

Reinterpretation of Energy Efficiency in Thomas Herzog's Architecture

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Abstract

Pioneering in development of buildings aligned to their place and context, Thomas Herzog repudiates design of closed systems independent of their location. Energy crisis can be suppressed through his ecologically-aware housing designs. The 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 key element of the building then is the envelope which is conceived as an energy-exchange medium that reacts to specific local conditions. This inductive assessment of the relationship between the building and its environment is a salient achievement which wards off the repeatable types or monolithic structures. Conventionally, Herzog's architecture aims to reach to a self-sufficiency in ecology while the application of technology is his main concern, which is in fact an example of "technicist development" in the contemporary architecture. Encompassing two case studies, this study is aimed at realizing how concepts are brought into construction by exploiting innovative energy efficient design. Further, it investigates less-focused concepts in establishing guidelines for future energy-efficient building design.

Keywords: energy efficiency, Thomas Herzog, sustainable architecture, environment

1. Introduction

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 from 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.

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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 equipment 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) 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' (Vaidehi A. Dakwale Sachin Mandavgane, 2011). An increase in energy efficiency and a reduction of energy demand in buildings must, therefore, be a basic condition for any successful climate change policy (Lehmann, 2011).

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 Herzog, 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)

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)

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 (Omer, 2002)

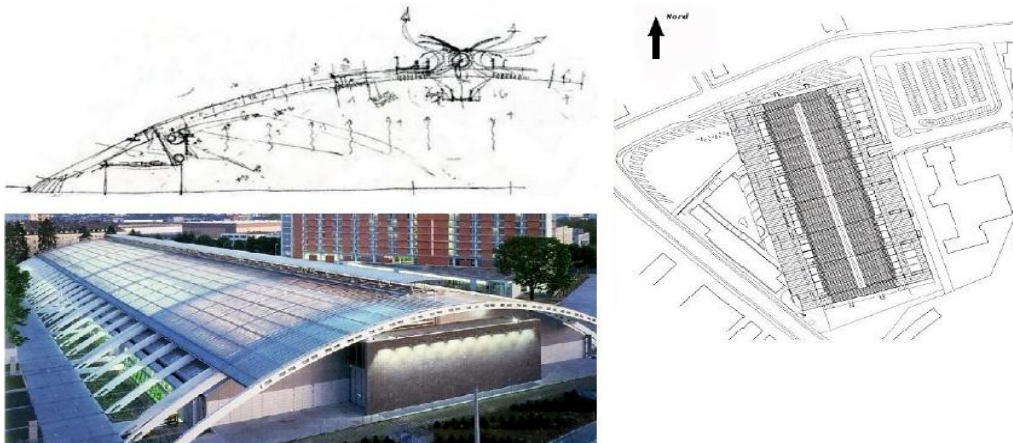
A truly sustainable design can only be achieved if energy efficiency is combined with material efficiency. It requires a sound understanding of the inter-linkages between various technical, environmental, social and economic criteria (Lehmann, 2011).

2. Energy Efficiency: A Multidisciplinary Approach

2-1 Case Study 1: Exhibition Hall in Linz 1988-1993

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 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 1) was to reduce the volume of air to a minimum (Herzog et al., 2001).

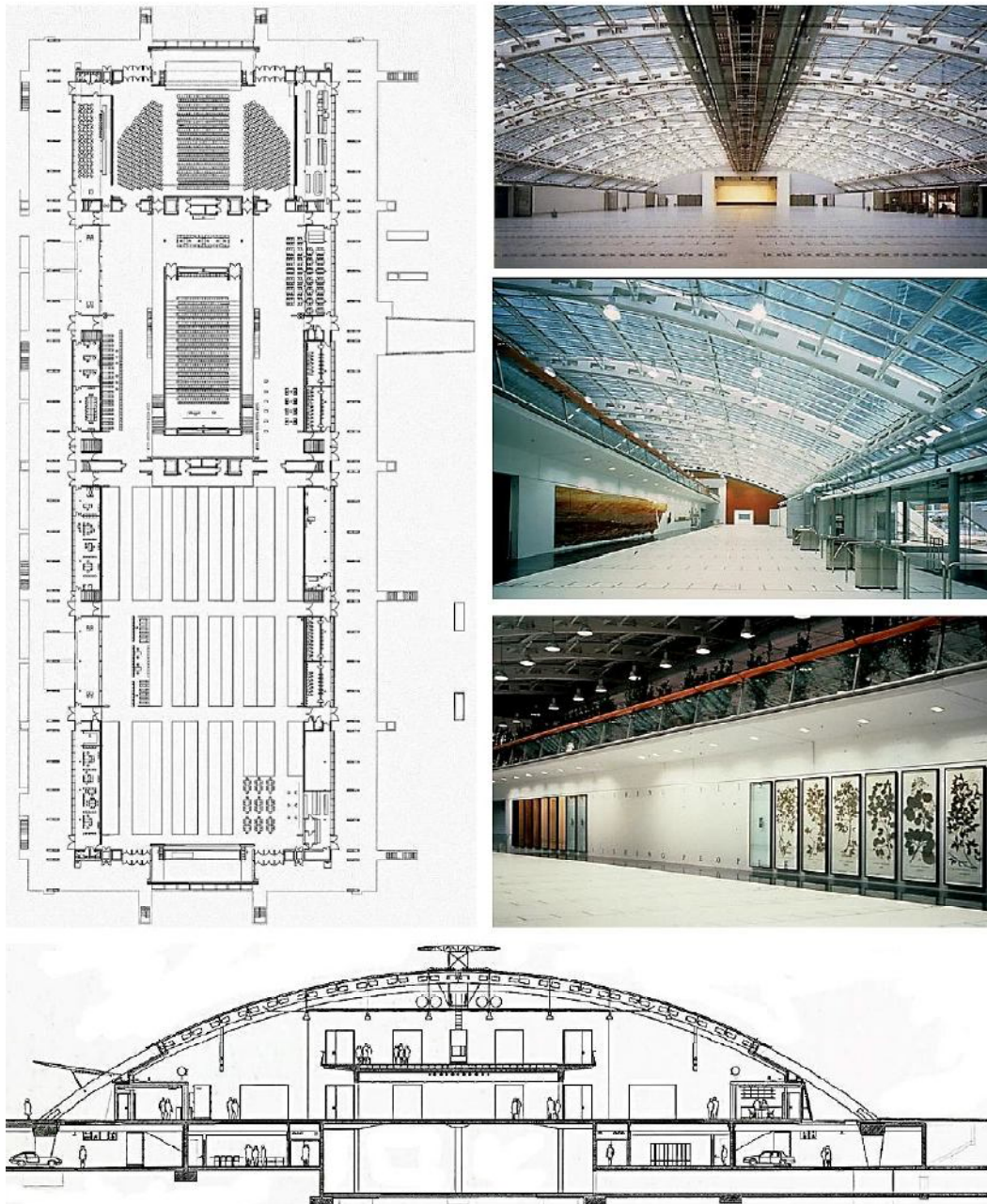
Figure 1: Exhibition Hall in Linz; Conceptual Sketch, site Plan and Aerial View



(Source: (Herzog et al., 2001))

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 3). The steel girders forming the Load-bearing roof structure span a distance of 76 m and cover an area 204x80 m in extent (Figure 2). 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 2) (Herzog et al., 2001).

Figure 2: Exhibition Hall in Linz; Ground Floor Plan, Interiors and Cross-Section



(Source: (Herzog et al., 2001))

To prevent overheating in summer it has been invented a new kind of envelope. Actually, a central aspect of the new glass roof (Figure 3) 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 3: Exhibition Hall in Linz with a Glazed Covering

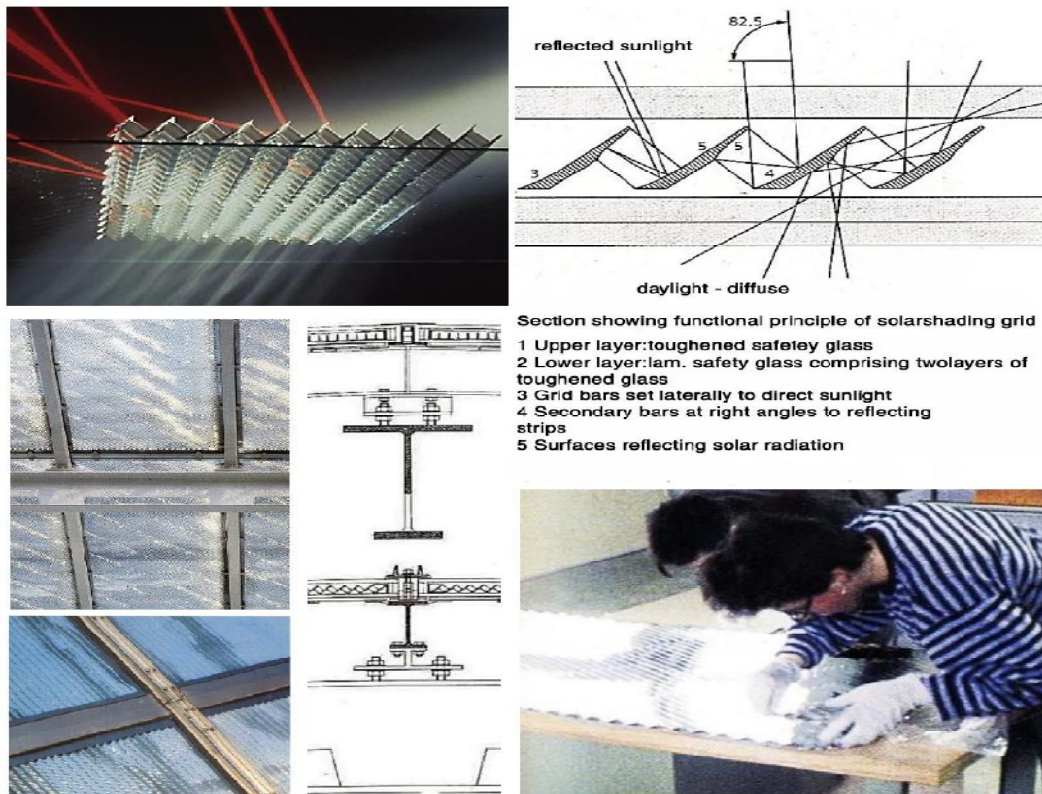


(Source: Internet)

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 an enterprise, 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 4) (Herzog et al., 2001).

Figure 4: Exhibition Hall in Linz; Glass Roof Construction with Inserted Grid Screens with Sections and Details



(Source: (Herzog et al., 2001))

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 5) (Bachman, 2003).

Figure 5: Exhibition Hall in Linz; Roof Panels

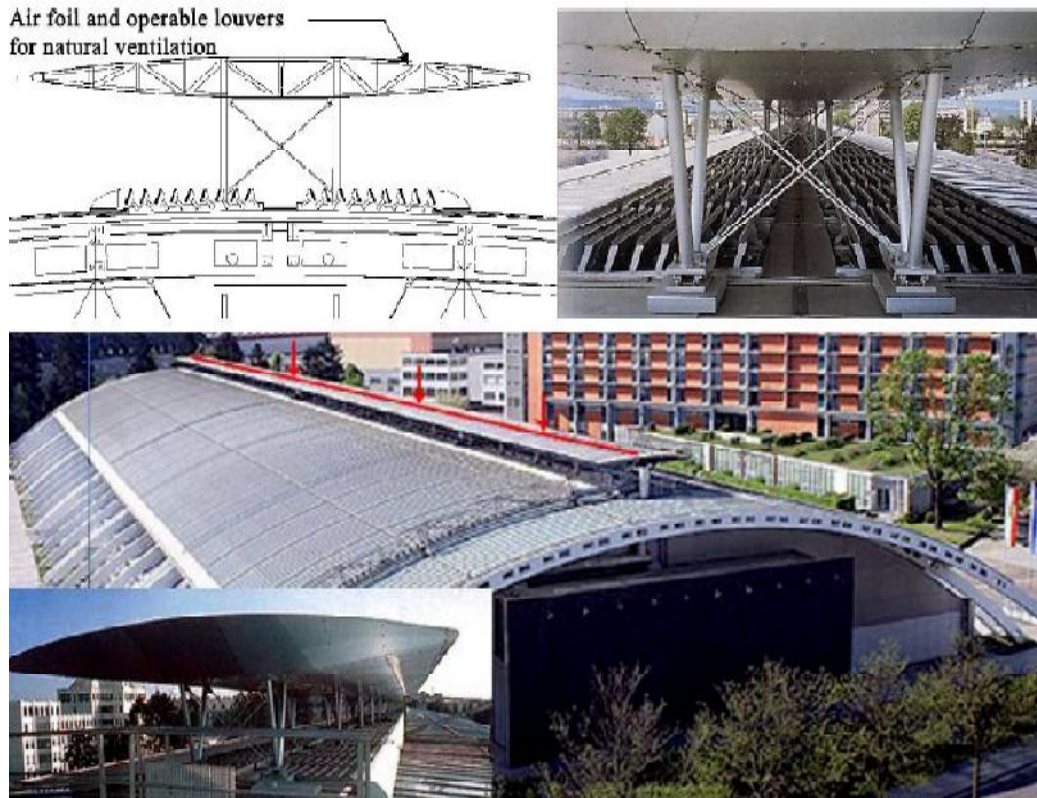


(Source: Internet)

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 (Herzog et al., 2001). These grids 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.

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 along the entire length of the building (Lee, 2001). 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. This 7-metre-wide element has a convex underside and exploits the "Venturi effect" 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 6) (Kolarevic & Malkawi, 2005).

Figure 6: Exhibition Hall in Linz; Ventilation Elements with “Venturi” Capping to Assist Natural Ventilation



(Source: (Herzog et al., 2001))

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 with its specially shaped "spoiler" is, therefore, the direct outcome of a contextual analysis of the climate (Herzog et al., 2001).

2-1-1 Discussion 1

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.

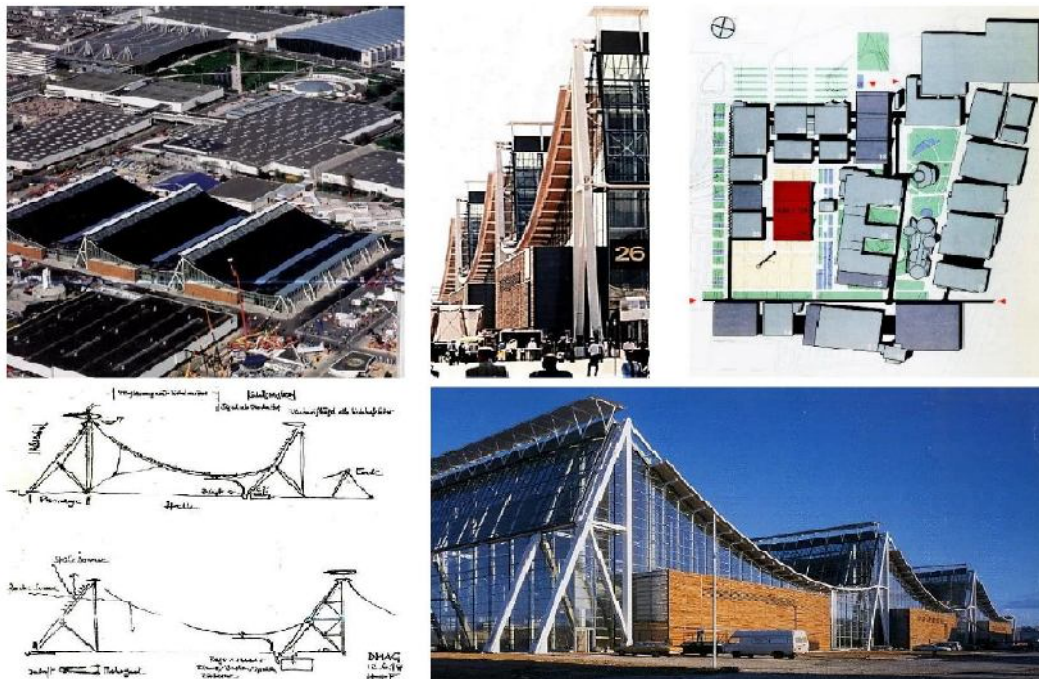
In fact, everyone has worked together as a unit and collaborated concurrently instead of sequentially. It (concurrent process) facilitates the integrated collaboration of knowledge experts that is required for an energy efficient architecture. The solutions for efficient buildings are typically involved 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. This is why collaborating 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 institutions through accessing the computer simulation and measuring thermal and also energy transmission for different skylight prototypes.

2-2 Case Study 2: Hall 26, Hannover 1994-1996

This project (Figure 7) has an impressive structure with forward-looking architecture. It is an innovative building that represents a new model form for a trade fair hall. 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 7: Hall 26, Hannover; Conceptual Sketches, Site Plan and different Views



(Source: (Herzog et al., 2001))

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 (Herzog & Heckmann, 1996).

Renewable raw materials were to be used in appropriate parts of the construction. The roof has an area of roughly 20,000 m², 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 8) (Herzog et al., 2001).

Figure 8: Hall 26, Hannover; Using Timber as a Renewable Material



(Source: (Herzog & Heckmann, 1996))

The huge exhibition hall, 220 m long x 116 m wide, was laid out in three bays (Figure 7). 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 9). In addition, mirrored areas in the soffit of the roof act as large-scale reflectors for natural and artificial light (Herzog et al., 2001).

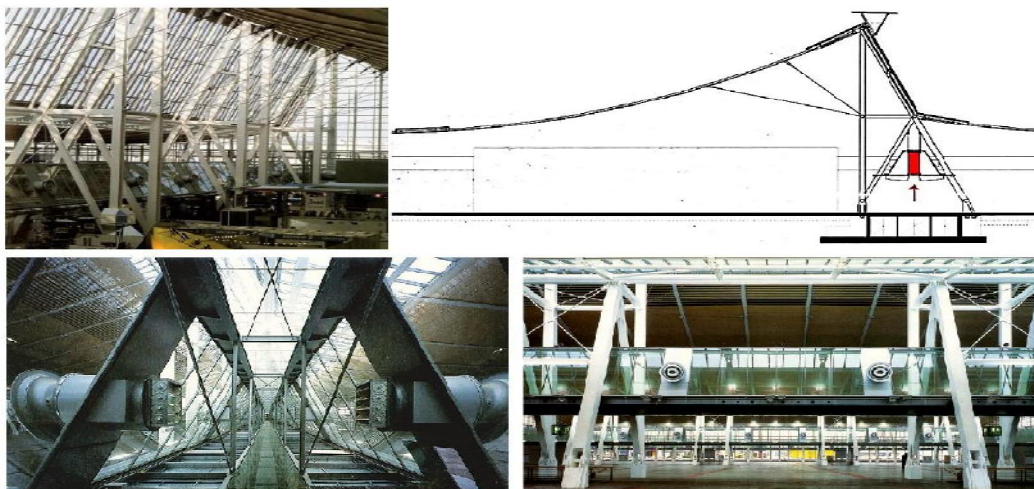
Figure 9: Hall 26, Hannover; North Face

(Source: (Herzog et al., 2001))

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 10). 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 10: Hall 26, Hannover; Glass Ventilation Ducts and Part Cross-Section

(Source: (Herzog & Heckmann, 1996))

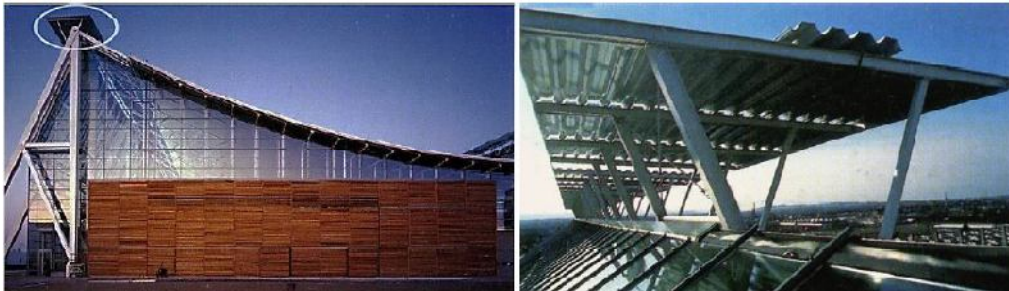
The evident advantages of this system lie in the better air quality and the greater degree of comfort experienced by those within the hall. Following the principle of thermal rising currents, used air leaves the building in the ridge zone. The system adopted for this scheme reduces the expenditure for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

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 13) 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 11) (Herzog & Heckmann, 1996).

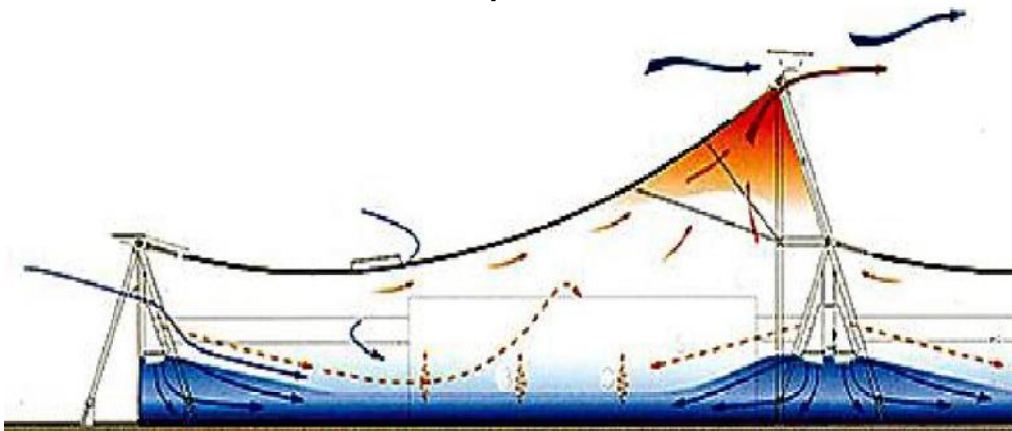
Figure 11: Hall 26, Hannover; "Venturi" Capping Over Crest of Roof



(Source: (Herzog & Heckmann, 1996))

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 (Figure 12).

Figure 12: Hall 26, Hannover; Application of Stack Effect to Draw Heat Out of a Large Volume Space



(Source: (Meredith, 2009))

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).

Figure 13: Hall 26, Hannover; Mechanical and Natural Ventilation Diagram

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

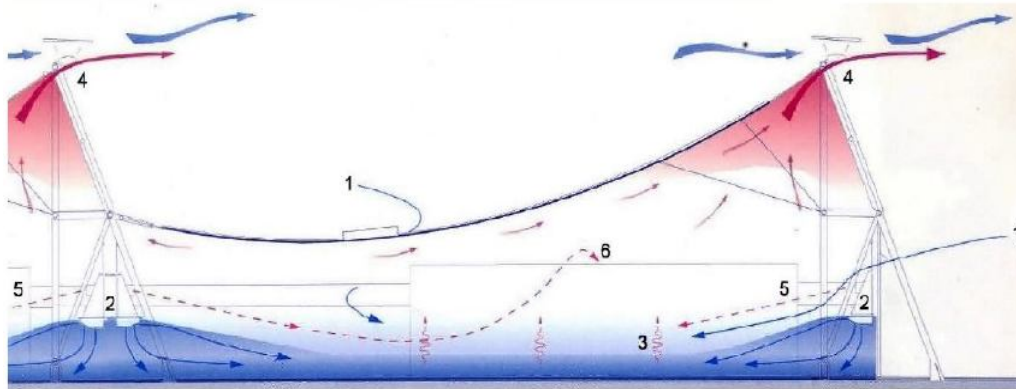


Diagram of mechanical and natural ventilation (as installed), longitudinal-section

Cooling operation:

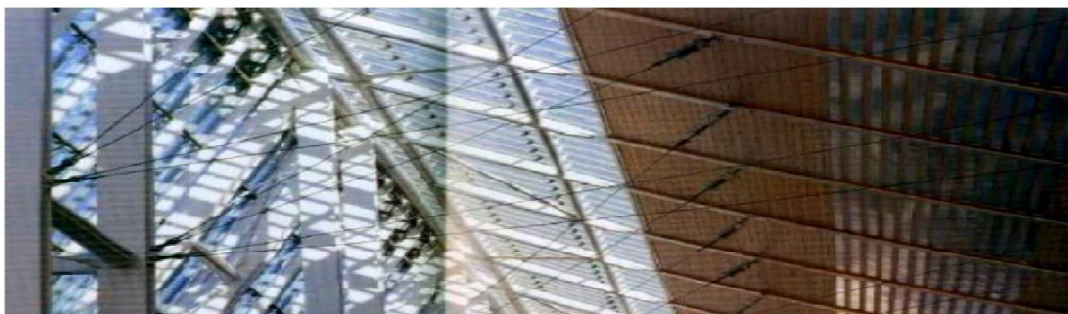
- 1 natural air supply via flaps in facade
- 2 glass ventilation duct with cool-air outlets in floor of duct
- 3 thermal up-currents (Thermal uplift) from internal heat sources
- 4 natural ventilation (natural air extract) via ridge flaps

Heating operation:

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

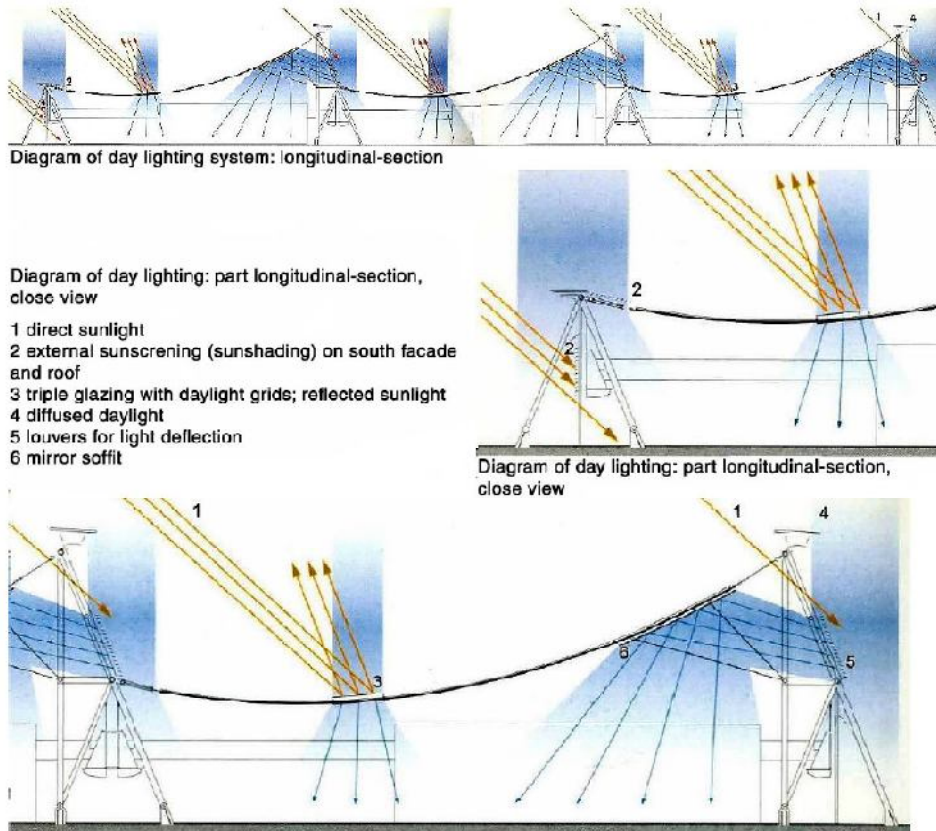
(Source: (Herzog & Heckmann, 1996))

Concerning daylighting and artificial lighting (Figure 15&16), Natural lighting (Figure 14) 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 14: Hall 26, Hannover; Daylight Deflection Via Reflectors

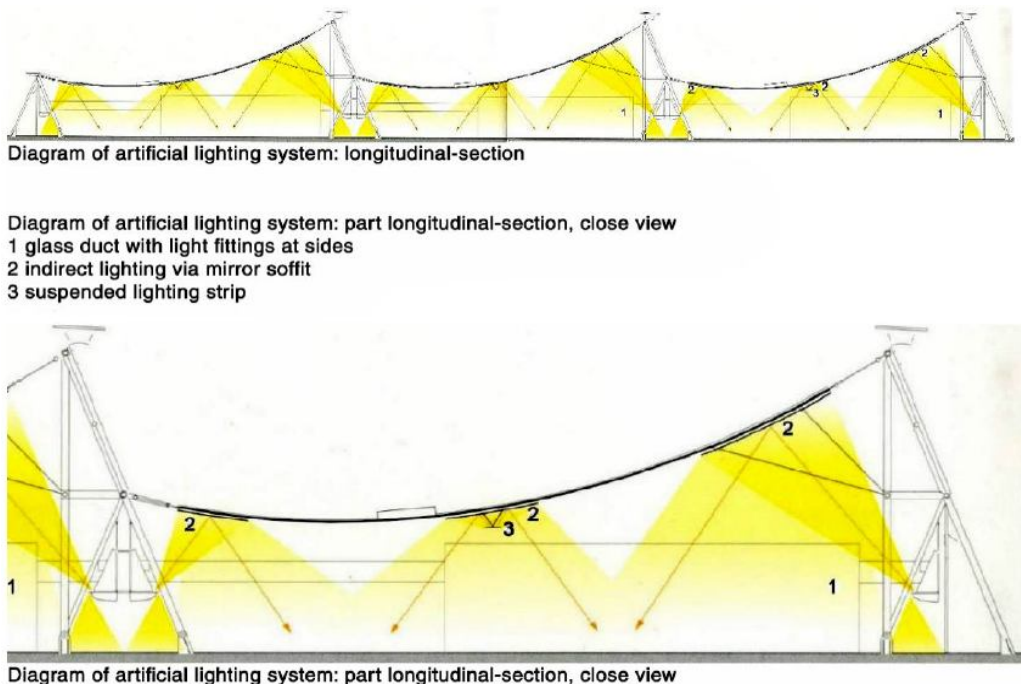
(Source: (Herzog et al., 2001))

Figure 15: Hall 26, Hannover; Daylighting System Diagram



(Source: (Herzog & Heckmann, 1996))

Figure 16: Hall 26, Hannover; Artificial Lighting System Diagram



(Source:(Herzog & Heckmann, 1996))

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 17)). 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 17: Hall 26, Hannover; the Curvaceous Roof

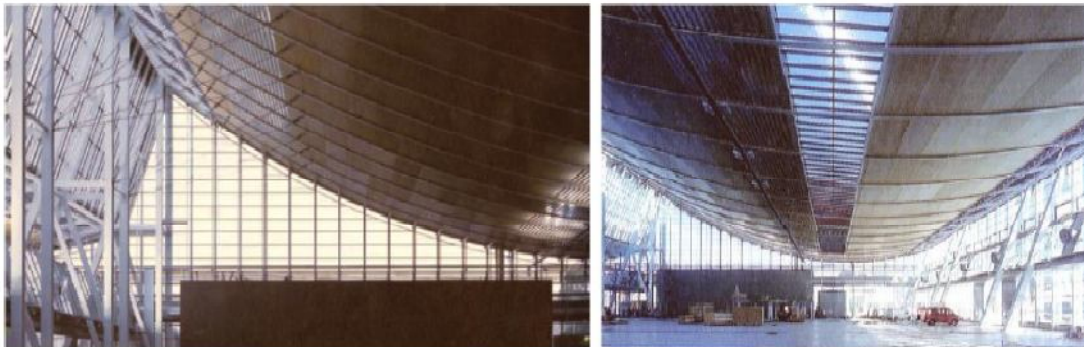


Figure 17: Hall 26, Hannover; the curvaceous roof (Source: (Herzog & Heckmann, 1996))

Large areas of the facades and the roof were designed to allow the ingress of daylight while reducing insolation (Figure 18).

Figure 18: Hall 26, Hannover; Glazed Facades



Figure 18: Hall 26, Hannover; glazed facades (Source: (Herzog & Heckmann, 1996))

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 (EXPO, 2000).

2-2-1 Discussion 2

Careful considerations were given to the natural ventilation which was the central important issue in developing the geometry of cross-section. In the other word, the high reference points were created, while the height of the roof was minimized, for enhancing the natural ventilation through thermal up-currents. Also introduction of the indirect daylight was contrived. Therefore the cross-section was evolved –which is imposed by the tensile construction.

Further, for creating a passive ventilation, a huge roof was needed to be made. The roof also 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.

This project proved that it is possible to work with a highly efficient steel structure system in combination with the wood which not only is a renewable resource but also is flexible to shape a curved ceiling and to provide a pleasant interior space.

In general, this sustainable building has taken the advantages of passive strategies to improve cooling, heating and lighting performances and has made strong statements of the modern architecture. Therefore it represents an innovative constructional work in which many new technologies have been applied and it wouldn't be too bold to remark that it has created the architectural history.

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).

Additionally, from the standpoint of 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).

3. Conclusion

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 representing 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.

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