cooling energy. It is a well-known fact, however, that the generation of cooling energy is considerably more expensive than producing heating energy. The energy supply concept for the present building is conceived on the basis of cooling with a minimum exploitation of resources. In comparison, the residual thermal needs for heating play a subordinate role. The energy required for this purpose is used merely to prevent the building from cooling out during the time it is not in use (at night, over the weekend, etc.).

Concerning hybrid forms of ventilation**,** every second facade bay contains a sliding window (2.0 x 1.0 m). Incorporated in the apron panels (Figure 113) are air inlets that provide a further means of ventilation when the windows are closed. A mechanical device connected to the casements (Bowden element) closes the air inlets when the sliding windows are opened. In this way a choice is allowed between natural and mechanical forms of ventilation. Vitiated air is removed via a central duct system and conducted over a rotary heat-exchange unit before being discharged from the building. (Herzog, 2000)

1 and 2 Office: inner facade layer with provision For natural and artificial ventilation; Air supply in apron wall
3 View into intermediate temperature zone of corridor facade

Figure 113: Administration building, Hannover, Air supply in apron wall & View into intermediate temperature zone of corridor facade

Concerning two-layer façade**,** the volume of air flowing through the corridor space between the two facade layers varies. The circulation is maintained by wind power. In order to reduce thermal transmission, the two-layer facade should be allowed to cool out as little as possible during the cold season. The volume of air entering this space is, therefore, kept to a minimum at that time of year. In summer, solar heat is removed by an increased volume of air flowing through the corridor. Horizontal ventilation of the facade space is regulated by adjustable flaps.

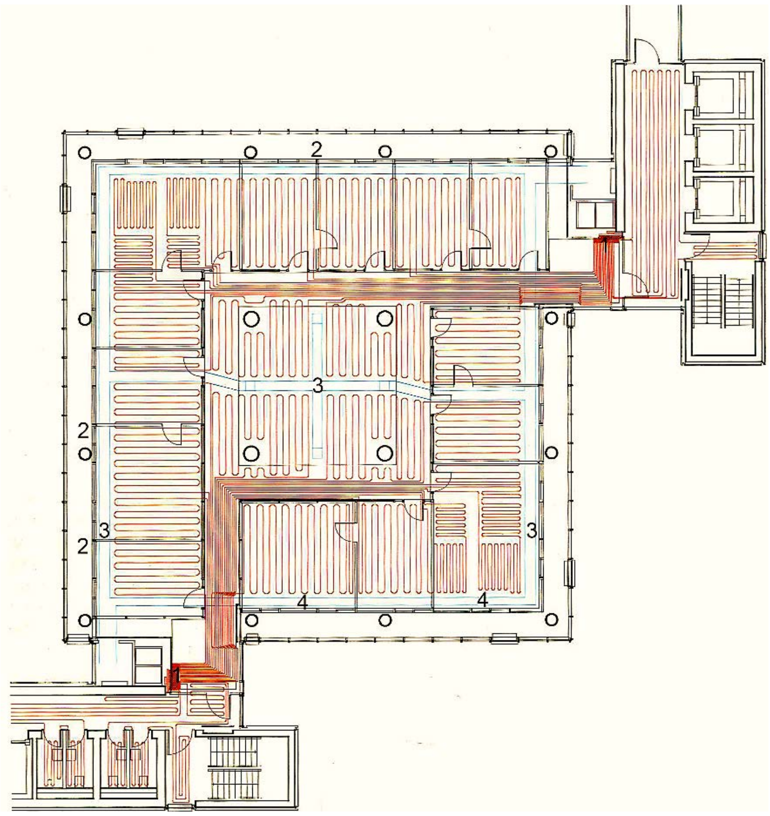
Expressed in simple terms, the laws of aerodynamics for buildings show that positive pressure prevails on the facade facing the wind, while negative pressure may be expected on the leeward side. In the present building, this pressure gradient is brought into a state of equilibrium by means of air inlet and outlet flaps in the outer skin of the two-layer facade. The dimensions of the individual flap openings, which depend on the direction and velocity of the wind and the external temperature, were determined on the basis of pressure conditions calculated in wind-tunnel tests.

Users have a choice between two systems. In winter, the natural ventilation system via the two-layer facade - the conditioned buffer zone - offers cooler air, while the mechanical system supplies warmer air. In summer, the system is reversed. The same principle applies during transitional periods as well, so that users can regulate their own spatial conditions through the choice of air temperature. (Herzog, 2000)

Concerning thermoactive floor slab (Figure 114-116), a solid floor slab can be thermally activated by means of water-bearing pipes. These are laid in the screed over the floor structure rather like the runs of an underfloor heating installation. In order to obtain a comparable flow of heating and cooling streams upwards and downwards, the usual acoustic insulation layer is omitted. The simultaneous heating of the floor and the ceiling means that two thermally active surfaces are created.

In this way, in contrast to normal underfloor heating systems, two thermally effective surfaces exist between stories in every room. This results in a huge reduction of the required difference between room temperature and active surface temperature.

To cover heating loads (external temp. < 0 °C), a surface temperature of approximately 23 °C is necessary. When room temperatures sink below 23 °C, therefore, the heating system comes into operation. Conversely, for cooling operations (external temp. > 0 °C), a surface temperature of 21°C is necessary. When the room temperature exceeds 21 °C, the thermoactive floor cools the room by means of extremely small temperature differences. (Herzog, 2000)



Thermoactive floor slab
Diagram of heating and cooling runs

1- Vertical heating and cooling runs
2- Pipe distribution layout, allowing for office partitions to be moved
3- Subfloor duct for electrical and communications runs
4- Electrical line connections at fix centers (1.8 m)

Spacing of coils: central office 20 cm;
corner office 15 cm
Flow temperature

Heating:	day	23 °C	(flow temp. = constant)
	night	23 °C	
		to 26 °C	(flow temp. = f/ext. temp.)
Cooling:	day	no cooling	
	night	18 °C	

Internal loads:

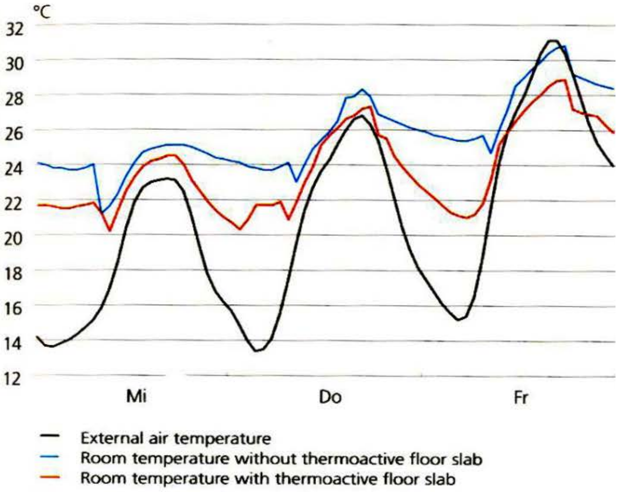
lighting	7 W/m^2
equipment	15 W/m^2
people	80 W/person
no. of persons	20 per floor

Figure 114: Administration building, Hannover, Thermoactive floor slab, Diagram of heating and cooling runs

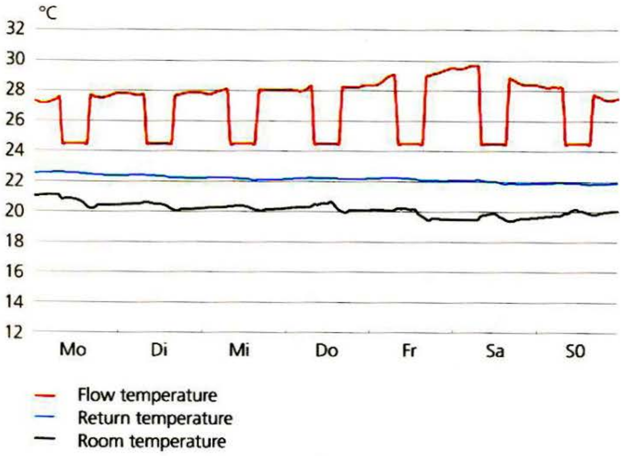
Figure 115: Administration building, Hannover, Thermoactive floor slab during construction

Additionally, in relevance to selected simulation data, the results of a dynamic simulation given below show the behavior of the thermoactive floor slab.

Behavior in summer
When the thermoactive floor slab is in operation, the room temperature will be up to about 3 °K lower than that in an uncooled room.



Behavior In winter
The data shown is for an unoccupied north- or west-facing room without internal loads during a cold week in winter. The room temperature does not sink below 20 °C.



Rooms with varying internal loads
The temperature range is shown for two adjoining rooms with different internal loads. Room 1 is unoccupied. Room 2 is crowded.

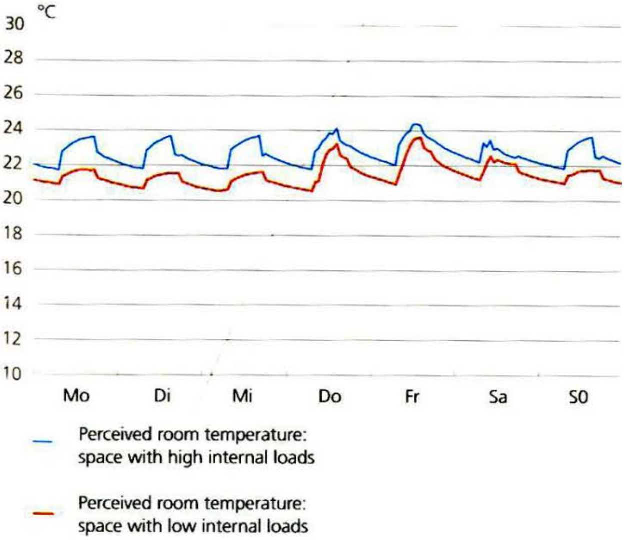


Figure 116: Administration building, Hannover, Thermoactive floor slab, Selected simulation data

In fact, concerning cooling -without wasting resources, the concept of cooling without wasting resources implies exploiting the potential of lower night-time temperatures. In order to use the night air, which is up to 15 °K cooler, it is necessary to store it until the following day. The structural members of the building - especially the concrete floor slabs - are an ideal thermal storage medium.

Additionally, concerning recooling, the cooling energy of the night air is transferred to a water circulation system by means of a hybrid cooling plant. This plant can also be used to exploit the evaporative heat of water sprayed on to the cooling elements. In this way, during warm summer nights, a cooling-water temperature of up to 18 °C can be achieved. The hybrid cooling plant is operated in summer and in the transitional seasons in two different forms. At night, it maintains a temperature level of roughly 18 °C in the thermoactive floor slabs. During the day, the recooling plant is operated in place of the cooling plant. The mechanical cooling energy generated is used for cooling special spaces such as the Hermes Lounge and technical services rooms.

Concerning mechanical ventilation, the fresh-air supply for all standard floors, including the executive level, is sucked into the northern core structure at roof level. The air is preheated with the aid of a rotary heat-exchange unit that recovers up to 85 per cent of the energy content from discharged exhaust air. After the process of air conditioning (heating/cooling) on the services floor, the air intake is fed into two large shafts. These supply each of the standard floors with a maximum of 2,000 cubic meters of air per hour - equivalent to an air exchange rate of 1.5. The actual volume of air supplied is determined on the basis of the air exchange rate required to maintain hygienic conditions. This reflects initial experience of user needs and can be finely adjusted during operation with the aid of C02 sensors. The volume of air does not serve to balance heating or cooling loads. Like the air intake, the air extract is drawn through two shafts, which merge in the services story at the top of the building. The air exchange rate for each story is controlled by electrically operated volume-flow regulators for the air intake and extract. In order to minimize the loss of pressure in the ducting network, the air supply and extract ducts are dimensioned for an air velocity of 1.0 to 2.0 meters per second (m/s). Within the straight-line central riser shafts, air velocities of up to 4.0 m/s occur. Fans with free-running rotors are installed above the northern core structure. These maintain the air circulation with the support of natural forces (thermal uplift and wind). Vitiated air is discharged at the top of the building. As a result of the relatively small pressure losses, the thermal uplift and the anticipated support of wind currents, air circulation within the building is maintained largely by natural means. This, in turn, reduces the operating time of the fans. (Herzog, 2000)

In fact, Natural ventilation via sliding windows forms a fundamental principle of the ventilation concept. The disturbing effects of wind and weather are offset by the two-layer facade construction and the internal (mechanical) ventilation system. Heating needs are met largely by the energy recovered from exhaust air. The heat-recovery plant incorporates a highly efficient rotary heat-exchange unit. As a result, it was possible to achieve a largely natural system of ventilation, which, with mechanical support, can be operated with only a small consumption of primary energy. (Herzog, 2000)

Actually, in this building, one of the special features is the coordination of the various building subsystems within an overall concept. In this way, it was possible to guarantee a high level of comfort with low energy consumption, and to harness sun and wind energy to control the indoor thermal environment and ventilation. A ventilation tower rises by about 30 m above the northern access core. The exploitation of thermal uplift is an important aspect of the natural air-supply and extract system for the entire building. (Herzog et al., 2001)

In brief, façade, structure and building services interwoven to form a complete system in terms of energy usage. The form of the building has derived from site conditions while it is a compact building to reduce heat losses. The building structure has thermal activation while is combined with façade and ventilation shaft and the ventilation tower has exploited the physical principle, stack effect (thermal buoyancy), for the natural ventilation of the whole building. The façade has used as a ventilation element. There is an optimized usage of ventilation openings and two-layer façade. The façade allows for night time cooling. The double skin façade acts as a buffer zone and it is possible for individual natural ventilation via sliding doors openings on to the façade cavity. In the outer façade, the controllable ventilation elements permit adjustments for suiting different pressure conditions. While the building has a low energy consumption, there is a high level of good-quality working environment and comfort.

Additionally, the layout is contained of the central working area (24x24) on the plan with two access cores –which is contained of ancillary spaces and is offset to two sides. This planning leads to a great flexibility for using the building.

Thomas Herzog’s Hannover Messe A.G. is a mature example of a “corridor façade”. The façade contribute to a wide variety of building climate functions and its expression is dominated by its role in the ventilation scheme. With the service cores removed from the central block, the buffer space accounts for 22 per cent of the remaining slab area. This is an investment in passive strategies that few in the U.S. would be willing to consider. (NIBS, 2006)

Furthermore, such facades lead to a new aesthetic characterized by layering and transparency. Most office buildings with double-skin facades have been built over the last 15 years in Germany, where we can currently find around 35 realized projects where this façade technology was applied. (Steffen Lehmann, 2006)

Additionally, “Dual-layered glass facades allow natural ventilation in high wind environments such as at the upper stories of high-rise buildings. This type, the most popular in Europe, enables users to control their working environment while helping to eliminate “sick building syndrome,” which can result from an over-reliance on air conditioning... According to some estimates by environmental engineers, certain types of ventilated facades show energy savings of 30 to 50 percent.” (E. Lee, 2002)

In this project Herzog took the advantages of passive strategies for improving the performance of heating, cooling and lighting, and make strong modern architectural statements.

The premise that the building works as an ecosystem is a reinterpretation of the idea of the building as machine for living. In most of his projects, the machine becomes an expressive element as well as providing the underlying order of the building. Herzog is also concerned about the human occupants of his buildings. Unlike many of his predecessors, the answer is not in creating a strictly technological response, but also to address the wider range of site, social and cultural issues. In this way, he shares some characteristics with Aalto.

"*What we are working on is a new material culture that must be fitted into an old material culture. We love new technology and new materials but we also love our old towns and cities. In no way am I prepared to abandon our whole cultural heritage just to pick up a few watts of free energy from the outside world."* (Pérez-Gómez, 2002)

Moreover, "In his architecture, Thomas Herzog unites technical and constructional skills with a strong sense of responsibility for the built environment. " He sets out on a quest and makes a number of discoveries on the way - in nature, in other cultures and in branches of industry that have nothing to do with building.

The ventilation concept for the Hanover tower, for example, is reminiscent of the complex, traditional, non-mechanical air-conditioning systems to be found in Iran and in Arab countries with extremely hot climates.

For this Munich architect, architecture is not just a matter of aesthetics. "In the traditional sense of the word, he is concerned with all three classical categories described by Vitruvius: functional efficiency, appropriate constructional techniques, and the beauty of a building." (Herzog, 2000)

2-3-7 Office complex in Wiesbaden 1993-2004

A fundamental aspect from the outset was to apply environmentally friendly types of energy in the form and quality in which they are locally available. This was to be implemented in accordance with relevant standards and guidelines, yet without neglecting requirements for the quality of the indoor climate. Where appropriate, specific details were to be given greater attention, such as the even quality of natural lighting (important for computer work) and the "perceived" indoor temperature.

A central aspect was to increase efficiency in the use of primary energy sources (minimizing energy losses within the system), while at the same time improving the level of comfort. This also implied a simple operation of the individual room components (semiautomatic: sensors that detect the presence of human beings- transition from standby to operational state; daylight sensors- automatic switching of artificial lighting, etc.). In this way, it was possible to ensure that the proportion of fossil energy sources necessary for the operation of the buildings was substantially reduced. In addition to the natural lighting mentioned above, this applies to areas such as heating, cooling, ventilation and the generation of electricity- in each specific case and as a whole.

To remain within the bounds of economic viability, investments in a building that *is* to be operated with renewable forms of energy should only minimally exceed those in conventional structures if at all. To achieve this goal, it is necessary to deviate from the usual course of project work. This will probably make it necessary to reconsider and redefine standard approaches, modes of operation and the assignment of tasks. (Herzog & Soka-Bau, 2006)

In the operation of a building, where changes in the energy balance are involved, as described above, everything of relevance in each individual situation has to be reconsidered. In this respect, local factors -climatic, cultural, environmental, topological, legislative, geothermal and many others - play a fundamental role. Weather statistics, showing extreme and average values, should be obtained so that the opportunities and risks involved in the use of a building can be recognized. In the present project, for example, local wind patterns were taken into account as a means of supporting the ventilation.

Where the appropriate degree of thermal conditioning is involved, the building must be apprehended above all by the architects (who bear the chief responsibility) as a single, comprehensive thermodynamic system. In this respect, there is a basic need for a far-reaching reorientation or extension of professional competence. It is no longer sufficient simply to understand buildings as designed volumes, the outer skin of which protects the interior from the vagaries of the weather, with additional installations such as heating and cooling plant, and perhaps with a ventilation or a full-blown air-conditioning system in the form of elaborate ancillary facilities dependent on external energy. Furthermore, it may be necessary to adapt the performance specifications of these systems to the built form and type of construction: the shape and layout of the rooms; the physical properties of the walls, floors and base slab; the type, size and position of the windows and so on.

In other words, as soon as the basic urban planning for the location has been completed and the layout of the elements has been clarified in relation to the surroundings (Figure 117), it will be necessary to consider all those parameters that mutually determine the indoor climate and, by varying certain physical features (like thermal conductivity and storage capacity; absorption and reflection of radiation from the long-wave range of the spectrum through the type of coloration and the texture of the surfaces; the control of light by means of multiple reflection, its concentration or dispersal, and many other aspects), to achieve, step by step, a holistic optimum energy performance in the construction of the building. (Herzog & Soka-Bau, 2006)

Figure 117: Office complex, Wiesbaden, Site plan depicting the linkage of the four new structures with the existing building via two access corridors in the context of the surroundings.

Concerning the budget of the project, there is a further essential condition if one wishes to create a building with significantly lower energy consumption on an economically acceptable basis.

Agreement is necessary on an overall cost target, yet without fixing the budgets for individual sections of the work- for building elements or whole subsystems, such as facades, load-bearing structure, staircases, etc. -as is sometimes the case with people who believe they have great experience in cost planning and defining goals for the design . Anyone who seeks to save costs in specific segments of the work, making reference to experience gained elsewhere, will only impede - or, indeed, prevent-innovation in the overall context. There will be no chance then for any far-reaching perspective with a free and spontaneous search for solutions.

On the other hand, the greater freedom advocated here means that the planners should possess far-reaching, state-of-the-art technical knowledge as well as the competence to develop the overall constructional system and the various parts it comprises. One must be able to elaborate the design concept based on an openly formulated brief and in areas that lie beyond standard solutions. In the case of our new development in Wiesbaden, these aspects may be summarized as follows. (Herzog & Soka-Bau, 2006)

The urban-planning concept is of public interest and resolves questions of integrating the scheme into the surrounding infrastructure, the reformulation of public space and the layout of the building volumes. On this basis, initial functional and urban-design decisions were taken in response to the multistage architectural competition. By laying out the multi-story buildings for office use in an east-west direction (i.e. with roughly half the spaces facing south and an equal number facing north), the rooms on the northern side would have the potential of optimum daylight conditions (via "studio windows";(Figure 118)), while the south-facing spaces would possibly benefit from solar gains during the heating period.

Figure 118: Office complex, Wiesbaden, Studio openings

Large development has been articulated in height and depth to create a varied sequence of built volumes and open spaces (Figure 119). In this way, it was possible to accommodate the various elements to the scale of the surrounding urban fabric. The development contains a floor area of nearly 70,000 m². (Herzog & Soka-Bau, 2006)

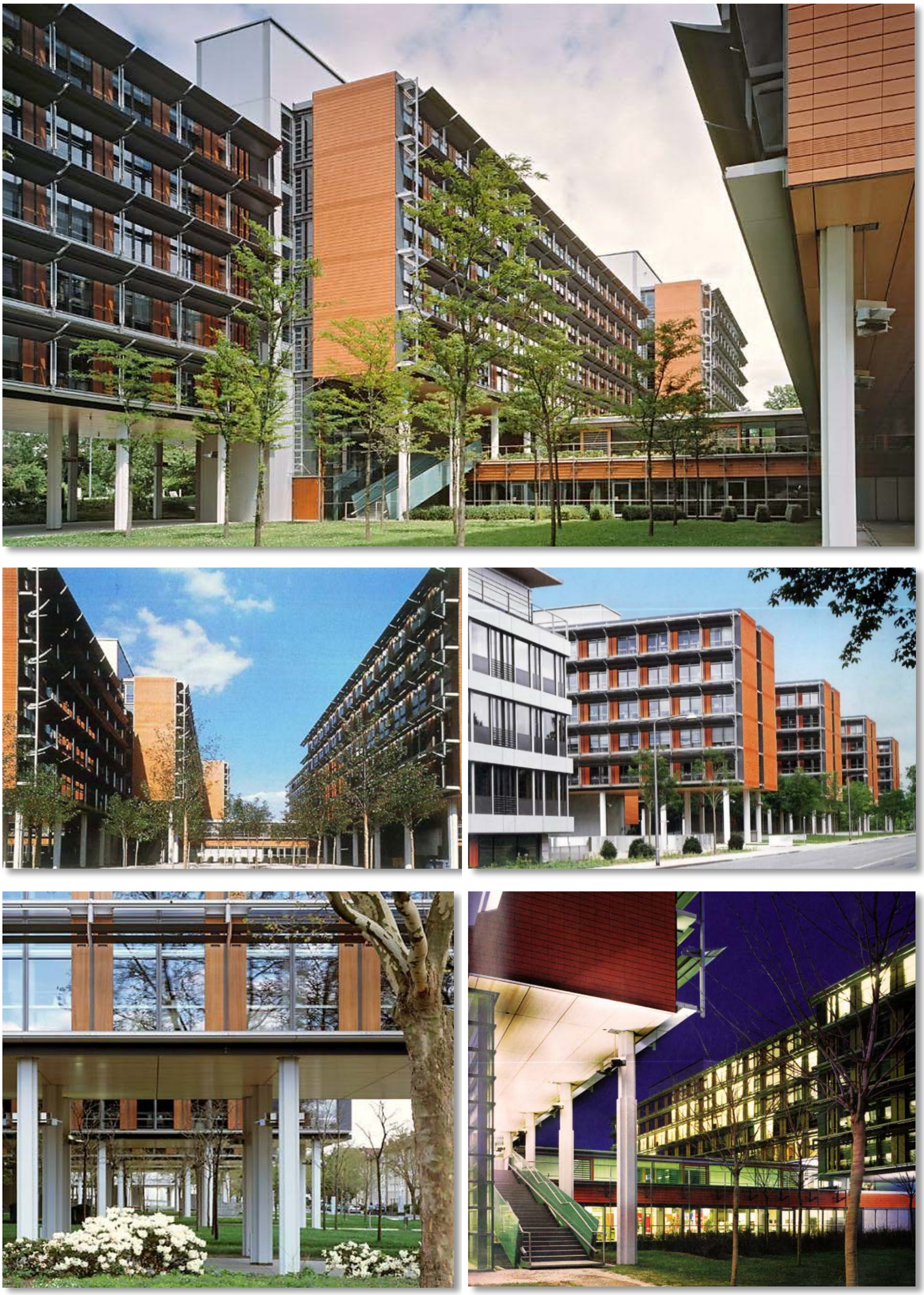
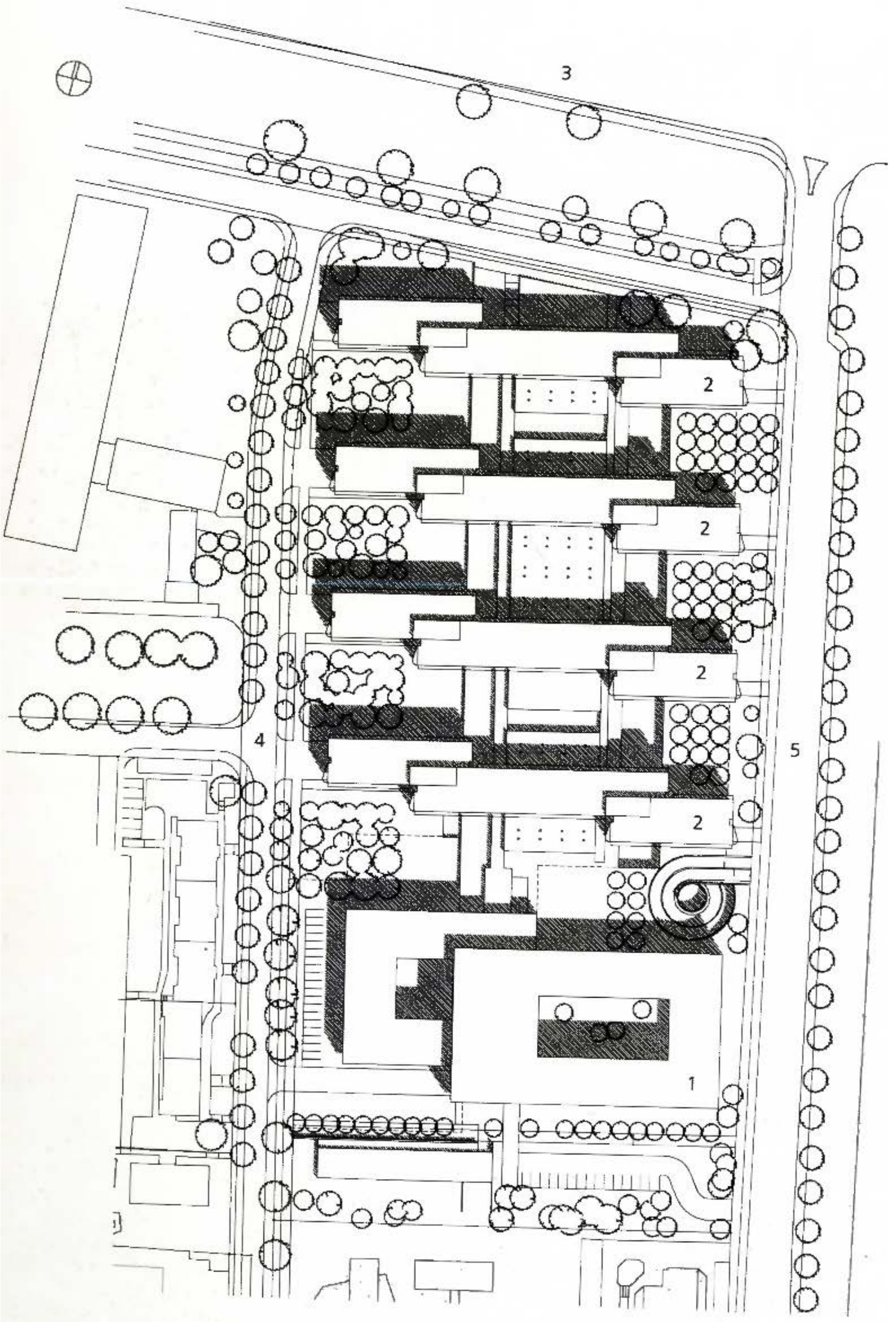


Figure 119: Office complex, Wiesbaden

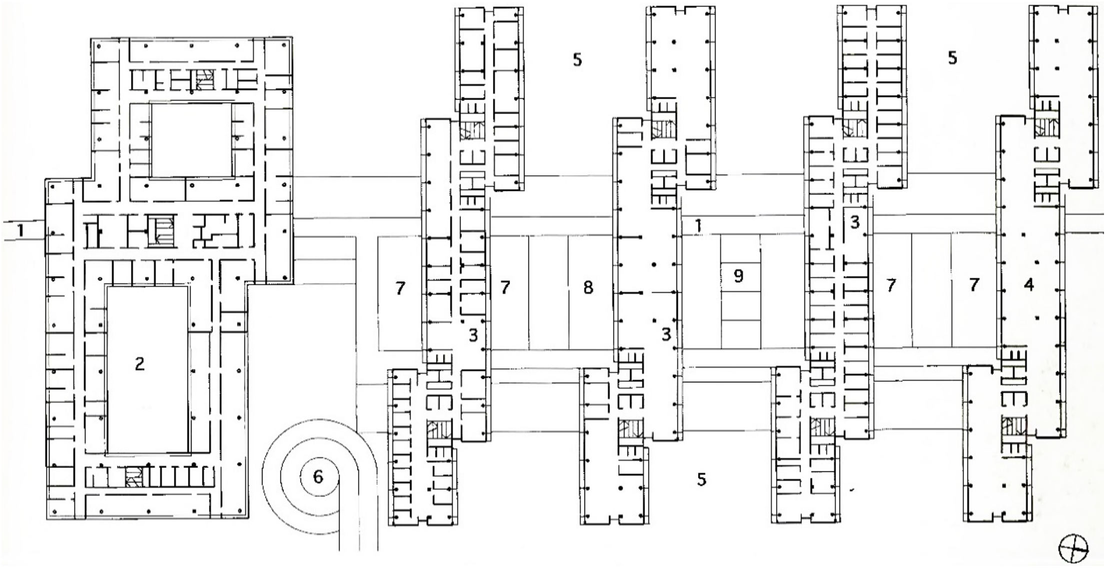
By fully exploiting the planning laws relating to the site (Figure 120), it was possible to articulate the large volume of the development into a spine structure with four separate office tracts set on top.



1 Existing building
2 New development
3Gustav-Stresemann Ring
4 SalierstraBe
5 WettinerstraBe

Figure 120: Office complex, Wiesbaden, Site plan of development

This layout had a number of advantages, including the fact that it facilitates natural ventilation along the length of the various sections of the complex (Figure 121&122).



First floor plan: 1 Public footpath 2 Existing administration building 3 Office tract 4 Office tract: main entrance north 5 Public landscaped area 6 Basement garage entrance / exit 7 Teaching and conference spaces 8 Kitchen, food counter 9 Restaurant

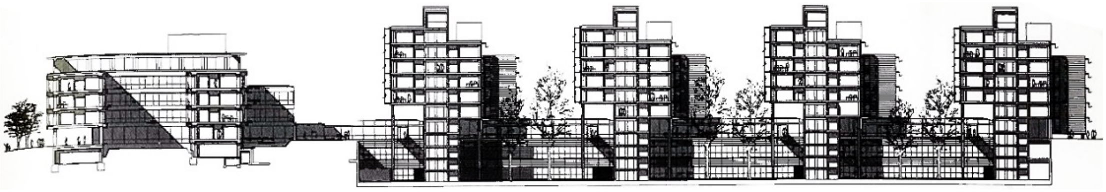
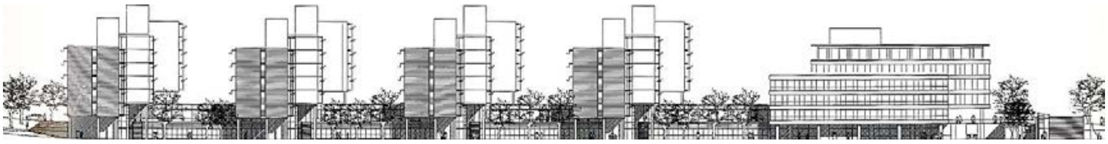


Figure 121: **Office complex, Wiesbaden, Plan & Section**

The 12-metre depth of the tracts, together with a facade layout based on a 1.50-metre modular dimension, allows the creation of individual, group, combination and open-plan offices (Herzog & Soka-Bau, 2006); aside from other advantages, the overall structure allows for natural cross-ventilation.

East elevation



West elevation

Figure 122: Office complex, Wiesbaden, East and west elevation

The location of the access cores facilitates the individual use of smaller, leasable areas. These can be linked both vertically and horizontally to form larger spatial units of generous proportions. The floor slabs were designed as solid elements for thermal activation. As a result, no suspended soffits or double-floor forms of construction were possible. In winter, the structural slabs are heated; in summer, the heat is removed from them. (Herzog & Soka-Bau, 2006) Controlled surface temperatures result in a comfortable indoor climate.

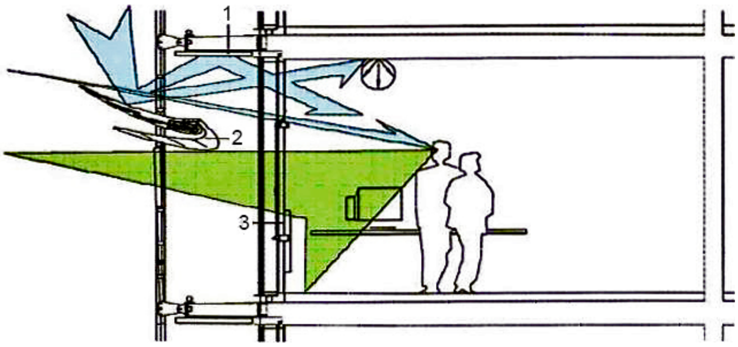
On the north side (Figure 123) of the office tracts, the cantilevered balconies, which form horizontal firebreaks, have surfaces that deflect zenith light into the depths of the internal spaces. When the south façade (Figure 123) is exposed to insolation, computer-controlled elements are moved into a sunscreen position. The light-deflecting elements along the south face are turned inwards and shade the upper part of the facade entirely. Groups of louvers reflect the required amount of direct sunlight into the rooms. It was nevertheless possible to minimize the energy gain resulting from this, so that the office spaces are not overheated in summer. (Herzog & Soka-Bau, 2006)

North side

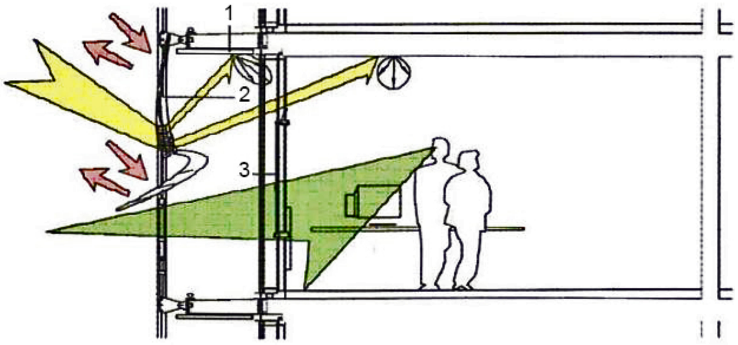
South side

Figure 123: Office complex, Wiesbaden, North & South face

Shading to the lower section of the facade is provided by a projecting element, the geometric form and the positioning of which nevertheless allow free views out of the offices (Figure 124).



Clouded sky



Sunny sky

1= aluminum panel, 2= daylight reflector, 3= glare shield

Figure 124: Office complex, Wiesbaden, Sunblind with daylight reflector

The following measures, among other things, help to achieve a high degree of comfort for the workplaces as well as low energy-consumption values (Herzog & Soka-Bau, 2006):

- Heating/cooling of the concrete floors
- Minimal low-temperature radiation: use of triple glazing
- Hygienic air supply through free natural ventilation
- Full natural lighting of internal spaces
- Non-glare computer workplaces
- Minimal fatigue of staff through avoidance of disturbing lighting contrasts
- Good orientation through glazing along corridor face of offices plus room-height glazing to external facade
- Flexible scope for furnishings

The design won first prize in a two-stage architectural competition held in 1993-94. After completion, the building was awarded the architectural prize for Outstanding Buildings in Hessen as well as the European Architecture & Technology Award 2006.
Innovative technical concepts can be developed with the aid of new instruments and materials, new methods of testing and other means, such as wind-tunnel

investigations, solar stations and the use of full-size models (Figure 125&126). (Herzog & Soka-Bau, 2006)

Figure 125: Office complex, Wiesbaden, Test models at LCD in Aldrans/Tyrol/Austria

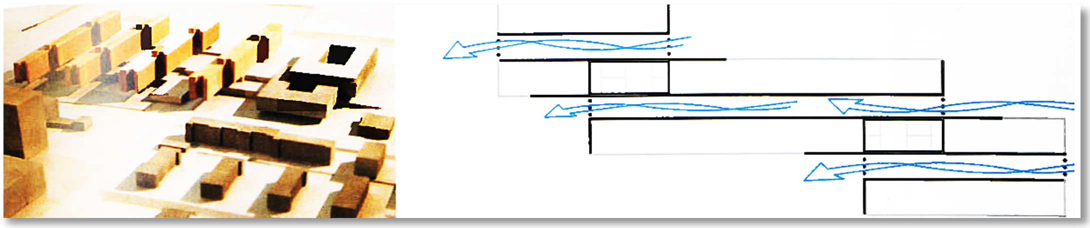


Figure 126: Office complex, Wiesbaden, Wind-tunnel model for investigating airflow

The new SOKA-BAU complex contains examples of many different innovative features that were conceived initially by the architects, that were then elaborated by the engineers, and that assumed concrete form through a process of calculation and simulation. Examples of this can be seen in developments such as (Herzog & Soka-Bau, 2006):

- Invention and implementation of an entirely new "intelligent facade" concept with special features for the reduction of fossil-fuel consumption;
- Automatically operated light-deflecting elements in the form of an outer façade layer that affords shade and serves to deflect light;
- Wooden elements -on the south and north side- in every section of the facade that can be precisely and individually controlled by users to provide natural ventilation;
- New development of linear skylights for restaurant daylighting, at the same time avoiding undesirable direct insolation (based on principles of non-imaging optics);
- The staggered layout of individual building blocks facilitates natural through ventilation along the length of the development;
- Rainwater is collected and used to water planted roof areas and internal courtyards;
- One of the main innovative features of the development is the accommodation of the entire service installations for the offices in the façade (Figure127). Fitted on the inside face at table height are "wooden boxes" that contain high- and low-voltage electrical outlets. In winter, a small convector on the outer face of the rooms heats the external air that enters via four ventilation openings in a large wooden panel. In summer, these panels serve as a means of natural ventilation;

Frontal view of façade axis with the following components: vertical ventilation flap, open (left), closed (right). composed of a frame of laminated spruce, plywood with cherry mahogany veneer, insulation, integrated, adjustable ventilation flaps, lighting strip, wood box (left) with convector, wood box (right) with power supply.

Diagonal view of façade axis with partially drawn glare protection

Figure 127: Office complex, Wiesbaden, Building technology installed on the facade

- Primary energy needs- for heating, cooling, ventilation and lighting - were reduced to below 90 kWh/m²/a.

Concerning facades, the office facades are in a single-skin, multilayer form of construction (Figure 128&129). The timber cladding to the north and south facades was executed in part in a thermally insulated panel construction, in which ventilation openings are incorporated. Depending on the external temperature and wind conditions, the opaque ventilation flaps -with air inlets- in the upper areas can be half or fully opened, or kept closed. They serve to control the natural intake of air for the rooms and guarantee the hygienically requisite air change. The areas of fixed triple glazing with an inert gas filling have excellent thermal insulation properties. The use of flint glass also ensures a high level of light transmittance. One innovation is the integration in the facade of the entire mechanical services for the offices. In winter, a small convector preheats the intake of external air through the ventilation flaps. The development was supported with funds from the German Federal Foundation for the Environment (Deutsche Bundesstiftung Umwelt). (Herzog et al., 2001)

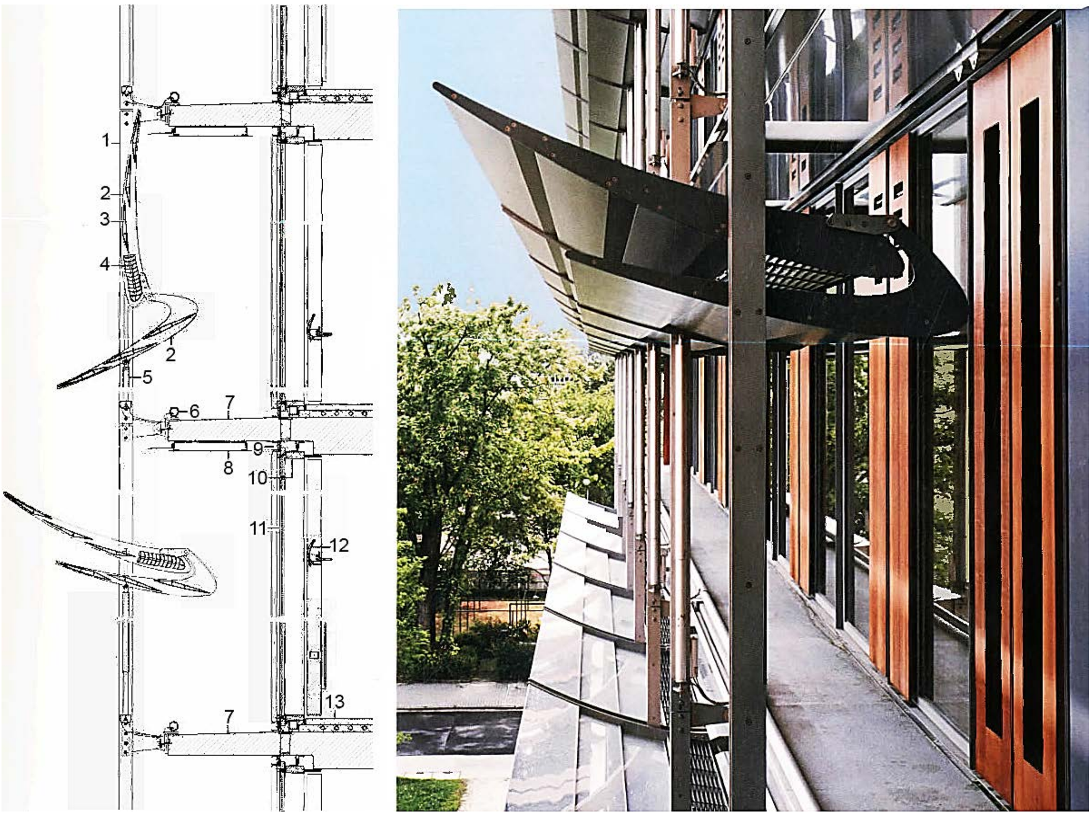
North façade
Vertical section

1 160 mm precast concrete element with polyurethane coating
2 aluminum light reflector
3 stainless-steel vertical fixing bracket
4 12 mm aluminum stirrup
5 highly reflective, extruded sheet aluminum section for light deflection, in fixed position
6 extruded aluminum facade sealing section with EPDM seal
7 triple insulating glazing With power-coated aluminum fixing strips
8 50/150 mm five-ply laminated and glued hemlock frame
9 lamp with aluminum reflector, light-diffusing glass sheet and integral anti-glare screening
10 floor construction:
50 mm screed micro-perforated membrane
50 mm screed around water-bearing pipes
280 mm reinforced concrete floor slab

Figure 128: Office complex, Wiesbaden, north façade with detailed vertical section

South façade
Vertical section

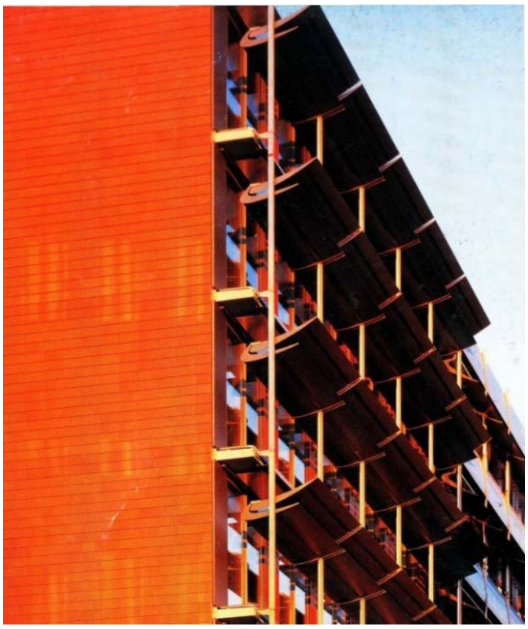
1 100/12 mm bead-blasted stainless steel section
2 powder-coated aluminum stirrup
3 highly reflective, extruded sheet- aluminum section for indirect light deflection
4 highly reflective, extruded sheet- aluminum section for reflection of direct sunlight
5 spindle hoisting motor
6 stainless steel tube as cable sheath
7 precast concrete element with polyurethane coating
8 aluminum light reflector
9 extruded aluminum facade sealing section With EPDM seal
10 triple insulation glazing with powder-coated aluminum fixing strips
11 50/150 mm five-ply laminated and glued hemlock frame
12 lamp With aluminum reflector, light-diffusing glass sheet and integral anti-glare screening
13 floor construction:
carpet 50 mm screed micro-perforated membrane
50 mm screed around water-bearing pipes
280 mm reinforced concrete floor slab



components are same as on north façade with additional, large and moveable light-deflecting and shading

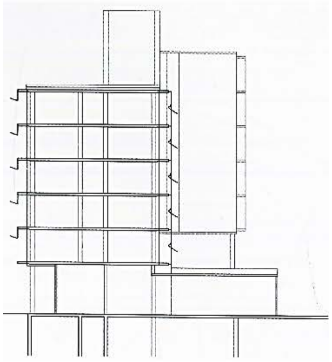
Figure 129: Office complex, Wiesbaden, south façade with detailed vertical section

The sheet-metal panels to the facades are another special feature of the scheme. On the north side, they deflect zenith light via the soffit into the depths of the rooms. An adjustable device was designed for the south face that also deflects zenith light- analogously to the system on the north side - on to the underside of the floors when the sky is overcast. When the sun shines, the elements move vertically into a sunshading position. Inward-pivoting light-deflecting elements in the top part of the facade bays allow a maximum degree of shading, while in the middle section, the requisite amount of direct sunlight is reflected into the rooms. The lower part of this system consists of a projecting element that also provides shading. Users nevertheless enjoy unimpeded views of the outside world. Within the rooms, artificial light is reflected on to the tabletops (Figure 130). (Herzog et al., 2001)

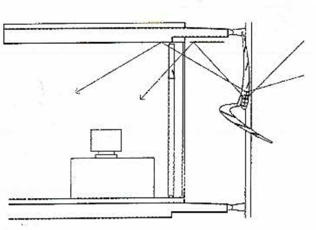


south façade of the office tract
combination of two shading elements pivoted about the horizontal axis:
-upper element with light-redirecting louvers for controlling daylight admittance, lower element acts like an awning to allow views of the outside
-additional (diffuse) daylight capture even with an overcast sky by means of shading elements with light-redirecting profiles

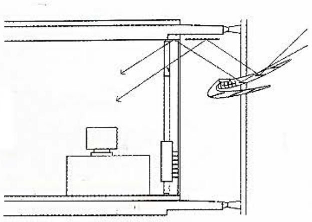
section of north façade
with stationary light-redirecting elements to capture overhead daylight like the south facade



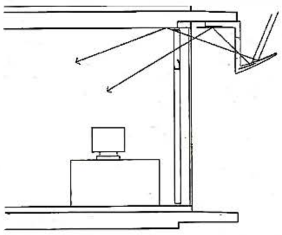
Office slab cross-section



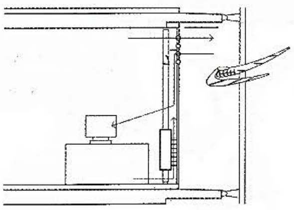
South face:
daylight deflection
when sun shining



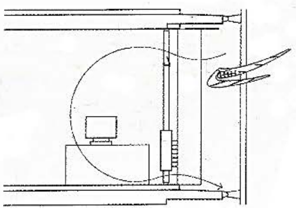
South face:
daylight deflection
when sky overcast



North face:
daylight deflection
when sky overcast



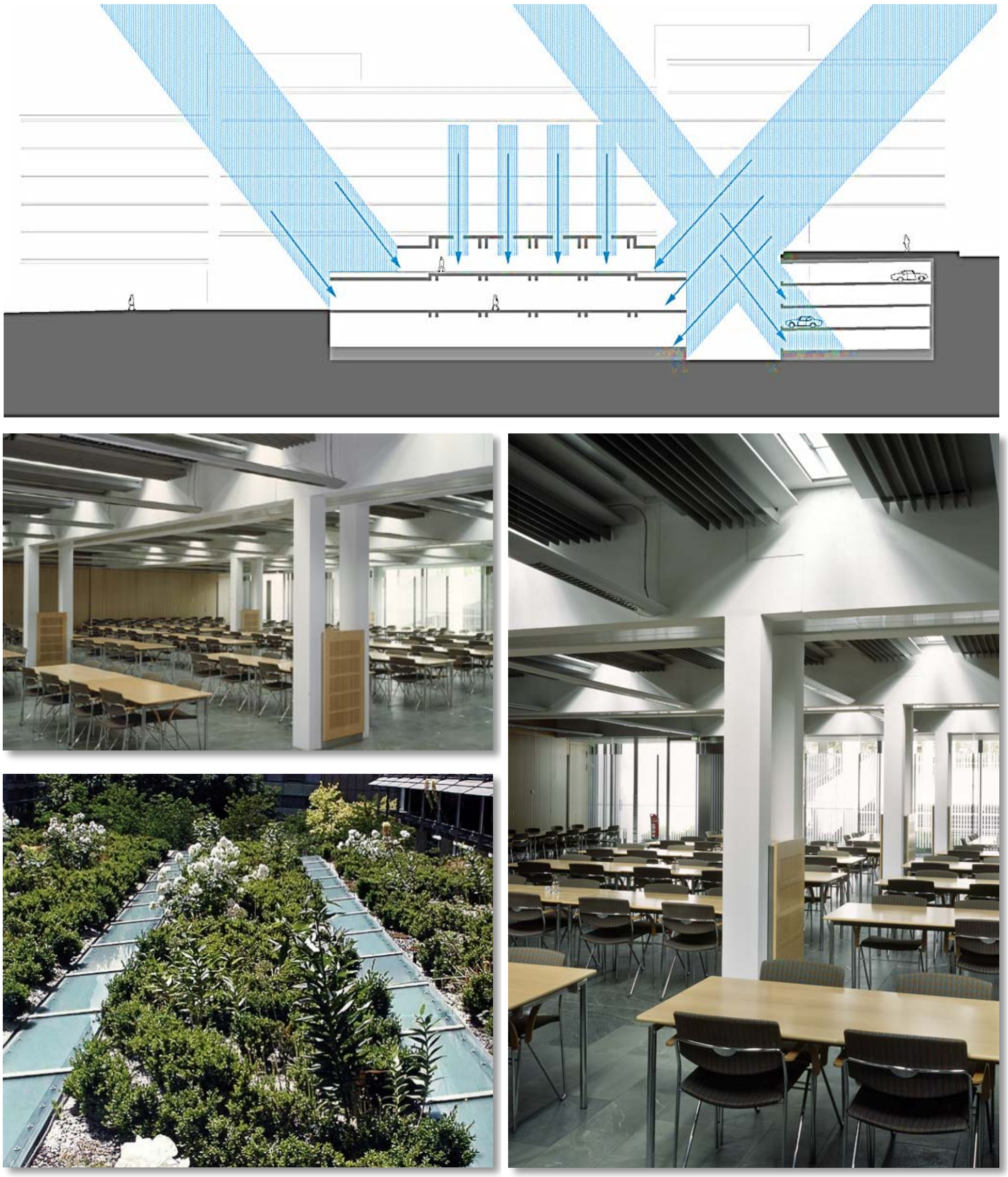
Centrally
controlled natural
ventilation



Natural
ventilation with open
ventilation flaps

Figure 130: Office complex, Wiesbaden, South and North façade of office tract

Near the windows - indirectly via the soffit, and directly via light-diffusing panels. In the linking tract, where greater room depths occur - in the restaurant (Figure 131&121), for example - natural lighting is provided by newly developed top-light strips that optimize the ingress of daylight. (Herzog et al., 2001)

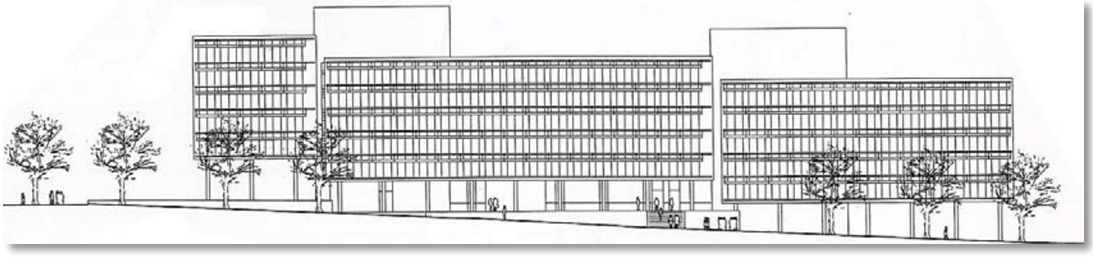


Light path in reflector closed to south and north

Figure 131: Office complex, Wiesbaden, Experimental development of linear roof lights for the restaurant

In fact, concerning facades with variable energy transmission, greatly improving the thermal transmission coefficient of the transparent façade areas (through the use of triple glazing with an additional inert-gas filling, for example) merely creates further problems. Indoor temperatures would be increased in summer as a result of thermal gains, and the weight of the panes of glass would be much greater, especially if one avoids unnecessary glazing divisions in order to ensure clearer views out of the building. This would necessitate the use of thicker glass to bear the horizontal loads, resulting in additional weight. If one were then to opt for natural ventilation in a form that everyone can understand and that can be simply controlled by individual users, it would conflict with the large, heavy panes of glass. That is the case, at least, as long as one believes that the movement of air between outside and inside has to occur at the point where light enters, and where there are fine views out to the beautiful landscaped courtyards and the roofs of the linking structures; for conventionally, ventilation openings are in the form of opening lights located in the glazed areas of a building. Moving away from this concept, however, provides an opportunity to develop finely regulable opening flaps that are independent of the glazed areas, that have a high thermal-insulation value and an effective geometry in terms of the internal temperature layers, and that avoid all the disadvantages described above (Figure 132).

Staggering of office wings, at twilight, not to scale



North elevation of an office wing, not to scale

Figure 132: Office complex, Wiesbaden, Office wings

In this project, wooden opening flaps were used. They are light in weight, and their functional advantages are exploited to the full.

As described above, the facade was subject to a number of conditions. These involve the southern aspects in particular and include factors like light deflection, shading to avoid undesirable thermal gains internally (while still maintaining visual links with the outdoor realm), and the avoidance of glare. In this respect, additional measures were implemented to protect computer workplaces in accordance with EU guidelines, which require uniform, balanced indoor lighting. A close analysis of the systems on the market ultimately showed that the existing ones would not meet these requirements to the desired degree. (A number of these systems were tested at the outset on full-size models.)

Cantilevered floor slabs as fire barriers between stories also function as areas for maintenance and cleaning, as well as providing shade in summer. Furthermore, they afforded scope for the construction of an appropriate outer facade layer that is able to respond closely to daily and annual changes in solar geometry as well as to factors that affect the indoor climate. In a close collaboration between the various specialist professions involved in this field (architects, lighting engineers, facade construction engineers), a "responsive" constructional system was created; i.e. one that can be adjusted to changing conditions. (Herzog & Soka-Bau, 2006)

Actually, concerning thermal activation of floor slabs (Figure 133), the special characteristics of the building skin, outlined before, find their continuation in an equally refined approach to the indoor climate, spatial use, construction, operating costs, and, not least, the appearance of the building. This was achieved by exploiting the principle of thermally activated building elements, a system that, as they contented, was first developed specifically for this project in the mid-1990s. Initially dimensioned in accordance with the results of simulation trials, the principle was then verified on the basis of tests carried out in a full-size model space by DS-Plan. They implemented the concept parallel to this scheme in the high-rise building for the German Trade Fair Organization (Deutsche Messe AG) in Hanover, as well as using it here to a large scale (in modified form) in the new pension fund building. (Herzog & Soka-Bau, 2006)

Figure 133: Office complex, Wiesbaden, Floor slabs

Depending on the type of subfloor heating that is specified, and with the use of the appropriate state-of-the-art technology, this thermal-storage system utilizes the reinforced concrete floor slabs of a building. These form the element in a skeleton-frame structure where the bulk of the constructional material is located, especially in buildings where free, variable layouts are desirable without load-bearing walls. The floor slabs in this project are activated as a thermal storage mass. The heavy material used in the slabs (Figure 134), which has not only a load-bearing function but usually plays a positive role in terms of airborne sound insulation where a normal floor construction is specified, is exploited for its favorable physical values. (Herzog & Soka-Bau, 2006)

Figure 134: Office complex, Wiesbaden, material used in the slabs

For roughly a century, one of the main concerns in building lay in improving the load-bearing capacity of the floors for economical reasons. This was achieved through the optimization of the structural system: by minimizing the amount of material used and thus reducing the weight and the outlay for transport and assembly. Today, one is concerned with increasing the efficiency of the slabs by exploiting their thermal-storage capacity in a 24-hour rhythm, as well as seeking further improvements in their load-bearing, sound-insulating and thermal capacities.

This may mean, on the one hand, that the slabs have a greater constructional depth than would be required for purely structural purposes. On the other hand, it is possible to provide spatial heating in winter at a low-temperature level through radiation upwards and downwards. This can be coupled with cooling in summer through the absorption of daytime thermal gains from outside, using the same water-bearing pipes in the floor/soffit. (The situation may be compared to the case of the facades described above). This obviously leads to certain conflicts and requires a wholly different layout for the service installations, including the ventilation (air supply and extract) and the high and low-voltage electrical outlets. Different concepts are needed for these functions, therefore. One can forget, for example, the internationally accepted principles applying to suspended soffits and voids in floors for the distribution of service ducts and cables. All that has to be abandoned, since the desired temperature control in the respective spaces can be achieved only where the thermally activated surfaces of the structural slab are in immediate contact with the room air. The occupants of these spaces experience an extremely pleasant sensation from the radiation emanating from the large floor and ceiling areas.

Measures of this kind mean, on the one hand, that within the permissible overall height of an office building, an additional full story can be achieved through the sum of the savings in the service voids in floors. That represents an increase in effective floor area of roughly 25 per cent. On the other hand, the concept requires adequate alternatives for standard functions such as impact-sound insulation, air exchange at the appropriate temperature and cable runs for the electrical supply.

The required degree of impact-sound insulation was achieved through the specification of high-quality floor finishings that are soft underfoot and comply with the relevant calculations. The finely adjustable ventilation system functions throughout the year solely via the facades. Electric cables are run at the height of the requisite safety barrier in front of the glazing on the inside face. The artificial lighting of the rooms follows the functional geometry of the daylighting system, using involute-shaped lamps that are also integrated in the facade construction.

Media facilities are easily accessible to staff via small, specially designed containers. These are incorporated in the facade construction at the appropriate height. Another advantage of this basically new form of accommodating the service installations, therefore, is that all elements remain easily and permanently accessible; alterations, replacements and the incorporation of technological advances are possible at any time without having to convert the workplaces. The system also allows a further undesirable aspect to be obviated - one that is neither economical nor satisfactory in terms of fire protection and ecology: namely, the many kilometers of redundant, usually PVC-coated cables that accumulate over the years as relics of changing users and with which one is familiar from so many large administration buildings. (Herzog & Soka-Bau, 2006)

Concerning materials, the aesthetic qualities of the materials used in this project have been brought out to advantage without coloration or other alienating effects. This lends them an enduring technical effectiveness. The material properties remain functionally and visually intact over the years. (Herzog & Soka-Bau, 2006)

In fact, concerning landscape features, the interaction of buildings and external space is necessary when creating optimal working and recreational facilities in respect of climate, lighting and energy.

From every space within the building one has a view of landscaped courtyards, roofs and terraced areas (Figure 135). These external spaces, situated on various levels, are not only of great aesthetic and social value for the people working here; as a "passive means of environmental conditioning", they also reinforce the sophisticated energy and climatic concept for the building. (Herzog & Soka-Bau, 2006)

Figure 135: Office complex, Wiesbaden, Landscaped courtyard

Various factors- solar radiation, shading, wind, cool air, thermal gains - and the influence they exert on the development were the subject of intensive studies also in relation to the external spaces. One outcome of these investigations was the meandering east-west configuration of the hedges in the courtyards and on the terraces. This layout does not impede the prevailing south-westerly airstream, which serves to cool the west facades and the plinth stories.

The court-like external spaces between the structures that are raised on columns open out to the street and thus form part of the public realm. Large-slab pavings in the entrance and access zones alternate with open grassed areas. The columns beneath the buildings form a visual extension of the trunks of the trees, which are planted in

open groves. The canopy formed by the crowns of the trees brings a glimpse of natural greenery into the office stories.
Robinias, with their fine foliage and pink-and-white blossoms, together with yellow-flowering gleditsias, filter the sunlight and significantly reduce the degree of insolation on the ground. The mist from fine vapor sprays creates a pleasant, cool sensation even on hot summer days (Figure 136). (Herzog & Soka-Bau, 2006)

Figure 136: Office complex, Wiesbaden, Reducing the degree of insulation on the ground by the plants

Columnar oaks and climbing plants continue the vegetation in a vertical direction. The various heights of growth and the play of light and shade evoke different planes of perception. Stones, leaves and blossoms are sprayed by fine vapor jets: the glistening coating of water enhances the visual structures, so that the image is legible even from a great height.
Seen as a whole, the "breathing" open surfaces, together with the controlled use of water, have a climatic effect that extends far into the building.
Here, too, the morning dew is imitated by technical means, conveying a sense of freshness and coolness.
Moreover, On the upper roof levels, specially selected soil types were used that retain rainwater; in dry periods, hundreds of jets spray excess water that has been collected in cisterns; and in response to concepts of urban ecology, robust plant structures develop as symbolic citations of nature. (Herzog & Soka-Bau, 2006)

The building is divided into three functional areas, to which heating and cooling energy are supplied at different times of day:
- Offices: night-time

- Plinth stories: daytime
- Data-processing center: at all times

The office areas are ventilated naturally. In winter, external air is heated to room temperature by convectors integrated in the facade. The floor slabs are thermally activated with pipe runs (similar to those used for underfloor heating) embedded in monolithic screeds. Hot or cold water is fed through the pipes, depending on needs (heating or cooling). The water temperatures range between a minimum of 18 °c and a maximum of 27 °c, according to requirements. In this way, the concrete mass of the floor slabs is heated or cooled during the night, and this thermal energy is slowly given off in the offices during the day. The solid concrete slabs with their thermal-storage capacity thus provide large-area heating/cooling surfaces that help to create comfortable spatial conditions (Figure 137). (Herzog & Soka-Bau, 2006)

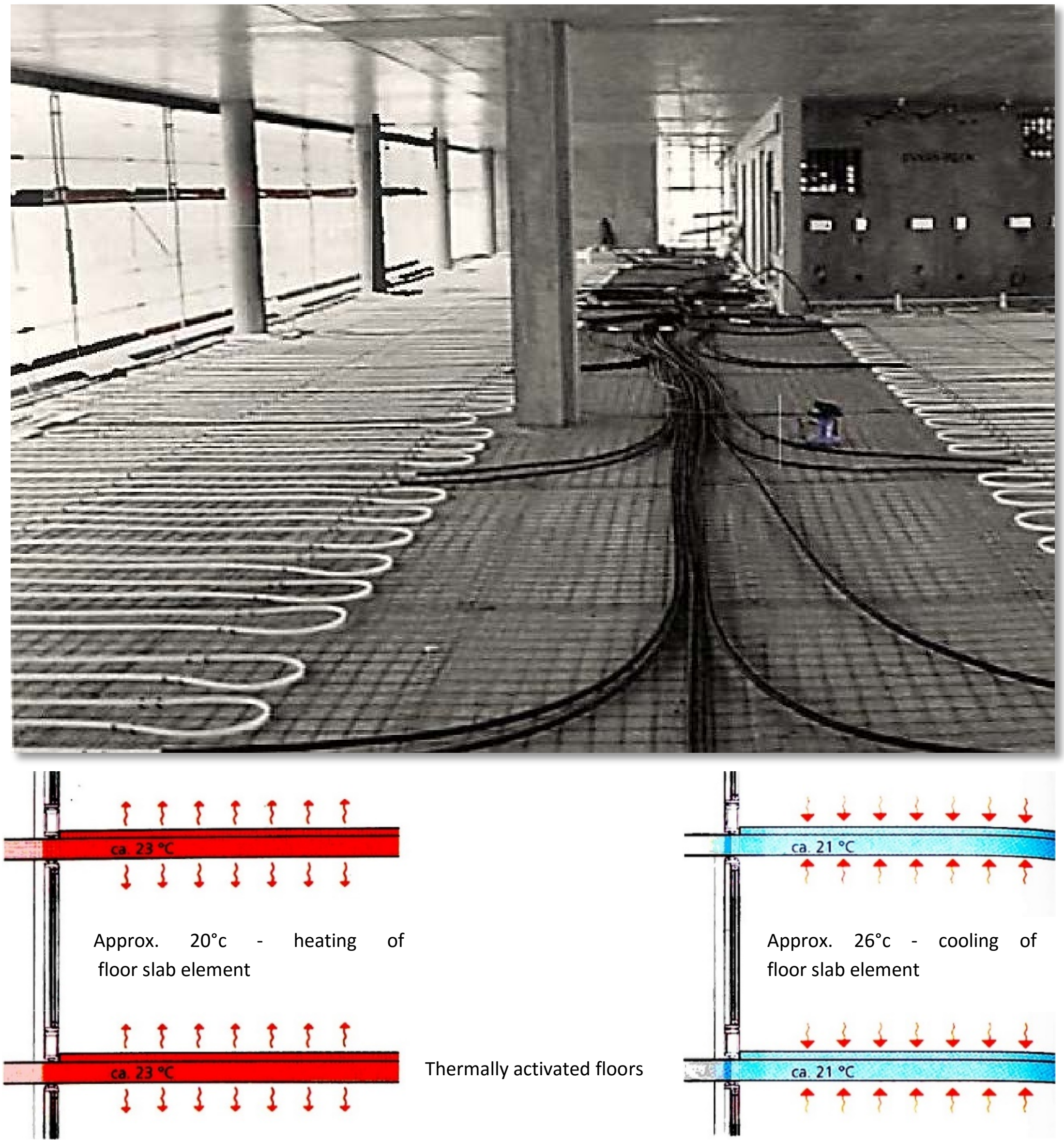


Figure 137: Office complex, Wiesbaden, Floor slabs heating & cooling

In view of the relatively high water temperatures (min. 18 °c), during cooler summer nights this process of thermal activation can be effected with the use of water circulated directly from the recooling plant of the refrigeration machines. In other words, a natural cooling of the water (evaporative cooling) takes place without the special use of the energy-intensive refrigeration units. To reduce the consumption of water, its processing in the recooling plants takes place via a decarbonizing installation.

On extremely cold or hot days, water from the district-heating supply or from the mechanical cooling plant can be fed into the thermal activated slab.

The plinth stories, which house the special functional zones of an office block, such as training and conference spaces, kitchens, canteens, printing and postal centers, stores technology and service spaces, are heated by means of radiators or the subfloor heating system and cooled via the air-conditioning or air-cooling plant. Since these areas are used only during the day, the energy supply is switched off at the end of the operational period.

The data-processing center is in operation 24 hours a day and therefore requires adequate, guaranteed power and cooling services. Cooling is effected by means of recirculated air from the cooling plant. Waste heat is used to heat the thermoactive floor slabs and thus the building as a whole. Since one part of the complex has to be served during the day and another part at night, it was possible to optimize the generation of heating and cooling energy by reducing dimensions and providing for longer operating periods (day and night), which in turn meant a better exploitation of the plant. (Herzog & Soka-Bau, 2006)

The entire heating and cooling service is provided by means of: (Herzog & Soka-Bau, 2006)

-A cogeneration unit (heat and power) in conjunction with an absorption cooling plant
- District heating
- Refrigeration plant
- Natural (free) cooling by means of recooling plant

In addition to guaranteeing modern comfort and cost efficiency, one of the most important goals of the scheme was flexibility. Walls and floors were created without service installations so that the structural components could be optimally used for heating and cooling the building.

A distribution network was, however, installed in the continuous basement floor slab. The modular form of construction facilitates service runs to workplaces as well as solutions on a room-for-room basis to enable general comfort and levels of artificial lighting (automatically linked to the presence of staff and daylight conditions) to be matched to individual user requirements. The flexible spatial regulation system is based on the European installation bus[26] (EIB). (Herzog & Soka-Bau, 2006)

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[26] The European Installation Bus (EIB) is an open, comprehensive system, which covers all aspects of Building Automation. This protocol is similar with the BACnet protocol and is manage by EIB Association.
The European Installation Bus (EIB) is designed as a management system in the field of electrical installation for load switching, environmental control and security, for different types of buildings.

In fact, the individual controls in the *office* areas are an important aspect of the systems concept for this complex. In an energy-conserving manner, they are in a constant "stand-by" state, ready to operate when needed. “Ready-state" is only activated when the user is present. Upon entering, the controlled natural ventilation coupled with the convector and the artificial light, which complements the daylighting with the help of control sensors, is activated to supplement the daylight level. Another important ecological balancing measure is the dense, differentiated planting scheme on the roofs.

In an overall view, the building project contains a wealth of innovative features- the outcome of a new interpretation of the design and construction brief, and based on ecologically relevant criteria. The concept also complies with modern scientific and technical standards in respect of the design and implementation of buildings. (Gonzalo & Habermann, 2006)

Its purpose is to ensure the monitoring and control of functions and processes such as lighting, window blinds, heating, ventilation, air-conditioning, load management, signaling, monitoring and alarms.

2-4 Discussion

Two-family House, Pullach

In fact, in this project, the architectural consequences made all the spaces south-facing. Admittedly, this action would eliminate the problem to transfer solar heat to the rooms which are placed on the north side in the winter. Therefore, in the house Pullach the concept of the design was resulted in an elegant cross-section which is extremely slender.

Additionally, different rooms around the building, in the cold season, have certain using hours throughout the 24 hours a day -some of them will have used 2 hours a day and the others 12 hours a day. Therefore, basically, it has decided to define completely different kinds of space and also different mechanical service systems as well as different building materials.

The most usage of glazing are focused in the long pavilion plan of the building in which for each square foot of floor is 0.5 ft^2 glass (a proportion of fifty percent) that this glazing area exploit to get heating by direct gain.

The solar collectors which are planted in the south face, can collected forty percent of the solar energy even in a completely overcast day in the winter.

Actually, in this project, there were many aspects to consider. Not only heating, cooling and ventilation, but also the optimization usage of daylight and exploit it for the generation of electricity.

Additionally, their aim was not only to incorporate the context throughout the design process -the surroundings and their scale and the kind of material used, but also to build a house which would be suit for the clients' needs and to meet their wishes, which, besides exploiting environmentally friendly forms of energy have a pleasant appearance aesthetically.

In fact, the building was to exploit the cutting-edge technology. The outcome of this climate appropriate house obviously illustrates Herzog´s philosophical attitudes toward building technology which shows that how the integration of functional and traditional aspects can immerge into a practical application in which the materials and resources are minimized.

Guest Building for Youth Educational Center, Windberg

The best advantages of the system are potential energy saving and also the low cost.

In fact, for conserving energy, the two main factors which was taken into account was the time-usage and temperature requirements for certain spaces. In this way those spaces which were supposed to use for several hours were separated from those spaces which were supposed to use for just a short period. Furthermore, different materials were used to build them.

In the other word, considerations of the energy consumption affected the design development; the main strategy was based on prioritizing the new rooms in accordance to the length of time that they would be used. The living spaces which were larger, located on the south side for using solar heat gain through the day with the enclosing walls and windows as thermal preservation elements. The smaller rooms which were on the northern side with short use, required little heating but were outfitted with insulation and an external wall with a high thermal performance. They use the solar water heaters for supplying both space heating and hot water.

Elements of the planar surfaces were generated from Herzog's ecological design strategy and the design was based on a modular structure for carrying the passive heating systems. In order to expand the daylight usage, there were erected the translucent insulation panels. Furthermore, in order to recover heat losing during the day, the mechanical ventilation systems were planted on top level.

The south facade of the building has divided into vertical segments of opaque walls and windows which are used alternatively.
For preventing the wall from overheating, through summer months, the exterior louvers can be lowered for shading the walls. This situation actually creates an interesting shift in perception, because one would not expect the shading devices in front of opaque wall elements in a conventional wall.

Moreover, an optimum form of wall construction was developed and tested which was based on the climatic and regional context. In this way, the statistical pattern of Local weather conditions was simulated in computer trials.

The spaces which are used for long periods are lit and heated with daylight and solar energy through using translucent thermal insulation, among the other materials.
Thermal energy distributes throughout the building which is based on orientation, temporal and programmatic calculations.

In addition to the main and primary function of the building, it also demonstrates the principles of the bioclimatic architectural design by making the students aware of the passive and active energy systems and also the environmental performances of this building -by making presentations by facilitating a digital information board which is placed on the entrance area, showing energy performance, visible service runs, storage elements and solar collectors.
Admittedly, this multidisciplinary attitudes toward building has educational and cultural values.

Exhibition hall in Linz

In fact, the primary and main consideration was to provide a quality of outdoor daylight into the building interiors.

The project was a development of the solar energy techniques and completely a new kind of ecological roof construction in a big scale.

Their aim was to make this building environmentally responsible as much as possible via minimizing resources. In this way, what served as a vehicle was energy efficiency to reach to this objective.

The design is reinterpretation of Crystal Palace's theme. The advantages of the daylight are evident in this type of building. A new system were developed by design team which is usable universally for the building envelopes. The indirect light was allowed by the system to enter through "light shafts", in tight rows which was set next to each other, while excluding direct sunlight.

It was innovated the Light Metrics system. A light grid system was inserted between two large glazed panels in which natural light is allowed to enter into the exhibition hall while excludes direct solar heat gain. This building is able to conserve the thermal and also the electrical energy by maximizing the natural daylight and also minimizing the unwanted solar radiation. By allowing only diffused light to the interiors, the overheating and also glaring –which is caused by the direct light- was prevented.

In fact, everyone has worked together as a unit and collaborated concurrently instead of sequentially. It (concurrent process) facilitates the integrated collaboration of knowledge experts that is required for an energy efficient architecture. The solutions for efficient buildings are typically involved of multiple components and also use of the specialized trades apart from usual mechanical consultants. Likewise, the invention of Light metrics in this project wouldn't have been viable without a continual collaborating with lighting research and also consulting firms.

Radicalizing the building paradigms, which are accepted, is a principal integral part of his method of design. In this way, collaborate with research institutions, including public and private, have been a vital point. Evidently, these institutions were productive to test his inventions, without whose assistance, the ideas and sketches wouldn't have evolved. As an example, the "Daylight Grid System" was designed successfully by Herzog with assistance of two of these institutions. Consequently by accessing to the computer simulation and measuring thermal and also energy transmission for different skylight prototypes, the aluminum sections and laminated glass were selected to produce worldwide; for the first time a grid-shaped material was designed for diffusing and reflecting a large quantity of light in a roof spanning structure with curved glass.

In fact, the Modernist expression can obviously be found in Herzog's professional practices and also in his research and academic practices. He is constantly seeking to experiment and apply the most advanced technologies to the services for his buildings. He believes that the Modernist architecture is still involved with a transition from the posture in 1970s in which the energy efficiency was overlooked for achieving visual statements of the material minimalism. But Herzog has an opposite idea about emerging role of the Modern architecture: to use new configurations and materials to exploit a functional relationship between building and environment. The evolution of this idea is evident throughout his career.

Solar city, Linz

Actually, it is one of the best examples for urban designing which is based on the sun and, also, it is a model state initiation for the ecological urban development which the extensive use of solar energy have incorporated. The individual buildings and residential areas were designed according to principles of the solar architecture – there were exploited from passive and active solar energy. Also it was emphasized to the aspects of the nature and the leisure.

"Energy supplies" is one of the parameters which has taken into consideration: the development, in the project, was not supplied by the electricity grid of the city, however, co-generating its own energy by "solar" installations which will make the neighborhood absolutely independent in the future and even allow it for returning its "energy surplus" to the energy grid of the city.

In the other word, the energy supply was a big innovation in this project. A shift of scale is in the solar energy production from single building to the whole urban zone. The solar power comes in the city as an alternative for a power station and an economic model.

The shape of the buildings have optimized, by following the sun's path and maximizing solar energy gain and also maximizing the daylight input, consequently the performances of the buildings have improved. The density studies of the buildings have revealed that the four-story and also naturally cross-ventilated buildings with the west-facing balconies, have offered a good typology for the current buildings as "energy-efficient residential buildings" –like townhouses.

Additionally, Substantial savings can be achieved by the passive systems –such as summer shading, natural ventilation and solar heat gain in the winter.

The height of the buildings and number of floors was decreased in order to make a suitable area for installation of the photovoltaic panels.

Actually, it was a flagship development for the use of renewable energies in an urban design scale while the priorities are given to utilization and using solar energy and relating contemporary technologies.

The aim of the project was to minimize the environmental impacts via energy generation systems with self-sufficiency.
Evidently, this project introduced a turning point to the architectural and landscape design and as an example of a public-private partnership to achieve to the sustainable planning, construction and design goals.
This sustainable city is a model for future cities to promote low energy consumption and low cost building methods and strategies on a worldwide basis.

Hall 26, Hannover

In the view of special usages, the natural ventilation was the central important issue. In developing the geometry of cross-section, careful considerations were given to that; i.e., natural ventilation.

Obviously, the minimization of the height of the roof with the high points has applied for enhancing the natural ventilation. Moreover, Use of direct sunlight is restricted. Additionally, a significant use of renewable materials is evident which leads to considerable saving in energy.

In the other word, the high reference points were created for the natural ventilation by using thermal up-currents. Also introduction of the indirect daylight was contrived. As result the cross-section of the building was evolved -which is derived largely from formal laws (and is imposed by the tensile construction) and demands of the natural air conditioning and daylight usage.

Moreover, the roof is combined of complex issues and main roles of the roof traditionally performed in the following aspects: It had to be supported and resistance from the excessive temperature and also to keep the moisture out from the current combined large roofs. Three more devices which have incorporated, to attach to the system, are passive ventilation strategy, passive lighting strategy and mechanical devices.

Actually, in this sustainable roof, the most important issue was to create passive ventilation. For creating a passive ventilation, a huge roof was needed to be made.

Evidently, it has shown that it is possible to work with this system of steel structure, which is highly efficient, in combination with the wood which not only is a renewable resource but also its flexibility to shape a curved ceiling, provides a pleasant interior space.

In general, it has taken the advantages of passive strategies to improve cooling, heating and lighting performances and has made strong statements of the modern architecture.

Furthermore, the building represents an innovative constructional work in which many new technologies have been applied and it wouldn't be too bold to remark that it creates architectural history.

Administration building, Hannover

An innovative usage of environmentally friendly forms of energy was evident for the operation of the building. Moreover, the design of the workplaces was in a top-quality. In addition, the layout of the building has a great flexibility in usage by articulating a central area of working (24 x 24 m) on the plan with two access cores which contains ancillary spaces and offset to both sides.

As we have seen, Herzog's designs of sustainable buildings have encompassed three decades of his career's aspects. The new materials development and their accompanying in construction processes set conservation of the energy in the center of his practices, who makes sensitive decisions on ecological issues according to the rules without any exception. Undoubtedly, the Administration Building is one of his projects which acknowledged the mentioned goals on an architectonic scale. Each aspect of this high-rise building is exemplary. In fact, façade of the building has a double skin system which incorporates the latest technological innovations by air transferring, with the aim of securing a big amount of energy savings.
In the perimeter of the floors is a chamber of ventilated air which is running and has almost four feet width which separates the exterior surface of the building from its interior. In this section of the building all the necessary adjustments of the temperature (to maintain the interiors of the building at a constant and a fixed air temperature) are orchestrated. The shading devices which are installed on the both surfaces and the ability for re-circulating the heat, which is generated within the cavity, increases the thermal comfort and also decreases any need for additional source of energy. Moreover, all the building details and the mechanical systems were incorporated to further support the operation of the façade.
In general, Herzog developed an honorable career throughout his innovative approaches to use the materials and also to rehabilitate of the art of building.

In general, this building has coordinated “form of the construction” with “energy concept” by applying the sound principles of the building physics and also exploiting the locally available forms of environmental energy.

Office complexes in Wiesbaden

In fact, a high degree of the cost efficiency, in the operation and construction of the buildings, was required by the clients besides the utilization of environmentally friendly forms of energy. Consequently the design of the building was defined.

For supplying energy, a combined energy system in which cooling, heat and power were coupled, was installed.

Actually, from the viewpoint of general objectives of sustainable design, exterior skin of the building will continue to filter and channel the natural air and the light into the interiors, and building components will be realized as the organs for body which contribute to growth and existence of the body as a general sense. The composition of the elements of the skin will form from a number of parameters such as: an understanding from external environment, heat radiation, convection, evaporative cooling, conduction and the reflection and transmission of daylight.
However, physical aspects of environment often have contradictions; elements of the systems for heating and airflow may be different from elements of the systems for natural lighting, in details and architectural forms –as a consequence of different performances- which may leads to form different configurations and mechanical elements. The application of the multiple skins, often resolves these fragmentations which has intensively used in this project.

In general, besides cooling and heating, energy demand for the artificial lighting was an important issue for energetic performance of the buildings. The buildings with a huge overall width, containing office buildings, are tended to have substantial demands of energy for the artificial lighting. In fact, developing a daylight innovation concept is the most important strategy for decreasing energy demand for the lighting. The daylight concepts have to be considered in a combination with the aspects for cooling and heating.

2-5 List of figures and tables

2-6 Bibliography chapter 2

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Chapter 3: Integrated Practice: High Performance Buildings

3 Chapter 3: Integrated Practice: High Performance Buildings

3-1 Introduction

3-1-1 Statement of the Problem

“The health status of millions of people is projected to be affected through, for example, increases in malnutrition; increased deaths, diseases and injury due to extreme weather events; increased burden of diarrheal diseases; increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone in urban areas related to climate change.” (O’Mara, 2012)
- *Climate Change 2007 Synthesis Report, IPCC*

Different from traditional construction approaches that emphasize only cost, schedule, and quality performance of projects, sustainable construction expands performance goals to attributes such as low energy consumption, reduced air emissions, and minimal waste generation. Although the market for sustainable buildings continues to expand, in recent years the scope of the required performance from such buildings has increased and now includes user satisfaction and occupant well-being. Such buildings, along with sustainability issues which address concerns of indoor environmental quality and user satisfaction, health, and productivity are known as sustainable, high-performance buildings. (Mollaoglu-Korkmaz, Swarup, & Riley, 2013)

High-performance buildings (both new and retrofitted) are an essential part of a global energy strategy to reduce carbon emission, fossil sources depletion and more in general, to obtain a reduced environmental impact in a cost-effective way. (Manfren, Aste, & Moshksar, 2013)

The concept of high performance or green building incorporates a variety of strategies during the design, construction and operation of building projects. Green building and energy efficient design encompass six key areas as outlined in this section and include economic, social and ecological benefits (Ranzi, Sean, Swanzey, Greene, & Ryan, 2006):

Six Key Principles of High Performance Building:

- Architecture and Design
- Building Materials
- Land Use
- Energy Use
- Water Use
- Interiors

‘High performance’ building encompasses a broad range of matters related to the built environment. The values and benefits of high performance building fall into at least the following categories (Zerkin, 2006):

Public health

- The direct beneficiaries are the people who work in buildings or who build and/or demolish them, and, more generally, the public-at-large;
- Employers are presumed to be indirect beneficiaries because enhanced employee health means, among other things, lower absenteeism, improved productivity, and reduced employer liability and insurance costs;

The environment, and therefore the public-at-large, as a function of reduced consumption of energy and water, reduced generation of solid waste, and reduced truck mileage; all of which should yield:

- Lower building operating costs;
- Public cost savings attributable to reduced cost of operations for public infrastructure and an avoidance of capital expenditures for their expansion;
- Lower risk of energy shortages at times of peak demand;
- Reduction in the contribution to global warming; and
- Improved outdoor air quality, both from the operation of the building and the reduction of truck traffic related to the delivery of construction materials and the operation of the building;

Systems reliability

For many high-tech operations, the historically acceptable levels of 99C% reliability of electric power supply is no longer adequate—in many cases, nothing less than 100% reliability is enough;

Flexibility in space utilization

- When building owners and tenants can adjust office space in accordance with changing needs, e.g. the possible need to sublease a portion of its space in the event of downsizing, the long-term cost-effectiveness of the space is greatly increased;

Individualized climate control

- The direct beneficiaries are employees;
- Indirectly, employers are beneficiaries because the ability of individuals to climate-control their personal space has implications for an employer's ability to recruit and retain key personnel for whom state-of-the-art comforts and 'extras' may be critical;
- Individualized climate control will also reduce operating costs, because individual climate control reduces the amount of total space volume that has to be heated or cooled and eliminates the common tendency of central heating/cooling systems to make buildings generally too hot or too cold in order to insure that the hardest to heat/cool places are at some acceptable minimum; and

Public security.

- High performance building is concerned not only with building design and building construction and renovation but also with the reuse and recycling of

> scrap construction and demolition materials and with the infrastructure that makes possible or limits all of the above. High performance building applies to commercial buildings, industrial buildings, infrastructure facilities and residential buildings (having enormous importance for the typically neglected operational affordability of ‘affordable’ housing).

Today’s high-performance green buildings are a significant improvement over the conventional buildings of the past. They consume significantly less energy, materials, and water; provide healthy living and working environments; and greatly improve the quality of the built environment. Although notable progress has been made in building performance, for the most part contemporary green buildings use existing materials and products; design approaches, and construction delivery systems. Ecological design, perhaps the key concept in creating high-performance buildings, is in its infancy and sorely needs articulation for there to be the possibility of creating truly green buildings. (Kibert & Rinker, 2007)

Accelerated depletion of natural resources, continuous damage to the natural environment, significant contributions to global waste generation, and increasing consumer awareness of these issues are but a few reasons for the escalation in demand for sustainable, high-performance buildings. Such buildings primarily aim to achieve low energy consumption, reduced air emissions, minimal waste generation, user satisfaction, and improved indoor environmental quality. According to the Smart Market Report (McGraw-Hill Construction Research and Analytics 2007), such buildings represented 4% of the building market in 2006 and the number is exponentially rising (Swarup, Korkmaz, A.M.ASCE, & Riley, 2011). However, although the pace of high-performance green building has been increasing, the rate of change has been far too slow to offset the depletion of resources, local, and global environmental degradation, and other negative consequences of transforming land and materials into infrastructure and buildings. Although BREEAM, LEED and other building assessment systems have resulted in noticeable change after their introduction, it is time for a significant shift in government policy, from voluntary to mandatory measures coupled with incentives that will dramatically accelerate the transformation of the construction industry and its products. (Kibert & Rinker, 2007)

Energy performance of buildings is today recognized as a major issue to address the worrying questions of human-induced global warming and depletion of fossil energy resources. To this purpose, several high energy performance building (HEPB) concepts have been proposed, from low-energy[1] building through passive building and zero-

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[1] “Low-energy” is a generic expression meaning that the performance level in terms of energy is better than the performance level of a standard building, whereas “passive” refers to the Passivhaus standard, developed in Germany by the Passivhaus Institute, which aims very low heating load and total energy demand. This standard defines three precise requirements that

energy building to positive energy building[2] and even autonomous building[3]. Nowadays a lot of national regulations introduce such concepts as targets for the buildings to be constructed. In particular, the recast of the European Energy Performance of Buildings Directive (EPBD) targets nearly zero-energy performance for all new buildings by the end of 2020. Beyond energy issues, high energy performance buildings are supposed to contribute to the reduction of the environmental burden of the building sector. Moreover it seems relevant to consider that the more energy-performing a building is, the less negative environmental impacts it induces. This is surely true during the operation phase of the building, but compared to standard buildings, a HEPB generally requires more material (thicker insulation, triple glazing windows, etc.) and more components (solar panels, etc.) and thus induces more environmental impacts during the other phases of the building life (construction, refurbishment, demolition). (Thiers & Peuportier, 2012)

Increasingly, there is recognition that green buildings must be designed from inception to minimize environmental impact throughout the building life cycle. Designing for high performance from a life-cycle[4] perspective is critical, and depends on several fairly recent innovations in the design/build process: Building Information Modelling (BIM[5]) and Integrated Project Delivery (IPD), and ever more sophisticated energy and financial modelling tools and methods.

High-performance green buildings of the next decade will be designed by cross-functional teams using complex energy and building modelling tools, and applying the newest information gleaned from these models. Looking to the enormous potential

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certified passive buildings have to fulfil: heating energy demand lower than 15 kWh m^{-2} yr^{-1}, total primary energy demand lower than 120 kWh m^{-2} yr^{-1} and air infiltration at 50 Pa lower than 0.6 vol h^{-1}.

[2] The “positive energy building” concept (PEB), closely related to “zero (-net) energy building” (ZEB) concept, combines energy saving and energy recovery from local renewable resources, such as solar radiation, wind, biomass or heat from the environment. Energy can be saved by the combination of a high insulation level, heat recovery from extracted air, a high level of air-tightness, and the use of efficient equipment. Thus, the “Passive-house” approach can be used to design a PEB. Energy recovery from local renewable resources can provide part or the whole building energy demand including heating load and hot water production, and can supply power for local consumption or to feed the electricity grid.

[3] An “autonomous” building is a type of ZEB with no connection to any energy distribution grid. Its energy needs are supplied by local resources at any moment, which practically requires the implementation of energy storage devices (see e.g. the experimental house build in Germany by the Fraunhofer Institute in 1992). In practice, this kind of building is indispensable in remote locations but is not considered today as a practical solution in locations where grid connection is possible.

[4] Life-Cycle: The owning, operating, maintaining, and (eventually) disposing of the building system(s) over a given study period

[5] Building information modelling (BIM) is one of the most promising recent developments in the architecture, engineering, and construction (AEC) industry. With BIM technology, an accurate virtual model of a building is digitally constructed. This model, known as a building information model, can be used for planning, design, construction, and operation of the facility. It helps architects, engineers, and constructors visualize what is to be built in a simulated environment to identify any potential design, construction, or operational issues. BIM represents a new paradigm within AEC, one that encourages integration of the roles of all stakeholders on a project.

within the green buildings movement and focusing on the triple bottom line, smart teams of people are collaborating, innovating, and partnering to bring a whole new breed of high-performance green buildings into the marketplace. (O’Mara, 2012)

According to the International Engineering Consortium, only about 25% of total life cycle cost of buildings in the U.S. occurs at the design and construction phase. Unfortunately, this is when many decisions are made that will affect the performance of a building for many years into the future. Since most of a building’s cost is associated with its ongoing operations, it is clear that to reduce energy use and CO2 emissions of buildings, we must move toward a new “design for life cycle performance” paradigm—from conception to ongoing operations and maintenance—infusing high-performance measures throughout every stage in the process.

As the green building marketplace evolves, high-performance buildings are becoming more intelligent entities that sustain results over time. Mirroring the human body which changes and adapts[6] automatically to its environment, a high-performance green building can make better and better automatic decisions with converged solutions. Learning from the messaging of its “nervous system,” these buildings make more intelligent decisions and strategic changes over time. [10]

Who is the customer of the building industry? Building customers are the people who come into commercial and industrial buildings every day to do their jobs, and the people who own the businesses that hope to profit from the work they do. To deliver a high performance building it must be clear to those designing the building what ‘high performance’ means to the building owners, occupants and to those who maintain it. The architects, engineers and contractors must know what these customers want to experience to best do their work, from how the air smells to the size of the checks they write for utility bills. Understanding these needs is essential for creating a building that is effective, efficient for users and profitable for its owners. Today’s top product developers use tried and true methods to collect this sort of information and use it to make sound decisions. The building industry has not typically employed such methods, yet it is critically important for high performing buildings.

In the words of Yogi Berra, “If you don’t know where you’re going, you’ll end up someplace else.” Setting the expectations for how a building will perform takes only a few weeks, but locks in how the building will perform for the next 50 or more years. Unfortunately, the building industry does not typically do this well, and the result is

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[6] A simple example of self-adapting systems would be “optimum start,” in which an algorithm uses historical data in conjunction with internal and external building conditions to predict the optimal time to start the building’s systems to achieve operational conditions at the beginning of occupancy. Conversely, “optimum stop” calculates the right time to stop a building’s systems while maintaining minimal drift in environmental conditions by the end of the building’s occupancy period.

mediocre performance in many buildings from the perspective of all customers. (Allen, Pennisi, & Norman, 2011)

Upgrading buildings to high-performance standards is rather like going from typewriters to notebook computers. One needs periodic maintenance; the other needs regular software upgrades and hardware changes. One stands alone; the other is networked to a global information system. In other words, the management of high-performance buildings requires a higher level of professional skill, and the capability to manage and upgrade complex systems in a technologically dynamic environment. (Orr, 2006)

Developing a sustainable, healthy, high performance building must begin in the predesign phase. The longer a project team delays in defining high level end goals, the more costly developing a sustainable, healthy, high performance project becomes as shown in Figure 1. (Enck, 2010)

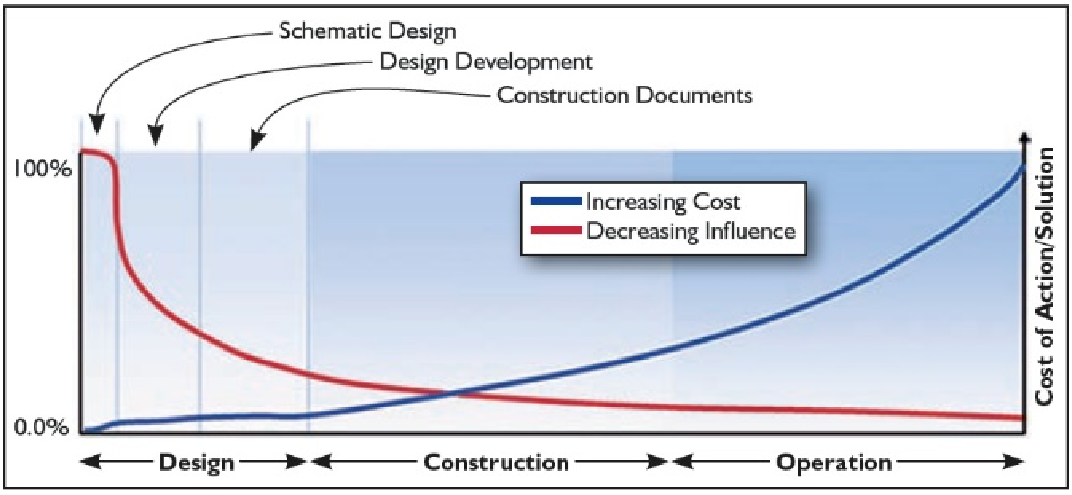

Figure 1: Costs increase the longer a project team delays in defining high level end goals.

One of the primary characteristics of successful sustainable design is the implementation of a multidisciplinary and integrated team approach, particularly during the early design phases. An integrated team approach, early involvement, and greater participation of the various project members and stakeholders, help ensure an end product that is more efficient and healthier for both owner and occupants. (Kubba, 2010)

An integral approach could result in synergy between rational problem-solving (based on engineering knowledge) and reflective practice (based on design knowledge). (Zeiler & Savanovic, 2011)

The main objective of integrated design is to improve the overall quality of buildings, in terms of energy demand, indoor environment, economics, and user satisfaction. To this end, the application of simulation tools has become increasingly important in the analysis and evaluation of various parameters and how they affect the daylight conditions and energy demand for the space and building being considered. The application of these advanced tools is typically handled by the engineer, while spatial considerations are typically handled by the architect, so there is a risk that daylight strategies are considered solely in terms of either aesthetic purposes or functional requirements (Baker, N. and Steemers, K. 2002). But if integrated design is defined as a process informed by interdisciplinary knowledge, the formulation and application of daylight strategies must include both spatial aesthetics and considerations concerning energy reductions and indoor environment. This implies that working with daylight is a field where there is great potential for architects and engineers to work together to achieve synergy and positive effects. (Jørgensen, Iversen, & Jensen, 2012)

Studies by government and industry researchers have found that using currently available high-performance technologies can reduce a building's energy consumption and CO2 emissions by 30%–50%. Furthermore, laboratory studies indicate that new technologies integrated holistically with the building design can reduce energy consumption and CO2 emissions by as much as 70%. With this level of improvement in energy efficiency, on-site renewable energy can in many cases supply the remaining energy needs. To the extent that these technologies become cost effective, they would enable the widespread adoption of net-zero energy[7], high-performance buildings. (*Federal Research and Development Agenda for Net-Zero Energy, High-Performance Green Buildings*, 2008)

From an energy perspective alone, as high-performance building technologies can already reduce building energy consumption on average by 30–50%, new technologies to achieve net-zero energy — buildings that over a set time period (typically a year) produce as much energy as they consume — must be developed and integrated holistically into the building design to make buildings more self-sufficient. Other

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[7] In agreement between ASHRAE, the American Institute of Architects (AIA), the U.S. Green Building Council (USGBC), and the Illuminating Engineering Society of North America (IESNA) a common definition was utilized in AHRAE Vision 2020; namely "...a NZEB is a building that produces as much energy as it uses when measured at the site. On an annual basis, it produces or consumes as much energy from renewable sources as it uses while maintaining an acceptable level of service and functionality. NZEBs can exchange energy with the power grid as long as the net energy balance is zero on an annual basis."

ASHRAE defines a NZEB as a building that produces as much energy as it uses when measured at the site. In general, a net-zero energy building will start with an integrated whole-building design process; maximize energy-efficient envelope, equipment, and design features (including daylighting and passive heating/cooling/ventilation where possible); and carefully monitor and control all installed mechanical and electrical systems (including plug loads) to assure that they only operate when needed. With these strategies reducing annual energy demand by about 80% compared with a typical building today, the remaining loads are at a scale where they can be met with on-site power generation (most commonly solar PV). (Harris, J., 2010)

Net Zero Energy target is meant to be the next logical step after High Performance buildings. Many countries have already set this target as a medium-long term objective (10-15 years).

considerations such as conserving water and material resources, improving indoor environmental quality (IEQ), and reducing Greenhouse Gas (GHG[8]) and other emissions are equally important. (*Federal Research and Development Agenda for Net-Zero Energy, High-Performance Green Buildings*, 2008)

A National Green Building Research Agenda, USGBC (2007) notes the need for integrated, transformational solutions to reach net-zero energy buildings:
"…to achieve net-zero energy buildings, prescriptive, independent measures will no longer suffice. Leaps forward in building performance require design that fully integrates building systems…"
There is a limit to the overall energy savings potential of mainstream approaches for reducing energy use in new buildings. Major national studies agree that this limit ranges from 30% to 50%. Integrating technologies with the building design (form) to create a building that delivers efficiency as a single system, however, can raise savings to 70% of building energy use compared with conventional new building design. With these dramatic reductions, renewable energy could provide the remaining energy needs and enable the widespread adoption of net-zero energy buildings.
New construction offers the greatest energy savings potential on a building-by-building basis, but the greatest potential on an overall, national basis lies with improvements to existing buildings because of their slow turnover (~1%/yr). Integrated, performance-based retrofits and renovations have reportedly led to operational savings of 40% to 75%, respectively.
To enable a transformation to performance-based design and operation of the nation's buildings, next-generation metrics[9], methods, and tools must be developed that permit a building's energy use to be seamlessly predicted, monitored, controlled, and minimized across the dimensions of performance, scale, and time. To achieve this, a building needs to be evaluated as a single, durable good. Its complex component systems are integrated during design and perform as a whole throughout its life cycle, including construction, operation and use, renovation, and waste management. The technical and nontechnical barriers that prevent this transformation are enormous, but so are the opportunities for significant, cost-effective energy and carbon reductions. Indeed, in 2007, the Nobel Prize-winning Intergovernmental Panel on

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[8] According to a recent study, key players in the buildings sector misjudge the costs and benefits of green buildings and create a major barrier to the adoption of energy efficiency technologies in the buildings sector. In this survey, 1,400 developers, agents, professional landlords, and corporate tenants grossly underestimated the GHG emissions of buildings (19% versus 40%) and incorrectly placed the additional cost of building green at 17% above conventional construction — more than triple the true cost difference of about 5%. These respondents also saw their role in green buildings as adopting incremental changes once they are tested and demonstrated to be effective or they become an industry standard (57%) or once clients or regulations require it (31%), but very few (12%) saw their role as leading the move to green building.

[9] Integrated design for energy-efficient, high-performance buildings begins with the practical application of sound performance metrics. This requires major advances in the capabilities and user- friendliness of building information modelling (BIM) and simulation tools for optimizing the design and operation of buildings. These next-generation tools and models will permit integrated energy modelling of advanced technologies, provide the capability to perform "what if" analyses, and help optimize energy-related design parameters and high-performance buildings.
Building energy simulation tools predict the energy performance of specific buildings based on extensive databases of building physics, climatological information, and engineering calculations involving thousands of measurement methods and computations (ANSI/ASHRAE 2007; Torcellini et al. 2006). Fundamental research is needed to validate the results of building energy simulations, to seamlessly integrate simulation results back into the BIM tools, and to develop the digital generation of building energy performance standards that will drive the design and optimization techniques.

Climate Change identified the buildings sector as having the highest GHG emissions, but also the best potential for dramatic emission reductions, such as those from net-zero energy buildings (Figure 2). (*Federal Research and Development Agenda for Net-Zero Energy, High-Performance Green Buildings*, 2008)

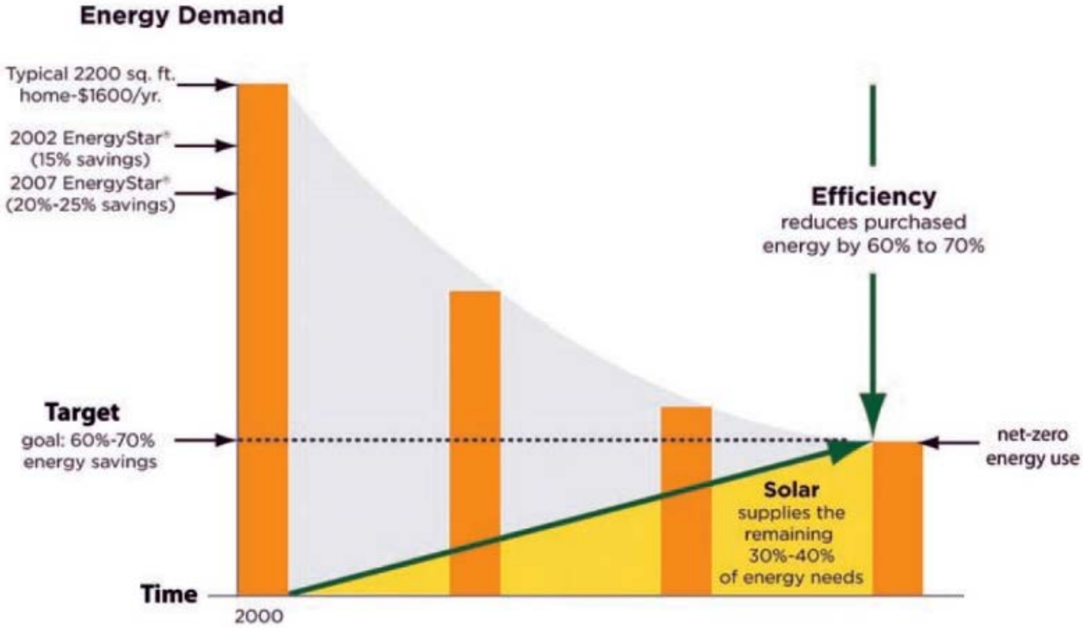

Figure 2: Approach for achieving Net-Zero-Energy Buildings

The building sector is identified as providing the largest potential for CO2 reduction by 2020 and many countries across the world have set very ambitious targets for energy efficiency improvements in buildings. To successfully achieve these targets it is necessary to identify and develop innovative building and energy technologies and solutions for the medium and long term which facilitates considerable energy savings and the implementation and integration of renewable energy devices within the built environment.

Environmental design and control of buildings can be divided into two very different approaches. In the usual “exclusive” approach energy efficient building concepts are created by excluding the indoor environment from the outdoor environment through a very well insulated and air tight building construction. Acceptable indoor environmental conditions are established by automatic control of efficient mechanical systems. Next to this, there is a growing interest for developing buildings that cooperate with nature and make use of the available environmental conditions. In this “selective” approach energy efficient building concepts are created by using the building form and envelope as an intermediate between the outdoor and the indoor environment. Acceptable indoor environmental conditions are established by user control of the building envelope and the mechanical systems. It is important that the building is responsive[10] to the fluctuations in the outdoor environment and the changing needs of the occupants, which means that the building should have the ability to dynamically adjust its physical properties and energetic performance. This ability could pertain to energy capture (as in window systems), energy transport (as air movement in cavities), and energy storage (as in building materials with high thermal storage capacity).

In a responsive building an optimum must be found between the, sometimes contradictory requirements from energy use, health and comfort. From the viewpoint of human coexistence with nature the approach is to make buildings “open” to the environment and to avoid barriers between indoors and outdoors, where from the viewpoint of energy savings the approach, for certain periods, is to exclude the buildings from the environment. The area between indoors and outdoors herewith becomes a more or less hybrid zone where the energy gains are not only rejected, but are stored, tempered, admitted or redirected, depending on the desired indoor conditions. Nowadays we are able to measure and control the performance of buildings, building services and energy systems with an advanced building management system (BMS). This opens a new world of opportunities. Buildings no longer act as ridged objects that need a large heating installation in winter and big cooling equipment during summer to “correct” the indoor climate, but buildings become an additional “living” skin around occupants, keeping them in contact with nature, but at the same time protecting them when necessary.

However, this design approach requires that building design completely changes from design of individual systems to integrated design of responsive building concepts, which should allow for optimal use of natural energy strategies (day lighting, natural ventilation, passive cooling, etc.) as well as integration of renewable energy devices. Design teams including both architects and engineers must be formed and the building design developed in an iterative process from the conceptual design ideas to the final detailed design. However, a number of barriers appear when the borderline between architecture and engineering is crossed; the design process contains a lot of challenges to those who participate in the process. (Dietrich Schmidt, 2010)

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[10] The manipulative environment is a passive one, one that is moved as opposed to one that moves. In contrast, responsive ... means the environment is taking an active role, initiating to a greater or lesser degree changes as a result and function of complex or simple computations ... maybe a house is not a home until it can learn to laugh at your jokes.

Responsive building concepts are design solutions in which an optimal environmental performance is realized in terms of energy performance, resource consumption, ecological loadings and indoor environmental quality. It follows that building concepts are design solutions that maintain an appropriate balance between optimum interior conditions and environmental performance by reacting in a controlled and holistic manner to changes in external or internal conditions and to occupant intervention and that develop from an integrated multidisciplinary design process.

The Integrated Design Philosophy
From component to concept

Efforts to minimize the building energy efficiency over the last decades have focused on efficiency improvements of specific building elements and building services equipment (component level). Significant improvement has been made. However the performance of individual elements is often heavily depending on the performance of the system they are part of. I.e. the performance of a heat pump depends on the performance of whole heating and cooling system which consists of a source, a distribution and a delivery part. The performance of a well-insulated window no longer only depends on the insulation level of the glazing, but also on the window frame, the spacers etc. Innovations are shifting from component level to system level. But also the system level approach is no longer appropriate. Buildings have become integrated concepts in which advanced systems work together to reach an optimal performance in terms of energy, comfort and health. And particularly on the overlapping field of building technology and building services, the responsive building elements, lies a great future potential to achieve the next steps in energy savings.

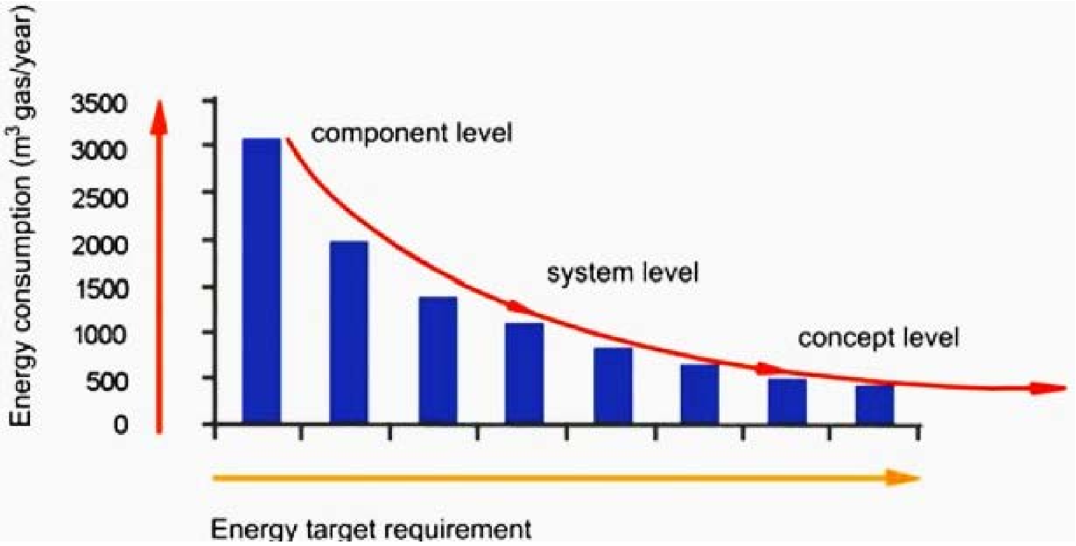

Figure 3: Energy efficiency in different levels of building design

With the integration of responsive building elements and building services, building design completely changes from design of individual systems to a design of integrated building concepts. (Dietrich Schmidt, 2010)

An integrated building concept includes all aspects of building construction (architecture, facades, structure, function, fire, acoustics, materials, energy use, indoor environmental quality, etc.). It can be defined to consist of three parts:

- an architectural building concept,
- a structural building concept and
- an energy and environmental building concept

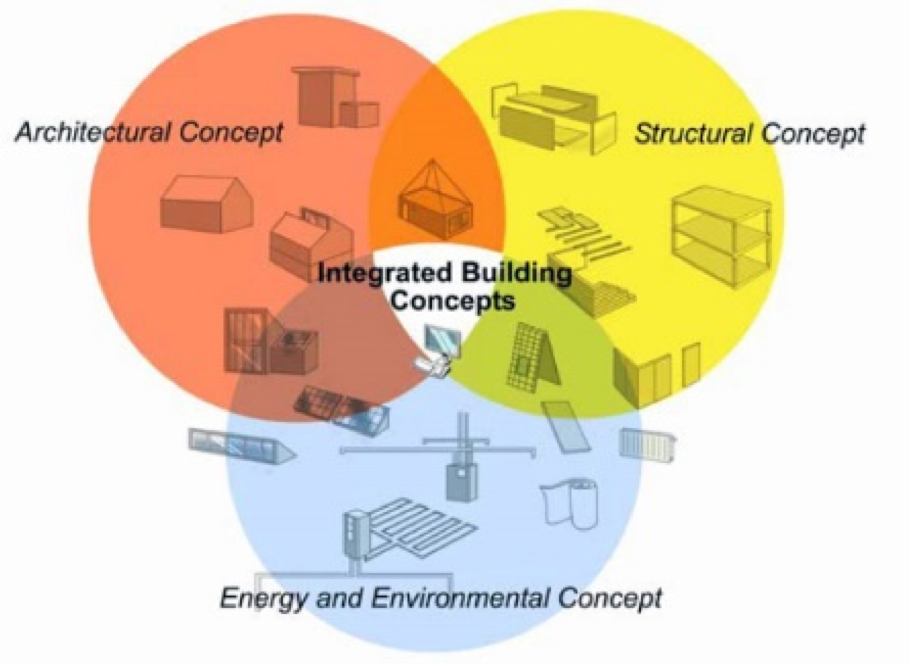

Figure 4: Integrated building concepts

This corresponds to the professions involved in the building design and each concept is developed in parallel by the three professions using their own set of methods and tools - but in an integrated design process leading to an integrated solution. (Dietrich Schmidt, 2010)

The integrated design process

A responsive building concept can only be developed by an integrated design approach. Design teams, including both architects and engineers, are formed and the building design is developed in an iterative process from the conceptual design ideas to the final detailed design. Building energy use and HVAC (heating, ventilating, and air conditioning) equipment size are reduced without the use of sophisticated technologies, but only through an effective integration of the architectural and HVAC designs. The integrated design approach achieves this improved energy utilization due to the relationship that exists between the building, its architecture and the HVAC equipment. Besides this the integrated design approach also achieves an improvement in the environmental performance of the building, as well as fewer construction problems and lower costs.
In a sequential design process the engineer at the later stages of design more or less act in a reactive way, thus correcting the architectural design. The risk that poor design

concepts are developed are therefore higher. There are a number of serious consequences if the proper decisions are not made at the conceptual design stage. The building will almost certainly cost more to build and operate (e.g. it often takes huge air conditioning equipment and much energy to compensate for poor orientation, window placement etc.). The cost is not only in terms of money, but also in the depletion of non-renewable resources, in the degradation of the environment and often also in poorer building performance in terms of comfort.

An integrated design process ensures that the knowledge and experience gained by an analytical consideration of design is formalized, structured and incorporated into the design practice. In the integrated design process the expertise of the engineers is available from the very beginning at the preliminary design stage and the optimization of the architectural and HVAC designs can start at the same time as the first conceptual design ideas are developed. The result is that participants contribute their ideas and their technical knowledge very early and collectively. The concepts of energy and building equipment will not be designed complementary to the architectural design but as an integral part of the building. (Dietrich Schmidt, 2010)

"A whole greater than the sum of its parts"

An integrated or 'whole building' design approach requires thinking about the building and its site as a series of interlinked and interdependent systems, so that a single design refinement might simultaneously improve several building systems' performance. Like the domino effect, one refinement can trigger multiple savings or other benefits. For example, careful decisions on building shape and window placement that take into account both prevailing wind and sun angles, may not only enhance a building's thermal performance, but can also result in improved daylighting. These measures will reduce both heating and cooling loads, and in turn, could generate first cost savings achieved through downsizing HVAC equipment and reducing mechanical space requirements. (Staff & Zachmann, 1999)

Conventional Versus Integrated Design (Figure 5&6 and Table 1)

The design of sustainable buildings requires a more collaborative approach than conventional methods allow. This is called an integrated whole building design process (IWBDP). Using this approach recognizes that a building is by definition a 'whole' physical object, and behaves as a 'whole' dynamic system, both directly and indirectly with the natural world. The IWBDP is an effective way of designing green buildings. (*Integrated Whole Building Design Guidelines*, 2008)

The conventional design process (Figure 5) is a linear approach in which project goals are identified and assigned to specific members of the design team. The design is developed in a segregated way with minimal interaction between the design team members. The result can be solutions that do not incorporate all of the design objectives. In a conventional design process, the design team's input peaks during detailed design and reduces during the construction phase and beyond. Optimization is difficult using a conventional design approach, and problems may subsequently occur during the operational phase of the building.

The nature of the conventional design process and the cash flow of fees is also currently frontend loaded which discourages the design team's involvement in the later construction, commissioning[11], post-occupancy and feedback stages of construction. (*Integrated Whole Building Design Guidelines*, 2008)

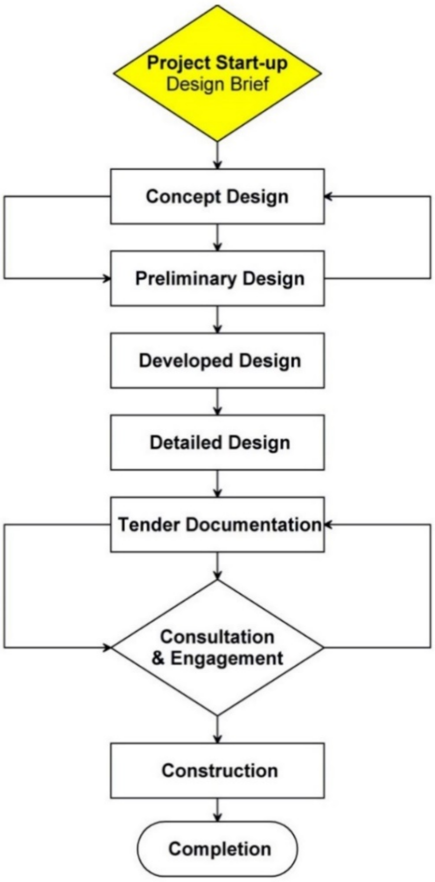

Figure 5: Conventional design process

The IWBDP is a design method which considers the building as a whole and requires the involvement of all stakeholders, design team members and future users or tenants. Integrated whole building design is a holistic, design-led approach that seeks to recognize the interconnectedness of a project's goals. Figure 6 is a schematic of the IWBDP, which is very different in structure from that of the conventional design

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[11] Commissioning: "The basic purpose of building Commissioning is to provide documented confirmation that building systems function in compliance with criteria set forth in the Project Documents to satisfy the owner's operational needs."

process in Figure 5 above. This diagram shows the interactive nature of the IWBDP through the multiple feedback loops at several stages in the design. (*Integrated Whole Building Design Guidelines*, 2008)

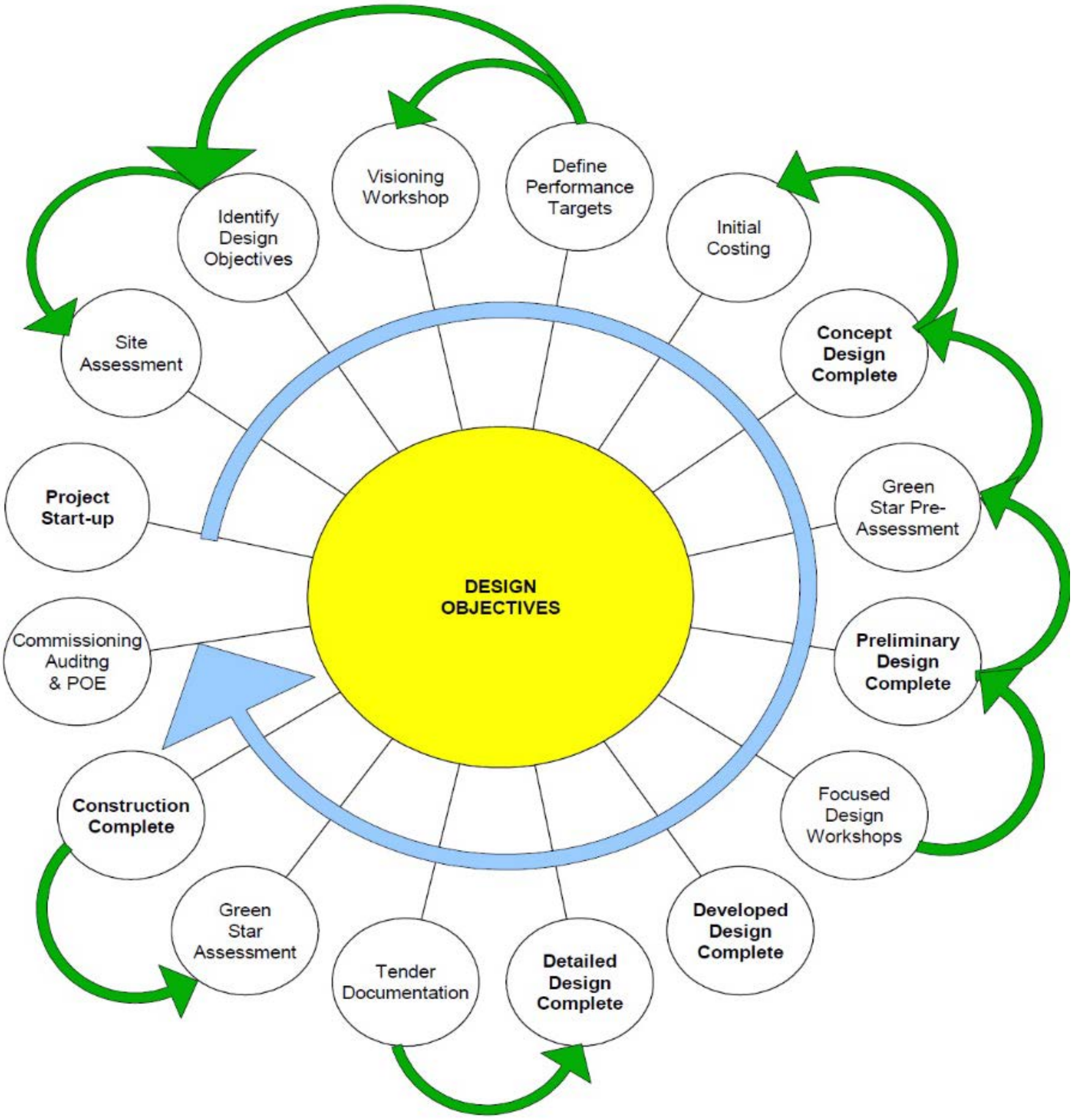


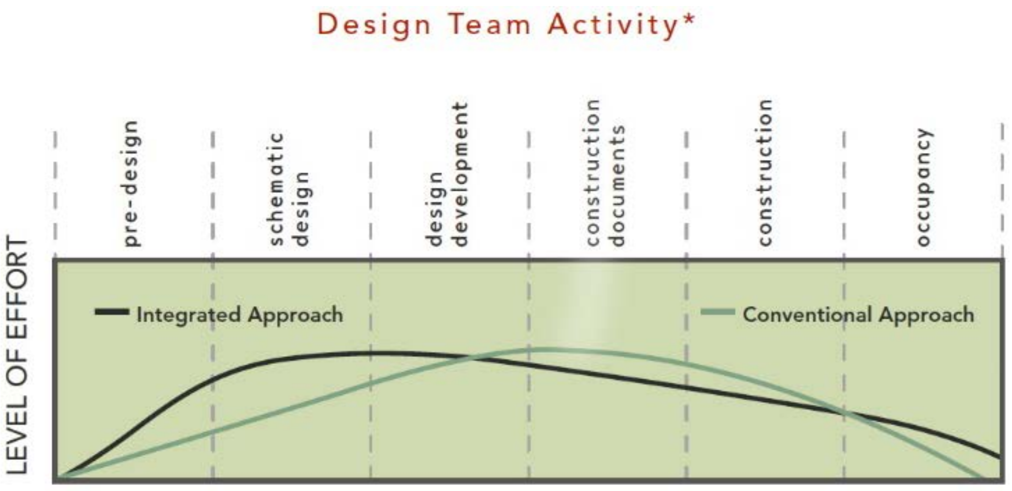
Figure 6: The IWBDP from project start-up through to commissioning, auditing and post occupancy evaluation (POE) and the possible feedback loops (shown by the green arrows)

Conventional design process	**IWBDP**
Architect draws up initial concept design	Whole project team involved in the initial design
Only main consultants involved in the initial decisions	Whole team are involved in decisions
Time, money and energy minimized during the initial design stages	Early involvement of design team means greater costs during the initial design stages
Feedback loops during concept and tender stages only	Feedback loops throughout the process
Systems considered and designed separately	Holistic thinking – whole picture considered
Optimization difficult due to segregation of concepts	Optimization easily achievable
Synergies difficult to identify and employ	Synergies easily identified and encouraged
Capital cost of building considered over whole-of-life costs	Life cycle costing used to see the bigger picture
Process ends when construction is complete	Process is ongoing and includes commissioning, auditing and post-occupancy evaluation

Table 1: The IWBDP versus the conventional design process

However, the conventional design process is not optimal for sustainable design as these projects are more challenging necessitated by a need for inter-disciplinary collaboration and intense performance requirements. The conventional (or traditional) design process for buildings begins with the client and architect determining the buildings core features, architecture and layout. Then the various disciplines are engaged to provide their division of the design (mechanical, civil, electrical, fire protection, etc.). This work is either performed in parallel or isolation and in some cases both. While it would be an oversimplification to state that conventional design does not integrate the design features of the various disciplines, it is fair to say that they are coordinated by the project management and not by a structured process.

The Integrated Design Process (IDP) improves on conventional design by providing a collaborative effort (Figure 7) that is multi-disciplinary and includes client and stakeholder engagement throughout the process. These stakeholders with the addition of the constructors and maintainers are continuously engaged in the process and take an active role. (Bersson, Mazzuchi, & Sarkani, 2012)



* Curves are conceptual and represent approximate results.
Source: BetterBricks, based on review of literature.

Figure 7: design team activity by level of efforts in Integrated & Conventional approaches throughout processes of pre-design[12], schematic design[13], design development[14], construction documents, construction & occupancy

A traditional design process is based on a sequential “hand-off” from owner, to architect, to engineers and to the contractors. Often engineers are not brought into the process until Design Development or later. This process results in limited interaction and discussion about design and engineering considerations that can greatly affect operating costs, health and comfort. Integrated design brings the design team, operations staff and building users together early, avoiding budget, functional and operational problems. (“Guide to the Design and Construction of High Performance Hospitals,” 2005)

Key Integrated Design Benefits
Reduced overall project costs and reduced risk

- *Reduced overall project costs:*

High performance designs draw on principles used in much older building practices. As such, they rely on the manipulation of land features, building form, and exterior materials to manage the climate and get the most out of the materials at hand *before* invoking electrical and mechanical assistance from energy-driven heating, cooling, and

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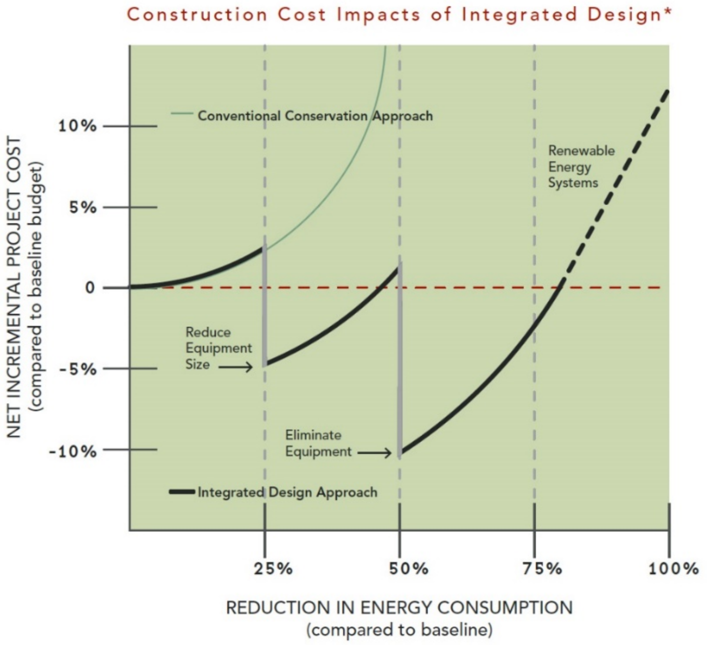
[12] Pre-Design (Programming): This phase identifies the program needs, assesses the feasibility and confirms the construction requirements for the project. It includes an initial study of site constraints and impacts, site-related design guidelines, diagrammatic floor and stacking plans, a space program, building systems description, a summary schedule and a preliminary budget.

[13] Schematic Design: This phase is where an interactive process develops and explores a variety of alternatives both at the whole building level and at the component level. The primary objective of this critical phase is to develop a clearly defined design including scale and relationships among the project components. Budget and schedule are also established and the project is submitted for permits.

[14] Design Development: This phase refines the scope of work started in Schematic Design, further developing the selected option. A clear, coordinated description of all aspects of the project is worked out. The Design Development phase is the last opportunity for significant design input, but any change to scope or program will likely incur budget and schedule impacts.

lighting systems. High performance design also favors ‘state-of-the-shelf’ technology over sophisticated ‘state-of-the-art’ equipment. The preference for keeping equipment as simple and maintenance-free as possible is vital to the interests of client agencies, given their limited operating budgets. (Staff & Zachmann, 1999)

Through Integrated Design, loads are minimized and equipment is right-sized or eliminated, resulting in lower mechanical, electrical, and plumbing (MEP) costs than for a conventionally designed building. These lower MEP costs will more than offset any cost increase that may result from additional design activities and the purchase of high efficiency equipment. With conventional energy conservation strategies, individual efficiency measures are added incrementally, cumulatively adding cost. With Integrated Design, the opportunity to downsize or eliminate equipment leads to substantial cost reduction as efficiency increases. After these reductions, to achieve further improvements in efficiency, there may be some cost increases resulting from improved materials or higher efficiency equipment, but typically the overall cost still remains below a conventional budget. This is illustrated in the upward sloping curves in the graph below (Figure 8). (“Guide to the Design and Construction of High Performance Hospitals,” 2005)


Construction Cost Impacts of Integrated Design*

This graph compares the effect on total project cost from a conventional conservation approach (i.e. adding individual efficiency measures and accumulating cost) versus an integrated design approach.

*Curves are conceptual and represent approximate results.
Source: BetterBricks, based on review of literature.

Figure 8: Construction cost impact of integrated design

An integrated building design process re-examines the use of traditional products or building assemblies, and identifies innovative technologies or green product and system alternatives that offer significantly improved environmental performance. These progressive design approaches can be further refined through the use of computer energy modelling. Energy modelling simulates the proposed design’s response to climate and season. Designers can preview and improve the performance of interdependent features such as orientation, daylighting, alternative building shell design, and various mechanical systems. Energy modelling quickly evaluates cost-effective design options for the building envelope or mechanical systems by simulating the various alternatives in combination. This process takes much of the guesswork out of green building design and specification, and enables a fairly accurate cost/benefit forecasting. (Staff & Zachmann, 1999)

- *Reduced risk; Reduced risk of costly re-design and change orders as well as start-up and operational issues:*

Reduced risk of costly re-design and change orders
High performance outcomes also demand a much more integrated team approach to the design process and mark a departure from traditional practices, where emerging designs are handed sequentially from architect to engineer to sub-consultant. A unified, more team-driven design and construction process brings together various experts early in the goal-setting process. This helps high performance buildings achieve significantly higher targets for energy efficiency and environmental performance.
A team-driven approach is, in effect, ‘front-loading’ of expertise. One or more facilitated workshops might involve the owner, design professionals, operators, and contractors (where possible) in a brainstorming session or ‘partnering’ approach that encourages cooperation in achieving high performance goals while breaking down traditional adversarial roles. During design development, frequent input from users and operators can accelerate progress, eliminate redundant efforts, engender commitment to decisions, reduce errors, and identify synergistic opportunities. [6]

Team members should all be motivated to creatively contribute to design solutions. This ensures that relevant team members are involved in and informed of key decisions and issues in a timely manner, reducing the risk of miscommunication and misunderstandings that can lead to costly and time-consuming modifications during Design Development or construction. (“Guide to the Design and Construction of High Performance Hospitals,” 2005)

The value of teamwork[15]
The building industry has traditionally used a bureaucracy because the design then build nature of the business leads individual firms to become very efficient at

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[15] *The team* is the alternative to a bureaucracy. The essence of a high performance team exudes from an American football team. Eleven players walk onto the field with the shared goal of moving the ball further than the opposing team. All 11 are strong and skilled, but no one can succeed without the others, so they work together with well-coordinated actions, and help one another; because only the 11 together can win or lose the game. Professional football players don’t go to camp to climb adult jungle gyms and have group hugs to become great teams, and neither should professionals who create buildings. People build teams by practicing team skills in everything they do every day they work.

designing pieces, or installing pieces, or assembling pieces. This is how they make sure their firm is most profitable, because they arrive, do their part, and depart. If they do their part right, but the system fails, that's the other guy's problem.
Bureaucratic building projects often look something like this: The architect and owner executive get together and conceive of the building. The size, shape and available space are often committed to and made public at this time, and if the architect is fond of the Bauhaus model, it's likely the building is made of glass. Then the architect hands-off to engineers who will design the systems to heat & cool the glass box, using standard methods at which they are very efficient. They will include energy conservation solutions that are required by code and maybe more efficient systems if it doesn't cost too much. The contractors then get the job of building what the architect designed and making the engineered systems fit. The contractors' jobs are often difficult, and they request design changes to allow equipment to fit in the available space and reduce cost. The architect gives up a little, the engineers give up a little, the contractor gets it built, the schedule gets longer, the costs go higher and the result is often mediocre. (Allen et al., 2011)

The Integrated Building Design chapter of the 2007 ASHRAE Handbook:

HVAC Applications describes two ways to design a building: sequential and integrated. It proposes abandoning the sequential (bureaucratic) method for the integrated (team) method, then explains the considerations to be made during design that can be done better by including the client in the process and using a collaborative team to carry out the design. (Allen et al., 2011)

Reduced risk of start-up and operational issues:
With Integrated Design, building operators and users are involved from the start— even at the master planning stage— to voice their needs and identify potential operational and functional problems as well as opportunities. Processes and protocols are established in anticipation of the building hand-off to operators, and operators are trained on systems and controls, with a particular focus on HVAC function and efficiency. In addition, the commissioning provider is involved as early as the Schematic Design stage to ensure the building's operating requirements are maintained through design, construction and start-up operation. ("Guide to the Design and Construction of High Performance Hospitals," 2005)

3-1-2 Purpose of the Study

This study is aimed at realizing how concepts are brought to construction through integrated design practices with a professional insight to achieve high performance building.

In this domain, the challenges and opportunities of high performance building design will be discussed.
Further, this study, attempts to investigate how integrated design practices contribute to accomplish a successful architecture in high performance buildings. In this regard, by revolving around an exquisite project of Thomas Herzog, a range of new technologies, which is entry to success the high performance building, will be identified. Subsequently, building researchers and practitioners will have a better realization of high performance building for taking further proper actions to create novel solutions and promote the building to the highest level of performance.

3-1-3 Hypotheses

High performance building promises a panoply of benefits, from the social benefits of reduced environmental impact to the economic and ‘value equation’ benefits of operational cost savings, greater occupant comfort, security and flexible space. (Zerkin, 2006)

To be sustainable High Performance Buildings must be economical, taking into account first costs, life-cycle costs and return on investments. Economy can be achieved on a system level and then on a component level. The system level for example will be building orientation and the component level could be variable frequency drives on pumps and air handling units. High performance buildings will use less material more effectively, are more durable and require less maintenance. (Abaza, 2011)

Fortunately, the observed trend from high-performance building is that in pursuit of aggressive energy performance the spatial and material quality of the building improves. Building footprint areas are often reduced, saving cost, material consumption, and reducing circulation distances. Changes in overall building form also tend to increase the sectional diversity of the building, increasing the richness of spatial experience. Day-lighting replaces electric lighting. Mechanical service delivery becomes simplified, but also augmented by hybrid natural approaches. Material quality focuses on durability or ease of replacement (or both), aiding building operations and maintenance. (Pope & Tardif, 2011)

This is the 21st century, with an entirely new situation for human society, and new problems and demands for the profession to respond to. Think of IDP as a new tool to add to the toolbox to address this new situation. (Zimmerman, 2007)
The integrated design process (IDP) is a holistic approach to building design that seeks to attain high performance on a wide variety of specific environmental and social goals while staying within budgetary and scheduling limitations. (*BC HOUSING Design Guidelines AND Construction Standards*, 2012)

A successfully implemented integrated design process can result in a project that:

- Increases the opportunity to achieve green building performance goals
- Maximizes cost effectiveness
- Optimizes energy efficiency
- Minimizes environmental impacts

The integrated design process can both minimize incremental capital cost and result in operational savings. Capital cost can be redistributed to achieve high performance goals without incremental costs. For example, the higher first cost of some energy efficiency strategies can be offset by the elimination or reduction in size of other equipment or systems. An integrated approach can also reduce operational expenditures through increased communication amongst the project team, resulting in a more efficient design.

Costs associated with an integrated design process may include things like additional consultant fees to facilitate a goal-setting workshop and time and associated costs of having project team members participate in additional meetings and coordination. ("NJ GREEN BUILDING MANUAL," 2011)

Integrated design involves a "whole building design" approach. A building is viewed as an interdependent system, as opposed to an accumulation of separate components (site, structure, systems, and use). The goal of looking at all systems together is to make sure that they all work in harmony with each other.

An effective IDP can ensure that the Design Team incorporates the needs of the Owner and Operators based on their concerns, function, and operational requirements. Also this kind of process can ensure information is shared on daily operations such as who will be performing regular maintenance and what their level of expertise is and what training will be required. (*BC HOUSING Design Guidelines AND Construction Standards*, 2012)

An integrated design process often generates more creative ideas and solutions. A good analogy is that the architect goes from being a soloist to being the conductor. In any performance the conductor is always visible, and wears a different suit and often his name is in the spotlight. (Zimmerman, 2007)

3-1-4 Methods

This study is performed based on reviewing and interpreting the most current resources in green architecture pursuing high-performance building design by focusing on all gathered information linked to Thomas Herzog´s project in the form of a case study. Further, his techniques and specific strategies will be evaluated based on his design in different spots.

3-2 Literature review

In general, high performance buildings are the buildings designed to maximize operational energy savings, improve comfort, health, and safety of occupants and visitors, and to limit detrimental effects on the environment.

Today, with the growing concerns for increasing energy costs and demand for healthy places to live and work, a high performance building (or green building) attracts attention because of its energy savings and environmentally friendly spaces. High performance buildings are buildings designed to maximize operational energy savings, improve comfort, health, and safety of occupants and visitors, and to limit detrimental effects on the environment. (Im & Haberl, n.d.)

A host of ecological impacts resulting from human activity, have produced ecosystems degradation that directly threatens our society. In the words of the UN's Millennium Ecosystem Assessment, competed in 2005:

> We are spending Earth's natural capital, putting such strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted.
>
> At the same time, the assessment shows that the future really is in our hands. We can reverse the degradation of many ecosystem services over the next 50 years, but the changes in policy and practice required are substantial and not currently underway. (Zimmerman, 2007)

A high-performance green building can be thought of as a living organism, and as with all living things, it must have a nurturing environment to achieve sustained health and performance over its life. Such buildings are designed for economic and environmental performance over time, with an appreciation for unique local climate and cultural needs, ultimately providing for the health, safety, and productivity of building occupants. Architectural, systems, and end-use design, coupled with continual care and monitoring, lead to lower energy use, reduced CO_2 emissions, and focused environmental stewardship while providing long term value to the community, building occupants, and building owners. Triple bottom line benefits can be expected—measurable benefits for people, profit, and the planet.

In addition, high-performance green buildings have intelligent connections with energy sources, including the smart grid, and increasingly are vital components of sustainable, smart[16] urban plans that leverage symbiotic, whole system design principles to minimize waste and maximize efficiency (Figure 9). (O'Mara, 2012)

Figure 9: Economic, environmental & social sustainability in high performance buildings

3-2-1 High performance attributes in older buildings

Historic buildings often exemplify integrated design by achieving comfort with an economy of means and without dependence on sophisticated mechanical and electrical systems.

For example, many early 20th Century New York City schools were constructed with C- or H-shaped floor plans, thermally efficient masonry walls, large built-in ventilation shafts, and operable transoms in the corridors. These features control temperature swings, maximize daylighting, and encourage cross-ventilation. Other historical examples include use of exterior courtyard spaces or rooftop terraces for summertime reading or dining, and activity areas in public libraries. (Staff & Zachmann, 1999)

"Synergy - the bonus that is achieved when things work together harmoniously." Great American author Mark Twain certainly had it right. And, the effects of Twain's synergistic "bonus" can clearly be seen in the built environment.

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[16] Within the design disciplines, the term "smart" has most frequently been used in reference to materials and surfaces. Addington and Schodek identify "smart materials" as systems possessing "embedded technological functions" that involve specific environmental responses, operating either through internal physical property changes or through external energy exchanges. They define the characteristics of smart materials as: "immediacy" (real-time response), "transiency" (responsive to more than one environmental state), "self-actuation" (internal intelligence), "selectivity" (a response is discrete and predictable) and "directness" (a response is local to the activating events). Smart surfaces and materials can play a significant role in intelligent, adaptive and responsive envelopes because of these intrinsic properties. Examples of smart materials used in high-performance building skins include: aerogel – the synthetic low-density translucent material used in window glazing, phase change materials such as micro-encapsulated wax, salt hydrates, thermochromic polymer films, and building integrated photovoltaics.

Buildings constructed from products that fit well together not only meet initial plans and specs, but also pay out an unanticipated bonus by exceeding the expectations of their owners and occupants. (Blum & Hoff, 2008)

The recent confluence of global economic, energy, and environmental concerns has highlighted the importance of building-system integration and how it can transform conventional buildings into synergistic, high-performance systems. This increased awareness has also stimulated action to understand the critical determinants of high-performance buildings and integrate them into everyday design and construction practices. Although recent high-performance building initiatives have been numerous and varied, all of these undertakings appear to share two important visions:

First, our concerns about economics, energy, and the environment are inexorably linked.

Second, these concerns must be addressed using integrated, holistic solutions. Recognizing that many high-performance measures may be incorporated with minimal upfront expense and still yield sizable cost savings over a building's lifetime, many forward-looking building organizations have established ambitious goals to expand the use of high-performance system concepts. Most notably, the American Institute of Architects (AIA) in Washington, D.C., has called for a 50-percent reduction of fossil fuels used to construct and operate buildings by 2010, with additional reductions every 5 years, to achieve carbon-neutral buildings by 2030. Following the AIA's lead, the American Society of Heating, Refrigerating and Air-Conditioning Engineers <ASHRAE> in Atlanta is beginning to move beyond its traditional "code-minimum" approach for building energy standards and is now calling for an "above-the-code" approach in its proposed *Standard for High-Performance Green Buildings.*

The vision of synergistic, high performance in buildings has been further expanded by the LEED Green Building Rating System, which was developed by the U.S. Green Building Council (USGBC). LEED provides a whole-building rating system designed to transform the built environment. To accomplish this transformation, LEED starts with a simple enumeration of the most-recognized characteristics of high-performance buildings, such as resource conservation, energy efficiency, and environmental sustainability. By combining these key attributes into one standard, LEED helps promote a holistic approach to building design. By developing a comprehensive rating and award system for these key attributes, LEED stimulates competition to achieve high-performance building goals. And, by promoting LEED as an easily recognized concept, the USGBC builds public support of its ultimate goal to transform the way buildings are designed, constructed, and maintained. (Blum & Hoff, 2008)

"We need to use a new collaborative integrated design process that can create new approaches and tools, and beautiful environments that can restore social, economic, and environmental vitality to our communities." (Zimmerman, 2007)
— Bob Berkebile, BNIM, Kansas City, one of the world's most respected green architects

In order to reach an integrated technical design solution and to develop an Energy and Environmental Building Concept it is necessary to define and apply a certain design strategy. In the IEA ECBCS Annex 44 project the design strategy is based on the method of the Trias Energetica method described by Lysen (1996). This Trias Energetica approach has been extended within the Annex 44 work with technologies that will be applied, depending on the design step (Figure 10). (Dietrich Schmidt, 2010)

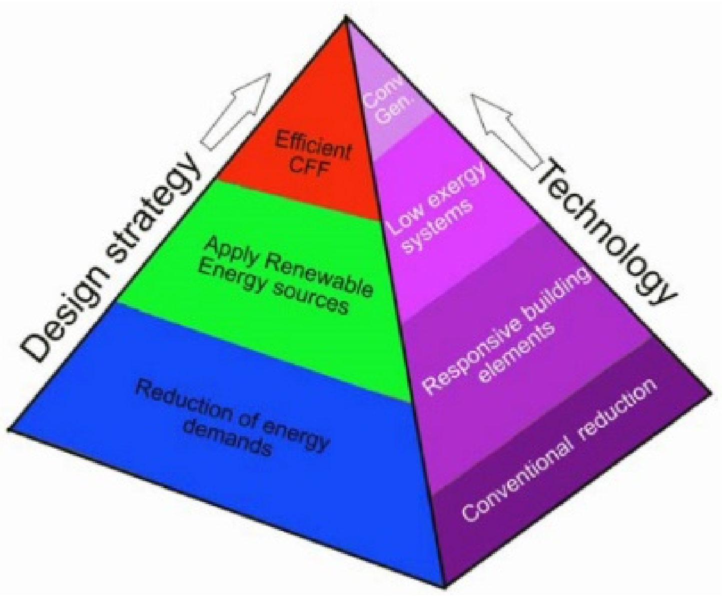


Figure 10: Illustration of IEA ECBCS Annex 44 Design Strategy and corresponding technologies

The left side of the pyramid shows the design strategy, and the right side of the pyramid shows the technical solutions in each of the steps. The figure clearly positions the responsive building elements as a technology that falls in the first step "reduction of energy demands" as well as in the second step "application of renewable energy sources". An integrated design strategy, starts at the bottom of the pyramid and applies the strategies and technologies as follows:

Step 1. Reduce energy demand. Optimize building form and zoning, apply well insulated and air tight conventional envelope constructions, apply efficient heat recovery of ventilation air during heating season, apply energy efficient electric lighting and equipment, ensure low pressure drops in ventilation air paths, etc. Apply Responsive Building Elements if appropriate including advanced façades with optimum window orientation, exploitation of daylight, proper use of thermal mass, redistribution of heat within the building, dynamic insulation, etc.

Step 2. Apply renewable energy sources. Provide optimal use of passive solar heating, day lighting, natural ventilation, night cooling, earth coupling. Apply solar collectors, solar cells, geothermal energy, ground water storage, biomass, etc. Optimize the use of renewable energy by application of low exergy systems.

Step 3. Efficient use of fossil fuels. If any auxiliary energy is needed, use the least polluting fossil fuels in an efficient way, e.g. heat pumps, high-efficient gas fired boilers, gas fired CHP-units, etc. Provide intelligent control of system including demand control of heating, ventilation, lighting and equipment. The main benefit of the method is that it stresses the importance of reducing the energy load before adding systems for energy supply. This promotes robust solutions with the lowest possible environmental loadings. (Dietrich Schmidt, 2010)

Recent reports from the New Building Institute (NBI) illustrate, moreover, that LEED certified buildings are not performing as designed. The NBI concluded, via case studies, that in order to realize buildings that consume less energy, social integration of design and construction processes is necessary. In 2006, the Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) documented sixteen high-performance buildings that confirm the findings of the NBI study. The factors that clearly contributed to the projects' success were not technologies such as renewable energy or highly resistant exterior walls; rather an integrated process unifying the technical and social aspects of practice was the most effective determinant for achieving high-performance goals.

Promoting process integration is an effective strategy for solving problems that are relentlessly complex. For example, in Rittel and Webber's evaluation of the complexities associated with the physical planning process, the most successful solutions fulfilling a number of contingencies - social, environmental and economic - were those resulting from a collaborative decision-making process, or integrated design process. According to process engineer Mark Dodgson, moreover, integration can serve as an appropriate model for answering the problem of high performance:

Although collaboration occurs in many different forms, and may reflect different motives, a number of generalizable assumptions underpin them. First is the belief that collaboration can lead to positive sum gains in the internal activities - that is, partners together can obtain mutual benefits that they could not achieve independently. Such benefit may include an increased scale and scope of activities, shared cost and risk, and improved ability to deal with complexity. (Trubiano, 2013)

Integrated design provides a conceptual and practical framework for increased communication and collaboration between owners, architects, engineers, contractors, specialty suppliers and a wide range of technical specialists during the construction of high-performance projects. It is a method of great promise given expected efficiencies and the higher chances it affords for meeting project goals,

budgets and schedules. It is widely adopted in North America and Europe for building projects large and small. In the United States, the American Institute of Architects (AlA), in affiliation with the AlA California Council, has developed a tool for promoting its use. "Integrated Project Delivery" provides a legal structure and "contract mechanism" supporting the Integrated Design Process. The AlA publication *Integrated Project Delivery*: A Guide offers possible approaches and details the implications of engaging in contractual arrangements in which design and construction teams "include members well beyond the basic triad of owner, architect, and contractor". More prescriptively, a number of certification systems for so-called "green" homes actually require the adoption of integrated project planning and delivery methods.
Integrated Design Process as a whole-building *approach* that recognizes the importance of establishing an all-inclusive team for building an integrated building. The 2003 National Renewable Energy Laboratories (NREU) guide *A Handbook for Planning and Conducting Charrettes for High-Performance Projects* identifies the whole-building approach as a design process that offers:

> a multidisciplinary strategy that effectively integrates all aspects of site development, building design, construction, and operations and maintenance to minimize a building's resource consumption and environmental impact while improving the comfort, health, and productivity of building occupants.

Author and practitioner Jerry Yudelson notes that the process "explores ... building orientation, massing and material choices as critical issues affecting energy use and Indoor air quality, and attempts to influence these decisions before the basic architectural design is fully developed". (Trubiano, 2013)

“It is not possible to do creative, progressive sustainable design without a strong, like-minded, integrated design team.” (Zimmerman, 2007)
– Peter Busby, Busby, Perkins + Wills

It is generally accepted that both the architect and the engineer are essential to the integrative Design Team. In her article "Integrated Design Process: From Analysis/Synthesis to Conjecture/Analysis", Maureen Trebilcock describes the partnership as requiring

> Architects and engineers to get closer in terms of sharing knowledge and skills. The architect needs to develop knowledge in architectural sciences and skills in simple environmental analysis, while the engineer needs to develop knowledge in architectural matters and skills in design. They share a common language, as well as sharing the character of designer.

Many share Trebilcock's advocacy of a "common language ". An Integrative Design Process that sets parameters for common goals and performance benchmarks provides a platform for respectful collaboration that values the specialized knowledge of all the various design professionals and energy experts. Camilla Brunsgaard, Mary-Ann Knudstrup and Per Heiselberg cite a similar viewpoint from the European Union's International Energy Agency (IEA) Task 23 document:

> In this approach the client takes a more active role than usual, the architect is a team leader instead of sole form-giver and the different engineers, including the energy specialist, take an active part in the early stages of the process. The process is based on the specialist knowledge of each [expert]. (Trubiano, 2013)

Natural Resources Canada initiated the C-2000 Program effort in 1993 to demonstrate energy and environmental performance in Advanced Commercial Buildings. The C-2000 Program initiative led to what is now referred to as the Integrated Design Process and served as the baseline model for the IDP efforts by the International Energy Association. The International Energy Association emphasized in their Integrated Design procedure (with a Design Process Development Model) a whole building system optimization and delivery of high level subsystem performance. “The best buildings result from active, consistent, organized collaboration among all players,” IDP accounts for the building as a system across the entire building lifecycle.

IDP is a collaborative team process that actively and continuously engages the key stakeholders to ensure a transparent process that result in a building design solution that optimizes the needs of the owner and occupants and the performance of the building. Keeler and Burke in their book, *Fundamentals of Integrated Design for Sustainable Building,* equate integrated design with sustainable (green) design. The DOE’s Greening Federal Facilities guide states, “Integrated design is the key to the most cost-effective green procurement strategy”. The USGBC has recognized the Integrated Design Process in Pilot Credit number 42 Integrated Process, which states, “Develop an early understanding of the relationships between technical systems, natural systems and occupants within a building project, its site, its context, and its intended use. Engage all key project team members for the purpose of making cost- and environmentally-effective integrated decisions throughout the design and construction process.” (Bersson et al., 2012)

An integrated design process is one in which the project team, including professionals drawn from multiple disciplines such as urban planning, architecture, engineering, interior design and construction, develop and integrate project objectives, building materials, systems, and assemblies that leverage benefits from across these disciplines. This approach is different from the typical planning and design process that relies on the expertise of professionals who work in their respective specialties somewhat isolated from each other. Throughout an integrated design process, the project team works to develop and implement a design that minimizes environmental impact, while maximizing financial performance and satisfaction for occupants and users of the building(s).

Integrated design facilitates higher building performance by introducing major issues and key participants into the project early in the design process. Engaging an interdisciplinary integrated team from the outset of a project nurtures a holistic approach and discourages linear decision-making.

Building systems are interdependent and require cooperation and creative thinking across disciplines. For example decision-making about building shape, orientation, and window placement relates to several green building considerations and relies on the knowledge of multiple disciplines. These building envelope strategies will impact heating and cooling loads as well as occupant satisfaction and even productivity, a function of thermal comfort and daylighting. With an integrated design process that considers these multiple benefits, and sometimes trade-offs among them, it is much more likely that the building will perform as intended and that any projected cost savings will be realized. ("NJ GREEN BUILDING MANUAL," 2011)

"Many high performance 'green' buildings cost no more, and even less, than their 'brown' equivalents—the key is integrated design." ("Guide to the Design and Construction of High Performance Hospitals," 2005)

— Robin Guenther, Guenther 5 Design and steering committee member of the Green Guide to Health Care

Sustainability and IWBDP go hand in hand. Busby Perkins+Will Stantec Consulting (2007) identify sustainability as one of the design objectives that should be considered on a project. In fact, it is difficult to design a building using IWBDP without incorporating sustainable features. The reverse is also true as acknowledged by Reed (2006) who states that an integrated design process is required for the success and cost-effectiveness of a green design. In a conventional process green features are often considered after the initial design has been formed which can be disruptive to the design process and also more costly, as noted by the US Department of Energy (2001).

> *This process often includes integrating green design strategies into conventional design criteria for building form, function, performance and cost. If a building is designed as usual green technologies are usually applied as an after-thought and this results in poor integration into the overall building design objectives and the greening strategies*

> *are more expensive to implement.* (*Integrated Whole Building Design Guidelines*, 2008)

Integrated design processes have been demonstrated to be effective in delivering buildings using half the energy or less of published energy codes from the late 1990s. In the experience of a Canadian high-performance building program, design teams could reliably achieve energy performance targets of 50% to 60% below ASHRAE Standard 90.1-1989 (and later MNECB 1997) on conventional construction budgets. These targets were even achieved by teams with no prior experience of high-performance design.

Studies at Natural Resources Canada (NRCan) and the US Department of Energy's National Renewable Energy Laboratory (NREL) have also shown that energy consumption reductions against late 1990's energy codes will need to be in the 80%-95% range to enable cost effective renewable energy installations for net-zero or near-zero energy performance. Accordingly, it can be said that integrated design processes are strongly recommended for the achievement of net-zero energy buildings.

Integrated design processes create a design environment where value decisions regarding building elements are rationalized on a whole building performance basis. Unusual design circumstances can be discussed with the participation of the owner, users, and all of the appropriate design professionals. In a NZEB project the owner's team is absorbing services that were formerly provided by a municipality and / or utility. Replacing services that were previously delivered "by others" requires changes to conventional work patterns and addition of new participants to a design effort. Coordination of new activities is made easier through the workshop type of design meetings used under IDP. (Pope & Tardif, 2011)

3-3 Integrated Practice in Pursuance of High Performance Buildings

3-3-1 Oskar von Miller Forum 2005-2010

With the Oskar von Miller Forum, Bavaria- in its role as a land of scholarship and culture-has now acquired one of the most modern and innovative platforms for education and the exchange of ideas in the field of construction. Future leaders in the building sector will be trained here to engage in international and interdisciplinary fields of activity. Here, they should acquire self-confidence and the ability to work in a team on multidisciplinary projects. They should not be just good engineers and architects; their actions should be based on higher values that have a universal validity. (Herzog, 2010)

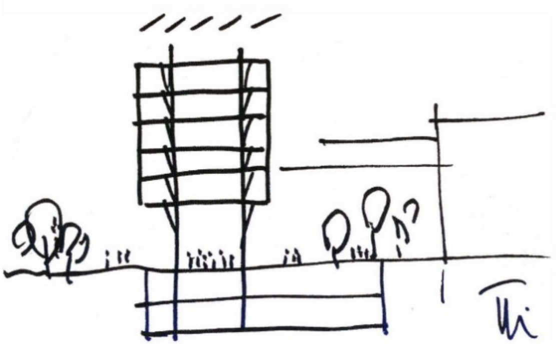


Figure 11: Oskar von Miller Forum, conceptual sketch

This building is a superb demonstration of the important role played by the partners in society, the parties involved in collective bargaining in the building sector in our country, and what we, employers and trade unions, can achieve together. Without the joint social-security benefits office, without strong unions and employers' organizations, the things that have been achieved here would not have been possible. When talent and endeavor are united, this forum will become a stage for new ideas that will advance our state, employers and employees alike.

Through the many international students here, a group should develop that will bring different cultures together. In this way, numerous ambassadors will return to their own countries in future decades, bearing part of Germany in their hearts and thus contributing to an understanding for joint enterprises. With this building, the training of engineers acquires the opportunity to explore a new International dimension. (Herzog, 2010)

In a prominent urban location in Munich where the old part of the city meets the university and museum district, an international center of communication has been created. Its purpose is to promote the education of outstanding engineers in the field of construction at the Technische Universitat Munchen (TUM) - the University of Technology. The sponsor is the Stiftung Bayerisches Baugewerbe (Bavarian Building Trades Foundation). The building (Figure was designed to comply with the tight parameters of the development plan. It consists of three tracts laid out in a U-shaped form about a central courtyard. (Herzog, 2010)

Figure 12: Oskar von Miller forum, different views of the building & site plan

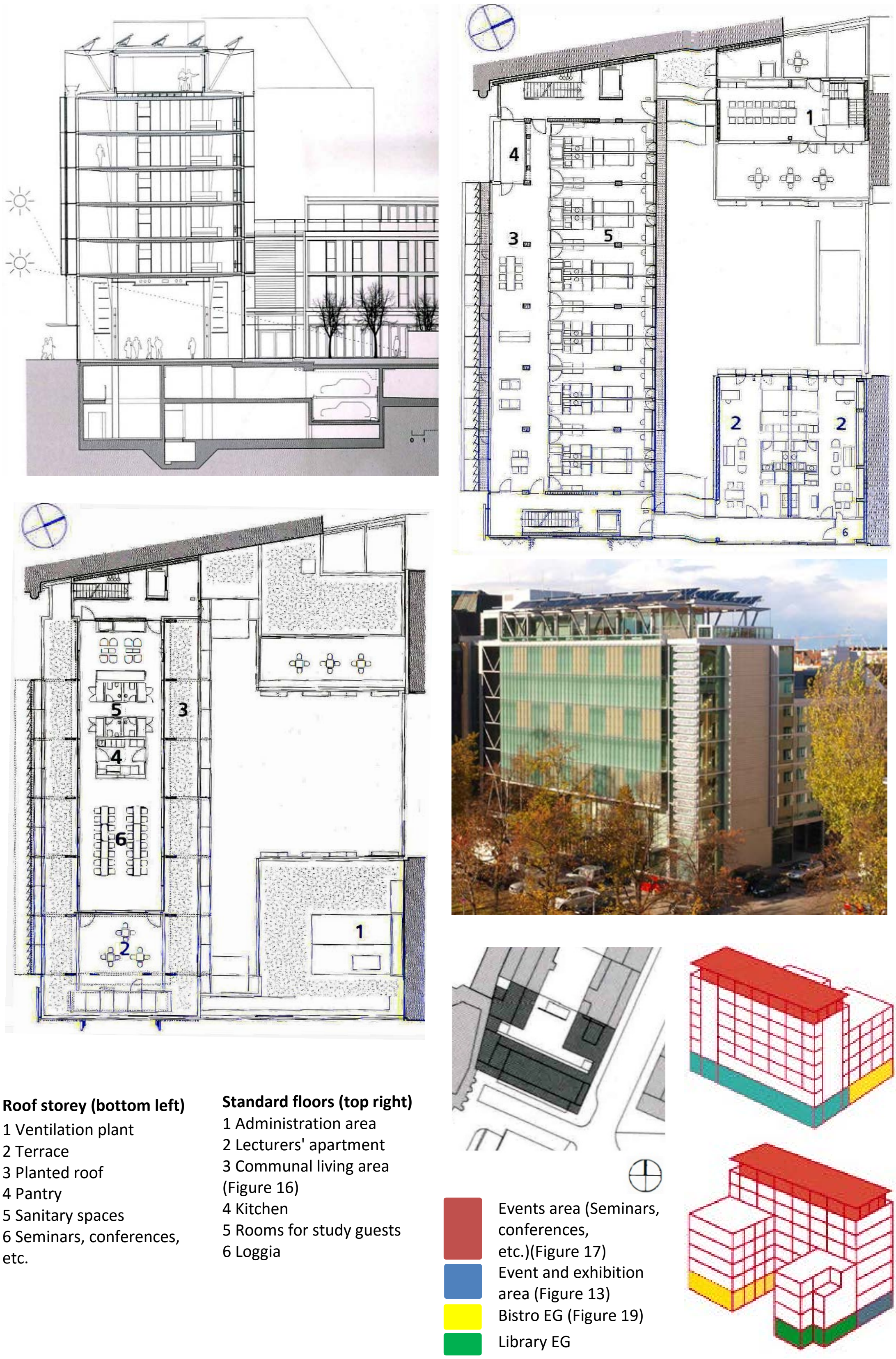
The complex contains rooms for selected guest students- those studying for a master's degree or doctorate, and people who are masters of a trade, for example - as well as apartments for visiting lecturers. In the more than six-meter-high flexible, transparent hall on the ground floor are folding membrane partitions that can be moved into various positions to create quite different layouts. As a result, this space can accommodate a wide range of functions, including exhibitions and public events, lectures, receptions and conferences (Figure 13). (Herzog, 2010)

Figure 13: Oscar von Miller Forum, conferences, events and exhibitions

Transparent glazed facades (Figure 14) that can be extensively opened create a link with the planted courtyard outside, which is flanked by the two wings of the building.

Figure 14: Oskar von Miller Forum, transparent glazed facades

Indoor and outdoor space are thus interwoven to create a subtly varied whole. The public open space in front of the development is urgently in need of redesign in collaboration with the Munich municipal authorities. The main front of the new building, which faces south, is subject to heavy pollution from traffic on the inner-city ring road. For that reason, the bedrooms- on the second to sixth floors - were located on the quiet north face (Figure 15). (Herzog, 2010)



Roof storey (bottom left)

1 Ventilation plant
2 Terrace
3 Planted roof
4 Pantry
5 Sanitary spaces
6 Seminars, conferences, etc.

Standard floors (top right)

1 Administration area
2 Lecturers' apartment
3 Communal living area (Figure 16)
4 Kitchen
5 Rooms for study guests
6 Loggia

🟥 Events area (Seminars, conferences, etc.)(Figure 17)
🟦 Event and exhibition area (Figure 13)
🟨 Bistro EG (Figure 19)
🟩 Library EG

Figure 15: Oskar von Miller forum; aerial view, site plan, section plan, standard floor plans, roof storey plans and isometric plan

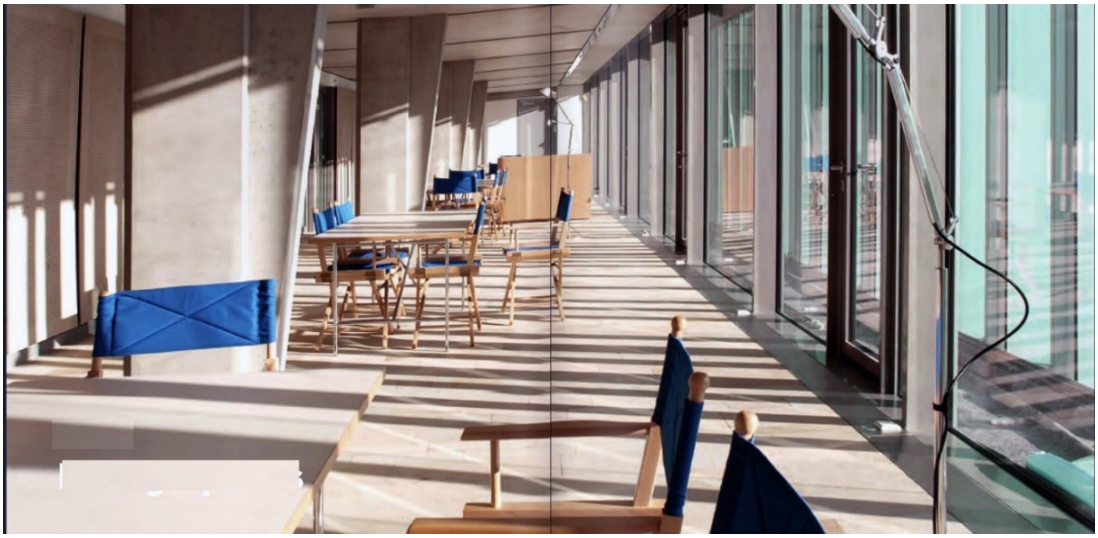


Figure 16: Oskar one Miller Forum, communal living area.

On the south side, a specially developed double-skin glazed façade (Figure 14), folded on the outside, provides solar and acoustic screening. Above the facade space, the outer communal zones on the various floors, housing lounge and working areas, the dining room and kitchen, are naturally ventilated.
On the seventh floor are spaces for smaller group meetings, discussions, seminars and receptions. From a covered loggia, there is a view to the south-east over the skyline of the city, and on clear days, one can see the Bavarian Alps in the distance (Figure 15&17). (Herzog, 2010)

Figure 17: Oskar von Miller Forum, events area (seminars, conferences, etc.) at seventh floor with overlooking Munich.

In the east wing are dwellings for guest lecturers (Figure 15&18) as well as the caretaker's office.

Figure 18: Oskar von Miller Forum, interior views of dwellings

A bistro for guests has been installed on the ground floor (Figure 15&19). In the west wing, oriented to the planted courtyard, is a "clubroom" with a small library, and above this offices and discussion spaces for the administration, as well as a small apartment. (Herzog, 2010)

Figure 19: Oskar von Miller Forum, bistro

The pre-planning was carried out with DS-Plan Stuttgart. Basic investigations were done to find a logical overall energy concept. Further work of the actual planning team finally led to a different solution which was then realized.

The heating system is connected to the nearby municipal district-heating supply in Amalienstrasse and is complemented by solar thermal collectors above roof level that also serve as a means of sun shading in summer. The thermal energy generated in this way can also be converted by an absorption chiller to operate a solar cooling system for the rooms when required. The floors are thermally activated and finished throughout with stone from the region.

In addition to individually regulable natural ventilation via the facades, all user areas can be mechanically ventilated. In the students' rooms, a climatically optimized basic ventilation system guarantees a minimum air change. Temperatures can be controlled on a room-by-room basis by means of individual radiators. In these areas, cooling is achieved by thermal activation of the floors. The closed sections of the facade have a high degree of thermal insulation and are clad with a rear-ventilated skin of large-scale ceramic tiles (Figure 20&27). (Herzog, 2010)

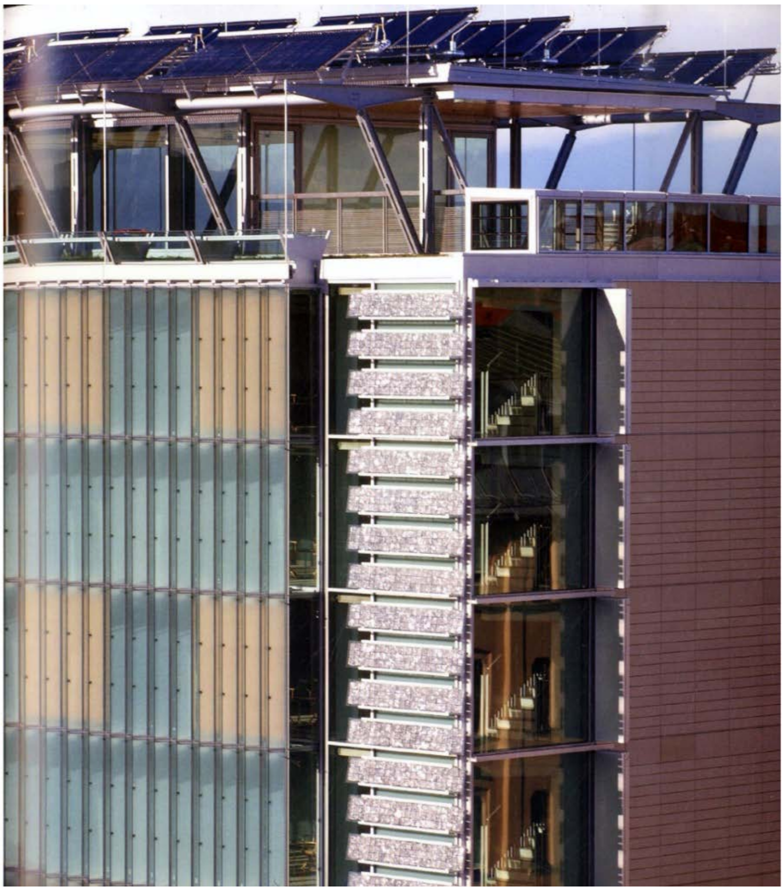


Figure 20: Oskar von Miller Forum, cladding with a rear-ventilated skin of large-scale ceramic tiles

Most of the load-bearing and bracing construction consists of precast reinforced concrete elements. These were left visible to reveal a structure laid out in accordance with the flow of forces. In this way, they demonstrate the potential of this form of construction in terms of precision and design. On top of the main building is an independent steel structure, over the south side (Figure 21) of which the outer facade layer extends. Suspended from this structure on the north side is a construction known as the "harp", consisting of escape balconies and a series of vertical rods (Figure 22). (Herzog, 2010)

Figure 21: Oskar von Miller Forum, independent steel structure, over the south side

Figure 22: Oskar von Miller Forum, escape balconies and a series of vertical rods

Louvres with shimmering silver-grey photovoltaic units screen the large glazed areas of the eastern staircase from overheating in the summer months. Exposed to the sun on this side, they generate power that is fed into the public network. Large folding shutters controlled by sensors regulate the gains from insolation on the east face.

The geometry of the construction bracing the load-bearing structure of the southern tract in the longitudinal direction (i.e. facing the city center) creates a bold image in the facade that is visible from afar. State-of-the-art Bavarian constructional technology is integrated into the architectural design of this building (Figure 12).

Large-scale art projects and additions to certain wall surfaces reflect the function and cultural dimension of the building. They have a strong influence on the texture and spatial part of this new institution and thus on its character and physical presence (Figure 23). (Herzog, 2010)

Figure 23: Oskar von Miller Forum, certain wall surfaces reflect the function and cultural dimension of the building

One aspect of the architectural and engineering task was to apply state-of-the-art technology and forms of construction in the appropriate places, as well as materials, components and products that would comply with high modern technical standards in terms of function and design. Examples of this are outlined below.

Steel arms

The outer facade planes of the south tract are suspended from large girders that cantilever out on both sides of the building above the seventh-floor roof level (Figure 24). The steel structures at the level of the terrace storey are sculpture-like modern engineering elements. The entire roof area is covered with high-performance tubular collectors, the state-of-the-art elegance of which is also visible from the space in the roof storey. A maximum of transparency was ensured by keeping both sides of the ground floor free of external vertical load-bearing elements for the full height of the hall. (Herzog, 2010)

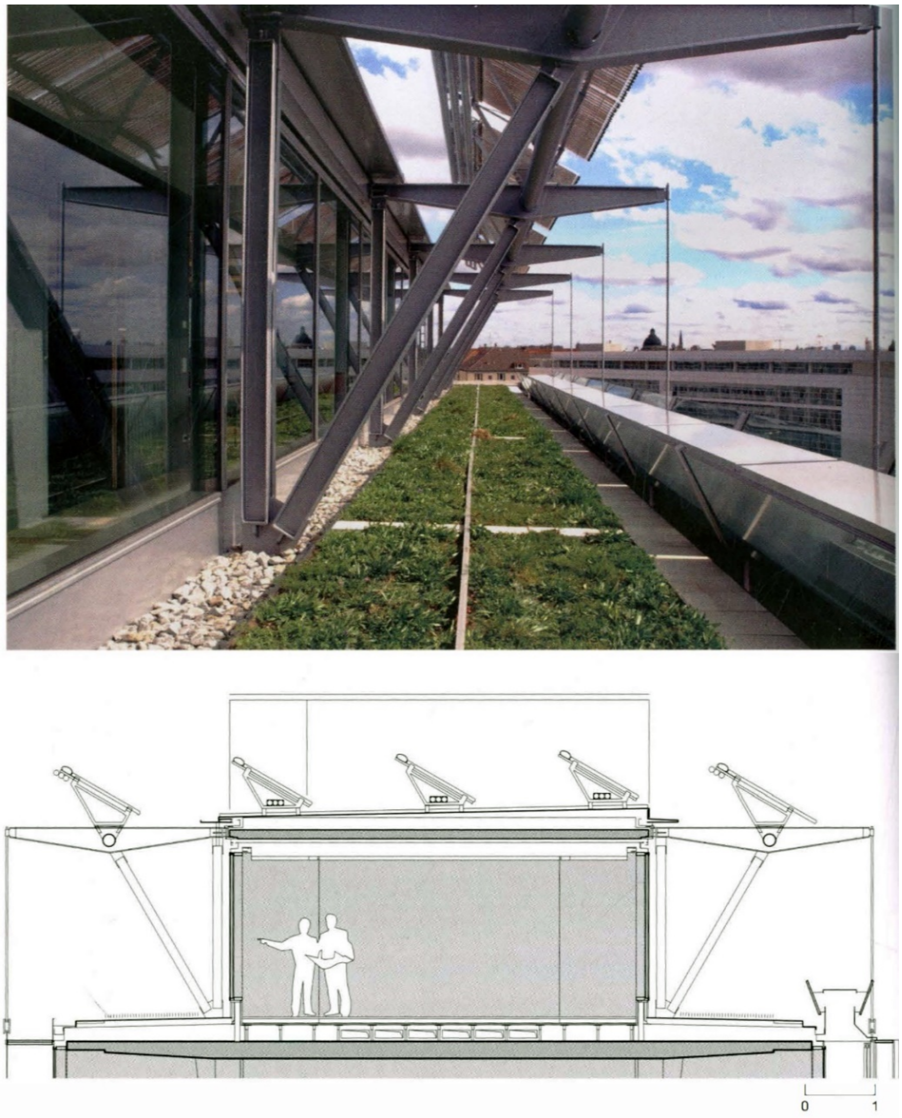


Figure 24: Oskar von Miller Forum, The steel structures above the seventh-floor

The building envelope

The inner layer of the double-skin façade on the south side consists of room-height double glazing with good thermal-insulation properties and with a number of ventilation openings to the facade intermediate space. The outer skin is formed with alternately transparent and translucent panes of glass with point fixings (Figure 25). The transparent panes are frameless and project slightly beyond the facade plane. The folded construction of the skin increases stability and resistance to horizontal forces. Scope is allowed for converting the present system to one with opening lights, should traffic on the inner-city ring road be significantly reduced in the future. Between the two glazed skins, a continuous vertical intermediate space was created as a means of ventilation. In addition to the positive effect this has in terms of sound insulation, the special appearance of this form of construction defines the identity of the building on the side facing the city center.

Large sliding shutters with wooden louvres in the intermediate space between the two skins of the outer wall form an effective means of shading, reducing unwanted heat gains in summer in the lounge areas. According to needs, the shutters can be extended floor by floor over the entire length of the south face; alternatively, they can be pushed back over each other to cover half the area of this glazed front. At all events, the effect of the large areas of wood has a great influence on the atmosphere in the communal spaces on the floors where students live. After repeated reflection, the light that enters also determines the color values of these large areas. (Herzog, 2010)

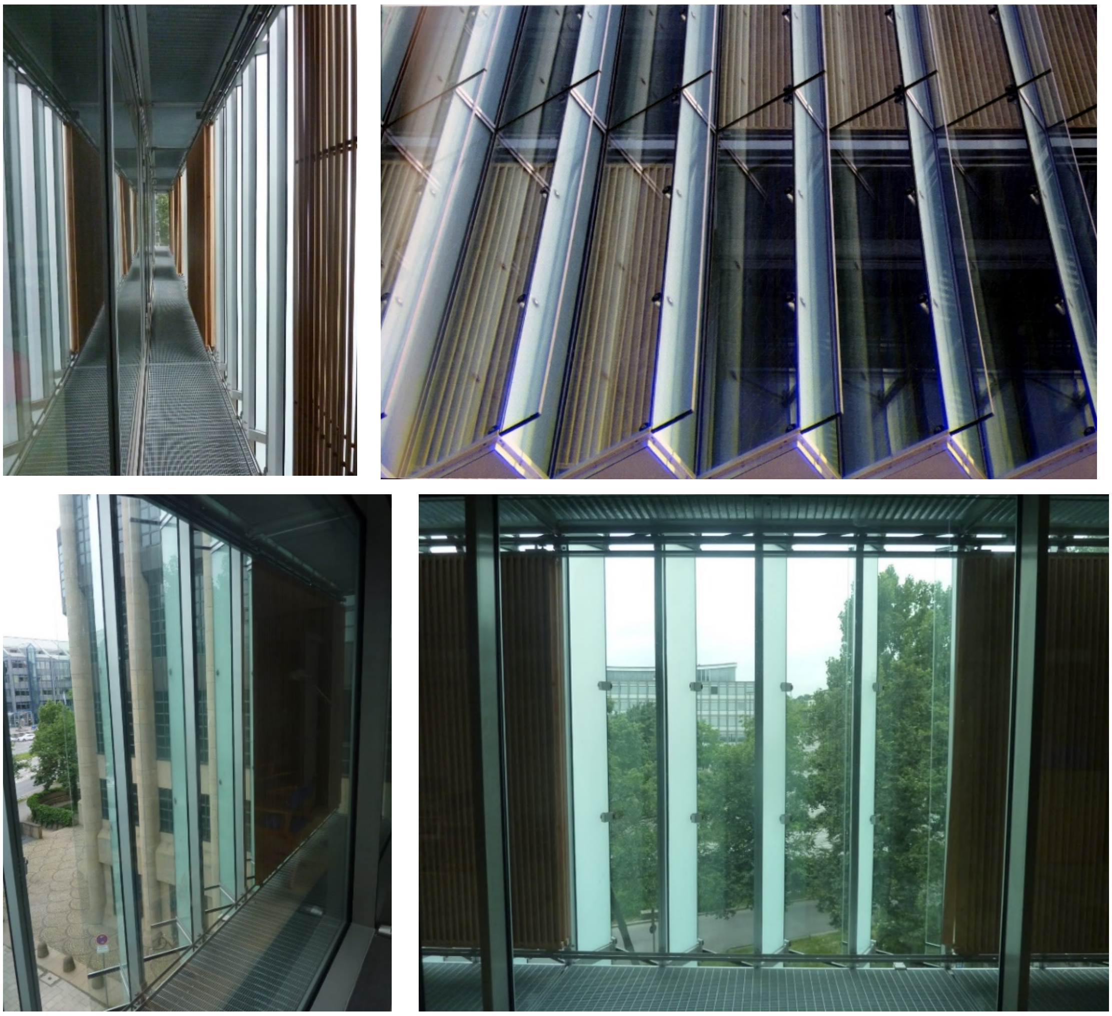


Figure 25: Oskar von Miller Forum, the building's envelope; south tract

The "harp" suspended on the north face supports the escape-balcony gratings. Furthermore, the closely spaced, inox rods, which are connected horizontally at balustrade height, form a barrier to prevent people falling from the balconies (Figure 22).

The facades to the east and west tracts (Figure 26) overlooking the courtyard are distinguished to a large extent by lightweight ventilation panels with vacuum insulation. The deep spaces in these tracts are extensively glazed in order to provide good views out and to maximize the exploitation of daylight. The requisite thermal-insulation effect could, therefore, be achieved only with high-quality triple glazing. Lightweight wood panels were constructed with a marine plywood lining and with a newly developed form of vacuum insulation internally. This has a thermal transmission that measurements show to be lower than that of conventional foam or mineral-wool insulation by a factor of 6. As a result, it was possible to design the panels with correspondingly slender dimensions. But only if the elements are fabricated completely at works, together with the insulation, and the panels are hung in position on site with the greatest of care does the use of this top-grade new building material appear to hold any promise for the future, since lack of precision in the manufacturing process and the damage that can so easily be caused on site have to be avoided at all costs. (Herzog, 2010)

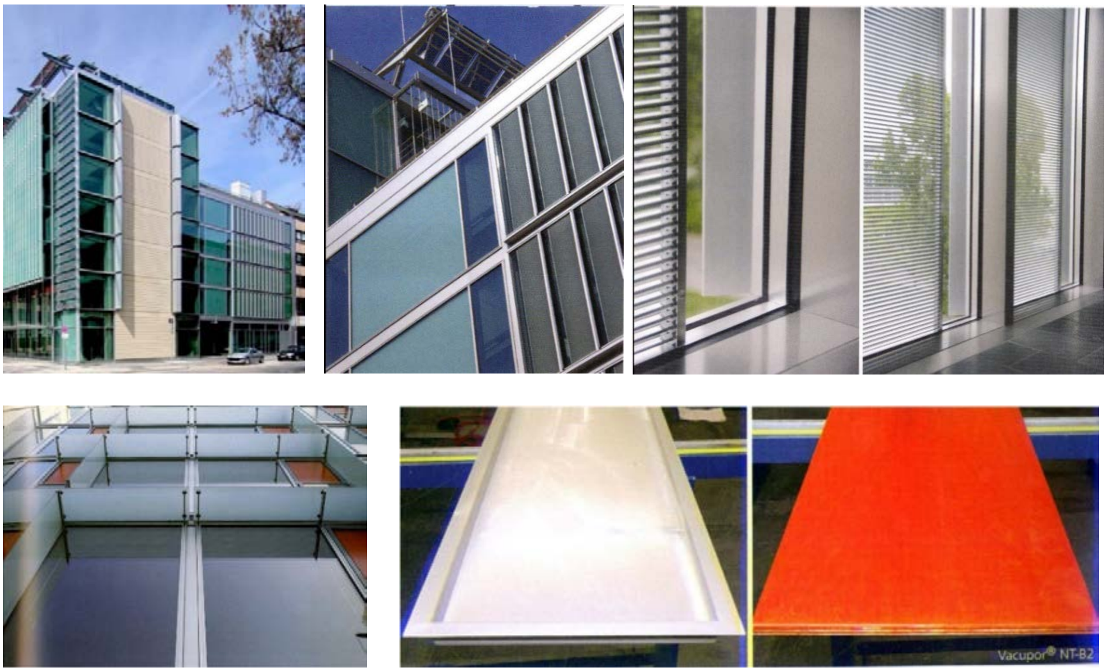


Figure 26: Oskar von Miller Forum, the facades to the east and west tracts

The daylight that enters through the glazed eastern front overlooking Amalienstrasse falls on the translucent internal walls of the lecturers' apartments on the upper floors. In the glazed outer skin, there are slender horizontal metal sections that act as reflectors. A narrow transparent strip in each façade element maintains a visual link with the outside. In order to prevent unwanted heat gains in summer caused by the morning sun penetrating these strips, vertical sheet-metal sections were fitted externally to provide partial shading.

The closed areas of the east-facing outer walls as well as those overlooking the courtyard are clad with rear-ventilated, thermally insulated ceramic facade panels (Figure 20&27). This form of construction, which we created at an earlier date in collaboration with a brickworks in Lower Bavaria, was developed further by the present manufacturer with a high-quality finish to produce-after decades of perfectioning - a large-scale building element. The size, shape and coloration of these panels consciously reflect the urban surroundings of LudwigstraBe. (Herzog, 2010)

Figure 27: Oskar von Miller Forum, cladded walls with rear-ventilated, thermally insulated ceramic facade panels

Activation of building components

The activation of building components in the form of the reinforced concrete floors is an underlying principle of the large-area spatial heating concept. This system, which is based on a very small difference between the temperature of the component and that of the air in the rooms, is one we applied for the first time more than ten years ago in a larger building scheme. In the meantime, it has found widespread application and has become a successful standard. The emission of heating or cooling energy via the large areas of floors and ceilings ensures a physiologically comfortable sensation akin to the effect of radiant heat in internal spaces where air convection is avoided. The dimensions of the reinforced concrete floors, therefore, were determined not only by structural needs, but also by the requisite thermal storage capacity. In this way, the exploitation of environmental energy becomes possible even at low temperature levels. (Herzog, 2010)

Floor finishes

All floors in this development were paved with stone. Circulation areas and other surfaces that are subject to heavy wear are covered with dark Anrochte "dolomite", a stone with great resilience. Individual rooms and communal spaces are paved with Sollnhofen Jura, a characteristic Bavarian product that is used in its rough quarried state. In this form, the great diversity of color and the many particles enclosed within this native sedimentary stone are effectively brought out.

Bathrooms

To install individual shower facilities in the relatively narrow student apartments, while at the same time minimizing the area required, a wet room was developed that could be varied in size. If the sanitary space is not used as a bathroom or serves merely as a WC, a space of only minimum width is necessary. If the bathroom is to be available over its full area, the glazed double doors can be turned outwards by 90°, allowing part of the lobby to be incorporated temporarily for this purpose. The bathroom then has the requisite size; otherwise it can be reduced to the depth of a largish cupboard. The technical logic of dry forms of construction was extensively applied in the internal finishings. Accordingly, where the bathroom walls do not consist of glass, large-area easy-to- clean Corian panels were used to enclose these spaces. The panels are gently curved at the junctions with other elements. Individual large-area wall units with integrated fittings were supplied by the manufacturer and simply had to be assembled on site. (Herzog, 2010)

Furnishings

Guests of the house should appreciate that a modern understanding of design has a long tradition in Bavaria. This was to be made apparent through visual perception and the use of important, original design classics. In this way, guests can expand their own experience, a process that should ideally further their aesthetic education. Of special importance in this respect is regular contact with everyday objects - objects that often have a physical proximity and form an important counterpart to one's own person. A specific design line for movable furnishings, fittings, lamps, etc. has been observed throughout the building (Figure 28). (Herzog, 2010)

Figure 28: Oskar von Miller Forum, furnishings

Movable wall system

To allow a realm to be created for special events within the large hall space, a wall system was developed, comprising a multilayer, translucent membrane structure that extends above door height. This construction is effectively penetrated by both daylight and, after dusk, by the internal artificial lighting. As a result, any sense of monumentality is avoided, and the brightly gleaming surfaces of the membrane help to overcome the impression of a visually hermetic spatial enclosure within the hall (Figure 29). (Herzog, 2010)

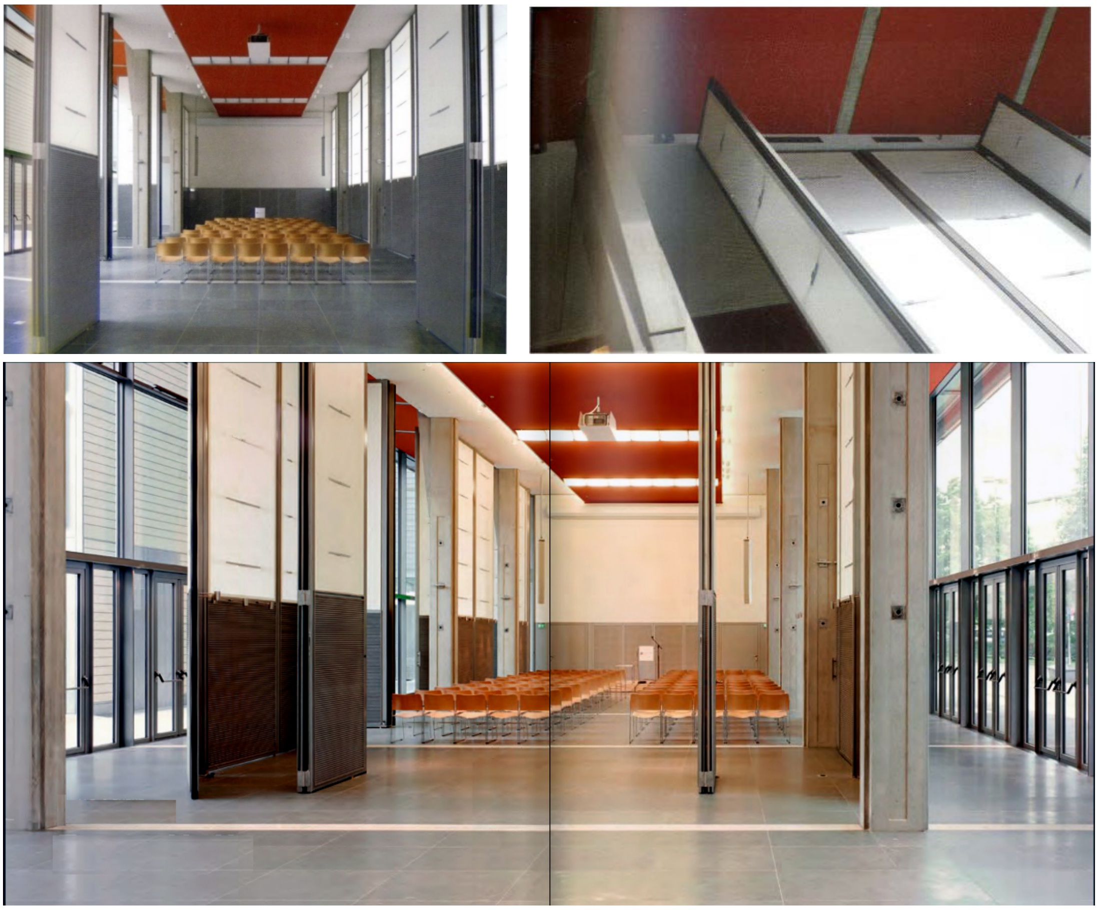


Figure 29: Oskar von Miller Forum, movable wall systems

As centers for the education and training of children and young people, schools and universities are the ideal objects through which to communicate and implement the goals of sustainability. At no other time in our lives are we so receptive; and we can profit and learn from high-quality spatial acoustics, sound insulation, natural and artificial lighting, the purity of the air, as well as a high level of hydro-thermal comfort as the outcome of good thermal insulation in a building. Via a process of demonstration, we can come to appreciate the environmental and economic effects that play a role in all these things and to recognize their advantages, so that we may aspire to similar qualities in other locations. In Germany in particular, we are obliged to ensure the best possible conditions in places of education and related institutions, for it is there that our most important regenerable resource has its origins.

The Oskar von Miller Forum, a residence realized by the Bavarian building sector to extend educational facilities for the younger generation in the building faculties of the Technische Universitat Munchen (TUM), accommodates outstanding teaching staff, students and young masters of the building trades. In this respect, the institution makes a major contribution as a meeting place and center for communication. In contrast to the usual school and university buildings, the forum also provides functions that considerably broaden one's range of experience. As a means of heightening the awareness of users and the many visitors to the Oskar von Miller Forum in terms of the production, distribution, storage and consumption of energy and their role and significance in the overall context of sustainability, an energy certificate was issued for the Oskar von Miller Forum, attesting its quality in this respect. A primary-energy index of 137 kWh/ (m^2a) confirms the high standards of the Oskar von Miller Forum and its environmental quality.

At the heart of the compact group of buildings comprising the Oskar von Miller Forum is an open glazed hall, the vitality of which is based on the relationship between two open areas a and on the contrast between constriction and breadth, private and communal activities. This large hall is an inviting space and also forms part of the public realm. The small, intimate courtyard has an airy design: dark green is contrasted with light-colored strips of concrete paving and white blossoms that form spots of light in the shade of the open space. The public forecourt is an important connecting zone between the well-known art gallery Haus der Kunst and the various Pinakothek galleries. It also forms a link between Amalienstrasse and the inner city. At present, this space suffers from the heavy traffic on the Oskar-von-Miller-Ring road and is not particularly inviting. People tend to cross it quickly without heeding the surroundings, which does not reflect its significance as part of the urban space, especially as it forms a common access area for St Mark's Church and the Oskar von Miller Forum. By day and also when evening events take place here, it should function not just as a through route: it should be a friendly, attractive public space. Suggestions have been made to link the various areas as far as the church by means of unified pavings with a generous layout and to create a series of related yet distinct recreational spaces. According to these plans, an attractive approach zone would be formed in front of the Oskar von Miller Forum that could also be used for special events with outdoor catering. The ring road would be screened off by tall trees, and a background of curving yew hedges with a long, broad bench in front would help to create a special atmosphere: a little oasis in the noisy city, a gain for the entire neighborhood (Figure 30). (Herzog, 2010)

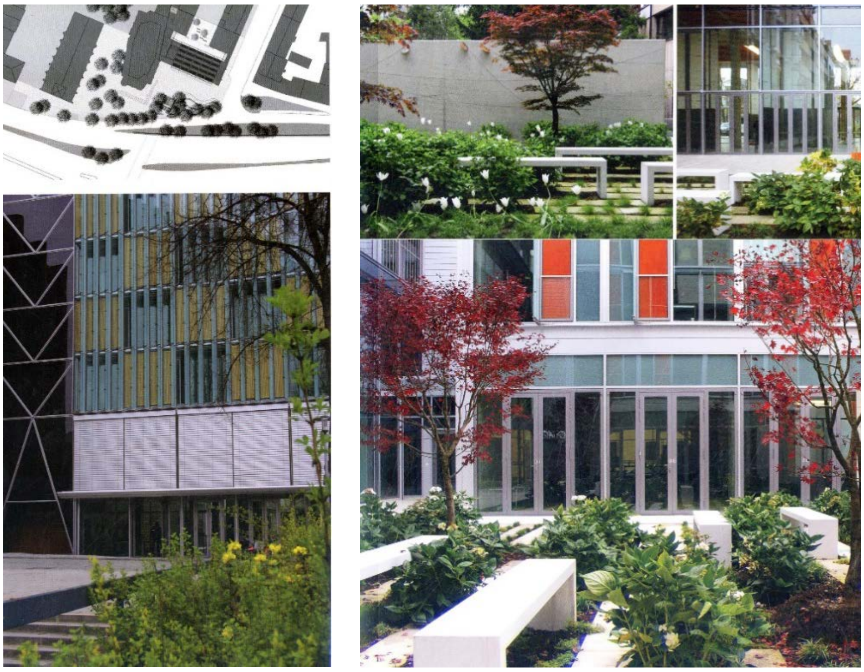
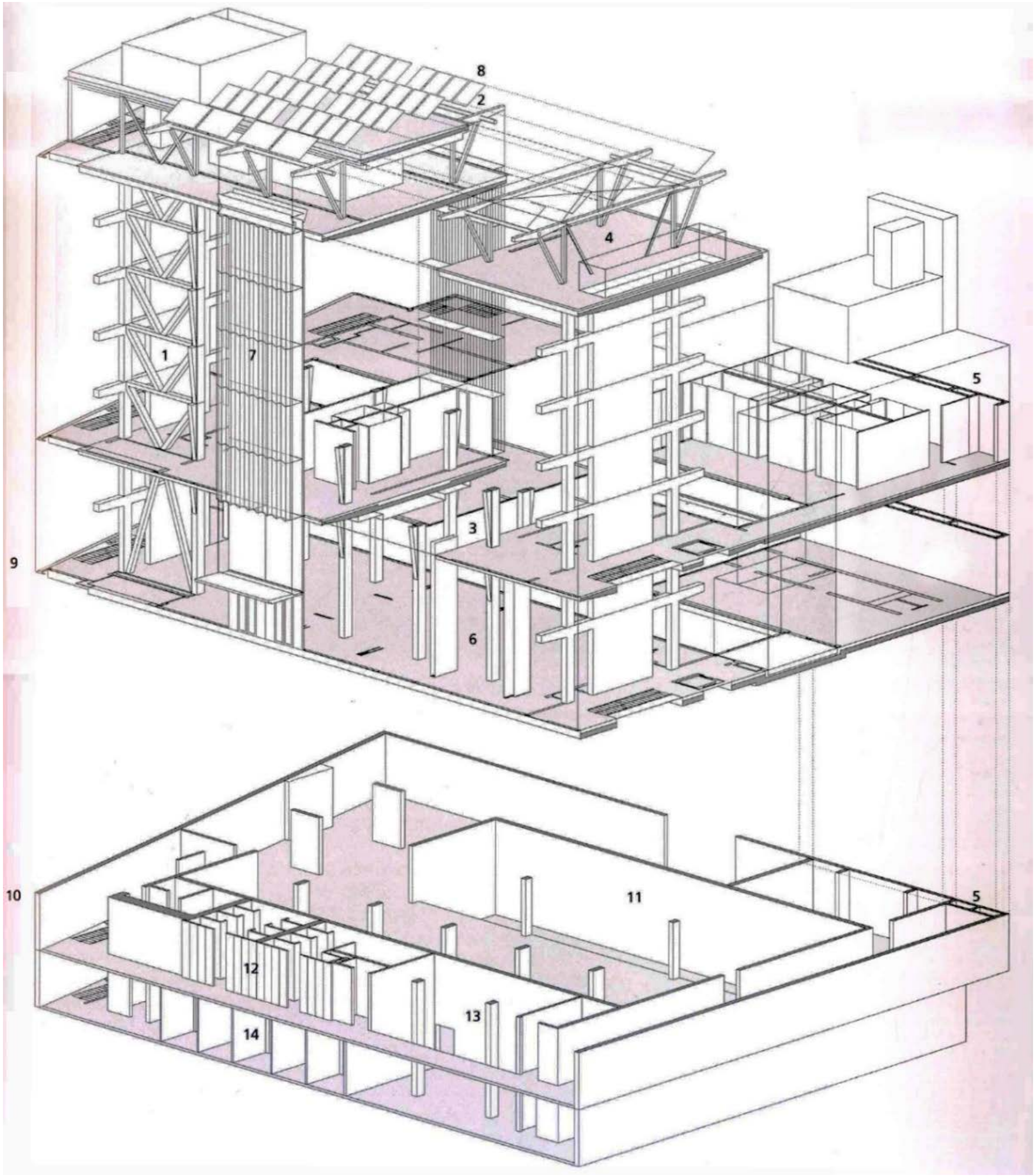


Figure 30: Oskar von Miller Forum, landscapes

Structural Planning

The building is braced using the floor slabs as diaphragms connecting to two shear walls in the east-west direction in the two side tracts as well as to four shear walls that run in the north-south direction in the main building. Since these east-west and north-south bracing walls are situated in different sections of the development, the linking bridges are of crucial significance. Only with a rigid, load-bearing connection of the side tracts to the main section of the building by means of these walkways was it possible to ensure the overall stability of the load-bearing system. As a result, further cross-walls were not necessary. To brace the upper floors of the main building, which rise above the side tracts, diagonal elements were inserted on each floor in a V-shaped form between two columns and the floors, creating a continuous, vertical framing system. By optimizing the bracing walls in this way, a maximum of transparency was achieved, which is evident when one looks through the building to the internal courtyard. Through the investigation of many different alternatives, a floor system was developed that not only met the structural requirements, but also allowed the creation of an open, flexible spatial structure. Flat slabs are supported in the lateral direction of the building by only two rows of columns. The central floor bays are assisted by the cantilevers towards the facades. The generous cantilevers were achieved by systematically anchoring the slabs in the columns. The floor spans and cross-sections were chosen in such a way to optimize the forces and balance out the deflections in both directions. Reflecting the degree of loading, the thickness of the cantilevered slabs decreases towards the facades. This is visible in the various floors as a deliberate architectural feature. The top surface of the central bays was recessed to accommodate service runs and technical installation. In order to obtain high-quality exposed-concrete surfaces, the columns were precast, and the floors were constructed in the form of semi-precast slabs 2.4 meters wide and up to 13.3 meters long (Figure 31). (Herzog, 2010)



1 reinforced concrete structure with bracing
2 reinforced concrete structure with suspension of outer facade skin on both sides
3 pre-cast concrete columns as half frames
4 floor slab, consisting of filigree concrete elements
5 service shafts
6 pivoting, folding doors
7 glazed outer facade layer
8 tubular thermal collectors
9 ground and upper floors
10 basement storeys
11 basement garage
12 sanitary installation
13 two-storey basement party space
14 storerooms

Figure 31: Oskar von Miller Forum, principal structural subsystems, rooms and building elements isometric diagram, south view

In developing the multifunctional double-skin facade construction (Figure 33) for the south front of the building, simulations (Figure 32) were carried out by Dipl.-Ing. Rolf-Dieter Lieb of the institute for lndustriedynamik GmbH at the University of Applied

Sciences, Aachen. The aim was to investigate the way the system functioned as well as its efficiency. The development of the construction was based on the results of the simulations. A limited selection of these are shown in the illustrations. The following details are taken from a summary of the findings.

"The findings of the first airflow simulation for the building show that, in view of the position of the staircases, the underlying idea of a supportive system of natural ventilation can be implemented with relatively few basic elements and largely in a manual form. Even with normal-sized openings, it would be possible to provide adequate air changes both in summer and in winter, as well as for celebrations that may be held here from time to time...

"Based on this, the outflow of air from the double-skin facade and in particular the detailing at the top were investigated in a second airflow simulation in the form of three-dimensional computational fluid dynamics (CFD[17]) with turbulent flow. It was shown that the construction at the top-based on industrial forms-could be optimized in the detailing. Nevertheless, with a clear width of only 50 cm, an efficient outflow can be achieved, and this would certainly be adequate in the event of fire. In addition, it would fulfil its function regardless of wind conditions."

Interestingly enough, in a further investigation of smoke extraction from the building in the event of fire, the author comes to the conclusion, after evaluating the results of three-dimensional CFD (turbulent flow), that "The simulation of summer ventilation had already shown that the double-skin façade should be ventilated to best advantage from bottom to top and not by creating opening sections in the front face, because in the latter case the occurrence of wind could interfere with the ventilation as well as with smoke extract operations. (The south to south-west orientation of the facade means that in Munich, it would be subject to direct winds for 25 per cent of the time in the course of the year.)" (Herzog, 2010)

Independently of this, an additional façade sprinkler system was deemed necessary.

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[17] Computational Fluid Dynamics (CFD) is the term used to describe a family of numerical methods used to calculate the temperature, velocity and various other fluid properties throughout a region of space.

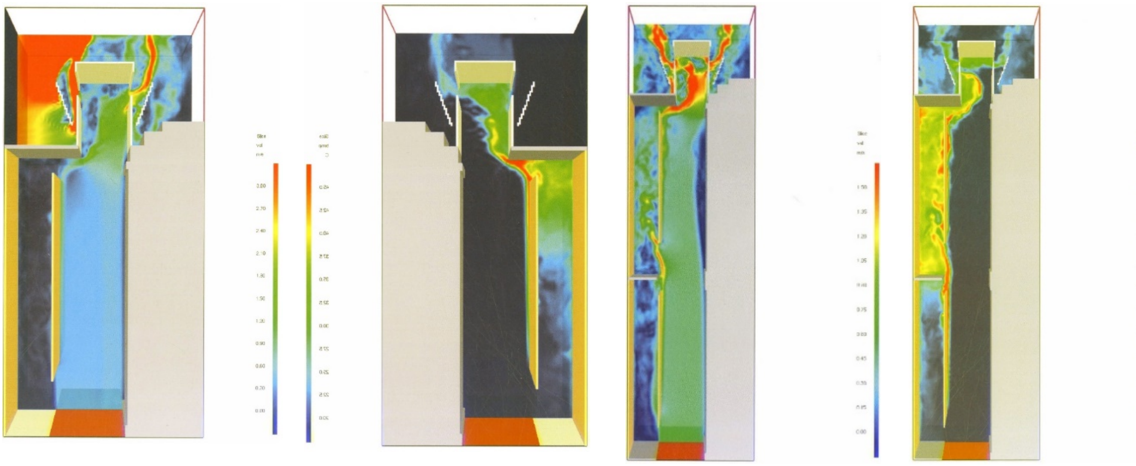
CFD when applied to buildings can provide the designer with information on probable air velocities, pressures and temperatures that will occur at any point through a predefined air volume in and around building spaces. Boundary conditions are specified which may include the effects of climate, internal heat gains and HVAC systems. DesignBuilder CFD can be used for both external and internal analyses.

External CFD analysis

External CFD analysis provides the distribution of air velocity and pressure around building structures due to the wind effect and this information can be used to assess pedestrian comfort, determine local pressures for positioning HVAC intakes/exhausts and to calculate more accurate pressure coefficients for EnergyPlus calculated natural ventilation simulations.

Internal CFD analysis

Internal CFD analysis provides information on the distribution of air velocity, pressure and temperature (and several other calculated parameters) throughout the inside of building spaces. Also calculated is 'age of air' to indicate the relative 'freshness' of the air through the domain and also a comfort index. This information can be used to assess the effectiveness of various HVAC and natural ventilation system designs and to evaluate consequent interior comfort conditions.



Simulation 4: 70-cm-wide grating from floor to floor; analysis of effects of side wind at 5 m/s from south (ill. left); **airflow speeds** in double-skin facade at top-storey level

Simulation 4: 70-cm-wide grating from floor to floor; analysis of effects of side wind at 5 m/s from south (ill. left); **temperature change** in double-skin facade at top-storey level

Simulation 6: 70-cm-wide grating from floor to floor; analysis of mutual influence of different storeys; **air speed** in double-skin facade at level of top two floors

Simulation 6: 70-cm-wide grating from floor to floor; analysis of mutual influence of different storeys; **temperature change** in double-skin facade at level of top two floors

Figure 32: Oskar von Miller Forum, simulations to: investigate the way the system functioned as well as its efficiency/ for the development of the construction

Outer facade layer
Double-skin façade

1. Inner facade layer, forming a thermal envelope: thermally insulating double glazing; openable windows to facade cavity for natural ventilation of internal spaces
2. Outermost facade layer: metal-and-glass construction suspended from roof structure as protection against external weather influences and noise immissions
3. Wood louvred shutters, horizontally sliding as protection against insolation and glare and as a means of visual screening; automatically and manually operable
4. Single glazing, translucent
5. Single glazing, transparent
6. Horizontal metal grating as sunscreen, capable of bearing foot traffic for maintenance and cleaning
7. Screening against solar radiation and glare: direct exposure of the inner facade skin to sunlight is prevented to a very high degree by the wood louvres and translucent glazing. The geometry of the louvres nevertheless permits the partial ingress of daylight. Light in the form of reflections is cast on the back of the louvres facing the internal spaces.
8. Visual screening: the horizontally sliding shutters and the translucent glazing allow views into and out of the building to be controlled.

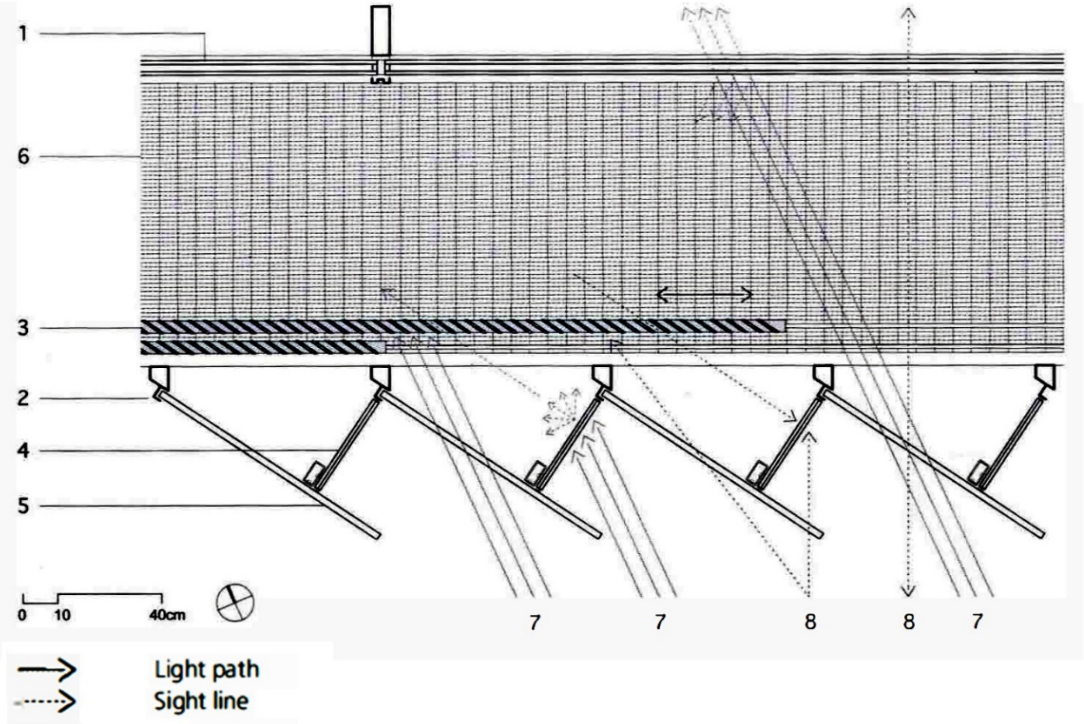


Figure 33: Oskar von Miller Forum, multifunctional double-skin facade construction for the south front of the building,

Services Systems

The aim of the planning was to implement a high-performance, energy-efficient building that would conserve resources. With the use of innovative constructional technology and modern plant and equipment, a structure was realized that has a low consumption of primary energy. To achieve this goal, the following systems were used:

-exploitation of solar energy for the hot-water supply, solar cooling and heating backup;
-mechanical ventilation of the living spaces with highly efficient heat-recovery system;
-genera/lighting control in accordance with daylight levels and movement detectors;
-control in working areas in accordance with daylighting;
-regulation of blinds in events spaces in accordance with position of sun;
-natural ventilation through control of facade louvres;
-Water-saving sanitary fittings. (Herzog, 2010)

Heat generation

In a bivalent heat-generation system, approximately 80 per cent of the heating-energy needs are covered by the municipal district-heating supply and about 20 per cent by solar thermal energy. The central-heating plant for the entire building is situated in the basement. The overall thermal output of all heating circuits is 400 kW.
The heating supply to individual parts of the building is as follows:
-static heating areas in the rooms, staircase areas and WCs;
-ventilation and air-conditioning plant in the west tract (ground to third floors); in the east tract (first to fourth floors) and in the bistro; in the south tract (living areas and the seventh floor events space as well as the hall; stores and mechanical services areas in the basement); Underfloor heating:
-hall area on ground floor of south tract;
-public areas on ground floor of west and east tracts;
-office on first floor of west tract;
-rooms oriented to the internal courtyard on the second floor and the roof storey of the west tract;
-communal areas adjoining the private rooms and the lecturers' apartments;
-rooms and lecturers' apartments in the south and east tracts;
-communal area in the roof storey of the south tract. (Herzog, 2010)

Automatic control systems for heating technology

The measurement, control and regulation plant was executed in direct digital control (DDC) technology. In the central plant room for heating, a bus connection supplies the primary server for the control system in the building. (Herzog, 2010)

Cooling plant

The generation of cooling energy was divided into the three following categories:
-"Free cooling" -this covers almost 70 per cent of cooling-energy needs with the aid of a cooling tower. Evaporative cooling ensures the requisite return cooling temperatures in a cost-efficient form, even with high external air temperatures;

-"Solar cooling" -solar collectors on the roof cover 16 per cent of cooling-energy needs. The hot water produced in the process is used to operate an absorption-cooling machine on the second basement level;
-"compression-cooling technology"- a standard compression cooling machine covers 15 per cent of the peak cooling-energy needs. (Herzog, 2010)

Cooling energy is required for the following purposes and in the following areas:
-ventilation and air-conditioning plant (west tract, ground- 3rd floor; east tract, 1st-4th floors; upper floors in south tract with events space on 7th floor; hall in south tract, and ground floor bistro in east tract)
-underfloor cooling, whereby the water temperature is not more than 2-3 ºC below room temperature in the following areas:
-ground floor hall, south tract;
-ground floor communal areas, west and east tracts;
-first floor "office", west tract;
-second floor rooms oriented to courtyard, and roof storey, west tract;
-communal areas outside students' rooms and lecturers' apartments, south and east tracts;
-students' rooms and lecturers' apartments, south and east tracts;
-communal areas, roof storey, south tract. (Herzog, 2010)

Control plant for cooling system
The whole of the measurement, control and regulation plant was executed in DDC (Direct Digital Control) technology. The information center is coupled with the main heating plant. (Herzog, 2010)

Ventilation and air conditioning (Figure 34)
Mechanical ventilation plant supplies the following areas with fresh air:

- *South tract-upper floors*

The students' working and bedroom areas, the communal spaces and the 7th floor of the south tract are mechanically ventilated (air supply and extract). The air conditioning of these two realms functions separately by means of zone distribution units.
The air-conditioning plant, with recovery of heating and cooling energy and with a humidifying function, is situated on the roof of the south tract.
By humidifying the air, the habitable quality/comfort of the internal spaces is improved in the winter months, and the risk of infection is reduced, especially in respect of the upper respiratory tracts.

The scope provided for opening windows individually allowed a hybrid ventilation system to be implemented in all areas.

- *West and east tracts*

The communal areas on the ground and first floors, as well as the dwellings on the 2nd and 3rd floors of the west tract and the eight lecturers' apartments, are mechanically ventilated (air supply and extract).

- *Ground floor hall, south tract*

A central air-handling unit (AHU) with recovery of heating and cooling energy and an air intake at basement level provides a controlled system of air renewal in the large hall on the ground floor via air-quality sensors, with a variable rate of flow in accordance with needs.

- *Ground floor bistro, east tract*

The ground floor bistro in the east tract can accommodate 60 people and is mechanically ventilated without a humidifying installation.

Storage and services areas in basement

The storage and services areas are mechanically ventilated without a humidifying installation.

- *Basement garage*: *air extract and supply*

The basement garage, access to which is via the adjoining site, has a fresh-air intake through a separate duct combined with the general air intake. Extract air is emitted above roof level. For the smoke-extract system in the basement garage, a tenfold air change is required.

- *Refuse room*

The refuse room is ventilated by means of a roof fan.

- *Battery room*

Exhaust air from the battery room on the first basement level may on occasion contain pollutants. The air is removed by a roof fan at the top of the east tract. (Herzog, 2010)

Automatic control systems

The automatic ventilation control systems were executed in direct digital control (DDC) technology and are linked with independent information points in four switching centers by means of bus interfaces to the central plant. (Herzog, 2010)

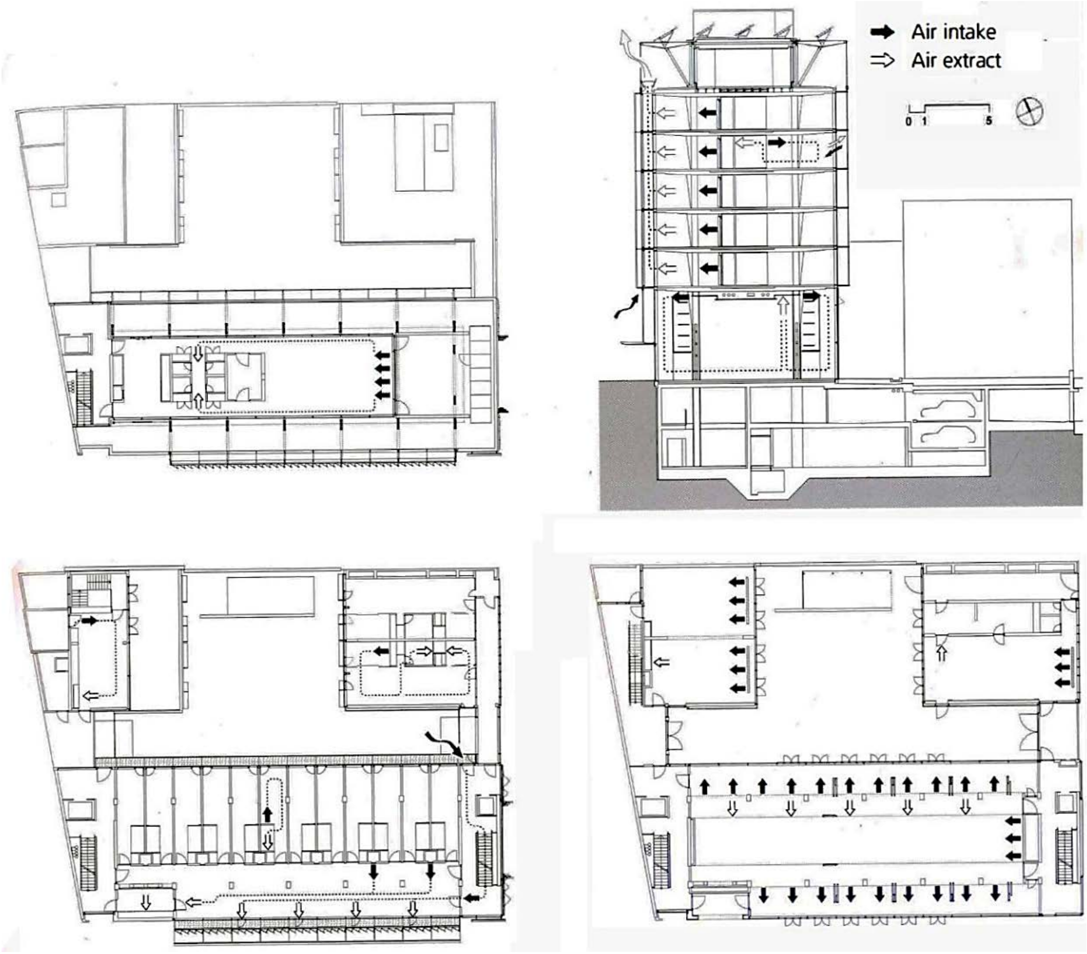


Figure 34: Oskar von Miller Forum, ventilation concepts for Roof storey, standard floor, ground floor and cross-section

Central building control system-networks

The automated centers are linked with each other by a communications system via the internal IT network. As a result, every possible form of data exchange between stations and with an overall management system can be exploited to ensure an optimized energy-efficient operation of the entire systems technology in the building. (Herzog, 2010)

Water supply

An existing drinking-water supply pipe (Ø 150mm nom.) branches off from the main run of the Munich municipal works in Amalienstrasse, entering the forum building (Ø 65mm nom.) at first basement level. An installation that provides protection against lime and calcium deposits in water transforms calcium-forming ions dissolved in the water into crystals in a natural process without the use of chemicals. The fine calcium grains are washed out when water is drawn off.

An *installation to disinfect drinking water* destroys, among other things, temperature-resistant legionellae in hot water. These can occur in empty units in critical periods of stagnation. The disinfection is achieved through a specific dosage of disinfectant against germs and bacteria.

Water is heated and stored centrally.

Distribution is via circulation runs. Installed in the room for service connections on the first basement level are the water meters and the distribution to the internal runs within the building. (Herzog, 2010)

Waste-water and rainwater drainage

Waste-water drainpipes beneath the ceilings on the first and second basement levels flow into the municipal sewage network. Vertical runs in the pipe ducts are ventilated above roof level.

Drainage of waste and soil water below the back-pressure level on the first and second basement floors is removed by means of a dual pumping plant. Waste water from the bistro kitchen is removed through a grease trap.

Since rain that falls on the site cannot seep away, it is drained off in a combined system via a trap, together with waste water, into the public sewers. (Herzog, 2010)

Sprinkler plant and water for firefighting

A high-pressure water-vapour fire-extinguishing plant protects the hall areas on the ground floor and the communal areas on the upper floors. The two main staircases are equipped with "dry" fire mains. Underfloor hydrants of the public water-supply system were installed along the adjoining roads. (Herzog, 2010)

The special fire protection concept prevents fire spreading within the double-skin facade. Special water-vapour sprinklers were used here.

Electrical and Information Technology

As part of the electrical engineering, an attempt was made to allow scope for individuality in the context of energy-efficient and environmentally sustainable operations. In addition to the exploitation of solar energy for the cooling and the electrical supply, intelligent control systems ensure automatic operations to meet the various needs within the building. The presentation and events spaces are laid out over three levels and are equipped with modern media technology. Here, exhibitions, lectures and many other events can be staged (Figure 35). (Herzog, 2010)

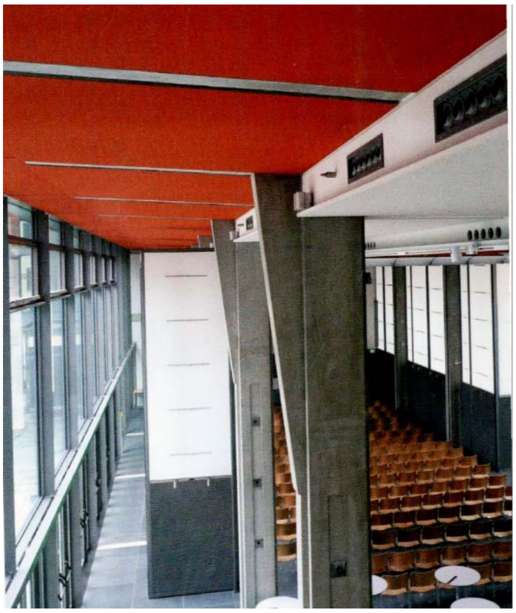


Figure 35: Oskar von Miller Forum, intelligent control systems which ensure automatic operations to meet the various needs within the building

Photovoltaic installation

On the south face of the eastern staircase is partially transparent photovoltaic installation (Figure 36). The return-flow energy that is generated is fed into the public network of the city of Munich. In spite of the vertical form of assembly, an optimal inclination to the sun was achieved through angled strip-like panels. Here, the partial shading of the internal spaces provided by the panels means that they also reduce heat gains significantly, in accordance with plans. (Herzog, 2010)

Figure 36: Oskar von Miller Forum, photovoltaic installations

Sound insulation against external noise

The location of the building at the intersection of major inner-city roads means that the south face is exposed to considerable noise disturbance. This was overcome in the design partly through the layout and partly by constructional measures in the form of an additional acoustic screen that functions in a number of ways and was specially developed for this purpose. The screen was set in front of the actual main facade, which has its own thermal and sound insulation.

The layout of the building also creates user areas that are oriented to the internal courtyard, where the facades are subject to relatively little noise disturbance.

For the areas on the ground floor that are used to stage various events, the requisite sound insulation is provided by a single-skin facade with acoustic and thermal insulation. For more demanding occasions, when lectures, conferences and the like are held, sound-absorbing pivoting and folding wall elements were installed inside the hall space as an additional means of reducing noise levels. (Herzog, 2010)

Sound insulation within the building

In view of the intense use to which the three tracts of the building are put, it was not entirely possible to avoid locating spaces with high noise levels alongside high-quality leisure areas by placing rooms with only moderate acoustic demands between the two. Nevertheless, it was a principle to avoid over-elaborate building measures by situating spaces with particularly high noise levels, like the party room, on different floors from more sensitive areas, such as the bedrooms and study spaces. In the southern tract, events spaces directly adjoin the recreational areas above. A high standard of noise protection was ensured by designing structural elements - first and foremost the floors between storeys - in a sound absorbing form of construction, as well as by the high standard of acoustic protection achieved by a complete separation of flanking external elements. The ground floor facade, for example, is wholly isolated from that of the upper floors; and as a result of the set-back skin of the events space in the roof storey, no constructional facade elements immediately adjoin those on the floor below. Here in particular, the floor was constructed with a maximum possible reduction of impact-sound transmittance; at the same time, this provided scope for accommodating air-conditioning service runs for the space above in a similar way to that found in conventional forms of construction.

To achieve as high a level of sound insulation as possible between the individual student rooms, a kind of room-within-a-room solution was created with the appropriate layout design.

Secondary functions are located in the access zones to the student apartments where one enters from the communal space. In this way, it was possible to create a certain distance, with the more sensitive study/sleeping areas oriented to the quiet courtyard. Using a system of dry walling with double layers of studding that are not connected, a high degree of airborne-sound insulation was achieved, as well as insulation against structure-borne sound between apartments. The spatial enclosure, in the form of dry-construction elements, is complemented by floated screeds, and individual facade elements on the courtyard face of each room that are separated from each other. In order not to reduce the high insulation values achieved through this form of construction by laying continuous service runs from room to room, the individual apartments are served by branch runs from the communal area. (Herzog, 2010)

Spatial acoustics

The spatial distribution of absorbent surfaces ensures an adequate reduction of noise levels and a high degree of intelligibility of speech in the events hall on the ground floor. This helps to avoid the danger of flutter echoes and poor sound diffusion. The absorbent and slightly sound-insulating folding and pivoting walls, which consist of translucent membranes above door height, are the outcome of special developments undertaken by the architects, with the author acting as a sound-engineering consultant. This form of construction was complemented by perforated sheet-metal absorbers in the lower sections of the walls. In addition to providing a visual screen and a limited amount of sound insulation, the aim of the design was to create efficient absorbers of low weight. By selecting the appropriate micro-perforated membranes, it was possible to achieve correspondingly good sound absorbency with a limited wall thickness and without acoustic insulation in the cavity. In order to dampen noise in the areas outside the events zones, even in a closed state, and to reduce the levels of noise disturbance, the pivoting/folding walls have absorbent surfaces on both sides. The choice of construction to achieve this absorbency in the lower part of the wall also contributes a small degree of sound insulation that is nevertheless effective in the closed wall surfaces. (Herzog, 2010)

3-4 Discussion

Oskar von Miller Forum's project in spotlight

Status of building technology

Herzog also proved that structurally and energetically optimized designs are able to stand out with a distinctive architectural style. Especially for his large halls, Herzog likes to use the term “form follows performance”: the shape is based on the thermal and lighting requirements these buildings have to meet. Whereas previously Herzog integrated the energy systems in the “skin” of the building as elegantly as possible, in his most recent project he created the opposite effect: in the Oskar von Miller Forum in Munich Herzog specifically puts these systems on show on the facade and on the roof to demonstrate their function. This building exhibits the German state-of-the-art in building technology.

The interests of the client, the purpose of the institution, the technical solutions and the appearance of the building all blend in perfect harmony. The Forum is an international meeting point that is aimed to support the university education of engineers in the field of construction at the Munich Technical University (TU München). It is an initiative of the Bavarian Construction Industry. On the one side the Forum houses a student's hall of residence that extends over several floors and accommodates guests of many nationalities – here the client was particularly keen for the future engineers to encounter sustainable technology. On the other side the forum has several large rooms for various events. The functional core is the six-metre high hall on the ground floor of the main building. This is suitable for lectures and conferences as well as for exhibitions and festive events. (Stock, 2012)

Enhanced urban development

The forum boasts a distinguished location between Munich's old city and the university quarter. It features three elements that surround a well-designed inner courtyard. The main building faces south, towards the centre ring road called the Altstadtring. To create a buffer for exhaust fumes the student's hall of residence has an unusual layout. Facing the road are the common living areas. From here the student's rooms lead off to the north, looking out onto the quiet inner courtyard. The East Building includes the apartments for guest lecturers that are situated above the in-house bistro restaurant. The administration is accommodated in the West Building. This technically elegant building design significantly enhances the surrounding urban area. (Stock, 2012)

Optimized structural and energetic design

The Forum can be seen as the sum total of Thomas Herzog's research work. The main supporting structure boasts an intelligent design of reinforced concrete that comprises minimized prefab structural elements that illustrate the flow of the load distribution. The main building is covered by an independent steel structure that cantilevers out from the top floor. In the south this steel structure supports the outer facade skin: a specially developed, outward-folding, glass double facade with shading and sound insulating functions. On the north side, escape balconies are suspended from the steel structure and rather resemble the shape of a harp. The glazing of the east stairway is louvered with silver-grey photovoltaic panels that protect it against excessive heat development during the summer months. The energy that is generated is fed into the main grid and distinguishes the building with a high level of energy production. The current "energy pass" specifies an extremely low value. This is also based on the optimized design of the heating, cooling, ventilation and insulation systems, also achieved through the installation of large solar thermal collectors on the roof, for example. (Stock, 2012)

A further highlight is the artwork by Sabine Kammerl, Nikolaus Lang and Rainer Wittenborn. In the public areas of the Forum subtle and demanding artworks underscore the cultural dimension of engineering, thus making the ideas of art enthusiast, Thomas Herzog omnipresent in his building. (Stock, 2012)

General discussion

Following IWBDP (integrated whole building design process) produces higher-performance buildings. They tend to be more energy efficient, have a better internal environment, are more comfortable and have less operating and maintenance issues and costs than other buildings. They are also more in tune with the environment. (*Integrated Whole Building Design Guidelines*, 2008)

> “According to Herzog, besides the actual design and used material, a building must be based on sustainable technology and boast social responsibility in order for it to deliver authentically.” (Stock, 2012)

According to Herzog’s beliefs, buildings designed through IWBDP have a better indoor environmental quality (IEQ) and recent studies have shown that occupants who work in buildings with good IEQ are healthier, happier and more productive. Fisk (2002) states in his study that speed or accuracy of workers can change by 2 to 20 percent for various office tasks due to a change in temperature of just a few degrees. Staff may find it easier to concentrate and are less likely to take sick days. Companies may find their popularity as an employer increases and staff turnover is reduced. All these things can improve the marketability of these buildings and they can be sold or rented out for higher amounts than conventionally designed buildings. (*Integrated Whole Building Design Guidelines*, 2008)

In an overall view, in the high performance buildings the stress has shift to ‘performance and envelope’ from ‘form and structure’ in which the envelope become the focal point of innovative ideas, research and development. In this way, energy modelling is a requisite for informing the design, monitoring post occupancy and commissioning a high performance building project.

Further, accomplishment of a high performance project is bound to a significant collaboration between different design disciplines. Put another way, in the high performance processes, by taking the advantages of integrated design, the emphasis is on interdisciplinary design as well as resource management along with using new tools for design. This is where the integrated design processes stands out from conventional processes.

The integrated design process intertwines architectural design process with knowledge elements of engineering to optimize the building performances.

Multidisciplinary and integrated approach for the team member, including stakeholders and project members, in early phases of design is vital to achieve to a high performance building.

3-5 List of figures and tables

3-6 Bibliography chapter 3

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3-7 Conclusion

The premise that the building works as an ecosystem is a reinterpretation of the idea of the building as machine for living. In most of his projects, the machine becomes an expressive element as well as providing the underlying order of the building. Herzog is also concerned about the human occupants of his buildings. Unlike many of his predecessors, the answer is not in creating a strictly technological response, but also to address the wider range of site, social and cultural issues. In this way, he shares some characteristics with Aalto:

"What we are working on is a new material culture that must be fitted into an old material culture. We love new technology and new materials but we also love our old towns and cities. In no way am I prepared to abandon our whole cultural heritage just to pick up a few watts of free energy from the outside world (Pérez-Gómez, 2002).

From a holistic standpoint, analysis of Herzog´s works and traces highlights the following posit: Performance-based approach to design will be a prescriptive recipe for our tomorrow's architectural solutions which is a vital point for improving our built environment ensuring quality designs and results for our clients.

In performative design, processes of making buildings' forms are based on indeterminable patterns. In this regard, architect's role is more focused on diversifying, multiplying, embedding and instigating their effects *in the material* and *in the time.* Put another way, architects should develop their performative techniques, of design, by changing their mind from scenographic appearance to the pragmatic imaginations of how a building works, what it does, and what action, event or effect it might engender in the time.

In the meantime, practicing "performance-based design" calls for architects to take "holistic approach" towards the problems which can be achieved by increasing an interdisciplinary consideration to an interaction among engineering and economics, natural and social sciences, arts and environmental design, providing that the latter be understood as a central discipline.

In tandem with the baselines of the mentioned projects, it has been strived to achieve a unique harmony between the implementation of cutting edge technologies of solar design and integration of the local and social aspects of architecture. In fact, the interplay between technology, ecology and philosophy is constantly interacting with the challenge of obtaining the highest aesthetic quality. Herzog pioneered in re-presenting solar building architecture influenced by aesthetics without being entrapped by the cliché that energy conscious building is translated into a hi-tech style.

Additionally, Herzog contends that “there isn’t any problem” but “opportunities”; therefore, the ecological problem is taken as an opportunity to achieve a high level of design in the architecture. Throughout the design processes, the aim has always been to take the context into consideration- the surroundings and their scale and the kind of materials which are used. Moreover, clients’ needs have always deserved attention. Apart from complying with their wishes, exploiting the environmentally-friendly forms of energy was in the center of attention while having aesthetically favorable appearances. Herzog contends that artistic potential derives from appreciation of technology which is not an irksome matter; instead, it is something that should be fun.

The buildings forms are expressive of techniques of construction and materials while the gathered information from assessing the available resources, at the site of the projects, particularly the potentials to use solar, wind and also geothermal heat sources, have been reflected in form, siting and organization of the buildings without excluding “cultural patterns and existing conventions”. Like modernists, he has developed a strong architectural lexicon which is based on this premise that the construction elements and materials be efficient in the form and also the production method.

Thomas Herzog is known to integrate technical and constructional skills with a strong sense of responsibility for the built environment. He states that the inputs which are generated by renewable resources should counterbalance the energy consumption in the buildings. Moreover, he suggests the architects to rely on the systems that are newly manufactured which render the material hardware more energy efficient and durable.

As demonstrated by Herzog, in the practice of contemporary architecture, the principal stress should be placed on holistic approach.

In an overall view, he has endowed more pragmatic approaches to render ecologically-efficient architecture. This is parallel with his approach which holds that “architectural expression” shouldn’t be neglected throughout the searches for ecological efficiency**.**

In the domain of high performance buildings, In keeping with the structural approaches witnessed in Herzog´s portfolio as well as all the discussed studies in this work, it can be construed that high performance buildings require more technological complications for understanding and operation in comparison with conventional buildings. As a result individuals, who wish to use and maintain them, are needed to be trained with appropriate theoretical methods and operations.

High performance buildings place an emphasis on human resources by helping to improve the quality of internal environment. This building wellness, by improving comfort and health as well as decreasing turnover and absenteeism of occupants, helps to keep the future costs away from ‘sick building syndrome’ corrections.

To achieve to high performance building, investment is a requirement for changing the process and methods of design. As a result the consultant engineers and architects will not be the major drivers for the changes without clients and building owners' willingness who will invest for implementing the changes.

The integrated design process is a precise process considering that it is interactive and iterative. Integrated design process facilitates serving the high performance goals in the best way. This process needs a new model of collaboration. In this process, an early collaborative engagement in planning process is needed for realizing high performance goals. This collaboration is between architects, engineers and constructors, throughout different phases of the project from conception to production -in order in the project's phases of conception, optimization and production. Considering it was explained, the social problems are very important even more than technical problems in high performance buildings. However, without the holistic approach, the social and structural barriers are very difficult to be identified by which the solutions will be found for processing innovations in high performance buildings deliverance. Integration needs a change in way of thinking, work method and the essence of relationships among different members of the project. Upgrading the technology needs the social system to be upgraded as well.

In an overall view, a *cultural change* is called for realization of a true integrated design process as a rule -in viewpoints of planning, designing, constructing, operation and demolition processes.

Additionally, the *energy performance* is a golden key to employ as a complementary for architectural solutions, in the integrated design process, to achieve high performance buildings.

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