

building physics

ARUP

Building physics

Building physics is the application of the principles of physics to improve the built environment.

Arup's range of advanced analytical tools, skills and techniques allows us to work with clients to design buildings that are comfortable to occupy, easy to use and light in their environmental impact.



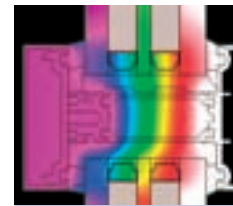
Energy modelling



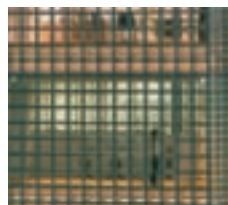
Dynamic thermal analysis



Daylighting, lighting and shading



Condensation modelling



Façade performance



Climate change impact assessments



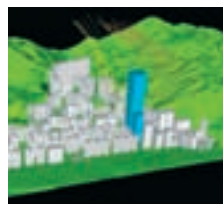
Comfort prediction



Airflow



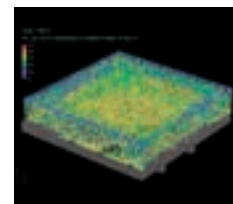
Microclimate design



External windflow



Green building assessment



Optimisation

Performance and value

Using advanced methods of analysis in combination with our design creativity, Arup helps clients achieve buildings that respond well to the climatic conditions of their chosen site, function efficiently, are pleasant to occupy and hence, economic to run.

Building physics techniques give us an in-depth understanding of the environment and physical properties of materials that affect buildings. By modelling current and future performance we are able to address the challenges to building designs posed by factors such as internal and external airflow, condensation, heating and ventilation, energy use and artificial/natural lighting and shading.

By using building physics, Arup delivers design solutions that ensure buildings are:

- sustainable and energy-efficient
- subject to reduced risk
- more usable
- more comfortable.

Sustainable and energy-efficient

Arup aims to create energy-efficient buildings that help reduce costs for both clients and end users, and consume fewer resources. In response to global drivers and regional legislation, we continue to give high priority to low-energy design and energy efficiency.

With world-leading expertise in new materials, thermal and energy modelling of buildings and the impacts of climate change, Arup is at the forefront of designing sustainable, resource-efficient buildings which will be future-resilient.

By using advanced building physics skills, our designers can advise clients on the costs and benefits of incorporating the most advanced design features.

Beddington Zero Energy Development, UK

case study

1



BedZED is a zero energy development, producing at least as much energy as it consumes. The project is an urban village incorporating housing units, work/office space and community accommodation. The village benefits from sustainable material sourcing, a renewable energy supply and a total water strategy. As the mechanical and electrical designers for this project, we were instrumental in delivering the client's zero energy aspirations.

Workspace placed in the shade zone of housing provides additional revenue to fund the ultra low energy specification. "Skygardens" placed on the workspace roof surfaces provide residents with access to green open space. Integral conservatories harvest winter sunlight and become open balconies in the summer.

All buildings have a high thermal mass, reducing the need for central heating, and all the dwellings face south to maximise opportunity for passive solar energy. The development is powered by a combined heat and power (CHP) plant (110kW), running on tree surgery waste, that will result in overall net zero CO₂ emissions. Willow coppicing on the adjacent landfill site will eventually provide fuel for the CHP plant.

The village's water consumption is reduced by the use of low-flush WCs and spray taps. Rainwater is collected from the uppermost parts of roofs and is stored in tanks below ground for non-potable use in dwellings and for irrigating the landscape.

Hangzhou Xihu Tiandi, China

case study 2



Xihu Tiandi in Hangzhou is a multi-use, leisure and lifestyle complex built around historical buildings, situated next to China's famed West Lake. Xihu Tiandi retains the serene beauty of ancient Hangzhou while helping to usher the city into a sustainable future.

We were employed as the building services consultants to provide advice on the sustainable strategy and system design. The buildings use a variety of techniques including ground heat storage,

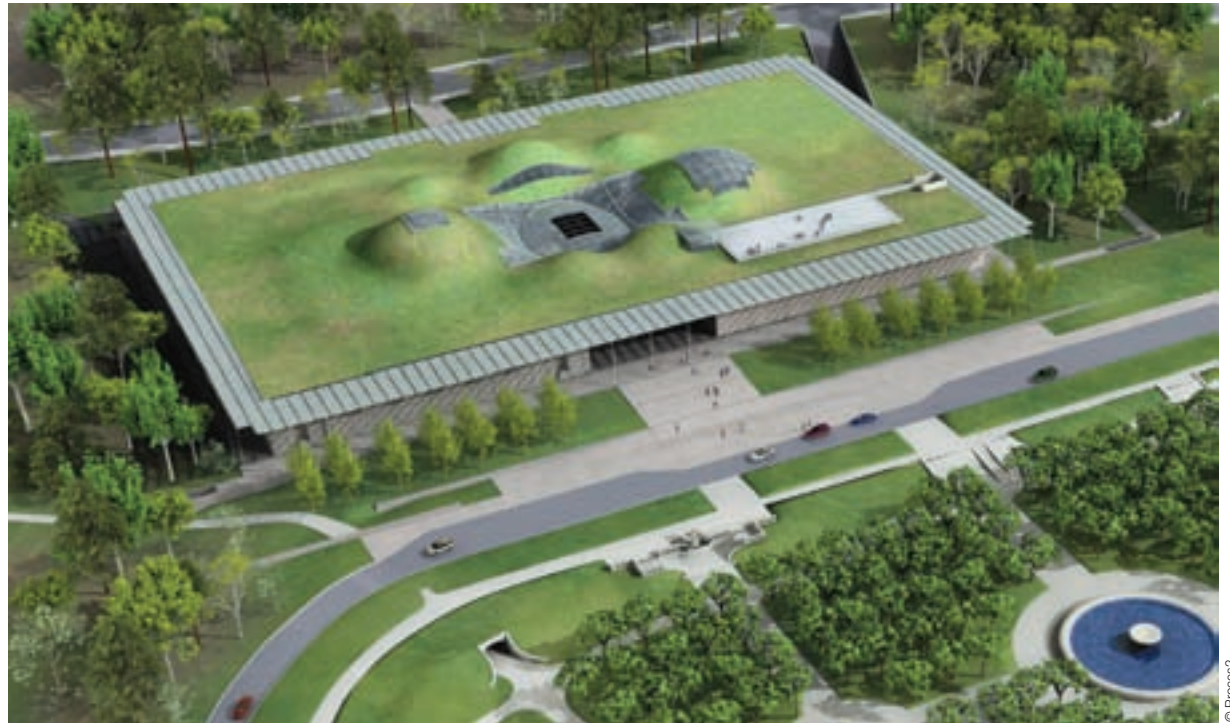
natural ventilation, and renewable energy sources to improve their performance. The development also includes green roofs, landscaping and planted courtyards.

We carried out the LEED® Assessment for the development, which includes sustainable analysis and extensive thermal modelling. As a result, the project has achieved the LEED-CS Platinum Pre-certification. This is the first LEED-CS Platinum Pre-certification not only in China, but in the world.

California Academy of Sciences, USA

case study

3



We provided the total engineering design for the California Academy of Sciences, which includes an aquarium, planetarium, natural history exhibits, research laboratories and classrooms. Its 1ha living, planted roof is blanketed with 1.7M native Californian plants.

The living roof reduces storm water run off by at least half, compared to a conventional roof, totalling as much as 7.5M litres annually. The aquarium will use salt water piped directly from the Pacific Ocean, which will be purified and recycled. The roof has 60 000 photovoltaic (PV) cells to generate electricity and solar panels to produce hot water.

Overall, the Academy should use 30% less energy than specified by federal requirements.

At least 90% of regularly occupied space benefits from natural light, reducing energy use and excess heat from electric lighting. Light controls will respond automatically to exterior light levels. A wind-driven natural ventilation system was developed for the building using computer simulation.

The building employs recycled and renewable materials, such as sustainably harvested wood. All demolition material from the old facility has been recycled, including 9000 tons of concrete, 12 000 tons of metal, and 120 tons of green waste.

Reduced risk

Management of risk is a fundamental element of every client brief, however control of risk can frequently be a constraint on building design. The potential for better performance through innovation may be sacrificed if the level of risk is too high.

Arup delivers value in this area on two counts. Our designers are amongst the most creative and innovative in the industry; and we have world-leading analytical and modelling skills that allow us to simulate accurately the basic physical processes at work behind a design.

Through the creation and analysis of precise computer models of performance, our teams can make innovative design decisions with confidence, substantially reducing risk for our clients.

Złote Tarasy, Poland

case study

1



The centrepiece of the Złote Tarasy development is a large shopping mall, consisting of several terraces of shops covered with a large transparent dome-shaped roof. The skin of the roof is required to cope with temperatures as low as -20°C in winter, but also prevent summer overheating.

Part of our role in the project was to provide building physics design advice regarding the roof. A number of alternative solutions were analysed, a crucial factor being the risk of condensation on the inside of the roof during busy periods in cold, wet weather. The risk is increased by the presence of fountains and other water features within the shopping dome.

We used a three-dimensional model to predict temperature, moisture concentration and airflow in order to determine under what conditions and at what time condensation would occur. This allowed the client and architect to decide with confidence the minimum insulation required in each section of the roof, thereby reducing its overall cost.

Eden Project, UK

case study 2



© Perry Hooper at Grimshaw

The Eden Project, one of the world's biggest ever controlled-environment projects, was built on 30ha of reclaimed land in Cornwall. The site contained a 14ha, 70m deep, south-facing disused claypit. In and around this were built 2.2ha of linked, climate-controlled transparent capsules (biomes) set in a designed landscape.

Botanists, architects and engineers worked together to create facilities large enough to enable the exhibition and study of a range of plants on a scale unprecedented anywhere in the world. Our principal role was as environmental engineer for the biomes, which range in span from 10m up to 100m, with clear internal heights of up to 45m.

The design takes advantage of the rock face at the back of the biomes to store the daytime heat from the sun, releasing it into the space at night. Additional heat is provided by a number of large warm air jets located at the perimeter. To minimise the number and the cost of these, a computer model of the entire space was used to predict the mixing and reach of the air jets, and how to keep the temperature uniform throughout.

Our predictions for both heating and natural ventilation significantly reduced the capital cost of the project.

National Swimming Centre, China

case study

3



The National Swimming Centre, also known as the Water Cube, is an iconic structure designed for the 2008 Beijing Olympics. The US \$100M centre contains a number of pools for competition and recreation, along with seating and facilities for 17 000 spectators.

The structural design is based on the arrangement of organic cells and the natural formation of soap bubbles. It is a solution that appears random but is repetitive and highly buildable. We delivered a comprehensive analysis of temperature and condensation to ensure acceptable performance of the building's skin throughout the year.

Twenty percent of the solar energy trapped within the building will heat the pools and the interior – the equivalent of covering the roof with PV cells. Covered in 100 000m² ethyl tetra fluoro ethylene (ETFE) bubble cladding, this tough recyclable material turns the building into an insulated greenhouse.

Our ability to analyse and predict the performance of the built environment gave the owner confidence in the risk levels of this new skin technology.

Greater usability

In an increasingly crowded world, the optimum use of space both inside and outside buildings is vital.

By applying expertise in designing with building physics, Arup can greatly enhance the amenity of spaces and make radical design improvements. These gains lead to a potential increase in lettable area and financial returns to the client.

Using building physics we aim to harness the wind, the sun and natural daylight. Modifying these natural resources via the design of architecture, landscape and other manmade interventions, we can create more usable spaces for work and leisure.

Sony Center, Germany

case study

1



© Ralph Richter/architecturphoto

The glass, fabric and steel roof spanning the central courtyard at the Sony Center in Berlin forms the architectural focus of the development. It also acts as a climate moderator for both the open space it shelters and the surrounding buildings.

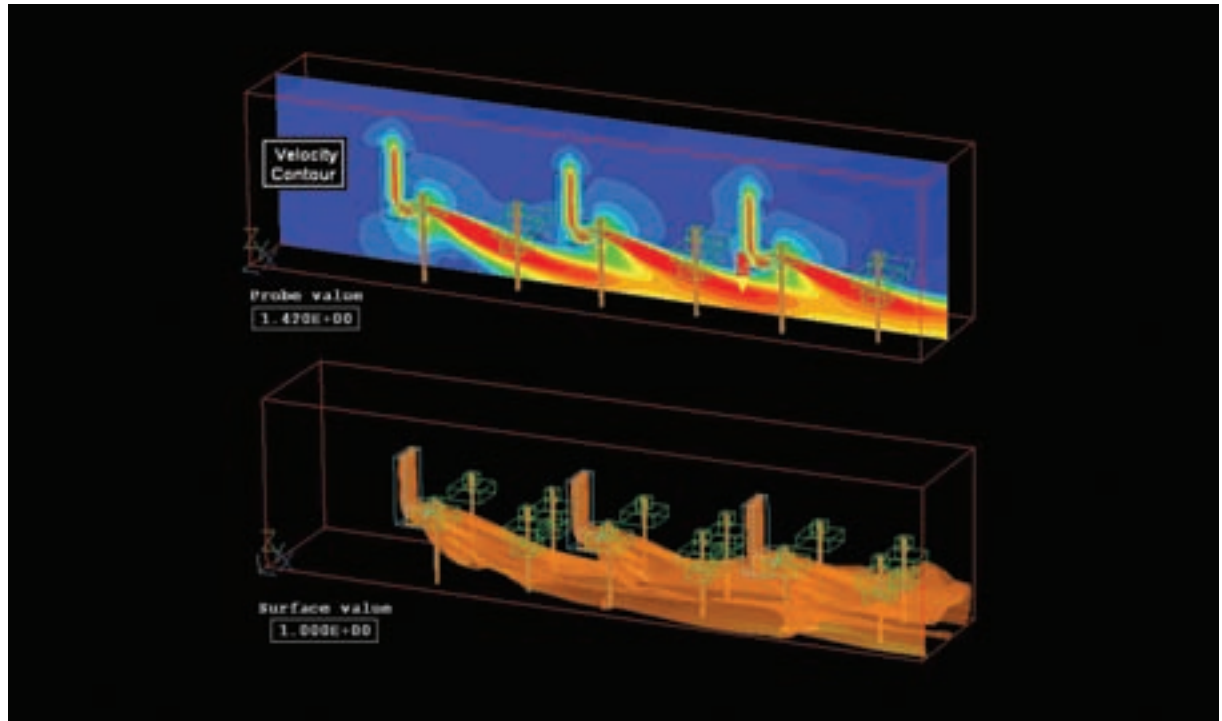
Economic justification for the roof was provided by an integrated study making use of dynamic thermal simulation, computational fluid dynamics (CFD) modelling, wind tunnel tests, daylight modelling and statistical weather analysis to evaluate its environmental impact.

Our study showed that the enhanced comfort conditions created in the courtyard by the roof would allow the space to be significantly more usable for outdoor cafés and media events, when compared to an equivalent uncovered space.

Analysis also demonstrated that the roof would ease the thermal, shading and daylight control constraints on the surrounding building façades, thereby allowing for a more transparent wall design while maintaining good energy performance.

Clarke Quay, Singapore

case study 2



Clarke Quay is a 23 000m² riverside site combining restaurants, shops and entertainment venues. We designed environmental control strategies for the precinct which are a benchmark in environmental design for Singapore.

Using canopies above the existing streetscape and colourful air jets to create breezes, the area has been reconfigured to create a more comfortable environment for shoppers in the hot and humid tropical climate. The canopy creates a pleasant dappled shade and visitors can enjoy the area without being exposed to rain or direct sun.

The light and durable ETFE roof is both resilient and recyclable.

A range of innovative modelling techniques were developed to finalise the structure of the canopy. A supplementary mechanical fan system was designed to mimic the natural cooling effect of wind in tropical environments. Specialised air modelling techniques were used to tweak the air distribution design for optimal occupant comfort, and to maintain air movement when natural wind speed is low.

Substantially improved usability of the site has been achieved, meeting the client's desire to increase commercial and leisure activity in the village. By introducing innovative thermal comfort strategies into the canopy design, we simplified the design without any additional cost to the client.

Valencia Institute of Modern Art (IVAM), Spain

case study

3



This project created new space by surrounding the existing IVAM museum with a fully perforated enclosure. The spaces between the enclosure and the museum, including the roof space, form a modified microclimate that can be used for circulation, cafés, sculpture displays, educational functions and concerts.

We conducted a detailed analysis of wind, sun direction and temperature to design the perforation and thickness of the skin on each face of the enclosure. Analysing a full year's weather data showed that the microclimate inside the enclosure was considerably cooler than outside during the

hot summer months, making the space more usable. Conversely, the space between the skin and the existing building did not benefit as much from the warming effect of the winter sun. We used detailed radiance, daylight and sunlight models to predict how the space would look under different sun conditions.

Our analysis was also used to modify the perforation pattern on certain critical points of the enclosure to prevent shadow spots interfering with the art display.

Greater comfort

Comfort is a key measure of the success of building design. Delivering greater comfort for users leads to decreased absenteeism, increased occupancy and fewer complaints.

Arup has the skills and experience to improve end user perception and business performance through effective design. We understand the impacts that design changes can have both on the comfort of a building's occupants and on the relationship between comfort and productivity.

In designing for greater comfort, Arup relies on a holistic approach. Our teams bring together an understanding of both psychological elements and environmental factors such as air movement and temperature, lighting and acoustics.

BT Brentwood, UK

case study

1



© Richard Bryant/Atcaid

British Telecom (BT) asked us to help provide them with a comfortable, energy-efficient environment to stimulate and motivate the building's users. We brought an holistic approach to the design of the office environment, using a range of building physics design and analysis skills.

The building has now been in operation for several years and feedback from occupants shows it to be much liked. They have become accustomed to the column-mounted coloured light indicators informing them whether it is a "windows open" or an "artificial environment" day.

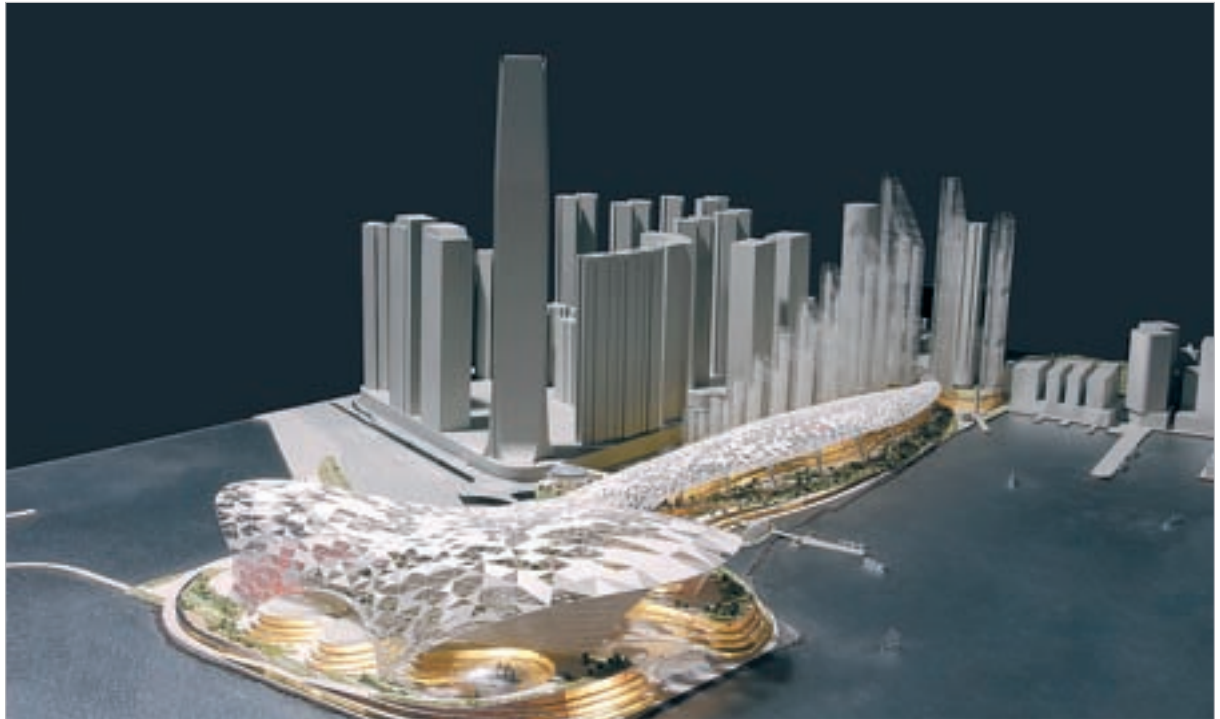
Unlike in many "naturally ventilated" buildings, people do open the windows. The sliding sash windows have been successful, making it possible to ventilate deep into the building, over the heads of the staff. The external skin is effective in reducing wind pressures, so that paper is not blown off the desks, yet allows good ventilation.

BT recently released the findings of a PROBE construction survey, the results of which are outstanding. For the indices on comfort, satisfaction, and summary the building was in the top 2.5% of buildings measured in similar studies. Occupants perceived an increase of 8% in productivity due to the building.

West Kowloon Cultural District, Hong Kong

case study

2



The Great Canopy is the most distinctive feature of the West Kowloon Cultural District development. The design of this unique sheltered environment involved careful selection of cladding materials, which consist of transparent, translucent or opaque modules, open trellis and louvres. The location of these different elements improves the microclimate of the space beneath so that it is more comfortable for various cultural and recreational activities.

As a climate modifier, the canopy shelters open piazzas, arts and cultural facilities and other areas on rainy days. It also filters excess sunlight, and impedes gusty wind entering the internal spaces or transforms it into a breeze.

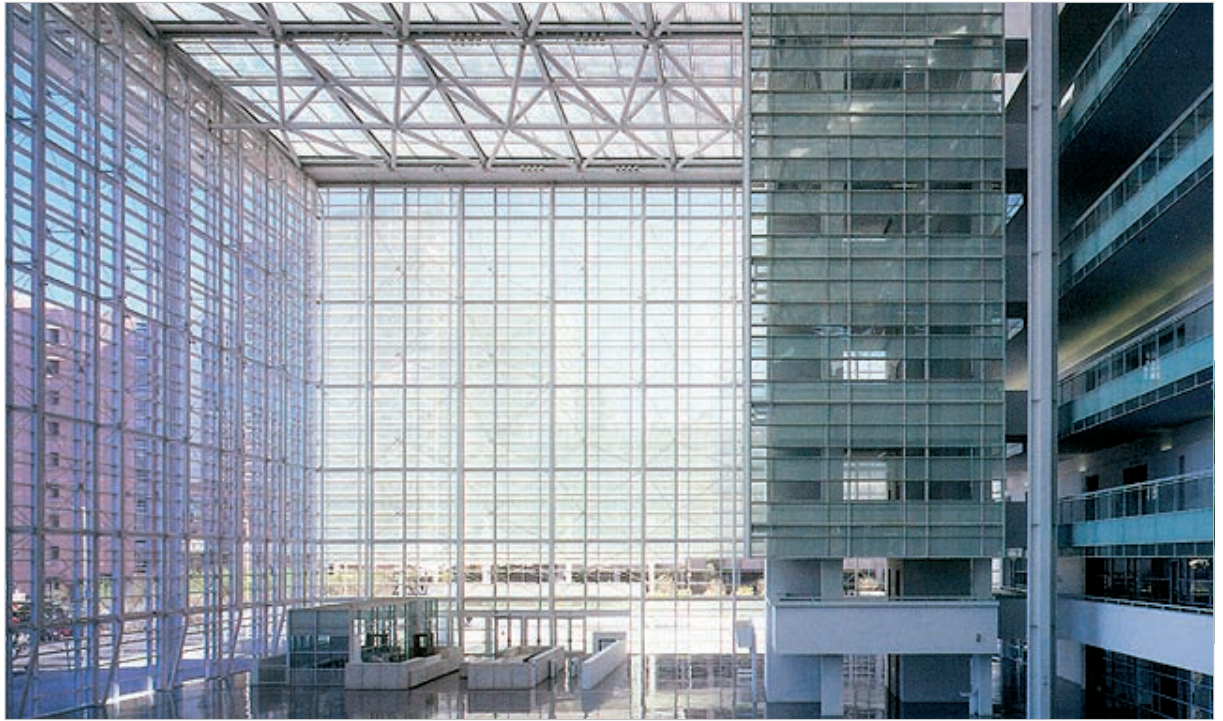
The canopy will also serve as a resource collector to convert rainwater, solar heat and wind into usable forms.

Economic justification for the roof rested on our integrated study that made use of dynamic thermal simulation, CFD modelling, wind tunnel tests, daylight and statistical weather analysis. The comfort of occupants was predicted at different points under the canopy and compared with a similar space with no roof. The improvements in comfort and hence utilisation of the space clearly demonstrated the value of the canopy within this scheme.

Phoenix Federal Courthouse, USA

case study

3



Located in the Sonora Desert, Phoenix Federal Courthouse incorporates a six-storey rectangular atrium. Such a space would normally require costly mechanical air conditioning. We were commissioned to design a passive climate control system for the 46 500m² courthouse building.

Our energy-conserving design solution was to use water mist adiabatic cooling, whereby a fine mist of water is sprayed into the air close to the roof of the atrium.

As the water evaporates it reduces the air temperature, producing a gentle circulation of cooled air within the atrium. Not only did this solution produce a comfortable environment, it also reduced costs by around 75% in comparison to the standard solution.

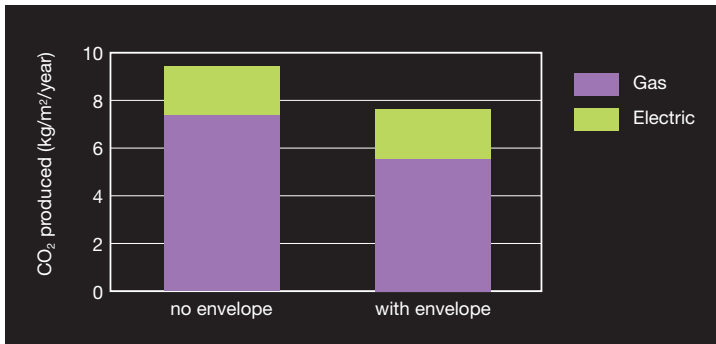
Energy modelling

Building energy modelling expertise is used to allow designers to create more efficient heating, ventilation and air conditioning systems.

Arup's advances in this area can deliver the benefits of district heating and cooling, and renewable energy systems.



© HG Esch Fotografie



Government Training Centre, Germany

The Government Training Centre in Mont Cenis features a large rectangular enclosure within which education and public buildings are located. The concept was to protect these buildings from extremes of the external climate with a glass envelope that creates a buffer zone.

The building also has a total of 8400m² of electricity-generating PV panels installed on the roof and uses methanol from old mine workings to generate heat. Energy modelling of the performance of the buildings through a whole year showed that the capture of heat from the sun, the improvement in insulation and reduction of wind gave an overall reduction in annual energy use of 20%.



© Van der Ryn/VBN

Kirsch Center for Environmental Studies, DeAnza College, USA

DeAnza College and its environmental studies students have demanded the best possible energy performance from their building. Through a combination of energy-saving measures, including a high quality building envelope, radiant cooling, natural ventilation and building-integrated PV, we have been able to deliver on these requirements cost-effectively.

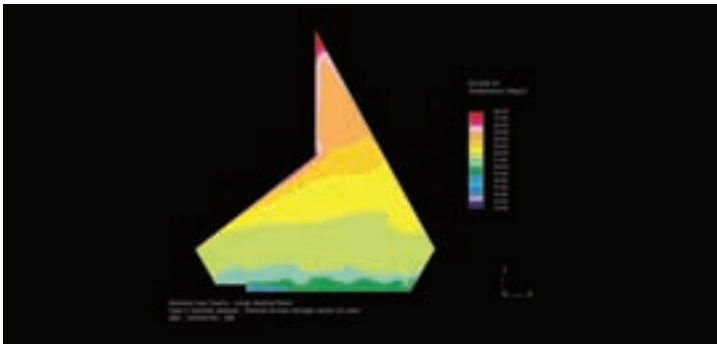
The resulting energy performance was shown to be approximately 70% lower than for a conventional building. The application of CFD, comfort analysis, life cycle cost analysis and detailed energy modelling aided us significantly in responding to the client's brief throughout the design process.

Dynamic thermal analysis

Dynamic thermal analysis is used to predict the variations of thermal and moisture conditions within a building. This type of modelling is particularly important for naturally-ventilated and mixed mode buildings and those using passive design features, such as exposed thermal mass.



© Buildingsagency



Antwerp Law Courts, Belgium

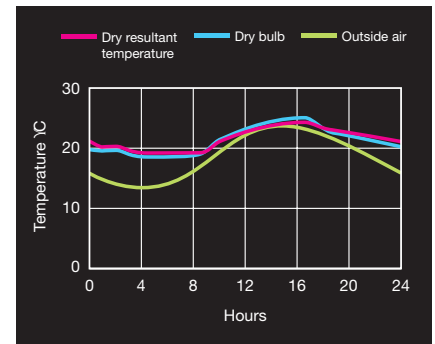
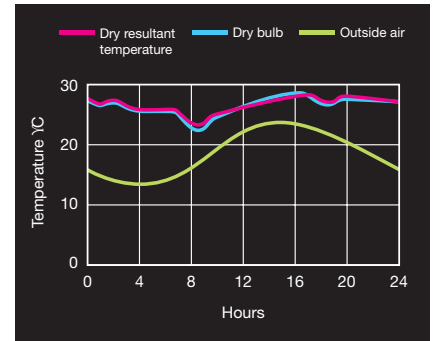
We used a range of thermal analysis techniques to develop and verify the design of the new Law Courts in Antwerp.

The design for hundreds of court officials' offices avoided the use of air conditioning by using a combination of natural and mechanical ventilation to control overheating. The authorities in Belgium demanded a detailed assessment using dynamic thermal analysis to prove that the night ventilation strategy would pre-cool the exposed concrete ceilings effectively.

The courtrooms were also analysed using CFD to demonstrate good air circulation, and dynamic radiative modelling to verify comfort conditions through all seasons. Through the application of building physics analysis, we demonstrated that the displacement ventilation system would provide comfortable conditions.



© Jens Willebrand



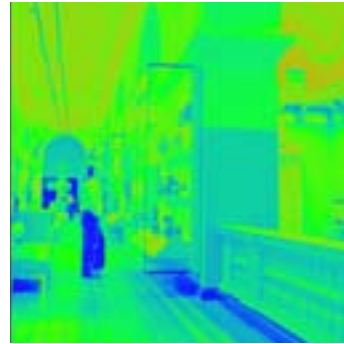
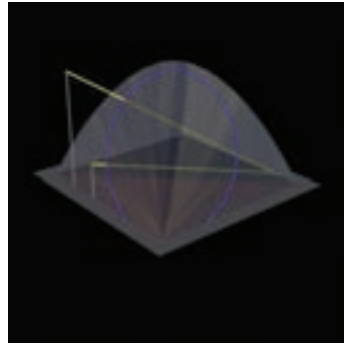
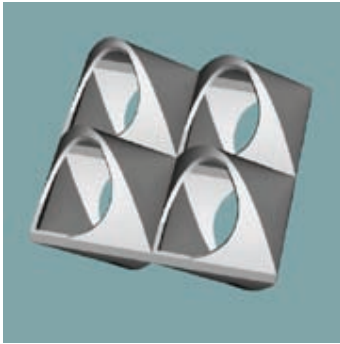
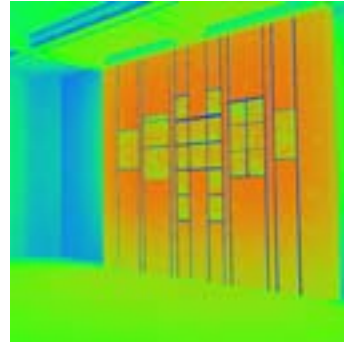
GSW Headquarters, Germany

This 22-storey building in Berlin was designed to operate with minimum new energy. In order to achieve this, natural ventilation and night-time cooling are used to remove much of the summer heat gains. External air is drawn through the building structure by a thermal glazed chimney which covers the whole of the south side of the building.

Extensive dynamic thermal modelling was used to predict how much of the daytime heat energy stored in the building fabric could be removed by the cooler night air. The modelling informed our strategy for the building cooling system, resulting in reduced mechanical intervention. This saved space, and also capital and running costs.

Daylighting, lighting and shading

Using advanced computer modelling techniques, Arup provides fully integrated solutions for daylight, electric lighting, and shade and glare control to match our clients' needs and design aspirations.



Nasher Sculpture Center, USA

The Nasher Sculpture Center in Dallas comprises a garden and an indoor sculpture museum. The client's aim was to create a light and transparent museum, whilst protecting the exhibits from the outside climate and the intense Texas sun.

The all-glass roof is protected by a three-dimensional screen which blocks direct sun from entering the space, but maximises and diffuses the daylight. Our design for the cast aluminium screen was computer-derived from solar geometry and light performance criteria. Its performance was also visualised under varying sky conditions before a full-scale mock-up was built. The owner is delighted that this highly-visible screen is both efficient and sculptural.

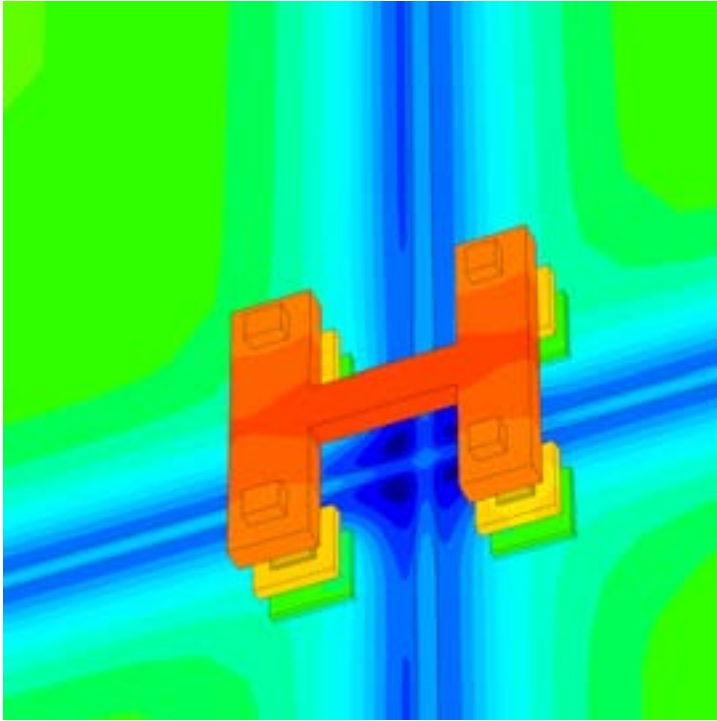
Victoria and Albert Museum (V&A), UK

At the V&A in London, we used advanced daylight simulation techniques to inform the design of a new suite of galleries. A key element of the project was that natural light levels must be predicted precisely in order that light-sensitive objects can be conserved.

We have developed new approaches that relate real world reference spaces to computer predictions. Frequently the decision process involves individuals who are not comfortable with technical analysis but do have a strong intuitive feel for design. Our new simulation techniques offer a means of effective communication, whilst providing precise physical data.

Condensation modelling

Condensation modelling can be used to identify the location and frequency of moisture build-up. This helps Arup designers to develop optimised cost-saving solutions for our clients.



Cedar Rapids Courthouse, USA

The original architectural concept for the façade of this courthouse in Iowa featured a point-fixed double-glazed façade. With a 45K temperature difference between outside and inside, our building physics analysis was vital in ensuring client confidence that the condensation risk for the design was understood and minimised.

We used detailed computer modelling of heat flows to study one possible intersection detail which featured four insulated glass panels and the point-fixing stainless steel 'H' bracket. The analysis was used to assess the point thermal transmittance of the fixing detail, to assess the risk of surface condensation and to demonstrate the need for using thermally broken glass spacers.



Wexner Center for the Arts, USA

For the Wexner Center at Ohio State University, we developed an integrated façade solution that resolved the condensation, thermal stability, solar heat gain and daylight control issues inherent in the original design of the building.

The design process involved the use of CFD and radiance programmes to examine performance. We also used a newly-developed dynamic technique for evaluating the formation and evaporation of moisture from internal glazed surfaces during long cold spells in order to realistically assess the risk of condensation. A range of improvements were achieved while meticulously maintaining the original architectural intent.

Façade performance

Arup has developed bespoke software to assess the energy and comfort benefits of complex, multi-skinned façades.

Understanding the benefits of these features enables our clients to realise cost-effective high-performance envelopes.



© John Gollings Photography

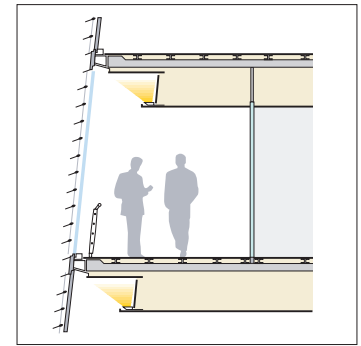
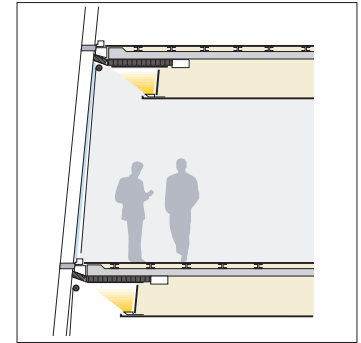
National@Docklands, Australia

We played a key role in designing environmentally-friendly façade features for this 59 000m² National Australia Bank headquarters in Melbourne. The aim was to create a sustainable building with an open and flexible working environment.

As part of the façade design, we developed screens to reduce the heat load and limit the glare induced by sun penetration onto the floor plates. The building also has operable windows in some zones and an automatic fresh air vent linked to thermal chimneys. These façade features, in combination with under-floor heating, ensure comfortable internal conditions for between 80-90% of the year using natural ventilation.



© Renzo Piano Building Workshop



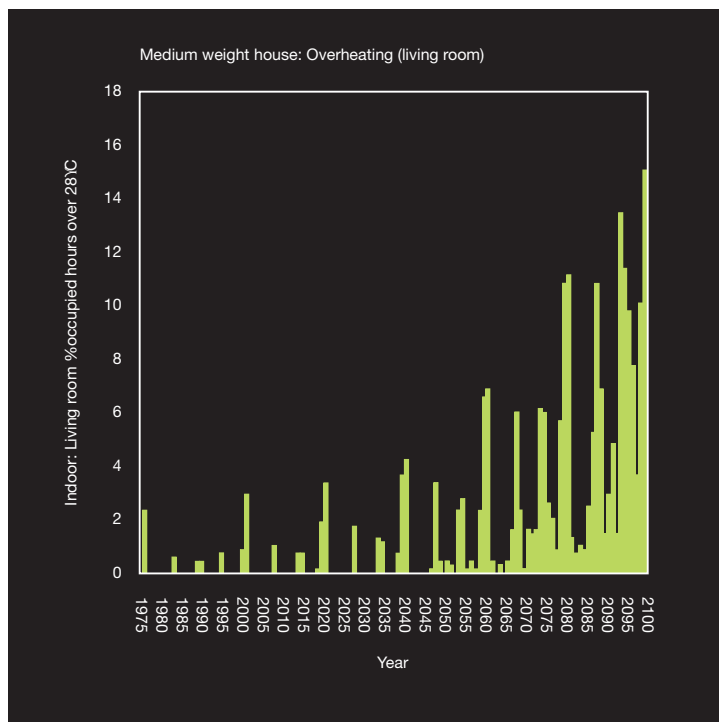
The Shard, UK

The scheme design for The Shard in London, a 300m landmark mixed-use tower, involved our team looking in detail at the performance of various façade solutions. In order to realise the vision of a shard of glass reaching to the sky, a number of multi-layered glass, active and passive alternatives were tested.

The design had to give excellent daylight with low energy consumption in both winter and summer and also meet regulatory requirements. The optimum façade uses three layers of clear glass, with the inner layer forming a cavity containing movable blinds, through which the building air is extracted. At some of the corners of the tower, semi-outside spaces with operable façades are created. These form areas connected with the exterior, to allow the building to breathe.

Climate change impact assessments

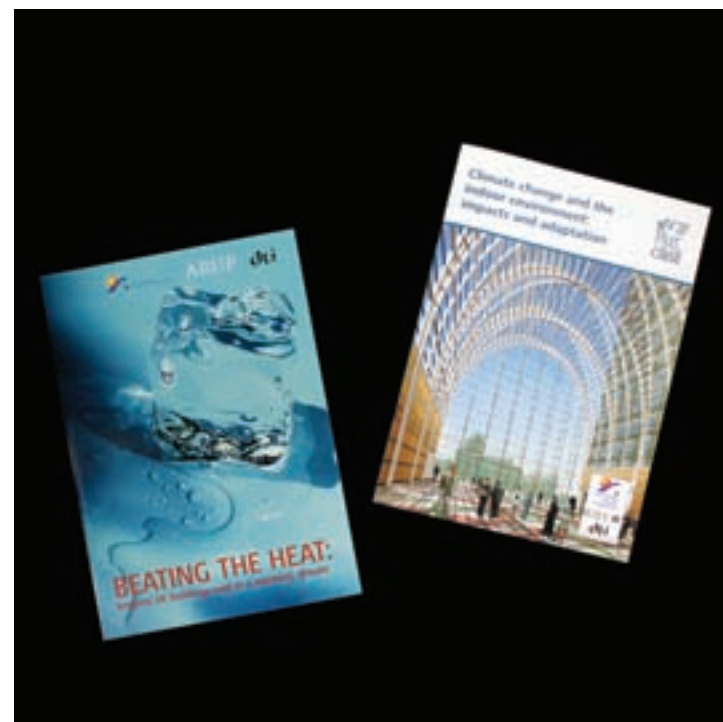
By assessing the potential impacts of global climate change, Arup enables clients worldwide to improve the resilience of their building designs to future environmental challenges.



Whole life performance of housing

Energy consumption and overheating risk for residential buildings all over the world depends on the local weather. It is crucial for the assessment of design options to understand the effects of regional climate variability and long-term global climate change.

Current best practice for revealing such whole life issues is to simulate a building's performance over a complete year. We have developed a new method that enables building performance assessments over the next 125 years. In addition to making it possible for likely future performance of housing projects to be assessed, our technique allows robust relationships to be determined between the predicted performance of buildings and the climate experienced in a given year. This advanced analysis means our designs for clients' projects can be effectively future-proofed against the risks of a changing climate.



Climate change and the indoor environment CIBSE TM36

We have taken a lead in developing guidance for the construction industry on the likely impacts of climate change on the internal built environment. As part of a UK government research project we combined our expertise in the areas of climate science and building physics to assess the response of a broad set of case-study buildings to changing environmental conditions. We also investigated how the impacts of warmer summers might be mitigated by design changes.

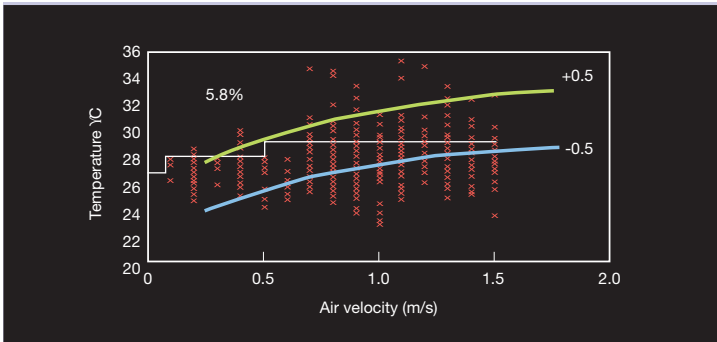
Our analysis has been published by the Chartered Institution of Buildings Service Engineers (CIBSE) and a concise version, aimed at the general public, has been published by the UK Climate Impacts Programme. The global applicability of the results of these studies has ensured their relevance to architects and construction professionals worldwide.

Comfort prediction

By linking human factors with the latest quantitative measures of comfort, Arup can predict and improve comfort levels for both internal and external conditions in our clients' building designs.



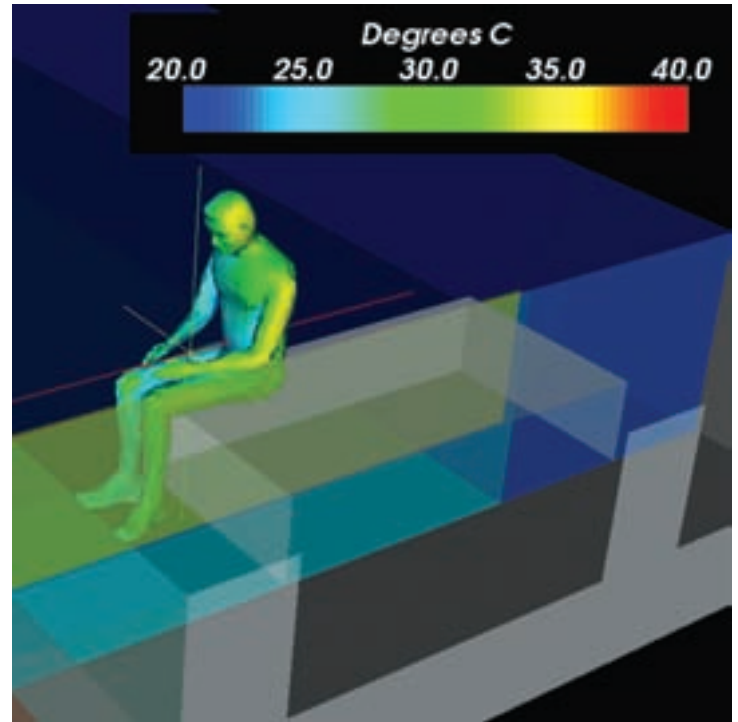
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Tjibaou Cultural Centre, New Caledonia

This spectacular building in Melanesia is sited on the edge of the Pacific Ocean. It is topped with large sail-like structures which trap coastal breezes and channel the fresh air through controlled openings into the exhibition and classroom spaces below.

The client stated that he would accept a natural ventilation strategy if it could be shown that the building's occupants would be comfortable for all but a small percentage of the hours of the day in the hottest months. To ascertain whether this was achievable we used hour-by-hour weather data to compute the temperature, air movement and humidity in a typical space operating with five different sequences of natural ventilation openings. For the example year, using the effective temperature index, the occupants were predicted to be comfortable for 94% of the time in February. Our analysis gave the client confidence that natural ventilation was an effective solution for this building.



Battersea West Hotel, UK

In this hotel on the redeveloped Battersea Power Station site in London, the baths for the bedrooms are designed to be located close to the west-facing glazed façade.

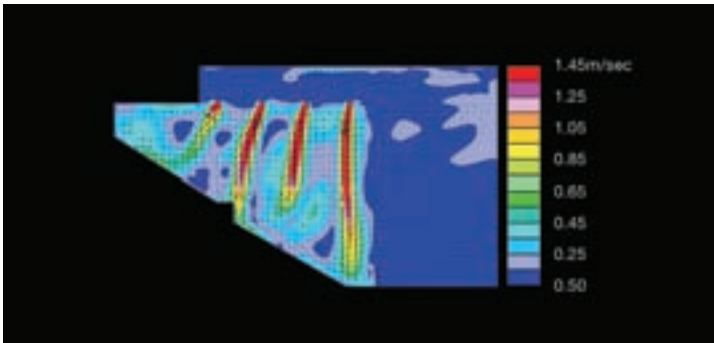
This arrangement raised questions about the comfort of the bather in and around the bath, due to the effects of cool glazing and warm sunshine in winter, and sunshine and hot glazing in summer. By carrying out detailed computer simulations of the radiant exchange between the bather and the surroundings, we were able to provide guidance on optimum glazing configuration, and other design factors, to improve comfort for the bather.

Airflow

Arup uses airflow modelling techniques in order to understand and improve air distribution and ventilation effectiveness. The detailed information provided frequently prompts beneficial design changes for our clients.



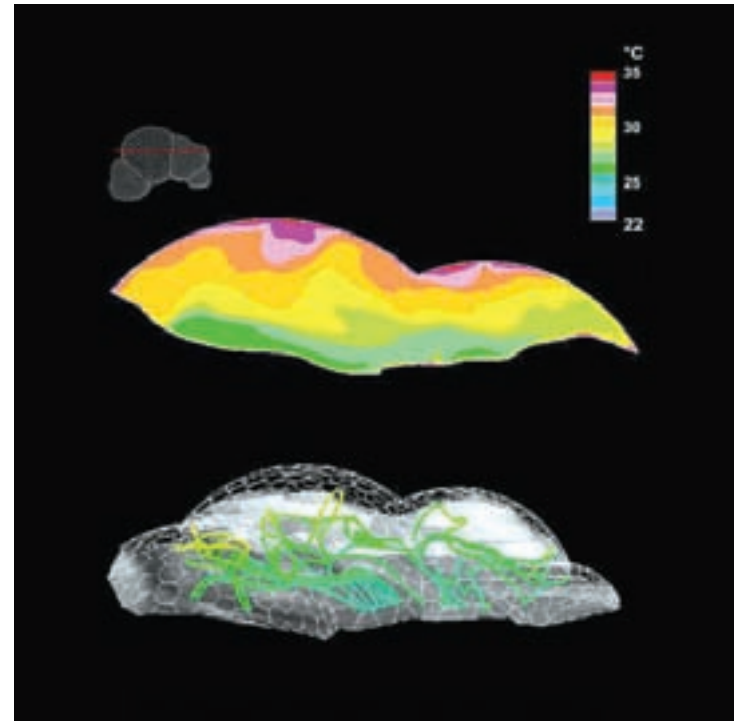
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Palahockey, Italy

The new ice hockey stadium for the Winter Olympics 2006 in Turin required a climate control system that maintained the ice surface in excellent condition for the hockey but also provided comfortable conditions for spectators. The cheapest and most efficient solution was to provide warm air to the spectators from high level over the seating.

We carried out CFD analysis to predict the performance of the warm air jets, virtually adjusting and modifying them to minimise the risk of heating the ice surface and to ensure that the spectators were comfortable. This also enabled a solution using minimum energy, as it avoided unnecessary heating of the overall space.



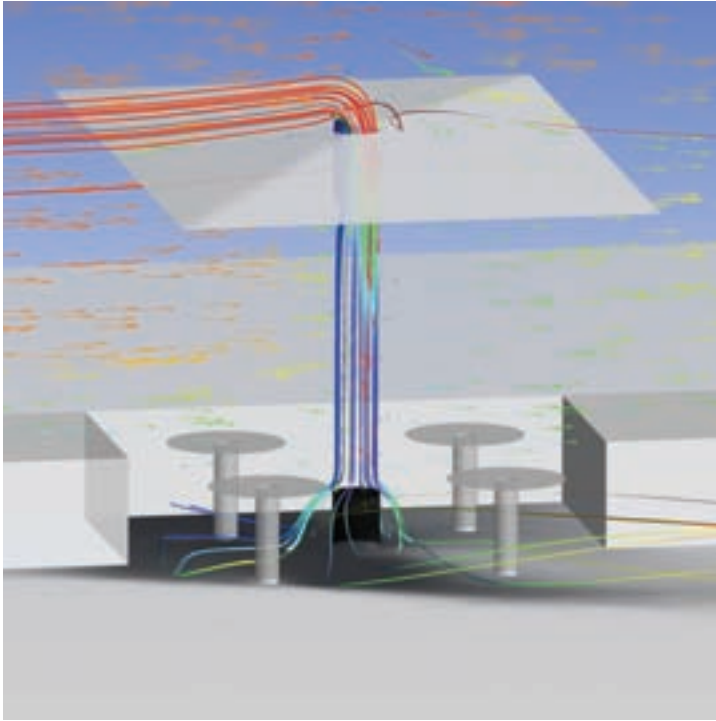
Eden Project, UK

The immense biomes of the Eden Project in Cornwall enclose a humid microclimate in which tropical plants thrive. This is achieved by a series of warm air jets at the perimeter of the space which blow up the inside surface creating circulation currents that warm the whole space.

A large three-dimensional CFD analysis was used to predict the airflow and distribution of temperature and humidity. This enabled decisions to be made on the number, location and performance of the jets, to refine the design and minimise cost. Our airflow analysis was also used to model the warmer times of the year and to predict the location and size of openings at the top and bottom of the biomes which control direct solar heating of the space.

Microclimate design

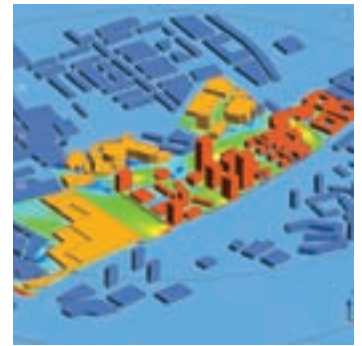
Arup brings to projects a holistic understanding of airflows inside and around buildings, distribution of natural light, and other environmental parameters. In this way we can help town planners and building designers to produce a comfortable and sustainable built environment.



Dubai Festival City, UAE

Dubai Festival City is a leisure and shopping complex, with cafés and restaurants, located alongside a canal. We were commissioned to help design the outside spaces so that the comfortable season for outside dining could be extended from just a few months in winter to all but the hottest of the summer months.

We proposed a series of microclimates using shading, displacement, misting, wind deflections, cool air pools and cooled surfaces to extend the comfortable season. These strategies were backed up by extensive analysis of the various interventions under different temperature and wind scenarios, including dynamic thermal analysis and CFD. Each space was then given a subjective comfort rating. This was subsequently used by the client to increase the value of the outside spaces when letting them.



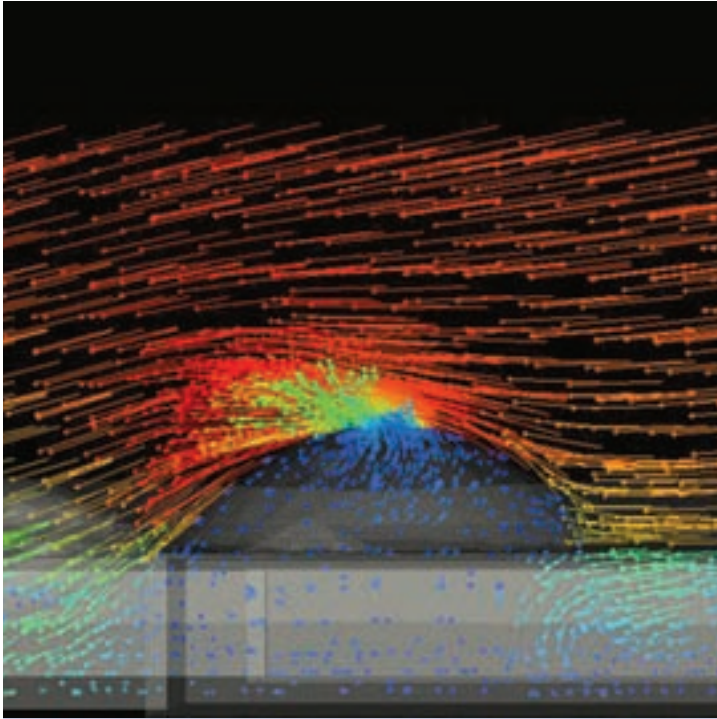
City masterplanning

In close collaboration with architects, we provide holistic assessments of external microclimates – the space between buildings – for different building massing schemes. Through assessment of airflow, temperature, daylight and sunshine, air quality and acoustics, we are able to make a fundamental contribution to the design at a very early stage.

For this work, our specialists have assembled a comprehensive suite of computational modelling tools. The assessment of these environmental parameters within a single virtual environment is unique to Arup and enables a truly holistic analytical approach in support of design.

External windflow

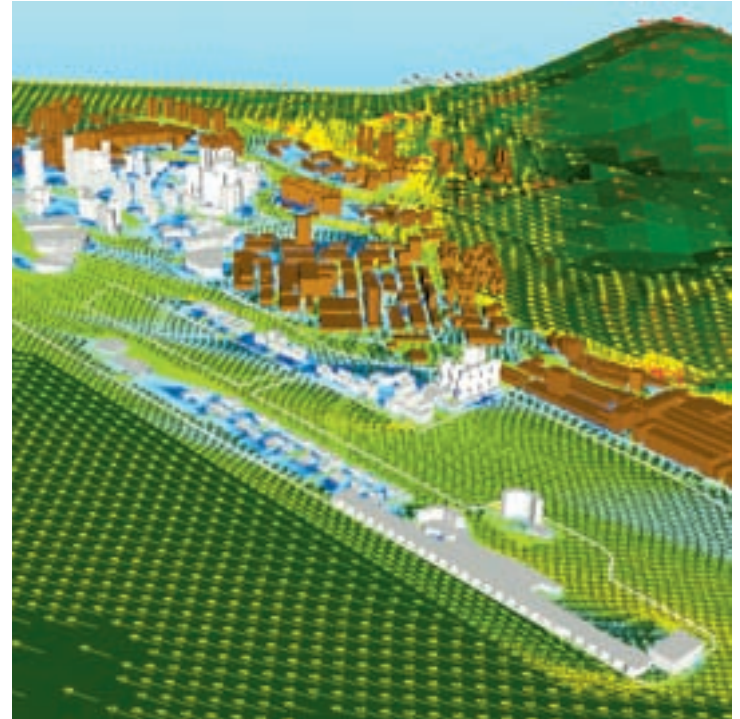
The simulation of external windflow around buildings provides valuable information for understanding the microclimate, improving natural ventilation and assessing the potential for wind energy.



California Academy of Sciences, USA

The Academy is located in San Francisco's Golden Gate Park which faces the Pacific Ocean. The design makes use of the mass of the building structure and the cool sea breezes to directly cool the large exhibition area which is the heart of the project.

As the breeze blows across the dome-shaped roof it creates a negative pressure in the openings at the top, sucking the air out and encouraging the breeze to blow in through the high-level openings in the perimeter walls. To confirm this strategy and visualise both air and temperature distribution in the exhibition hall, we used an extensive three-dimensional CFD model. Our analysis encompassed the external and internal airflows and demonstrated the interactions between them, allowing openings to be accurately sized.



South East Kowloon, Hong Kong

South East Kowloon, the largest town planning scheme in Hong Kong, consists of a development area of about 580ha. It is designed to accommodate an overall population of 285 500 people. An important goal of the project was to open up the harbour front for public enjoyment.

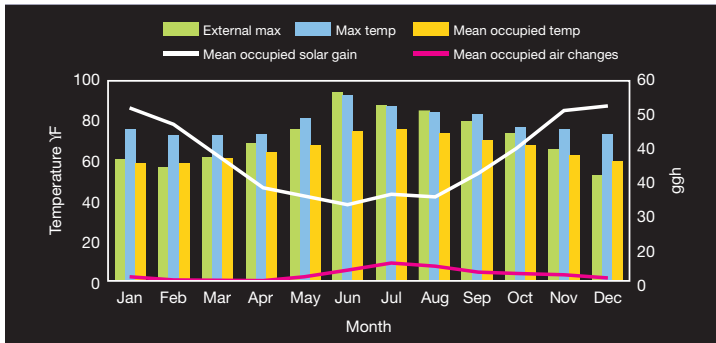
As part of this masterplan, we conducted a comprehensive analysis of the wind environment around the site, looking at both a ventilation assessment and the effect of the wind on the local microclimate within the development. Through this analysis the sustainability of the development was improved and the usability of the whole site enhanced.

Green building assessment

Demonstrating the sustainability credentials of buildings is an increasingly high priority for many of our clients. Arup has world-leading expertise in the principal assessment processes including LEED® and BREEAM, and applies these techniques throughout the design process.



© Hopkins/Burns-Wald Hopkins



Northern Arizona University Applied Research and Development Facility, USA

NAU intends its Applied Research and Development Facility to be not only a landmark sustainable building but a didactic one too, teaching students and visitors alike about the benefits of green building. The combination of Arup's multidisciplinary engineering services and our co-ordination of the LEED® certification gives this project the best potential for achieving a Platinum LEED® rating.

High performance features of the building include triple pane windows, under-floor ventilation system, solar hot water and PV, high volume flyash concrete and radiant cooling. The facility occupies a natural drainage site and run-off water will help to cool the building. The interior is also exceptionally well lit by daylight and a large proportion benefits from natural ventilation.



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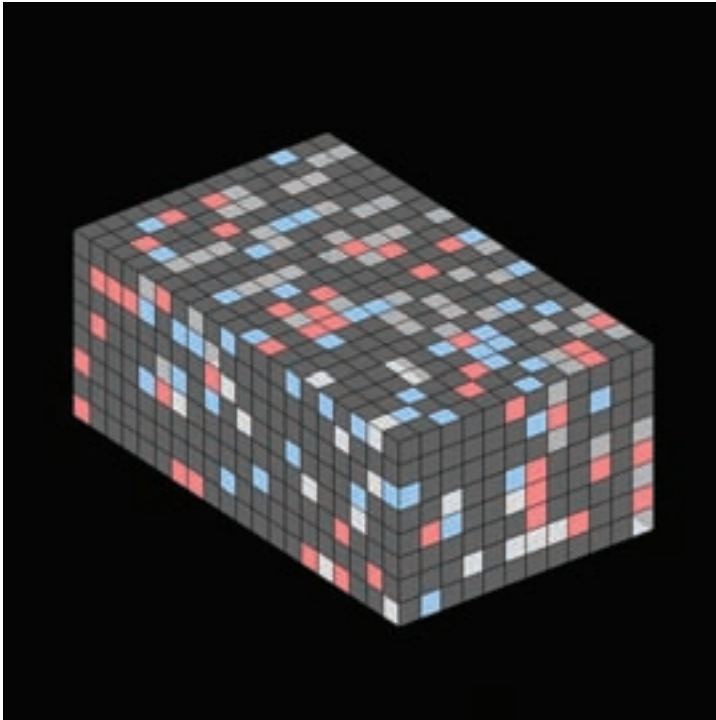
40 Grosvenor Place, UK

We designed the building services engineering for this 26 000m² office block in London. One of our client's aims was that this project should achieve the best green building assessment for a speculative office.

In order to achieve this, a floor plenum was used to supply air at low level, and a radiant-cooled ceiling was designed to reduce cooling and fan energy use. This was combined with detailed modelling of the window openings and façade and the plan of the building, grouped around a naturally-ventilated atrium. These elements achieve healthy environmental control while consuming 20% less energy than conventionally air conditioned buildings. The building has been awarded an "Excellent" BREEAM rating.

Optimisation

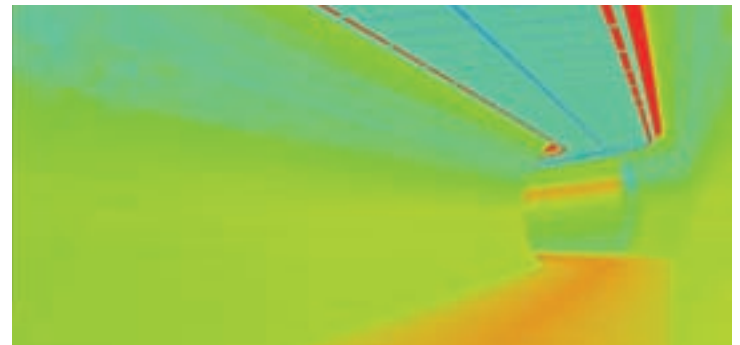
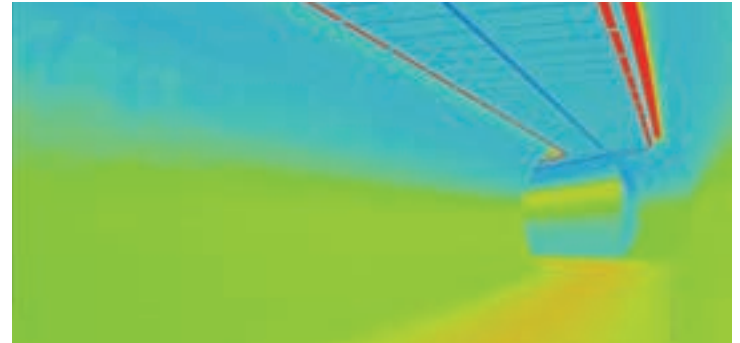
By applying mathematical optimisation techniques Arup helps create the most advantageous design solutions and reduces costs for our clients, whatever the nature of their project.



Optimisation techniques

The design of modern building envelopes requires the simultaneous balancing of many different performance criteria. These may include heat loss, heat gain, daylight levels, sun protection and views out, as well as cost. Advanced methods of computer optimisation give new insights into the range of potential solutions.

Optimised solutions can be derived via mathematical techniques. These solutions change depending on the relative importance of each parameter to the client. For example, if heat loss is most important to our client, then the optimised design solution is likely to have smaller windows. Conversely, if views out are most important, then windows are likely to be larger. A pre-assembled set of solutions allows many combinations of parameters to be explored interactively during a design session. By using these techniques, we can help clients understand the impact of their evolving designs on optimised engineering solutions.



King's Cross Station, UK

For the redevelopment of King's Cross railway station in London, we applied computational optimisation techniques to enhance the lighting design. This is a vital element of the scheme, as passengers' positive experience of underground tunnels (including perceived personal safety) depends significantly on the type and level of lighting installed.

Optimisation methods were applied to help determine the best possible shape for a light reflector, in order to maximise illumination on pedestrian tunnel walls from a series of ceiling-mounted fluorescent linear lights. Using a fully three-dimensional computer model, we calculated iteratively the performances of alternative configurations. The resulting optimised design provided 50% improvement on performance in comparison to a standard treatment.

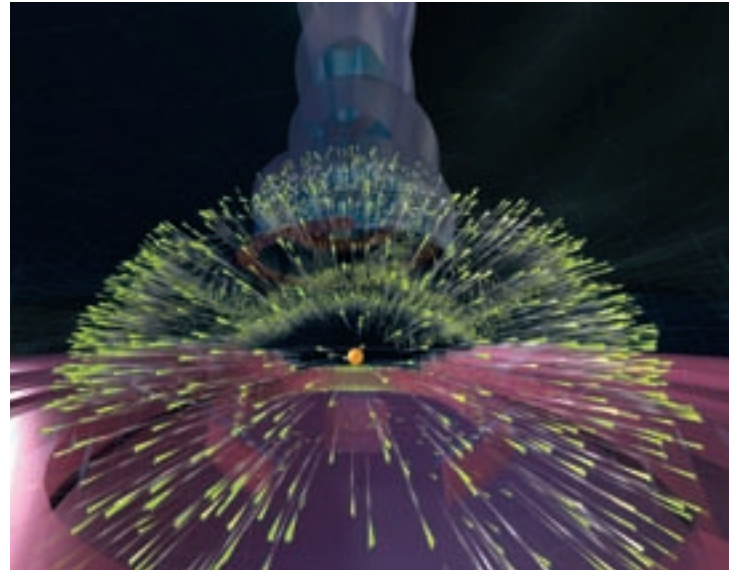
Related skills and techniques



Fire safety design

Successful fire strategies for buildings are those which address the need for the safety and reassurance of building owners, occupiers and insurers. We work to overcome the challenges inherent in achieving holistic fire safety design that is cost effective, non-intrusive, and allows for optimum functionality.

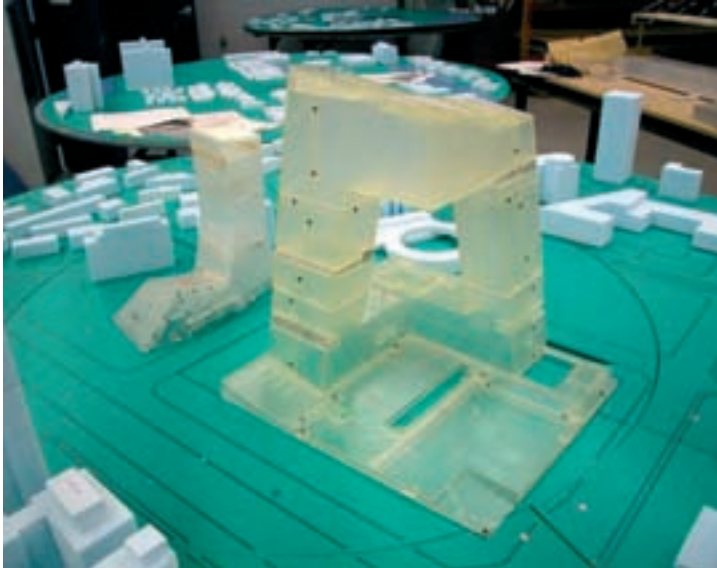
It is essential to address the key issues of control of fire, management of escape and speed of fire brigade access and set-up, whilst tackling the individual characteristics and needs of the building. Benefits achieved in our designs include: optimised structural fire protection, more efficient use of space, optimisation of escape and reduced business interruption.



Acoustics

The acoustic response of a space is a significant building physics parameter. It can determine not only objective factors such as speech intelligibility (face-to-face, telephone and emergency loudspeaker instruction) and conversely privacy, but also occupants' subjective response to a space (whether it feels tranquil or noisy, supportive or distracting, calming or brutal).

We use advanced auralisation techniques to simulate the acoustics of spaces before they are built. Our approach assists in determining the essential balances between acoustics and other building physics parameters. Improvements can be shown in, for example, the balance of sound-absorbing surfaces with high thermal mass surfaces, and noise insulation with natural ventilation.



Physical modelling

Arup complements the application of computer modelling with a range of physical modelling techniques, where appropriate. Most of these methods involve the creation of small scale models (typically at 1:100 scale) and performing tests in specially equipped laboratories. One example of this approach is wind tunnel testing, which can be used to provide information on environmental wind conditions around buildings. Other techniques include water bath modelling in which clear and dyed water represent cold and warm air.

Physical modelling techniques can sometimes provide the most accurate predictions. Alternatively, they may be used to physically demonstrate phenomena that can be harder to interpret on a computer screen.



Material science

Our wealth of knowledge and experience in material science and engineering allows us to provide the most appropriate solutions from concept design through to demolition projects, even in unusual or demanding contexts.

We are able to provide recommendations for material selection and design, environmental impact and sustainable use of materials as well as maintenance, reuse and refurbishment. In partnership with leading researchers, the applicability of new products and emerging technologies - such as “smart” and nanomaterials - are assessed for their use in our clients’ projects.

The team

Arup is a global design and business consulting firm. Our services are available to clients singly or in combination, to suit the particular circumstance of the job, delivered by some 7000 staff based in more than 33 countries.

Our core strength is our people. We pride ourselves on building strong, open and collaborative project teams, as we believe that this way of working gives the best results for clients.

Located across the world, our building physicists from diverse disciplines combine to form a powerful international team that offers unique understanding of our clients' design challenges and their commercial impacts.

Each expert is a leader in their own field, as well as highly experienced in working in multidisciplinary teams, and aware of the impact that any decision will have on other aspects of our clients' designs. Every member of the team is part of our collective global skills network, and this culture of knowledge sharing helps us to provide the most focused response to each client's needs.

For further information contact:

buildingphysics@arup.com

