WHY?

Behnisch Architekten and Transsolar have established and maintained a long-term working relationship, completing numerous projects in both central Europe and North America. The common foundation of this collaboration is the belief and confidence that high-quality built environments can be realized with less consumption of natural resources. Curiosity, commodity, and delight drive this process to discover new topics and technologies, and to improve upon what has already been achieved. This exhibition, ‘Ecology . Design . Synergy’, conveys how architects and energy consultants work together, and what can be accomplished by such a collaborative effort.

The construction and operation of buildings naturally consumes considerable amounts of energy. How can we, as architects and environmental engineers, create buildings which are better integrated in our world, and how can we place less strain on our environment through the process of building? These questions seem contradictory at their very essence. We believe that we are charged with making a balanced, considered response to resolving the respectful tempering of the natural environment - based on local cultural and climatic conditions - with the basic necessity of providing shelter.

Where can we effectively save energy and materials? Without a doubt, it is the users of a building who can influence ecological value through their behavior and energy demands. In seeking to provide “idealized conditions,” the second half of the last century saw the rhythms of nature increasingly ignored. The construction of office buildings has led to a continual growth in the implementation of technical equipment, and, with it, numerous examples of stagnant, often inhospitable spaces with obvious consequences on occupant satisfaction, staffing efficiency, and attendance levels. The inefficient application of technology not only consumes energy, but produces considerable heat as a by-product, contributing to greater dependence upon cooling systems in the summer. This vicious cycle is difficult to break. Just as a wrongly buttoned shirt, once commenced, is impossible to correct without starting anew, it is essential that we return to basic ecological principles in the development of contemporary buildings.

It is our responsibility to integrate technical and aesthetic aspects in developing a sustainable architecture. We are absolutely convinced that it is necessary to espouse a holistic view, one driven by environmental quality rather than formal considerations. But it is simplistic for design focus to be centered on energy consumption while overlooking physical parameters; it is also insufficient to judge “sustainable” architecture based on energy consumption per square foot - neither approach adequately addresses either quality or environment. Flexibility and adaptability for different modes of occupation are essential for sustainable design.

Over the past twelve years, Behnisch Architekten and Transsolar have designed and realized many distinguished buildings, some of which have become benchmarks in the field of contemporary environmentally responsible architecture. The exhibition, ‘Ecology . Design . Synergy’, highlights both realized projects and works in progress, providing insight into the working process and expressing our views on sustainable design. With this exhibition, we hope to demonstrate that investigating solutions to current environmental woes and preventing new problems pose both fascinating tasks and rewarding challenges.
ON ECOLOGY

*Ecology and sustainability* are two terms that currently describe the new focus on our natural environment and resources, but need amplification. The term ecology stems from the Greek concepts of “house” and “discipline,” and refers to the “household of nature.” Today, ecology is defined as the study of the complex relationships between living organisms and their environments, centered on research of ecosystems and the idea of ecological balance. There are also some fundamental environmental and philosophical considerations, which, since the early 1960s, have directed this science in a rather political, even pseudo-religious manner. Part of our problem today in dealing with the imbalanced ecosystem lies in its limited definition. Each ecological system must be considered as part of the entire world - as one huge, complex system. The complexity of modern sciences and mathematics has only complicated the individual organism’s relationship to environment, rendering it incomprehensible.

We often use the term *ecology* incorrectly as being something inherently healthy (implying that a balanced ecological system is in itself good, with mankind as the central element), so that systems are considered well-balanced if they create a living environment for mankind. Such a view is anthropocentric and naturally presumptuous. Rather than calling the system ecological - as in an ecological movement - we should refer to it as ecologically sound.

The term *sustainability* was first used in 1712 in reference to conservation attitudes of the forestry industry. It described an approach that dictates that the annual harvest should be restricted to the amount of new growth on the same area of land per year. A sustainable approach to the use of natural resources means, in principle, that we would not consume more natural resources in any given period than could be regenerated in the course of that same time span. Unfortunately, we draw upon the wrong resources. In three seconds, we use approximately as much fossil fuel energy as is produced within twenty-four hours. It is clear that the present emphasis on fossil fuels is far from sustainable. As we continue to make extreme demands on nature, it is essential that we treat our natural habitat with respect. It is, therefore, necessary to acknowledge the finite nature of resources and to carefully review our behavioral patterns.

Sustainability has come to mean all things to all people. Increasingly misused in architecture, the term is in danger of becoming a mere label. The Brundtland Report of 1987 (World Commission on Environment and Development) illustrated the widespread concern for the state of the environment, and popularized the phrase *sustainable development* as a way to meet “the needs of the present without compromising the ability of future generations to meet their own needs.” The political definition of sustainable development has since been extended to include social development and economic progress. What really matters is that we learn to live and work with our environment in such a manner that there will be no future shortages, and that we do not solely focus on its constraints, but also celebrate the wealth and diversity of nature.

Sustainability is less a political than a humanistic issue. In our relatively short occupation of the Earth, we have succeeded in acutely threatening its future and our habitat. Now we appear to be rapidly gaining a common understanding of the urgency of these matters. Perhaps we have reached a ‘tipping point,’ where we cannot remain in denial. Even in countries where an understanding of ecological problems seems to be restricted to an enlightened minority, environmental movements are rapidly gaining pace.
As architects and engineers, we are now experiencing a change in attitude toward building, as many clients expect us to design, develop, and deliver environmentally responsible buildings. Lead by various not-for-profit organizations, business too has recognized the value of a healthy indoor and outdoor environment. In 1993 the United States Green Building Council was begun, and soon after initiated the LEED (Leadership in Energy and Environmental Design) rating system, a tool that looks beyond the purely quantitative aspects of the environmental impact of buildings. It is a system that will continue to evolve, but is the most comprehensive evaluation system today. Its use is now widespread. However, the issue of political will remains with some reluctant parties and politicians who continue to insist that economically and ecologically sound behaviors are unrelated, whereas in other enlightened economic circles, the protection of our environment is seen as an absolute necessity, and as an opportunity for potential growth.

Stuttgart, October 2006

BEHNISCH ARCHITEKTEN

The architectural practice Behnish Architekten emerged from a branch office founded by Behnish & Partner in 1989, when Günter and Stefan Behnish decided to establish an “offshoot” in downtown Stuttgart. Working as an independent firm in parallel with Behnish & Partner, the new practice changed its partnership structure and, accordingly, its name several times. It has existed in its present form since the summer of 2005. In 1999, Behnish, Behnish & Partner, as the practice was called at that time, founded a branch office in Los Angeles. Today, the Stuttgart office, Behnish Architekten, is headed by Stefan Behnish, David Cook and Martin Haas. The Los Angeles office, Behnish Architects, Inc., is headed by Stefan Behnish and Christof Jantzen.

The two Behnish offices collaborate on a variety of projects, particularly in North America. While the Stuttgart office usually realizes projects located in Germany, Europe and portions of the eastern United States, the LA office, Behnish Architects Inc., works primarily on projects in California, Arizona and Chicago.

The history: Günter Behnish founded his architectural practice in 1952. This practice, since the sixties called Behnish & Partner, operated under different partnership structures until 2005. It became renowned for the facilities for the Olympic Games in Munich, 1972, and for the German Bundestag in Bonn. The last project completed by Günter Behnish and his partner Manfred Sabatke was the new building for the Academy of the Arts in Berlin.

The Behnish practices currently employ 75 people in their Stuttgart and Los Angeles offices. They value good working relationships and have realized several projects together with other architectural and engineering firms. Since Behnish Architekten often acts as a General Planner, especially in North America, these collaborations are especially important.

With Transsolar, for example, a long collaboration has developed since their first common project, the Landesversicherungsanstalt in Lübeck. Today Behnish Architekten and Transsolar work together on many projects in Germany, including the marine museum “Ozeaneum” in Stralsund and the thermal spa in Bad Aibling. Common projects in the USA include the Harvard Science Complex; Deming Place Apartments in Chicago; the renovation and modernization of the Chicago Police Station and law court; the renovation of the Daley Center in Chicago, and the so-called “French Lofts” in Venice, California.
The purpose of climate engineering for buildings is to ensure the highest possible comfort for occupants with the lowest possible impact on the environment. Transsolar accomplishes this by developing and validating innovative climate and energy concepts. Transsolar was founded in 1992 as a climate consulting company and is now working worldwide with thirty-two engineers in offices in Stuttgart, Munich, and New York. The firm’s scope is to provide highly comfortable environments with a minimum of energy use, while recognizing that environmental conditions are influenced by all aspects of design. The firm works collaboratively with clients, architects, mechanical engineers, and other consultants from the start of the building design process, considering each step from the standpoint of fundamental thermodynamics and physics. This generates a climate concept in which local conditions, form, material, and mechanical systems are synergistic components of a well-orchestrated climate control system.

The firm thus goes far beyond the limited idea of energy conservation based upon maximizing thermal properties of the building envelope or skin, towards a more holistic design recognizing the interdependence of comfort issues and integration of all building systems and components. We address daylight, natural ventilation, air quality, air temperature, acoustics, and the well-being of people.

Our approach also recognizes the interdependence of the built and natural environments, and ensures that natural laws are respected, even with the building intervention. We employ sustainable strategies in our concepts as they apply to specific site, building type, and user needs. Potential strategems are considered and evaluated for each project, intended to create a strong identity and individual expression for every unique situation.

Transsolar’s projects have each been groundbreaking in different ways: the DATAPEC office building in (1995) was the first result of planning in a design team; the Suvarnabhumi Airport in Bangkok (2005) found ways to cross boundaries; the administration center, Nord/LB, in Hannover (2002) proved the solution to temper a large complex building solely by concrete core activation, supported by a geothermal system; the Deutsche Post AG headquarters, in Bonn (2002), verified that a decentralized ventilation system, in combination with a double façade, allows users to individually control their environment. Then, in 2004, the first large-scale office building in North America – the Manitoba Hydro Downtown Office Headquarters in Winnipeg – called for an energetic optimization and climate engineering in extremes.

Our aims are comfortable, ecological, economical and high-value buildings for living and working. In short, we see climate engineering as an attitude respecting both people and nature.
THANKS

We would like to thank our supporters and exhibition sponsors, without whom this work would not have been possible. But we owe them much more, as all of them have, over the years, continued to have faith in our endeavours to create a human-friendly architecture, either by developing specific components for our buildings, or by assisting us in finding appropriate and innovative solutions to each specific task; or, as clients, by giving us the opportunity to build for them, to discuss common objectives, and to turn these objectives into practice.

This exhibition is evidence of these joint efforts, but is also meant to serve as a stimulant for the creativity within all of us, which will, hopefully, enable us to find innovative and creative responses to the many challenges lying ahead.
temperature

The human body burns food, which creates heat that it needs to dissipate (100 kcal/h = 120 Wh).

When the heat produced by a person is in balance with the heat they dissipate, they will feel comfortable.

Some examples of caloric content:
- 1 apple with skin (150g - 0.33 lb) 81 kcal, 338 kJ
- 1 Glass of Coca Cola (0.33 ltr - 1.25 qt) 185 kcal, 795 kJ
- 1 chocolate bar (100 g - 0.22 lb) 530 kcal, 2,210 kJ
- Supersized Big Mac (219 g - 0.5 lb) 757 kcal, 3,171 kJ

The human body dissipates 1/3 of its heat (sensible heat) through convection, 1/3 through radiation with surrounding surfaces, and 1/3 (latent heat) through the respiration and perspiration.

The sensible heat produced by the human body varies according to activity: 50 W while sleeping and 400 W while jogging.

A person emits 35 g (0.08 lb) of moisture per hour while standing and 125 g (0.28 lb) per hour while doing strenuous activity.

With a temperature of 60,000° Kelvin, the sun creates a radiation spectrum of wavelengths ranging from ultraviolet through visible to infrared.

Receptors in the human skin detect whether we feel too cold or too warm. The face, hands and feet have up to ten receptors per cm² (0.16 in 2) to detect cold, but only one receptor per cm² to detect warmth.

The human body can adapt to different thermal conditions by:
- Shivering, which increases the metabolic rate
- Concentrating heat to its core while reducing the temperature of its arms and legs
- Sweating, which cools the skin with evaporative cooling
- Changing the temperature of the skin by providing blood through veins that are within the skin (closer to the surface)
- Increasing the frequency of breathing

People are most sensitive to drafts at their neck and ankles.

Thermal comfort can be quantified and predicted by calculating a person’s heat production, which is based on actual activity (=metabolic rate), versus their heat dissipated, which is based on clothing factor and convective, radiant, and latent heat transfer.

Beyond these physical correlations it is obvious that there is a psychological component to whether people feel comfortable, which can be driven by expectation and/or adaptation to certain conditions.
Surveys show that people accept a wider temperature and humidity swing if they can influence their own environment, especially with operable windows.

Heating 1m² (35 ft²) of air by 1°K (i.e. 20 to 21°C or 68 to 69.8°F) demands 1.281 kJ, or 307 cal. Heating 1m² of water by 1°K demands 4180 kJ, or 1000 kcal.

temperature

The sense of temperature describes the ability to sense warm and cold stimuli and react accordingly. In humans, the sense of temperature is limited to the skin and certain mucous membranes, namely to warm and cold spots on these membranes.

The skin contains sensors, which react to changes in the surrounding temperature. On the skin, there are different sensors that can only sense one type of sensation, either cold or warm. On the face and the extremities, there are up to ten cold spots and one warm spot per square centimeter. The physiological zero point is defined as the skin temperature, at which there is no temperature sensation. Depending on the part of the body the zero point lies between 28 and 33°C (82.4 and 91.4°F).

In order for the metabolic processes in the human body to function properly, the body temperature has to be kept at 37°C (98.6°F).

below lower limit, death
25°C (77°F)
omodate hypothermia
33°C (91.4°F)
mland hypothermia
35°C (95°F)
normal temperature (afebrile)
36 - 37°C (96.8 - 98.6°F)
elevated temperature (subfebrile)
37 - 38°C (98.6 - 100.4°F)
mild fever (febrile)
38 - 39°C (100.4 - 102.2°F)
high fever
39 - 40.5°C (102.2 - 104.9°F)
very high fever (hyperpyrexia)
41°C (105.8°F)
circulatory failure
42°C (107.6°F)
over 42.6°C death through denaturation of proteins and enzymes

If the temperature rises above the desired value, the blood flow to skin and extremities is increased in order to increase heat exchange through the body surface. The condensation of water, which is excreted by perspiratory glands, increases the cooling effect.

The human body has 2-4 million perspiratory glands.
Shivering is a natural reaction to a low surrounding temperature. Using this protective reflex, the body tries to prevent an extreme decline in body temperature. The blood vessels in the skin contract, the blood flow to body extremities which are not indispensable to life, like fingers, toes, ears, etc., is limited, the fine body hairs are raised (goose bumps), and the muscles start trembling.

head
Heat loss via the head can be up to 40% of over-all heat loss.

neck
The sensitivity for temperature is highest at the neck.

skin
The skin of an adult covers, depending on height, a surface of 1.5 to 2 square meters (1.8 to 2.4 square yards). It weighs one sixth of total body weight, on average 10-12 kg (22-26.5 lb).

fingers
The blood flow to the skin can be regulated to the greatest extent in these regions, where it is most beneficial. In the fingers, there is 60 times more blood flow in extreme heat than in extreme cold.

ankle
It is at the ankles where we are most sensitive to air draughts.

temperature

Behnisch Architekten and Transsolar believe that there are no standard criteria for ensuring the well-being of a building’s occupants. The concept of well-being is not easily grasped in purely quantitative terms; more subjective and less measurable qualitative elements must also be taken into account.

The maximum permissible interior temperature of a building is often set at arbitrary levels, neglecting varying needs, wherein some people will find a 30°C (86°F) interior pleasant, and others find 26°C (78.8°F) intolerably hot. In many contemporary office buildings - with rooms lined in synthetic materials, poor ventilation and air movement, wall-to-wall carpets, dropped ceilings, and inoperable windows - a temperature of 24°C (75.2°F) can be considered hot. However, tall, airy spaces with stone and wood surfaces, unglazed openings, and decorative light-filtering grilles - such as inside the Alhambra in Granada, Spain, which has water splashing from fountains, and shade from abundant vegetation - relatively high temperatures are not considered uncomfortable. As architects and engineers, we continually seek clues to human perceptual psychology in such apparent discrepancies, and often draw on natural phenomena to inform the design of our buildings.
In developing further the ancient idea of enclosed atria, we have discovered a variety of relatively simple methods for controlling the microclimate in our buildings. Atria, which originated as the open courtyards of Roman villas, served as a central family gathering places and inner sanctums, surrounded and protected by the functional spaces of the villa. In early Christian times, and in Romanesque architecture, the atrium evolved into a colonnaded entry hall in front of a church. It is not therefore surprising that atria have been referred to as manifestations of paradise. Today, a roofed-over atrium can be exploited as an oasis, simultaneously performing an important role in the building’s indoor climate and promoting both natural ventilation and daylight. Atria in large buildings with workforces of over one thousand people can be used to create attractive, central focus points, which can foster communication and help counter feelings of anonymity.

Atria may also be used as thermal buffers between interior and exterior spaces, especially in the winter, and substantially reduce heat loss through the building envelope. In tempering the “external” climate, adjacent spaces could use operable windows year-round. Solar gain may be used to pre-heat supply air, which can be “cleansed” with extensive planting and generous water features. In the summer, shading devices can reduce heat gain, and - combined with planting and water features - contribute to relatively mild climate conditions through evaporative cooling.

temperature

Thermal discomfort has been identified as the leading source of occupant complaints and decrease in productivity.

The term thermal discomfort often implies temperatures that are too high or too low, although other physical parameters, such as clothing, metabolic rate (activity), air velocity, humidity level and radiation, also influence comfort conditions.

Although air temperature is important, the radiant temperature, defined as the mean temperature of all surrounding surfaces, is just as important for the thermal comfort of a person.

Controlling the radiant temperature, as opposed to air conditioning, creates a more comfortable, draft free environment that is energy efficient. One can control the environment at higher temperatures during the summer and lower temperatures during the winter, without necessarily affecting comfort levels.

Congruently, while the air temperature can be in the right range, solar radiation as low as 20% of the maximum outdoor intensity can cause thermal discomfort (e.g. solar radiation through absorptive sun control glazing).

Radiant (heat) emission can be controlled by adjusting the emissivity of a surface, or by using materials with a low emissivity coefficient (i.e. stainless steel).

In a warm environment, slight air movement, especially in combination with turbulence, increases thermal comfort.
Natural stratification of temperature and humidity (warm and humid air raises), which occurs in rooms with tall ceilings, can increase comfort conditions within the lower, occupied areas, while typical air conditioning mixes the entire air volume.

Semi-conditioned (tempered) buffer zones, such as atria, winter gardens, accessible double facades, etc., increase a building’s energy performance while also providing thermal sensation, which stimulates the human body (i.e. sauna vs. ice water).

Certain room layouts imply a certain expectation of thermal conditions: for example, a wooden deck combined with plants will give a person the impression of a covered outdoor space (a winter garden), which lowers the expectations of thermal comfort, while a lounge in the same space implies a fully conditioned environment.

SENSCITY PARADISE UNIVERSE
Las Vegas, NV, USA, 2003
Behnisch Architekten . Transsolar

The concept for Senscity was first developed for a client in the United States, then modified to suit the demands of another site, with a slightly different climate, in Dubai, in the United Arab Emirates. The revolutionary project combines elements of a typical theme park, such as a game arcade, theater, auditoria, restaurants, public gardens, and exhibition spaces, and a series of playgrounds. Together, they create a unique experience of a new, artificial landscape.

A primary objective of the project is to create a leisure park for families that also serves as a large-scale inhabitable educational tool capable of demonstrating nature and natural laws. Visitors will be able to directly experience how the forces of the inhospitable local climate - sun, wind, and extreme temperature ranges - can, through a progressive, sustainable design approach, be tempered to benefit the immediate microclimate, creating an oasis in the midst of the desert. Reduced consumption of non-renewable energy will be an essential element of the design concept.

The project’s large exhibition halls are not conceived as conventional buildings, but as elements firmly embedded in the landscape, with a park running between and across the undulating rooftops. The central feature of the new park is a central ‘valley’ formed between the halls, with its large artificial lake and extensive vegetation. The ‘valley’ provides the visitor with clear orientation, and plays an important role in the energy concept.

The creation, in the desert, of a comfortable outdoor climate suitable for year-round recreation is a potentially energy-taxing demand. In the very dry, hot desert, green outdoor spaces require sufficient water and efficient sun protection. An integrated design process between the architect and the structural and mechanical engineers led to the development of a series of innovative, multi-purpose ‘flower-like’ structures, which call upon the remedial qualities of tree and plant clusters. The one-hundred-twenty-feet-high, three-hundred-feet-wide structures will span large parts of the park, providing both shade and cool air, on even the hottest summer day. Beyond their climatic capabilities, these flower-like elements will be icons for the overall concept. The formal geometry, individual variations and multiple functions of their ‘leaves’ will combine to provide a graceful, practical and differentiated canopy.

The Las Vegas desert climate affords an ideal opportunity to take advantage of the phenomenon of evaporative cooling, this is instigated by pumping water through hollows in the leaf forms. While the evaporating water on the leaf cools the surrounding air, the flower
height causes them to act like chimneys, with a stack effect generating beneficial down-draft airflows. The cold air streams into the ‘valley’ at their base dramatically improving outdoor comfort levels. The park’s distinct topography will shelter against prevailing winds, and hold a stratum of cool air within the ‘valley’. Functioning as exhaust shafts, the flowers also provide for natural ventilation of the exhibition halls below the ground; again geometry of the leaves can be adapted to capitalize upon the Venturi-effect.

The leaves are envisaged as energy collectors as well: photovoltaic cells or solar collectors within their construction are capable of transforming radiation into electricity or heat, which could, for example, be used to operate an absorption chiller. Cooling loads for the halls will be further reduced by the covering park’s insulation properties, which takes advantage of the relatively stable temperatures below the earth’s surface. At the center of each flower is a stamen-like, highly efficient, vertical-axis wind turbine that will transform wind energy into electricity.

Senscity Paradise Universe, Las Vegas, NV, USA
Acropolis Universe, Dubai, United Arab Emirates
Client: WCP Group, Glenview, CA, USA
Architect and General Planner: Behnisch Architekten
Environmental Consultancy: Transsolar Klima Engineering
Project Study: 2004/2005
Site Area: 86 ha

temperature : key project

SENSCITY PARADISE UNIVERSE
LAS VEGAS, NV, USA, 2004
Behnisch Architekten . Transsolar
The development of an energy-efficient and enjoyable environment for this project addressed two specific questions:

1. How can the micro-climate be improved to ‘extend’ the 4 month period of comfortable conditions (daily temps. ~15-25°C/60-75°F) available in the desert, reducing the 7 month period of extreme conditions?
2. How can available resources be used to achieve a highly efficient building standard during extreme conditions (daily temps. ~25-45°C/75-110°F)?

Clues are to be found in nature; we have all experienced a cool forest floor on a hot summer day. This effect is due to a combination of evaporative cooling and shade. A desert climate, however, requires air-conditioning for certain periods of the year, therefore, efforts must be made to reduce both loads and heat gains.

The Las Vegas desert climate provides opportunities for evaporative cooling. The cool summer nights in the desert offer ideal conditions for the utilization of radiant techniques. The cooling leaf unit combines this effect with the stack effect (down draft chimney in this case). A thermal chimney works as a function of temperature difference and height.
Due to a dispersion of water at the top of the leaf, the air cools down. The height of the leaves is used to generate a down draft airflow. At the bottom of the leaf the cold air flows laterally out into the public space. Additionally, the surface of the leaf will be cooled by cold air inside of the leaf which will provide radiant cooling. The landscape modulation provides shelter against wind. Here, a layer of cold air combined with shade and shelter from winds will create a very comfortable environment.

Water is circulated through a network of black water pipes open to the sky on the leaf surface. The cool water is used to cool the concrete ceilings of the underground halls. The material’s thermal capacity allows this cooling potential to be stored until the following day, dramatically reducing dependency on air-conditioning systems. During the daytime the black piping can be used to generate hot water for use in restaurants, showers, etc.

Constant below ground temperatures are exploited by conceiving the halls as a series of ‘caves’, allowing floor slabs, walls and ceilings to be cooled by the earth.

Displacement ventilation takes advantage of the natural temperature stratification and is very effective in spaces with high ceilings. Fresh air will be provided at a low level. Warm air will rise up to ceiling to be cooled by the heavily insulated concrete structure. Using this strategy only the lower occupied zone will require air conditioning.

In addition, the leaves are used to generate green power by cladding the upper surface with PVs and vertical axis wind turbines.
Temperature and humidity factors greatly influence design. Outside air temperatures provide the primary information for potential use of geothermal resources, as the annual average temperature is similar to the ground temperature which is constant at a certain depth. The comparison of outside air temperature extremes to the annual average temperature defines the potential for passive, geothermal preconditioning of makeup air. The daily temperature range determines the practicality of night flush techniques and natural ventilation, in order to reduce the amplitude of indoor temperatures.

The psychrometric chart is the most important tool for designers in terms of air conditioning, comfort levels and energy consumption. Each dot in the figure represents one hour per year at its respective temperature and humidity level. These parameters define the relative humidity as shown as curves in the diagram. ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) has established a certain range within the psychometric chart for comfortable indoor conditions. As shown in the example: Zone A requires dehumidification, Zone B sensible cooling, Zone C sensible heating and Zone D humidification and sensible heating.
The brownfield site for these twin low-energy buildings is at the western edge of the city of Ravenna, in a transitional area between the urban fabric and the natural beauty of the surrounding landscape. A primary objective in both the site layout and design of the individual buildings is to respond to and strengthen the qualities of this landscape, rather than promote the sprawl of the city. Both the roof forms, with their generous cantilevers, and roof build-ups, with extensive planting, serve to protect the buildings from overheating. Excessive solar gains are controlled by external timber screens which have been shaped and bent in response to the building's site specific shading and natural lighting requirements.

Studio Behnisch with Politecnica Ingegneria et Architettura
Lighting: Nimbus Design
Component cooling is achieved by circulating water through hydronic tubing cast into the concrete floor slabs. Suspended ceilings are avoided, allowing the entire surface to contribute towards cooling, fully exploiting the thermal capacity of the structure. Such a strategy reduces floor-to-floor heights, building volume and building envelope accordingly, leading to obvious advantages in terms of heat losses and costs - both investment and operational. However, room acoustics require that the properties of a suspended ceiling be replicated elsewhere within each room. Greater attention must also be made to any service placement (lighting, ductwork, etc.) as this can no longer be easily concealed.
Norddeutsche Landesbank
In the offices located within the perimeter block, radiant slab cooling in open massive ceilings is used. The exhaust air passes through the hallways either by overflow openings above the door, or through the suspended ceiling. It is then drawn into air ducts which exhaust to the exterior through chimneys. Fresh air is supplied through manually controlled windows in the double facade cavity, which connects to the inner courtyard, the source of fresh, conditioned air for this project.
EXPERIMENTAL CLOUD
FRANKFURT/MAIN, GERMANY, 2002
Transsolar: Concept
The project objective was to construct a stable cloud as part of a show titled “Constructing Atmospheres,” which was included at the Light & Building/Aircontec 2002 exhibition. Twice a day, within the Galleria Frankfurt, a cloud, several hundred cubic meters in size, was to be generated from air layers varying in humidity and temperature. At nightfall, the Experimental Cloud would then transform into an illuminated body hanging over the ‘Cloud Club.’

The cloud experiment illustrated how stable air can be layered within a wide range of physical properties. To achieve a stable “cloud layer,” the air within the cloud needs to be highly saturated. Yet, because the density of air decreases as humidity increases, it is essential to prevent the humid cloud layer from rising. Therefore, it is necessary to create a warm but dry layer of air above. The experiment showed that within a 1 foot difference in height, air temperature can increase by 10°C and by 10 g of H2O/kg dry air. Concept: Atelier Markgraph, Frankfurt/ Main with Transsolar, Stuttgart
Transsolar: Ice Pillar

The mandatory dehumidification of a swimming pool hall usually takes place in a hidden technical facility room, but here it presents itself in the form of an ice pillar. The dehumidification of the swimming pool hall at Fildorado occurs at columns that are essentially large condensers. Ice forms as the humidity in the air condenses on the surface of the columns. Because the heat pump that creates the ice also services the pool water heating system, the ice provides an efficient method of latent heat recovery. The ice columns provide a source of physical, thermal sensation and are therefore an engaging attraction.

Architect: Kauffmann, Theilig & Partner, Ostfildern

Air

Air is a basic element and is the base of all life on our planet.

Through the process of breathing, the body assimilates O2, which is used for internal cellular processes in exchange to CO2. Water, in form of high humidity within the lungs, assimilates CO2, and transports heat from the body.

Ambient air is composed of 78% nitrogen, 21% oxygen, 1% argon and 0.03% carbon dioxide.

The air that leaves a person’s lungs during exhalation contains 14% oxygen and 4.4% carbon dioxide.

The density of air at 20°C (68°F) is 1.2 kg/m3 (33.2 lb/in3). At higher temperatures the density of air decreases; at lower temperatures it increases. This phenomena leads to the stratification of air, with warm air above and cooler air below, in relatively stabile layers.

Analogous to temperature stratification of air, humidity content will also stratify the air due to a density difference - the presence of water molecules lowers the density of air, causing humid air to remain above dry, denser air.

Evaporative cooling by sweating occurs through the skin, which carries with it odor.

The scent quality of air is measured in a unit called an “olf”, derived from the Latin word olfactus, meaning “sense of scent”.

One olf is defined as the scent emission of an “average person“ - a sitting adult that takes an average of 0.7 baths per day (1 shower/bath every 36 hours), and whose skin has a total area of 1.8 m2 (19.4 ft2).

A heavy smoker has a scent emission of 25 olf, an athlete an emission of 30 olf.

A stone surface, such as marble, emits with 0.01 olf/m2, while carpeting made of synthetic fibres emits 0.4 olf/m2.
In colloquial terms, we use the word air to describe the mixture of gases in the earth’s atmosphere. Air predominantly consists of two gases, nitrogen (78%) and oxygen (21%). Apart from these gases, there are relatively high concentrations of argon (0.9%) and carbon dioxide (0.03%). In its natural state, air is odorless and tasteless. The oxygen which is contained in the air is indispensable to life for all aerobic land animals. All animals need it to breathe. Plants require the carbon dioxide in the air for photosynthesis. Air is the sole source of carbon for almost all plants.

The term respiration generally defines the aerobic (which means oxygen consuming) dissimilation of substances for the purpose of energy production, as well as the concurrent release of carbon dioxide.

When breathing, air flows into the body either through the mouth (oropharynx) or the nose (nasopharynx). When breathing through the nose, the air is first gets cleaned by nasal hairs and mucous membranes, it is humidified and warmed. Next, the air flows through the pharynx, past the larynx and the vocal chords into the windpipe (trachea).

The windpipe branches out into two bronchi, which divide further into smaller and smaller branches (bronchioles). Finally, the air enters the pulmonary alveoli in the lungs, through whose thin membrane oxygen passes over into the capillaries and in exchange carbon dioxide is released from the blood to the lungs.

In a relaxed state, an adult breathes with a frequency of 12 times per minute, a child 20 times per minute, and an infant 30 to 40 times per minute.

During an average lifetime a person breathes about 5,000,000 m³ of air.

In a relaxed state, a person exhales about 19 W, 3 W sensible heat, and 22 g zvwater into their surroundings per hour.

The surface area of the human lungs is about 100 m², or 1,111 ft².

Perceptions of odors are transmitted directly from the nose to those areas of the brain, which are part of the limbic system and therefore responsible for the regulation of emotions. Hence, the brain functions on the premise that odors are always important for emotions.

If we are surrounded by a certain smell for an extended period of time the perception of that particular smell finally disappears (adaptation), without hampering our ability to smell other odors.

Usually women are more sensitive to smells than men.

nose
Humans have about 6 million smell receptors in the mucous membranes of the nose. 10,000 different substances can be detected, and still half of them can be recognised at a later stage.

lungs
Respiration through the lungs accounts for 99% of the body’s air exchange.
A single human breath takes in 0.5 to 0.8 litres (0.4 to 0.7 quarts) of air.

Respiration through the skin accounts for 1% of the body’s air exchange.

Air pollution is a major environmental concern; air quality affects the health of the community and directly impacts lifestyle and productivity. Research suggests that a great proportion of the population spends up to ninety percent of their time indoors. It follows that, for many people, health risks caused by exposure to air pollution may actually be greater indoors than outdoors.

The term “sick building syndrome” (SBS) is used to describe general situations in which building occupants experience acute health and comfort problems that appear to be related to a building, but where no specific illness or cause can be identified. Symptoms may include: allergies, breathing difficulties, skin irritations, persistent headaches, depression or anxiety. The complaints may be localized, or may be widespread throughout the building. In contrast, the term “building-related illness” (BRI) is used when symptoms of diagnosable illness are identified, and can be attributed directly to airborne building contaminants.

What is known as the “stack effect” is the ventilation, in buildings as well as flue gas stacks and chimneys, resulting from thermal differences between indoor and outside temperature. The greater the thermal difference and height of the structure, the greater the stack effect and opportunity for pursuing natural ventilation strategies. Since buildings are generally not completely sealed, the stack effect will induce air infiltration. During the winter, indoors, used air will rise up through the building to escape through ventilation openings. The rising warm air reduces the pressure in the base of the building, allowing the less buoyant cold air to infiltrate through open doors, windows, or other ventilation openings, as well as through general leakage. In many cases, atria can exploit the natural phenomenon of stack effect, ensuring the healthy movement of air and performing essential roles in the building’s climatic concept system, thus eliminating the need for space-consuming return-air ducts.

A solar chimney is a relatively simple way of augmenting the natural ventilation of a building by taking advantage of the convection of air heated by passive solar energy. During the day, solar energy heats the chimney, leading to an updraft of air within. The suction created at its base can be used to both ventilate and cool the building below, an ideal form of natural ventilation on hot, windless days. The chimneys have been used since Roman times, and were also used in the ancient Middle East. To further increase the cooling effect, the fresh supply-air can be drawn indoors from either shaded outdoor areas or — taking advantage of relatively stable subterranean temperatures — through simple concrete ductwork integrated into the foundation system.

Outdoor environmental quality is critical to the success of urban developments, regardless of scale. Air quality is just one factor. Street patterns, building massing, location and orientation can influence the immediate outdoor climate throughout the seasonal weather cycle. In winter, shelter may be required from prevailing winds; and building heights may need to be restricted to allow low winter sun into courtyards, gardens, and surrounding streets. In summer, cool,
prevailing winds, properly harnessed, provide ideal opportunities for air exchange, preventing contaminant build-up and a potential heat island effect.

Research by Lawrence Berkeley National Laboratory has proven that a person’s productivity in the workplace increases by 7% with better air quality, and if combined with individual controllability, productivity increases by 13%.

Limited airflows reduce or exclude air recirculation, one of the primary causes of “sick building syndrome.”

It is Transsolar’s goal to allow people to have direct access to fresh outdoor air, even if it is warmer and/or more humid than the interior air. Because operable facade elements allow direct contact with fresh air, daylight and exterior noise, a person doesn’t feel as though they are trapped inside. Additionally, a person is more accepting of interior climate conditions that vary from basic standards if they are able to open a window.

Single sided ventilation has a similar access depth to optimized natural daylight (two-and-a-half times the height of the space).

The use of air to warm or cool a space is very inefficient when compared to the use of water — to achieve the same result, 4 times the weight of water and 3,500 times its volume is required when using air.

Therefore, our systems supply sufficient fresh air to feed people, and instead use water to heat and cool spaces.

In addition to the circulation of fresh air, indoor air quality is also affected by “pollutants” emanating from sources such as humans, building materials (e.g. carpet, adhesives), furniture and air ventilation systems, which often reduce the quality of supply-air relative to outdoor air.

Although air filters are intended to clean air, they can also pollute air if they are not maintained regularly - and, in this case no filter is better.

Long and extended air distribution systems dramatically reduce air quality; therefore, short air paths, like those found in decentralized facade systems, are preferable and much easier to clean.

Displacement ventilation systems supply fresh air at the occupants’ level, which avoids mixing used air and fresh air, which allows higher air qualities with less fresh air.

Plants create an indoor clean-air microclimate: Banana trees break down formaldehyde, ivy’s decompose benzene, and a ficus benjamini tree can increase humidity by releasing 15-30 g (0.5-1.0 oz) of water per hour into the air. The indoor environment becomes a microcosm of the large parks in cities that act as green lungs, or the Amazon forests and their role in the billion-year precedent set by our planet.

Infiltration is the uncontrolled exchange of outdoor/indoor air through cracks and leaky building envelops. Historically, buildings could rely on this for their basic fresh air supply.
High infiltration rates during winter ensured a dry indoor climate but resulted in high-energy losses. By sealing up our buildings, we need to be aware that we increase interior humidity levels, which demands a well-insulated building envelop to prevent condensation and mold growth.

LVA STATE INSURANCE AGENCY SCHLESWIG-HOLSTEIN
Lübeck, Germany, 1997
Behnisch & Partner, Büro Innenstadt. Transsolar

LVA, a one-hundred-year-old state insurance agency, required a new regional headquarters for their previously dispersed offices, which had been located in and around the medieval city center of Lübeck. LVA’s new suburban site needed to offer compensatory attractions - namely, a much improved and more generous working environment - by orienting the building to the landscape to allow panoramic views of the historic city.

In order not to alienate the individual worker, the architects designed a building that respects the complex organizational demands of the different departments, while creating a series of focus points to promote staff communication and offer respite from cellular office spaces. These special places include: the entrance hall, which operates very much as a “market square”; the refectory, which extends into one of the landscaped courtyards; the rooftop conference rooms, offering a decidedly different geometry; the tea kitchens, designed as “sun spots” and communication areas; the sports hall, community activities; various circulation areas, such as corridors, galleries and open stairs, which create horizontal and vertical links, niches and spatial contexts, and visual connections; meeting rooms opening out toward the corridors; and the roof terraces and greenhouses.

The low-lying, starfish-shaped building radiates out from a central entrance hall toward the corners of the site. Shallow floor plans (maximum fourteen meters deep) ensure that all workplaces are directly against the façade, with views out into the surrounding landscape or green garden courts. All workplaces receive abundant daylight and are naturally ventilated, with manually operated tilt-turn window openings and trickle vents. In response to the design brief, mechanical systems are kept to an absolute minimum, informing not only the layout, but materials employed, and subsequent use of the building. Operating costs are substantially lower than with comparable, fully mechanical buildings.

The climatic concept is based on numerous thermal-load and air-flow simulations. Exposed concrete floor plates provide necessary thermal mass and avoid suspended ceilings, displacing higher daytime temperatures toward late afternoon when the building is largely empty. This not only contributes to the general aesthetic, but, more importantly, requires that staff learn to work with their immediate environment as they do at home. A certain discipline is required to operate the technology, such as closing blinds and opening trickle vents to ensure adequate cross-ventilation and night ‘flushing.’

A combination of exposed thermal mass and the strategically placed ventilation openings, supplemented by a large, centrally located solar chimney, prevent the overheating of the hall. The chimney utilizes a stack effect to extract warm, used air, while drawing fresh air from below. The simple glazed construction of the chimney is optimized to heat up from the sun, ensuring internal temperatures as high as sixty degrees and increasing its performance.

A south-facing, multi-story entrance hall is the center of the building. Open floor plates are connected by a series of stairs crisscrossing the central void. The hall is protected by two
large, inclined glazed planes, ensuring that daylight reaches deep inside the building, while taking advantage of valuable solar gain. Natural ventilation (with support from minimal technology) maintains a stable climate. During the mild seasons, mechanically operated ventilation openings allow fresh outdoor air directly into the hall. The geometry of the hall allows warm air to rise to a natural high point above the uppermost floor. The form of the roof, as well as precisely sized and located computer-controlled ventilation openings, ensure that the prevailing winds are used to full advantage to harness a natural exhaust system. During the extremes of summer and winter, outdoor air is tempered through a one-hundred-meter-long earth channel in a concrete tunnel situated below the groundwater table and integrated into the building’s foundation system; it supplies the hall, through a floor grate, with fresh air. In the summer, a combination of the earth and groundwater ensure that the air is cooled by three to four degrees, while in winter the effect is reversed, with the air pre-warmed before being delivered to the hall.

Client:
Landesversicherungsanstalt Schleswig-Holstein, Lübeck, Germany
Architects:
Behnisch & Partner, Büro Innenstadt
Environmental Engineers:
Transsolar Klima Engineering
Competition: 1992
Completion: 1997
Gross: 37,109m²

LVA SCHLESWIG-HOLSTEIN
INSURANCE HEADQUARTERS
LÜBECK, GERMANY, 1997
Behnisch & Partner Büro Innenstadt. Transsolar
The entrance hall is the center of daily activities, a meeting point for staff and visitors. Here, a pleasant climate prevails, one attained via natural ventilation, with support from minimal technology via computer controlled ventilation openings. The specific form of the hall was developed in response to anticipated air movements in the relative heating and cooling seasons. Instead of fighting warm air build-up the geometry simply promotes air flow patterns which do not conflict with areas of occupancy. Heat build-up is avoided through ample ventilation. The concrete floor plates and walls to lift shafts and stairs are left exposed to take advantage of thermal mass capabilities. Depending on outdoor conditions, fresh air can be introduced into the hall from all sides. In the evenings the hall can be ‘flushed’ with cool air through the earth channel, thus avoiding security problems associated with low-level vents.
The main issue concerning pedestrian comfort is the reduction and control of wind velocity. Within an urban context, high wind velocities are caused by a number of building-dependent factors that include:

- tear of edges,
- tunnel effects,
- downdrafts,
- wind acceleration due to shapes of buildings.

These effects can be reduced by optimizing building shapes and/or modifying building locations (which may include the rearrangement of buildings). The average wind velocity in Boston is about 5.4 m/s at the 10 m height and 4.5 m/s at the 1 m height. Areas that receive wind speeds greater than the average velocities should be analyzed in detail. This is especially important for cafes, playgrounds and all outdoor gathering areas that need to be optimized with regard to extended occupation times.

WIND ROSE DIAGRAM
The wind rose diagram summarizes the occurrence of winds at a location, showing their strength, direction and relative frequency. The specific wind roses generated for the Allston Science Complex development area indicate a pattern of prevailing westerly winds, ranging in speeds from 3 to 9 m/s. This information is essential in the design and layout of buildings to assure pedestrian comfort, good city ventilation patterns and reduced energy consumption.
Harvard University is moving forward to create the new Allston portion of its 21st century campus by the planning of a state-of-the-art science complex in Allston, MA. The vision is to build a campus and to strengthen the position of Boston as the life sciences capital of the world. The 100,000 m² complex responds to a pressing need for new kinds of spaces that facilitate interdisciplinary scientific research at Harvard.

Harvard has a long standing tradition of vital campus life. The ‘center’ of the traditional campus is characterized by a seemingly endless network of courtyards, lawns, squares and parks. The yards are spatially and functionally complex. They are sensitive of human scale, providing both access and thoroughfares, and offer places to rest or study in different degrees of shelter and protection.

Harvard’s Allston Science Complex will set new standards in energy efficiency and quality of the working environments. Passive strategies will be adopted wherever possible, and where necessary supported by sophisticated HVAC equipment. In all cases, the individual is to be afforded a degree of control over their own environment. The complex will adopt a number of progressive design strategies that strive to reduce demands on energy resources. These include flexible programming, geothermal sources, wind turbines, natural ventilation, advanced methods of heat recovery, roof gardens, storm water management, wind and solar strategies, sophisticated facade systems, site remediation and daylight enhancement systems.

Wind studies (see film above) were conducted in order to optimize outdoor environmental quality. Energy targets for the Harvard Allston Science Complex far surpass current legal certification requirements, and strive to reduce primary energy use by 60% compared to ‘base line facilities.’ The aim of the design investigations is to pursue a maximum reduction in CO2 demands. These targets can only be reached by pursuing progressive strategies for air-handling, the major source of energy consumption in a modern laboratory building.
BAD AIBLING SPA BATHS
BAD AIBLING, GERMANY, 2007
Behnisch Architekten . Transsolar

Bad Aibling, a small town 60 km southeast of Munich, and home to the oldest ‘moor’ spa in Bavaria, plans to complement the existing leisure facilities with a new spa baths, which include wellness areas and outdoor swimming pools. The new baths are to provide an attractive health-oriented focus for both the local community and the region, very much in the tradition of the town.

The new facilities are characterised by the various domes, which house the individual pools and treatment areas. Connected by a glass-enclosed, de-materialized wintergarden, the domes will provide a prominent visual presence and play an important role in the project’s energy-saving strategy.

The wintergarden is filled with rich plantings, creating an ecological micro-climate. Slight modulations to the sloping site allow the surrounding bathing areas to freely undulate into the landscape.

The energy-saving plan is largely driven by the development of seasonal climatic zones in the interior spaces. The zones are spatially configured and designed to provide thermal comfort levels appropriate to each area. The pool and spa domes maintain a hot, humid temperature, while the air in the winter garden is comfortable and dry. The flexible structural construction of the domes allows for them to be partially dismantled during summer months and opened to the surrounding landscape, facilitating natural ventilation.
Fresh air is introduced to this building’s occupied spaces either through the façade or through ceiling grilles. All perimeter work stations are provided with operable windows allowing for both ventilation and contact to the surroundings. All windows and vents are linked to the building management system, allowing the envelope to be opened up for night-cooling. A double-facade covers over 30% of the building envelope. This generous interstitial space serves as an extension to the workplace and as a climatic buffer zone. It helps reduce solar gains in summer by exhausting the heat away before it enters the office beyond. In winter, the double facade offers the opportunity to close down vents and open shading devices in order to make the best use of solar gains while reducing heat losses.

The atrium void serves as a huge return air duct. Used air is drawn, through pressure differentials, up and out of the atrium via a combination of stack effect and exhaust fans / heat recovery units located near the central skylight.

The extensive planting of the seventeen interior gardens substantially improves the indoor climate by increasing the oxygen content and binding pollutants.

Environmental: Buro Happold
Wind pressure on building surfaces increases with height. The concept of external shading devices and operable windows in this forty-story, fully glazed office tower therefore required a protective double facade. A CFD (computational fluid dynamic) simulation shows the balancing of the external pressure differences within double skin plenum and without horizontal obstructions, using flaps that open according to wind pressure levels. The building management system has temperature sensors in every room, and within the facade, which constantly monitor comfort levels.

The graph illustrates the different temperature profiles during an extreme hot summer day. By the utilization of specifically designed ventilation flaps, the facade plenum reaches a maximum temperature difference to the outside of 5 Kelvin (9° F). The office space is primarily conditioned by the cold ceiling and a preconditioning of the supply air via the air intake unit.

The combination of the radiant cooling from the ceiling and decentralized intake and conditioning units create a very simple space conditioning system which operates at an individual scale.

Architect: Murphy/Jahn, Chicago, USA

sound

Sound is a mechanical wave resulting from the motion of particles of the material that the wave moves through. As the energy of a sound wave moves through air, particles of air are displaced parallel to the direction of the energy transport.

Natural sources of sound vary significantly from technical ones. People generally characterize natural ones in a positive manner, while technical sources are regarded as noise.

The frequency of a sound wave approximately within the range of 20 and 20,000 vibrations per second (hertz) is audible to the human ear. Frequencies that are above this hearing range are considered ultrasound, while those that fall below are infrasound.

The amplitude of a sound wave is defined by its pressure, and the intensity level of sound is measured on a logarithmic decibel (dB) amplitude scale.

A building should provide a high quality indoor acoustical environment, and should limit transmission of sound waves from outside to inside and vice versa.

The material properties of the medium through which sound waves travel affect the propagation and transmission of the waves themselves. Such material factors include absorption and reflection. Ceiling tiles, for example, absorb sound and eliminate echoes.

Reverberation is defined as the sound that continues to reflect off surfaces, even while the original sound source has ceased, until it is fully absorbed. The reverberation time of a room
depends on the dimensions of a room and the absorptive qualities of all the surfaces it contains.

The audibility of a sound environment depends on several factors. The combination of sounds that are present at lower levels produce an effect characterized as “ambience.” On the other hand, a lower sound can be difficult to discern when combined with a louder sound, even as the louder sound may fall within the same frequency.

Background noise can cover other sources of noise and can provide privacy.

sound

The sense of hearing is an important precondition for communication and orientation, and it determines our emotions considerably. In contrast to our eyes, we cannot close our ears – we hear non-stop what happens around us.

The human ear consists of the outer ear (earlobe and ear canal), the middle ear (including the bones of the middle ear, or ‘ossicles’), and the inner ear (cochlea and semicircular canals, which provide for the sense of balance).

30,000 receptors (hair cells) in the inner ear react to the dissemination of minute pressure and density changes in elastic media (gases, fluids, solids). They transform acoustic waves into electrical impulses and transmit these acoustic signals to the brain via the acoustic nerve.

The shape of the ear canal causes resonance effects, which lead to an acoustic amplification of frequencies between 3000 and 4000 Hz. This is the frequency range in which human hearing is optimal and which is used for most of our spoken communication.

The stapedius reflex protects our ear from sound levels above 80 to 100 dB: The muscles in the middle ear contract, limiting movement of the ossicles and hence transmission of vibrations to the inner ear. This protective reflex sets in quickly (about 50 ms after perception of the sound) and persists for some time after the sound level is lowered again. This regulating mechanism enables sounds, which increase in volume slowly, to be ‘adjusted down’, however, it is too slow for sudden sounds, which are therefore perceived ‘undampened’ and subjectively louder.

One of the ear’s functions is orientation in space, i.e. to localise sources of sounds. In order to achieve this, the direction and the distance of a sound source have to be determined.

Natural sounds are significantly different to technical or synthetic sounds. This explains why we attribute positive associations to natural sounds, whereas technical or synthetic sounds of the same sound level are perceived as noise.

We can also hear via the bones in our body. Bones conduct sound very well. When we speak, we hear ourselves with our ears (air conduction) as well as through vibrations of our bones (bone conduction). This is why our own voice sounds unfamiliar to us when it is recorded.
The ear is the most precise organ of the human body. We can hear sounds from sources which are too distant for us to see. Our ears are so sensitive that even a minor increase in sensitivity would enable us to hear oxygen molecules hitting each other.

voice box
The primary sound is produced in the voice box. It is then modified in air containing spaces (vocal tract) above the vocal chords (pharynx, mouth and nose) and becomes the human voice.

diaphragm
Low frequencies are sensed by our whole body, in particular by the diaphragm and the abdomen.

sound
Sound assumes myriad forms. It is crucial to the quality of our lives, and one of our primary means of communication. Music has the ability to influence emotions, and soundscapes affect our interactions. Sound which interferes with normal hearing is considered noise, some barely heard but still provoking a desire for quiet. In the fields of science, architecture, and engineering, noise is generally an undesirable element which obscures or disturbs - such as car traffic, loud conversation in public corridors, the persistent running of machines, even the subdued murmuring of an audience. Four common sound characteristics - intensity, loudness, annoyance, and offensiveness - determine listener response and their evaluation of sound as “noise.” Excessive noise has an adverse effect on personal health (such as hearing loss) and productivity, in general (such as one’s ability to perform a concentrated task).

Acoustic science, the study of sound, cuts across many disciplines: physicists work to understand how sound waves behave; engineers to produce solutions to noise; and social scientists to understand how human beings interact with, and react to, sound. Acoustics is the science of controlling a room’s surface, based upon manipulating the various sound-absorbing and reflecting properties of materials used in its construction. A room’s “sound quality” can be exaggerated or reduced by changing the absorption and diffusion capacities of its various surfaces.

Size, geometry, and material determine a room’s acoustic quality. The dimensions determine its resonant frequencies, and its geometry - the position and angle of its walls, floor, and ceiling - determines the direction of sound reflections. Sound waves in a room are reflected, absorbed, and dispersed by its surfaces, furniture, and occupants. The acoustics are changed as soon as a person enters, and furniture, carpets, curtains, and coverings, play a fundamental role. Each material has its own vibrational character, through which sound is transmitted at different rates. These vibrations generate new sound waves of reduced intensity on the other side of the building element; this passage of sound into a room from a source located in another space inside or outside, is called “sound transmission.”

Communication is basically about hearing and being heard. Intelligibility of speech is fundamental, whether in informal one-on-one conversation, or formal meetings with several
people. Ideally, speech should not be masked by background noises, such as ventilation systems or nearby conversations, therefore, it is necessary to plan for good speech differentiation in buildings. Research shows that other voices are the main threat to individual concentration, therefore separate acoustic solutions are needed for open-plan and cellular offices in order to achieve a suitable acoustic environment.

One function of a building is to protect its occupants from unwanted noise from all sources. Since today buildings are constructed closer together than ever before and adjacent to noise sources such as highways, railways, and airports, acoustic control becomes an increasingly complex matter. The control of sound inside buildings may be classified with respect to its origins, namely, sound originating inside a room, and those from without. Efficient and economic control is dependent not only upon this factor, but also the design of the enclosure and the type of occupancy. Depending on the source, acoustic control may be achieved through a wide variety of means - from building form, location and protective vegetation to materials, construction methods and building components, such as double facades and box windows. The sheer mass of concrete construction, versus wood or steel frame construction, for instance, can reduce the penetration of sound through walls by over eighty percent. Sound-absorbing materials may be used around window reveals if they do not interfere with ventilation, and water features, or vegetation which rustles with air currents, can also be inserted to mask noise.

sound

A double facade can attenuate sound even though an inner window is open for natural ventilation.

A waterfall, especially in an atrium, creates a positive background noise, which covers other sounds, in addition to providing privacy.

In order to keep airflow from transmitting noise, one can run the air along a sound absorbing surface (noise damper), or more effectively, through an absorbing labyrinth, which can be integrated in a partition wall.

Buildings that utilize high thermal mass require exposed concrete ceilings; therefore, intelligent solutions are necessary for surfaces for sound absorption, such as curtains, micro-perforated blinds and foils, and highly absorbent floors.

Noise pollution caused by mechanical systems, both indoors (ventilation and fan coils) and outdoors (cooling towers and chiller condensers), can be minimized or avoided altogether by using passive systems for airflow and recooling.

NORDDEUTSCHE LANDESBANK
Hannover, Germany, 2002
Behnisch, Behnisch & Partner . Transsolar

The new Norddeutsche Landesbank is located in the city center of Hannover. Immediately to the west lies the City Hall and the adjacent Maschpark, a large sports and recreational park. Aegidientorplatz, to the northeast, and Friedrichswall, which separates the site from the city center, are both adversely affected by heavy traffic.
The new building’s location and use as an administrative headquarters, along with its size, make it difficult to fully integrate into either the commercial city center to the north, or residential districts to the south. Instead, the building - which occupies an entire city block (in particular, the publicly accessible ground floor) - acts as an intermediate or transitional zone, mediating between various city activities: retail, commercial, residential, cultural, sports, and leisure. In accordance with urban planning guidelines, the four-to-six-story, shallow-plan, perimeter building is aligned with existing streets, complementing its surroundings. Variation in height allows it to respond to both the scale of its direct neighbors and the existing fabric of the city.

From the exterior, the area resembles a traditional city block, but at its center, protected from the noise of the surrounding streets, lies an ‘oasis’ - a large, new courtyard, characterised, but not dominated, by the daily operations of the bank itself and further enlivened by shops, restaurants, cafés, galleries, large reflecting pools, public art, and extensive plantings. The courtyard provides a new publicly accessible space in the city.

A distinctive, seventy-meter-high building rises from the courtyard, detaching itself through a series of twists and turns from the formal order of the lower, perimeter building, and establishing formal and visual links to the city beyond.

The environmental strategy adopted for the Norddeutsche Landesbank is both extensive and sophisticated. As in the case of the Genzyme Center and IBN Wageningen both user well-being and low-energy systems were pursued in responding to the particularities of the urban location and program. In seeking to make the best use of natural phenomena and resources such as the sun, wind, outdoor air and constant sub-surface water temperatures, air conditioning was considered redundant. Operational costs were thus considerably reduced.

Optimization of daylight in the offices reduces reliance upon artificial lighting. Performance of both the blind systems and the glazing has been determined by computer-assisted shading studies. The blind systems are designed in such a way that, while protecting against sunlight, the paradoxical situation of over-darkening, with a necessity for use of artificial lighting, is avoided. Here, the uppermost slats are angled independently of the rest so that daylight is redirected to the reflective ceiling and into the depths of the building. The walls along the corridors are glazed, substantially increasing natural lighting levels and further reducing the tendency for building occupants to reach for the light switch.

The areas of “double façade” have manifold benefits, providing protection against noise as well as vehicle emissions, lending wind protection to and therefore increasing the efficiency of the external blind systems, and serving as a supply air duct to adjacent offices. By introducing the “clean” air from the beneficial microclimate of the courtyard into the void of the double façade, it is possible to achieve window ventilation at those sides of the building exposed to street traffic. All rooms can thereby be ventilated naturally through simple window openings and exploiting the cooling potential of outdoor air, which exceeds 22°C during less than five percent of the year. Air vents within the walls to the corridors complete the natural ventilation system by exploiting stack effect. Heat recovery units are used at the roof level.

During the summer months, the cooling potential of the outdoor air may not be sufficient. In this case, active cooling of the offices is provided by direct cooling of the superstructure. This is achieved by directing water with a temperature of 18°C through a system of polyethylene pipework integrated into the concrete floor slabs. During normal summer days, it is sufficient to ‘flush’ the solid concrete slab at night with stored coolness gradually released into the
rooms during the course of the day. A traditional cooling plant is not necessary, as cold water is provided by a ground heat exchanger connected to the foundation piles.

The geothermal energy is used in two ways. The heat absorbed by the ground in summer is stored until the winter months, when the superstructure’s integrated pipework is used as a low-temperature heating installation. For this purpose, water with a temperature of 6°C circulates through the ground heat exchangers, then a heat pump raises the water temperature to approximately 30°C, the low temperature increase making the pump highly efficient. In summer, the operations of the system are reversed, with heat from the offices directed into the ground via the superstructure. The circulating water, which has a temperature of around 25°C, is cooled by the ground heat exchangers and again made available for cooling of the slabs. Only the circulation pump requires the expensive, high-quality energy of electric power. Importantly the annual energy balance for heat introduced and extracted from the ground breaks even.

Client:
Demuro Grundstücksverwaltung GmbH & Co KG
(Commissioned by: Norddeutsche Landesbank)
Architect and General Planner, Building and Interiors:
Behnisch, Behnisch & Partner, Stuttgart, Germany
Environmental Consultancy:
Transsolar Klima Engineering
Natural and Artificial Lighting Consultancy:
Bartenbach LichtLabor, Aldrans, Austria
Competition: 1996
Completion: 2002
Gross Floor Area: 75,000m²
Volume: 296,000m³
No. of Workplaces: 1,500

sound : key project

NORDDEUTSCHE LANDESBANK
BANK HEADQUARTER
HANNOVER, GERMANY, 2002
Behnisch, Behnisch & Partner . Transsolar
The architectural treatment of the large inner courtyard is informed by the geometry of the building. An artificial landscape has been created with the sloping glazed planes of the entrance hall and canteen complemented by 3 reflecting pools. These are connected by a series of shallow waterfalls, producing pleasant ambient sounds which help mask the noise of passing traffic and encourage building occupants to open up their windows onto the courtyard for natural ventilation. The changes in level also ensure that the water remains in constant movement, thereby restricting algae build-up. The pools also benefit the natural lighting levels within the court.

Planting is restricted to the roofs of the canteen and the terraces above. The benefits of these planted areas are manifold. Seasonal color changes provide a visual stimulus. In addition the vegetation offers increased acoustic absorbancy, additional insulation, a habitat for insects and birds and a visual contrast to the architecture.
sound : basics

An important aspect in the design of architectural space is that which cannot be seen – sound. Often overlooked and oversimplified, acoustics is an integral part of design, and should be considered in the design phase as it has the potential to dramatically elevate the quality and comfort levels of a space. Whether creating a quiet, contemplative space, or a lively social gathering place, acoustic design is essential to the functioning of almost every type of environment. It is therefore essential that acoustic qualities are tailored to meet the particular demands of a space, from open spaces, recreation areas and office space, to class rooms, spas and worship centers.

Because acoustic levels, quality and comfort should be appropriate to the particular use of each space, the materials used to manage sound should complement, rather than contradict the architecture. Thermally-active slabs generally imply exposed concrete ceilings, the surfaces of which often reflect noise and sound, creating an acoustic environment that may be considered harsh or uncomfortable. The use of sound-absorptive materials, such as absorbent floors and acoustic ceiling tiles can dampen sound reverberation and noise, but an indiscriminate application of them can also deaden a space. Rather than a blanket approach to sound control, the intelligent selection of materials that shape acoustic quality must also add to the visual dynamic of the space, and not appear as an alibi. A water feature that conditions the indoor climate also provides a soothing backdrop of ambient noise; intensive planting dampens sound and adds life and fresh air; curtains that absorb sound add color and create privacy.

Designing with respect to acoustic considerations increases functionality, utilizes material resources effectively and increases the acceptance of a space and its usability – essential in the creation of a sustainable building.
RAVENNA PUBLIC ADMINISTRATION OFFICES AND REGIONAL ENVIRONMENTAL PROTECTION AGENCY (ARPA)
RAVENNA, ITALY, 2007
Studio Behnisch . Transsolar
A rich network of walkways, paths, water channels, hedgerows, trees and various kinds of planting provide the setting for the low-lying buildings. Their appearance is deliberately restrained and they share many common features, for example shallow plans. Both buildings respond to the same concerns with regard to a stimulating working environment, low energy strategies and concerns for occupant well-being which influence both the layout and orientation. Noise protection is provided by a careful choice of insulating materials. A water wall extending over the full atrium height enhances the climate while creating a pleasant continuous sound and mood.
Architects: Studio Behnisch with Politecnica Ingegneria et Architettura
Public indoor leisure facilities such as swimming pools, with a large area of hard acoustically reflective surfaces, generally prove to be a challenge for acousticians. In the case of the Spa Baths in Bad Aibling, Bavaria, Germany, 2007, noise levels on the pool deck are reduced, while actually maintaining, or even exaggerating, the characteristic sounds of the main attraction – the stirring of the waters in the different pools. By housing each water attraction in its own ‘cabinet’ - effectively a free-standing room within a room, in the form of a dome - it is possible to control the noise at source before it can spread to the rest of the pool deck and become a source of disturbance. The sound absorbing timber ceiling above the pool deck promotes an acoustically dampened space, heightening the contrast with the acoustic environment in each of the ‘cabinets’ and complementing the rich spatial and sensory experiences afforded to the guest in this unique facility. 

Acoustics: Bobran Ingenieure
Furniture provides, except for clothes, the most immediate element of our environment. If a chair is too high, too warm or too hard, or if the table is too high, or too cold, we feel uncomfortable and are unable to fully concentrate on our work. A person’s absence from their personal workspace is often a consequence of such uncomfortable situations. Going for a cup of coffee, for example, is one way of escaping such a situation.

The furniture in the Genzyme Center comes in a variety of colors, shapes and materials, offering manifold haptic, visual, spatial and acoustic experiences. Tables, chairs, screens and planters are combined with floor coverings and curtains to identify specific spaces for; concentrated work, recreation and communal activities. Curtains not only provide an important source of color and an added layer of insulation, they play an important role in reducing noise levels. Carpets reduce problems of foot fall and a further absorbing surface. Environmental: Buro Happold
SUVARNABHUMI AIRPORT
BANGKOK, 2006
Transsolar: Membrane Concept

With an area of 500,000 m\textsuperscript{2}, the new international airport in Bangkok is one of the largest airports in the world. The brief called for a new development in materials that would address special demands, including that of sound protection. The solution developed is a triple layer membrane system which spans the entire 3.5 km long concourse. Since the sound protection requirement could not be fulfilled with a single membrane, the project team developed a concept which incorporates three membranes separated by air layers. The outer membrane, weighing 1200g/m\textsuperscript{2}, is a PTFE-coated glass fiber composite, distinguished by high reflectance, tensile strength, dirt repellence and durability. The middle layer, 6 mm transparent PC sheets attached to a steel cable mesh, serves primarily as sound protection. The inner layer of the system, which has a low-e coating on the interior side, is an open-weave glass-fiber material that allows the interior noise to pass through to the middle layer. The membrane combines excellent low-e (low emittance of heat radiation) and acoustic absorption properties in addition to translucency. The entire roof construction attains a sound reduction index of 35 dB.

Architect: MJTA Consortium with Murphy/Jahn, Chicago, USA, TAMS, Chicago, USA ACT, Bangkok, Thailand in cooperation with Laboratorium Blum, Stuttgart, Germany.
ADIDAS CANTEEN
HERZOGENABURACH, GERMANY, 1999
Transsolar: Membrane Concept
In order to create a comfortable environment within the Adidas cafeteria which serves 1,100 employees, a multi-functional foil is suspended 0.5 m beneath the double-glazed roof. It conditions sound, light and temperature within the space.
Its acoustical absorptive qualities are created by microperforations ranging in size from 0.2 to 0.8 mm. When sound waves hit the foil, a physical reaction takes place. The friction created at the edges of the perforations transform the sound energy into heat. The reverberation time and sound level are reduced, resulting in a sound absorption coefficient value of ~0.5.
This microsorber foil is also partly fritted for shading, and has a low emissive coating which reduces heat radiation into the room below while increasing thermal comfort.
Architect: Kauffmann, Theilig & Partner, Ostfildern, Germany

material
The differing physical aspects of various materials will have a distinct impact on the environmental quality of a space. Proper selection and combination of materials is essential in the design of a high quality environment.

A material’s conductivity defines its ability to conduct heat, and therefore it defines the material’s insulation performance.

The heat capacity of a material describes how much heat that material can store. For example, the heat capacity of reinforced concrete = 1,800 kJ/kg·K, water = 4.18 kJ/kg·K, timber = 1.7-2.8 kJ/kg·K and rock wool insulation = 0.8-1.2 kJ/kg·K.

The porosity of a material will affect its ability to absorb and desorb moisture, while its reflectivity will describe its ability to reflect and transmit light.

Reflectivity also characterizes a material’s absorption and transmittance of sound, which will also have a strong impact on the acoustical quality of space.

The energy required for the manufacture and transport (“cradle to site”) of building materials is often defined and tabled as “embodied energy,” although values will vary according to region and distance from factory to site. The embodied energy of 1 m3 (35 ft3) of high strength concrete = 3,642 MJ; 1 brick = 12 MJ; 1-4’x8’ sheet of 3/4” plywood = 510 MJ.

So-called phase change materials can store a high amount of heat energy in order to change their phase from solid to liquid or liquid to gas at a constant temperature. This property can be utilized as a heat sink in buildings (e.g. heating 1 kg of water from 0°C to 100°C requires 420 kJ; melting 1 kg 0°C ice to 0°C water requires 330 kJ; boiling 1 kg 100°C water to 100°C steam requires 2440 kJ).

In order to consider the sustainable aspects of a material and its respective use in a building, it is essential to consider its durability and its ability to be recycled or biodegraded.

material
Haptic perception (from Greek: ‘haptikos’ = ‘tangible’; colloquial also ‘sense of touch’) is defined as a sensory perception, with which certain mechanical stimuli can be sensed. Haptic perceptions in their entirety enable the brain to localize and evaluate touch, pressure, and temperature.

The sense of touch communicates to the brain all the necessary information to identify form, weight, direction and speed of movement, as well as the surface properties of objects. In addition to this, it also serves proprioception, e.g. the perception of pressure at the soles of the feet feeds information to the brain about the position of the center of gravity of the body.

In the skin, there are several different types of receptors, specializing in various functions. They react optimally to different stimuli like pain, temperature, touch, stretching, movement and vibration, and transmit these stimuli to the brain using separate pathways.

Compared to other parts of the body, hands and mouth draw upon a disproportionately high number of neurons in both the somatosensory as well as in the motor cortex. It is a prerequisite for the most fundamental human behaviours, like eating, speaking, and feeling objects, that mouth and hands be highly sensitive to touch.

The skin of an adult covers, depending on height, a surface of 1.5 to 2 m\(^2\) (1.8 to 2.4 yd\(^2\)), it weighs one sixth of total body weight, on average 10-12 kg (22 - 26.5 lb).

The importance of the skin as a sensory organ can also be seen in the fact that the brain regions, which are responsible for processing the signals from the skin, are relatively large. For example, the nerve fibers, which transmit tactile stimuli from the skin to the brain, are usually bigger in diameter than nerve fibers, which transmit stimuli from other sense organs to the brain.

Large areas of the brain are involved in processing stimuli from the skin. Sensory perceptions from the hands (especially from the index fingers) and the lips are of special importance and take up disproportionately large areas of the cerebral cortex.

Receptors for cold, warmth, pressure and touch, vibration, and pain are located in the skin.

Most of the tactile receptors are found in the fingertips. Humans are able to feel differences in weight of 0.106 g (0.0037 oz), or pressure of 0.101 g (0.0036 oz).

At the soles of the feet and at the toes there is a high density of receptors for skin senses. Walking bare foot increases the sense of touch.
All materials have individual properties and characteristics, which can be perceived and appreciated by touch (handrails, desks, and seating elements, for instance), or by smell and observation (wood, leather, and steel for instance). A combination of materials can stimulate disparate senses and counterbalance the monotony of the workplace.

The earth’s resources are usually defined as being either ‘renewable’ (i.e., timber, which may be reasonably forested and regularly harvested), or ‘non-renewable’ (i.e., metals - many of which are finite). It is also standard to divide these into ‘usable’ and ‘non-usable’ categories.

All construction projects with a sustainable goal require a response to their environmental impact due to material extraction, processing, manufacturing, transportation, erection, dismantling, and demolition. For some materials, such as softwoods, this renewal is unequivocally positive for others, such as non-recycled aluminium, it is severely negative. However, neither durability, overall performance, nor financial considerations can be totally ignored, and, as such, individual materials with a poorer environmental reputation may in certain cases actually prove to be the most appropriate. The international construction industry has made many efforts to establish evaluation systems for the objective analysis of the environmental profile of a material during its lifespan, but currently there is no universally accepted system.

The choice of construction materials is widely predicated on issues of aesthetics and cost, but this is not socially responsible enough, given today’s concerns for building-lifecycle costs and environmental impact. When considering choices of materials as well as construction methods it is necessary to assess not only initial costs, but also the longevity of the material and impact of maintenance, replacement, and/or demolition. It is also necessary to build with an economic use of materials - to minimize loss and waste of materials on-site, and to maximize the potential for re-use or recycling following demolition.

The recycling of building products and construction components, when undertaken responsibly, can prevent further environmental damage. Recycling may be categorized into Re-use, Recycling, and Energy Recovery. Re-use is dependent upon the lifespan of the respective component and upon using the same component in generally the same manner. Efficient and direct re-use demands simple products, but in an age of extensive quality control, there are presently few mechanisms that permit easy application of re-use strategies. Designing with future disassembly in mind can promote both re-use and recycling. The suitability of a material for recycling is dependent upon its purity. Recycling composites is a notoriously complicated process, often requiring extreme methods and resulting in materials of inferior quality. Energy Recovery is, effectively, the production of energy during a material’s disposal by incineration. However, this procedure is not without problems, such as pollution and the subsequent treatment of residue.

Exposed thermal mass, such as concrete structural elements, mitigates the amplitude of indoor temperatures by storing heat during the day and by discharging it through night air flushing.

Hydronic piping within the concrete increases the thermal activation process, allowing heating or cooling during periods with free energy capacities, either naturally or as waste.
Glazed areas that supply daylight and give people a view to the outside are mandatory for occupied space and indoor quality.

Metallic coatings, inert gas fillings and integrated adaptive-shading devices enhance the performance of glazing in order to meet the challenges of daylight transmission, shading, insulation, noise attenuation and safety issues.

Lightweight membrane constructions, which may be comprised of multiple layers with dedicated functions, and foil cushion roofs are adaptive to different requirements, providing the ability to create tailor-made indoor environments.

Metallic finishes and coatings, which have low emissivity, reduce heat radiation emission and reflect heat (long wave radiation), and have the potential to influence the perception of temperatures.

Compounds containing phase-changing materials store energy at a constant temperature, which significantly increases the heat storage capacity of a wall or ceiling.

Clay regulates humidity levels because of its excellent absorption and desorption capabilities.

In certain environments water can be used to manipulate acoustic conditions (as background noise), thermal conditions (via evaporative cooling or dehumidification on a tempered water surface) and visual conditions (as a daylight reflector).

Very thin foils (< 70 micrometer) become “transparent” for noise, but still can carry all the surface properties of an emissive surface in respect to light and heat radiation.

INSTITUTE FOR FORESTRY AND NATURE RESEARCH
(re-named Alterra)
Wageningen, The Netherlands, 1998
Behnisch & Behnisch

The new laboratory and administration building for the Institute for Forestry and Nature Research - now “Alterra” - in Wageningen, The Netherlands, completed in 1998, was a European Union pilot project for ecological investigation into building. In a cooperative venture between the Ministry of Agriculture, Nature, and Fishery and the Ministry for Housing, Planning, and Environment, the project analyzed planning, construction, and subsequent occupation and followed the motto of “human and environmentally friendly building for the future”, in the spirit of the Rio de Janeiro Summit. The project provided for a maximum reduction of carbon dioxide emissions; furthermore, the building was to be constructed within a standard budget, to demonstrate that durable and sustainable building strategies can be realized without inordinate investment.

At first glance, the site made available - over-fertilized, nutrient-exhausted agricultural land north of the university town - seemed inappropriate for a project of this nature, offering exceptional challenges to experts involved in sustainable landscape design and other ecological aspects of the project. Instead of attempting a “re-naturalization” - in the sense of making a wild, or pseudo-natural landscape - a design strategy was developed that drew on the few remaining ecological qualities of the landscape to create a diverse new habitat with vegetation which could sustain insects and animal species and be hospitable to the
organization’s staff. Elements such as dry-stone walls, scattered tree groves and alleys, hedges, berms, ponds, swamps, and water channels were introduced, creating intricate, varied microclimates and restoring delicately balanced ecosystems.

The new building was designed not to dominate its rural setting, but to embrace the landscape, with all workplaces in direct contact with indoor and outdoor gardens. Two indoor gardens provide the focus for daily activities, and function as both test-beds and informal meeting areas for researchers; an integral component of the energy concept, they serve as the “lungs” of the building, improving the performance of the external envelope.

The design brief demanded that all materials be ecologically sound, and promote rational use of energy. The building is also highly flexible - capable of adapting to the changing requirements of the Institute and promoting self-expression and self-determination in occupant staff. (Certainly, the less dogmatic the architectural language employed, the easier it is to make additions, and the easier it is for occupants to claim parts of the building for themselves.) Formal unobtrusiveness is supported by the reduced palette of materials employed throughout.

The design’s deliberate aesthetic imperfection is an appeal to an unmediated, primarily sensory experience of architecture. The building has a maximum of pre-fabricated systems and elements, which have considerable environmental advantages over labor-intensive, handcrafted construction products: first, industrial products are subject to continual refinement, with a view to achieving the most favorable relationship between resources and performance; second, serial production is generally associated with optimum manufacturing conditions and minimum waste; third, market forces tend to ensure a good price-to-quality ratio.

For the interior winter gardens, Behnisch Architekten chose to use standard, mass-produced roofs for horticultural greenhouses, costing seventy-five percent less than custom-made roofs. The degree of standardization of the industrial roof components - together with ventilation openings and tailor-made, adjustable sun-shading devices - result in a near-optimal relationship between resource consumption and product performance. Traditionally, window frames consist of galvanized steel with a considerable proportion of extruded aluminum; dialogue and collaboration with a manufacturer led to the development of new, intricately folded, galvanized-steel profiles that do not require aluminum for this project. They are now offered as standard products by the manufacturer, and fall within the same price range as conventional frames.

The production, management, and harvesting of timber is a major field of research at the institute. Indigenous species are used throughout the building for facades, handrails, furniture, and flooring. Due to wood’s low thermal conductivity, it always feels warm to the touch; because it is generally treated with vegetable oils, it also provides a stimulus to our sense of smell. Due to these and other factors, early studies considered timber for the primary structure, however financial limitations led ultimately to an exposed in-situ concrete system. That design decision, though ideal in terms of thermal capacity, makes much higher demands on the environment. Timber was used for the façades. “Off-cuts,” normally treated as waste, were used in “glue-lam” elements to create visually appealing and highly tactile mullions and transoms, as well as a unified curtain-wall system. Detailing of existing, standard Dutch timber facades was improved upon, resulting in various production innovations, including insulation with recycled cotton products. Residual construction site materials were used to create the external garden areas, reducing transportation and disposal issues.
Evaluating the true efficiency of building materials is not a straightforward task. It requires efforts by the entire design team, particularly during the initial stages of the design process. Methodologies such as measuring specific efficiencies against physical performance can be applied to elements such as the structural frame. However, if we were to evaluate the strength of a structural member in relation to its own weight, then, we might select a completely different material than if we were to evaluate its strength in relation to its embodied energy, or indeed, its thermal capacity. Detailed studies of this nature were undertaken with the Dutch Government for the IBN Wageningen.

Energy Concept: Fraunhofer Institute for Building Physics, Stuttgart
material : maintenance

RAVENNA PUBLIC ADMINISTRATION OFFICES AND REGIONAL ENVIRONMENTAL PROTECTION AGENCY (ARPA)
RAVENNA, ITALY, 2007
Studio Behnisch . TRANSOLAR
A small palette of materials and reduced reliance upon mechanical systems contribute to a resulting reduction in transport requirements and mounting/maintenance costs while ensuring considerable ecological benefits. The roof of the atrium will be a light-weight steel structure with a sound-absorbing plasterboard finish. Preference is given to materials produced in an environment-friendly manner. Wood accounts for a large portion of the materials used, in particular local untreated timber which requires little maintenance over the building’s life span.
OZEANEUM
GERMAN OCEANOGRAPHIC MUSEUM
STRALSUND, GERMANY, 2008
Behnisch Architekten . Transsolar
The Baltic port of Stralsund is a Unesco World Heritage Site. The new Oceanographic Museum is to be built on the city’s historic waterfront. The proposed design is an open structure, literally flooded from all sides by both people and light, similar to the way that stones along a shoreline are periodically surrounded by tidal waters. From each very different approach the ever-changing visual relationship between these ‘stones’ lends the museum an unmistakable identity and makes a unique contribution towards Stralsund’s silhouette.
The layout of the museum allows visitors to take a spectacular journey of discovery, through and between the ‘stones’. Each ‘stone’ or building element covers a specific exhibition topic. Two accommodate exhibits from the North and Baltic Seas in large aquaria, while another accommodates the skeleton of a huge whale. Freely slung ribbons of steel, reminiscent of sails billowing in the wind, determine the shape of the respective ‘stones’. Appearing as thin as paper, light-weight and elegant, they are neither static nor rigid.
Large-scale steel plates, pre-formed in local wharfs, can be mounted without the need for extra sub-structure, taking full advantage of the know-how available from the local shipbuilding industry. In addition to reducing the amount of materials employed, local production has many advantages, including the employment of local companies, the reduction of environmental impact and most importantly the fostering of pride in the local community.
When the outdoor temperature is 35°C (95°F), the airport terminal is filled with heat producing electrical equipment, and vast numbers of people are passing through the building around the clock, the design of a comfortable indoor environment requires special solutions. In the 3.5-km-long concourses of Suvarnabhumi Airport in Bangkok, the solution was to reduce the roof sunlight transmission level to the minimum required for natural daylighting, and to apply a low-e coating on the inner side of a lightweight, triple layer membrane roof. Short wave radiation (light) and long wave radiation (heat) strongly impact user comfort. This is a particular concern in high rooms and spaces, where the air volume is thermally-stratified and amplified by solar radiation that is transmitted through a transluscent roof. In addition, heat in the upper layer of the space, and within the roof itself, emits long wave radiation downwards, which has negative impact on user comfort.

To meet thermal comfort criteria without massive energy imput, cooler air is provided only where it is needed. The transluscent roof reflects most of the sun’s energy, yet ensures sufficient daylight for the waiting areas. Additionally, large glass surfaces are made of a special type of glass that blocks the sun’s rays yet allows light to pass and offers views to the outside. Simultaneously, cool and dry air is introduced at floor level, where it then gradually rises as it warms up. The result is a "pool" of cool air at occupancy level that remains comfortable at all times. Also, the floor is equipped with a radiant cooling system that works as a heat sink.

Architect: MJTA Consortium with Murphy/Jahn, Chicago; USATAMS, Chicago; ACT, Bangkok, Thailand in cooperation with Werner Sobek Ingenieure, Stuttgart, Germany.

SUVARNABHUMI AIRPORT
BANGKOK, 2006
Transsolar: Membrane Concept / Low-e coating

Wenn die Außentemperatur bei 35°C liegt und das Flughafen Terminal mit wärmeabgebenden elektrischen Geräten ausgestattet ist und eine große Anzahl von Menschen sich rund um die Uhr durch das Gebäude bewegen, braucht es eine besondere Lösung für den Nutzerkomfort. In den 3,5 km langen Concourses des Suvarnabhumi Airport in Bangkok, liegt die Lösung darin die Sonneneinstrahlung auf die für die Tageslichtnutzung notwendige zu reduzieren und die Innenseite des dreilagigen Membrandachs mit einer Low-E Beschichtung auszustatten. Die kurzwellige Strahlung (Licht) und die langwellige Strahlung (Wärme) haben starken Einfluss auf das Wohlbefinden der Nutzer. Dies ist von besonderer Bedeutung in hohen Räumen mit transluzentem Dach, in der die thermischer Schichtung durch die Sonneneinstrahlung verstärkt wird. Die Wärme innerhalb des Daches und die erhitzte Luftschicht direkt unter der Dachfläche gibt langwellige Strahlung nach unten ab und hat negativen Einfluß auf das Komfortempfinden der Nutzer.

The new administrative centre for the BW Bank (formerly Landesgirokasse) is located in the center of Stuttgart. The building occupies an entire city block and houses facilities for more than 1,000 financial service staff. The appearance of a city monostructure is avoided through sensitive massing, humanizing rhythms of the facades and the introduction of a range of public amenities, including a cinema and restaurant, at ground level.

Haptic, simple materials are combined in a manner which improves building transparency and contributes to the public realm. Wooden handrails, upholstered seats and a glazed reception desk in the cinema, in addition to water features, a gold-plated wall element, and the use of glass and stone allow for a rich variety of haptic and sensual experiences, “softening” the rigid image associated with bank administration.

An individual (from Latin: ‘individuus’ = ‘indivisible’) is understood to be a single being in its entirety, together with all its peculiarities and characteristics; the overall structure of which in turn defines its individuality. The term thus defines the spatially and qualitatively unique singular being.

The term personality generally defines an individual who has managed to stand out from the masses.

In sociology, the term society refers to a large group of people living together. In contrast to community, society is understood to be a tool that helps one achieve one’s goals.

A group of individuals who have joined together is defined as a community, so long as this group is characterised by a degree of emotional cohesiveness and possesses a feeling of togetherness among its members.

A notable human trait is the capability to assemble in highly organised large groups. This trait is not unique to humans, as it can be seen, albeit in a much less complex form, in wolves, lions, or monkeys, for example. It is aided by the relatively complex human language, which facilitates a sophisticated division of labour.

Biological evolution has taken a back seat to the faster ‘cultural’ evolution, which is supported by human language. Through their intellectual or cultural ‘skills’, humans are capable of reacting much better and faster to changing environmental conditions than any other being.

Human beings are aware of their own self and their own mortality. The capacity to foresee one’s own death leads humans to contemplate the meaning of life and speculate as to whether there is a life after death.

the human being in numbers
surface: 1.8 - 2.0 m2 (2.2 - 2.4 yd2)
average weight: 60 - 80 kg (132 - 176 lb)
average height: 175 cm (5 ft 9 in)
10 to 100 trillion cells, 1 million new cells per hour
average lifespan (worldwide): 73 years

60 - 70% water
0.6% carbohydrates
15% protein
10% fat
5% mineral salts
206 bones, weight 10 kg (22 lb)
32 teeth
639 muscles
5 - 7 litres of blood (4.4 - 6.2 quarts)
100 billion nerve cells
brain mass 1350 - 1500 g (48 - 53 oz)
humans can only store 5 - 7 items (digits) in short term memory
during a lifetime, one meets 2000 people by name, 150 become friends for some time

the heart beats 70 times per minute,
37 million times a year
without food, a human can survive for up to 40 days,
without drinking 3 - 6 days

16 breaths per minute
25 years: sleeping
12 years: talking
12 years: watching TV
8 years: working
3.5 years: eating
2 years: talking on the telephone
2 years: travelling in a vehicle
6 months: standing in traffic jams
6 months: sitting on the toilet
2 weeks: kissing

human scale

Understanding human behavior starts with understanding how people notice and respond to their immediate environments. Environmental psychology examines the interrelationship between environments and human behavior. When addressing problems involving human-environment interactions, whether global or local, one must have as a starting point a model of human nature predicting the conditions under which occupants will behave both decently and creatively.

The design of each of our buildings is, from the competition onwards, very much focused on the activities of the future occupants. Given that people will often spend a significant portion of their life inside them, it is logical that the series of designed spaces should be as user-friendly and as “human” as possible.
The issue of spatial scale provides a way to discuss relative lengths, areas, distances, and sizes. A microclimate is one occurring locally, such as in a mountain valley or near a lake, whereas a megatrend is one involving the earth as a whole. People tend to seek out places where they feel comfortable, competent, and confident; where they can make sense of the environment, while also being engaged with it. Research has expanded the notion of preference to include coherence (a sense that things in the environment hang together) and legibility (the inference that one can explore an environment without becoming lost or overwhelmed). For people to be involved with and want to explore an environment requires one with both complexity (enough variety to make it worth learning about) and mystery (the promise of being able to learn more).

Human beings are not normative, for we celebrate our individuality. We all perceive our environment quite differently, and we have different interests and diverse requirements. As such, we, as architects and engineers, are charged with creating appropriate environments; environments that acknowledge and promote diversity. It follows that the buildings in them cannot be prescriptive and should certainly be performative.

A modern fact that is currently underestimated, but rapidly gaining in importance, is that ever fewer jobs are being created in the developed world. And available jobs require ever-increasing qualifications, leading to greater competition and related recruitment and staff-retention difficulties. Worker motivation can only be in part financial; the so-called “New Workforce” expects high quality workplaces in environments, which correspond to their own values, politics, and ideals. It is therefore reasonable to assume that in future there will be increasing pressure on both building owners and architects to plan facilities people can identify with; buildings that allow the individual to customize their own workplaces, to individually control their environments - their microclimates, providing them with contact with the exterior world. We believe that this fosters individual responsibility, as well as a stronger affinity with and acceptance of one’s surroundings.

human scale

Dense cities are the future of a sustainable living.

Each building site has its own global climate, microclimate, specific boundaries and local resources which must be explored.

For every place on this planet, the temperature 10 m (33 feet) below the surface of the soil is roughly equal to the annual mean temperature of the outside air.

According to German building regulations, a permanent place of work requires direct access to fresh air and natural light; therefore, the maximum depth of a room is limited to about ten meters for open space use.

Natural daylight and fresh air supply in a single side access case are limited to around 2.5 times of the space height.

If air movement in a space is limited to about 36 m³/h/person (1,271 ft³/h/person) during winter months, the production of humidity by a person, which is about 60 g/h (2 oz/h), will compensate for low humidity levels, and a 35% humidity level will be maintained, which falls within the lower comfort level.
New building blocks on Odaiba Island in Tokyo Bay have reduced the natural city ventilation of Tokyo, increasing summer temperatures in the city by 4° C or 7° F.

Correctly positioned high-rise buildings can support city ventilation as they induce upstream airflows.

The reuse of a building through renovation, or at least the reuse of its construction elements, is more sustainable than recycling, which mostly entails down cycling, or reuse on a lower function level.

RIVERPARC DEVELOPMENT
Pittsburgh, PA, USA, 2007 - 2015
Behnisch Architekten . Transsolar

Historically, there has been only a small residential population in the downtown core of Pittsburgh. With the demise of industry and continued spread of the suburbs, Pittsburgh’s downtown core continues to suffer. The Pittsburgh Cultural Trust aims to rectify the situation by encouraging residents to move back to the city with a new development called RiverParc.

RiverParc is an ensemble of flexible, mixed-use buildings on six acres, commissioned through an invitational design competition in 2006. With seven hundred residential units offering varied forms of urban living and mixed uses of retail, restaurants, leisure facilities, hotel, and convention facilities, the development will contribute to the future life of the city and offer the kind of diversity that will ensure a healthy, vigorous economy.

For RiverParc to become a lively, integral part of Pittsburgh, it is important to understand and respond to the demands of various potential user groups. As is true of many successful city districts, the RiverParc Development will have its own unique character. Each residential block within it will have a distinct identity, which respects human scale, provides individual addresses, and contributes to a much improved public realm.

A vibrant community is dependent upon the individual residents who comprise it. Design strategies must, therefore, emphasize varied needs - of residents, workers, and tourists alike. An environment in which pedestrian accessibility is a priority allows for spaces to thrive through intensive use, of intricately linked, efficient networks. Within RiverParc, unique neighbourhoods are expressed as “urban living rooms” or social intersections, which offer a wide range of opportunities for people of all ages to enjoy downtown living and which encourage residents to linger, meet, and interact.

A simple street hierarchy is proposed within the orthogonal grid structure of the city. Individual blocks are designed take advantage of their specific placement within the overall development. Buildings incorporate abundant ground-floor amenities, so that public streets and squares invite exchange and maximize opportunities for neighbors to sit and socialize, take ownership of, and animate the public sphere. Contributing to this rich interface is a mix of retail, studio, and live-work spaces, townhouses, and lobby spaces for apartment buildings.

Basic orientation strategies - such as locating public spaces and recreational areas on the southern, sunny sides of residential streets - further encourage urban life. Apartment layouts and narrow block depths allow for all units to be flooded with daylight. Ranging in height between three to five (townhouse) and thirty (apartment tower) stories, all residential units
have views in at least two directions. RiverParc’s public space plan is developed to provide a structure of diverse, distinct areas with varying degrees of privacy. Since one square meter of high-quality, recreational space outside the home as in a small backyard, can be more valuable than ten square meters of recreational space half a kilometer away, private green spaces are included with the residential units and houses and woven into rooftops and balconies, providing a three-dimensional, green carpet throughout the development.

RiverParc provides an exceptional opportunity to address collective social and environmental issues in a densely urban context. Any sustainable approach to environmental design begins with attention to existing conditions, ascertaining the resources at hand; integrating the old and the new, and, most importantly, reconsidering and tapping potential offered by existing structures, rather than starting completely from scratch.

In Pittsburgh, examples of re-use abound: the McNally Building has become a fashionable, dynamic hotel; the Union Building, a new multi-use performing arts center. A number of existing buildings - both the historically protected and the functional (e.g., the parking structures) - will be integrated into RiverParc. The embedded energy in such structures is considerable and must be exploited in any form of sustainable development. Ground-floor facades will be altered to create interior niches and lively exteriors, and rooftscapes will provide further public amenities.

As in many cities, the river in Pittsburgh is a much under-utilized resource; the RiverParc project appreciates the qualities it offers to downtown living. The highway, which currently separates the theater district from the Allegheny River, will therefore be sunk below ground and roofed over with a waterfront park, reclaiming the river for the community.

Client:
Pittsburgh Cultural trust
Developer:
Concord Eastridge
Architect & Masterplanner:
Behnisch Architekten with architectsAlliance, Toronto, Canada
Gehl architects, Copenhagen, Denmark
WTW architects Pittsburgh, USA
Environmental Concept:
Transsolar Climate Engineering
Competition: 2006
Ground-breaking: scheduled for mid-2007

human scale: work process

PITTSBURGH PUBLIC LIFE ANALYSIS
The purpose of the public life part of the study is to examine how the urban spaces are used. It provides information on where people walk and stay either as part of their daily activities or for recreational purposes. It also addresses the places where people sit, stand or carry out various stationary activities in the city. This study leads to a comprehensive understanding of existing relationships, which helps to inform future decisions as to which should be kept, modified or strengthened.
The public life analysis diagram (right) shows transit and movement patterns (A) along with areas of passive activity (B). Pedestrian activities were mapped in Pittsburgh on average summer and winter days. This “activity mapping” exercise gave a snapshot of the activities which occur in specific public spaces at given times.

A-Recordings: Transit/Movement Patterns. Pedestrian counts on an average summer or winter day, focusing on three core times of day - going to work/lunch break/going to the theatre.

B-Recordings: Recording of activities and use of public space on an average summer or winter day. Activity mapping essentially is a snap shot of “stationary activities” occurring in carefully chosen public spaces at a given time. Activities recorded include but are not limited to sitting on benches, physical activities such as children playing, and commercial activity such as buskers or sidewalk merchants.

A high number of pedestrians walking in the city does not necessarily indicate a high level of quality. However, a high number of people choosing to spend time in the city is a good indicator of a lively, high quality urban environment.

SUSTAINABLE DESIGN
For building design to embody the ethic of sustainable development, it should enable reduced resource consumption while fostering an environmental awareness on the part of building occupants and society at large.

To achieve this, the designer must be attentive to the following measures, not only in respect to technical performance, but in the ways in which they raise awareness:

1. Energy efficiency
2. Water conservation
3. Quality of the built outdoor environment
4. Quality of the built indoor environment
5. Flexibility for a future change in use

The RiverParc Development is an exceptional opportunity to contend with our collective social and environmental consciousness within a dense urban context. With demand for natural resources steadily increasing, the need for sustainable design has never been more urgent. As sustainable development becomes more common, the RiverParc Development will serve as an example of best practice. It presents a rare and critical opportunity to influence large scale development with a visionary social and environmental ethic.

CLIMATIC FACTORS
A sustainable approach to environmental design requires attention to existing conditions, along with a thorough understanding of eco-systems and natural processes. The most challenging climatic problems can often be solved through passive means. Specific site conditions are analyzed to determine which possible sustainable solutions are most pragmatic and cost effective.

An analysis of the local weather conditions in Pittsburgh indicates:
- a continental climate pattern with cold winters and hot summers, and an annual temperature swing of almost 100°F,
- a 2 to 3 month summer period with fairly high humidity,
- outdoor temperatures that make natural ventilation feasible for more than half the year,
- a fairly high annual solar radiation (higher than most European cities, e.g. Milan),
- prevailing winds primarily from the west, and a high average wind speed (~ 9 mph).

ENERGY EFFICIENCY
The primary goal of the energy concept is to achieve optimal environmental conditions with minimized energy demand by:
- supplying as much of the demand as possible through passive measures,
- supplying the remaining demands with high-performance, building-integrated systems,
- and sourcing those systems as much as possible with renewable sources.

Passive measures include:
- highly insulated and tightly sealed facades with operable windows,
- optimized daylight utilization through building form, glazing, and light-redirecting elements,
- buffer zones (such as wintergardens) that harvest solar energy and allow natural ventilation under cold and/or windy conditions,
- and thorough solar shading.

High-performance, building-integrated systems include:
- slab-embedded radiant heating and cooling,
- mechanical ventilation with exhaust air heat recovery,
- and 100% outdoor air displacement ventilation.

Natural sources include:
- natural ventilation for fresh air and/or cooling,
- geothermal heating and cooling supply, with a reversible heat pump connected to the underground natural aquifer,
- facade integrated photovoltaics that capture solar energy,
- and wind power (noiseless longitudinal axis wind turbines).

WATER CONSERVATION
Measures to minimize water consumption include:
- grey water reuse,
- irrigation-free landscaping and green roofs,
- omission of cooling tower water use through use of geothermal system,
- waterless, or low-flow, sanitary fixtures,
- rain water for outdoor water features,
- and grey/rain water use for remaining irrigation purposes.

QUALITY OF THE BUILT OUTDOOR ENVIRONMENT
The aim of the concept is to provide the most comfortable outdoor climate possible during all weather conditions by utilizing 100% passive means. In winter, this entails shelter from the wind and exposure to the sun. Building mass will be structured to buffer the cold westerly winds, in addition to stepping back from north-south extending alleys (lanes) to allow ample sunlight at ground level in the middle of the day.
In summer, cool breezes, shading, water features and ample greenery cool and soften the human-scale climate, while attention to building forms and materials minimize the larger urban heat island effect. Additionally, the use of a geothermal system will omit cooling towers, reducing noise levels.

QUALITY OF THE BUILT INDOOR ENVIRONMENT
It is the purpose of the buildings to provide a vital human environment. To achieve this goal, certain technical qualities are essential:
- level and brightness distribution of natural light,
- thermal comfort,
- indoor air quality,
- and acoustic comfort.

Further, in order to satisfy peoples’ needs it is important to give them individual control over their own comfort. For instance, a shading device controls the quality of daylight and solar radiation, similarly an operable window controls thermal comfort, air quality and acoustical conditions.

Daylighting
- Retail spaces may not require much daylight, yet shoppers appreciate a naturally-lit environment when they circulate between stores.
- An office environment requires plenty of glare-free daylight. This suggests north-facing offices, light-redirection systems and glare control devices.
- A residential environment values direct sunlight, yet to avoid extensive cooling loads, it is important to control solar gains in summer for all types of space.

Thermal comfort
- Radiant heating and cooling is highly energy efficient and comfortable. It allows for the use of highly efficient ventilation systems with superior air quality.
- Radiant heating and cooling reduces drafts and the blast-furnace-effect of moving between indoor and extreme outdoor conditions
- The blast-furnace effect is also overcome by the use of semi-conditioned buffer zones.
- Buffer zones exist between the indoor and outdoor environments. They offer strong technical advantages for energy efficiency as well.
- User control: Occupants not only tolerate, but actually prefer temperatures closer to outdoor temperatures in buildings where they have control over the thermal environment.

Indoor air quality
- Low velocity displacement ventilation using 100% outside air provides superior air quality. Cool, fresh supply air stays at low levels, in the breathing zone, while warmer stale air collects at ceiling level, where it is exhausted.
- Operable windows allow natural ventilation, both for cooling and hygienic purposes.
- Low-emission and dust-free materials are selected to minimize indoor air pollution.

Acoustical comfort
- Interior surfaces are designed for sound absorption, without compromising the potential of the exposed slab for radiant heating and cooling.
- Buffer zones are also of special value for acoustically isolating interior from exterior.

FLEXIBILITY FOR A FURTHER CHANGE IN USE
The building should last at least a century to make the most of the natural resources expended in construction. Therefore, it must be flexible in order to adapt to future use. Considerations include:
- ample shaft space and accessibility to allow for future technical renovations,
- layout of partitions and load bearing walls for maximum flexibility,
- and generous floor to floor height to allow for a variety of future uses.

THERMALLY ACTIVE SLAB
Thermo-active slabs combine the thermal lag effect of exposed thermal mass with radiant heating and cooling systems. The thermal lag effect is useful in offsetting peak cooling loads so that cooling equipment size may be reduced, and operating efficiency improved. The exposed slab surface influences operative temperature through radiant exchange with the occupants. The surface of the slab, therefore, must not be covered (for example, with a suspended ceiling).

The thermal mass is activated by integrated pipes supplied by cool or warm water. The power of slab ceiling cooling systems can reach up to 35 W/m2. The construction of such a thermo-active ceiling is shown below, including the concrete ceiling, reinforcement and integrated pipes. The pipes are made of cross-linked polyethylene (PeX) – a material with a very low air diffusion rate. The pipes are fixed to the reinforcement before concrete is poured.

The greatest advantage of a thermo-active slab is the relatively high temperature of the circulating water for cooling and low temperature for heating. This allows the use of natural energy sources, such as heat to or from ground-coupled heat exchangers.
The main attraction of the residential tower is the fantastic view to downtown. While a lively and urbane residential community appears to be developing, the reality of the site today is that industrial traffic, warehouses and manufacturing dominate the experience of the place.

Each element of the complex makes an individual statement while being mindful of the other parts.

The building will capture the atmosphere and materiality within the context of the location paired with the attributes of contemporary living. It is a modern application of the loft concept and leaves exposed concrete ceilings, electrical and mechanical ductwork, and other industrial finishes exposed. The design establishes economy through inventive floor layouts which respond to the demand for minimal corridors.

The building’s exterior is an expression of the variety that is developed from the inside out (concrete structure, unit types, access pattern, etc.) The silhouette changes constantly as you move around concrete, glass and metal facades. The play of sun and shadow will have a vivid effect on the building’s envelope.
The philosophy of sustainability recommends the consideration of the whole life cost of a building, both in terms of economics and environmental impact. It follows that in the case of civic buildings such as a police station with a design life of 60 years, the cost of ownership and operation actually exceeds the cost of construction. Buildings can only be truly sustainable if they suit their purpose and are efficient to operate, otherwise they consume unnecessary resources, are a burden to the owners and risk premature replacement.

Although its appearance is not particularly striking the existing 135,000 ft², two storey building is structurally intact, though clearly outdated in terms of the quality of its working environment and the level of technical installation. Initial analysis immediately revealed certain spatial, if under-utilized, qualities; the central courtyard being the prime example.

The retention of the existing superstructure, stripped of the superfluous, enables the construction works to be accelerated avoiding phases of full scale demolition ground works and structure.

The available budget can be focused on developing a flexible, and dynamic civic amenity which makes much reduced demands on resources. The introduction of a central internal garden plays an important role in both the appearance of the police station and, as an integral part of the buildings new energy concept, in the quality of the working environment.
DESIGN SCHOOL ZOLLVEREIN
ESSEN, GERMANY, 2006
Transsolar: Energy Concept
As a base for the integrated energy and comfort concept for any project, we research all local site and boundary conditions. This includes the macro- and micro-climates, noise and air quality, soil conditions and available energy sources. The climate in Essen is very moderate, seldom reaching temperatures below freezing and rarely exceeding 30°C (86°F).
A local coalmine, Zeche Zollverein, was closed 15 years ago, but the mine shafts and tunnels, down to a depth of 1000 m, are still kept accessible for possible future use. As a consequence, DSK, the public owner of the mines, has to permanently pump the ground water from these depths in order to keep the mines from flooding. This water, which is partially contaminated with heavy metals and minerals, has a consistent temperature of 29°C (84°F). It is dumped into the Emsch river at a rate of 600 m³/h. The water is a CO2 free energy source that is utilized for the conditioning of the building, allowing to build a monolithic concrete wall, with an active insulation layer.
Architects: SANAA - Sejima Nishizawa, Tokyo, Japan; Heinrich Böll, Essen, Germany