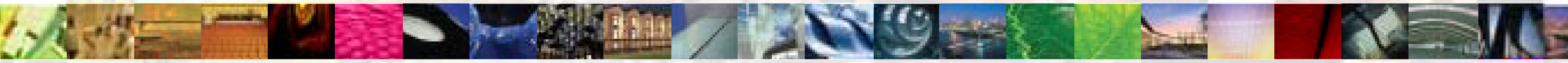
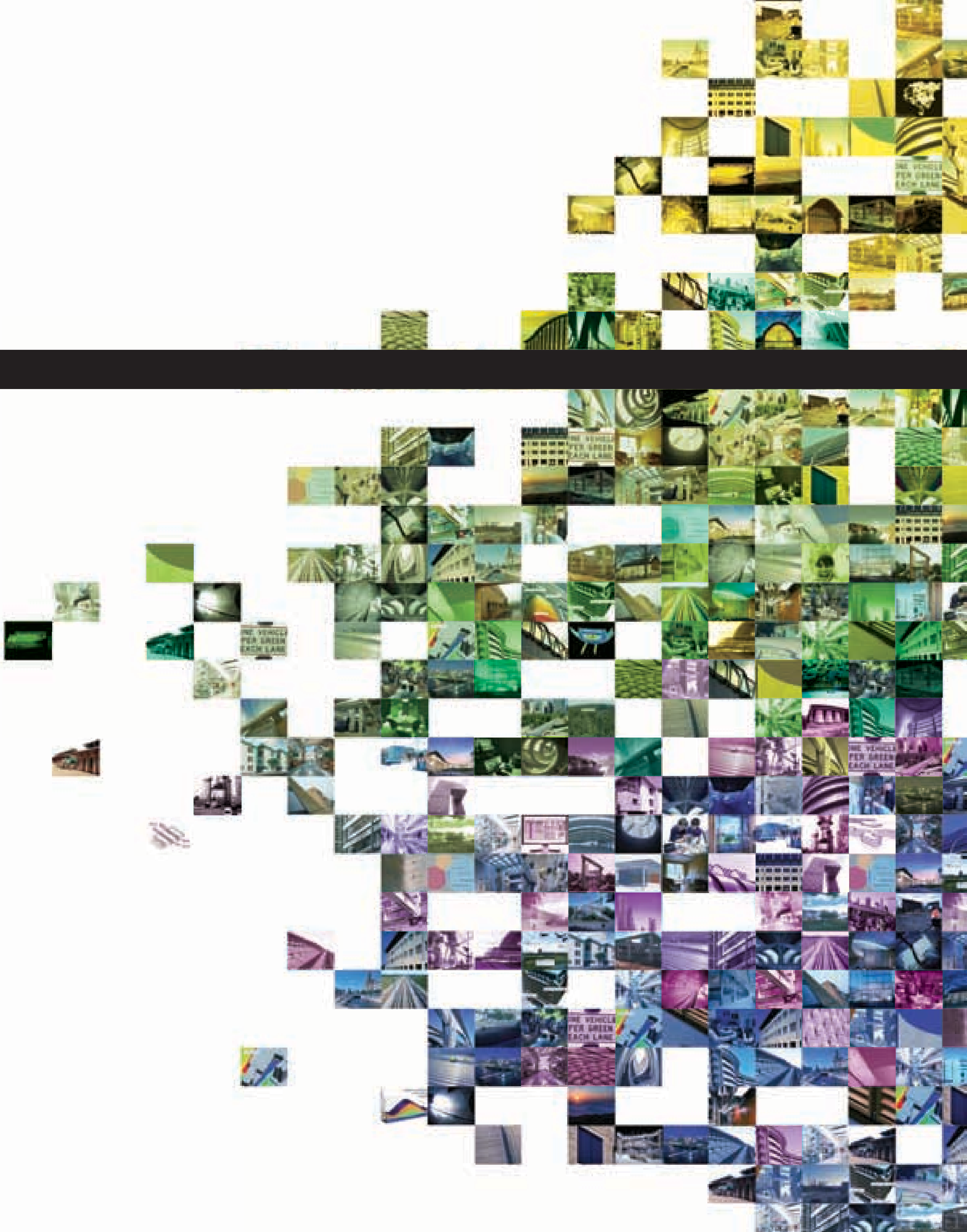
Design Yearbook 2009



A glimpse into Arup's creative world

ARUP



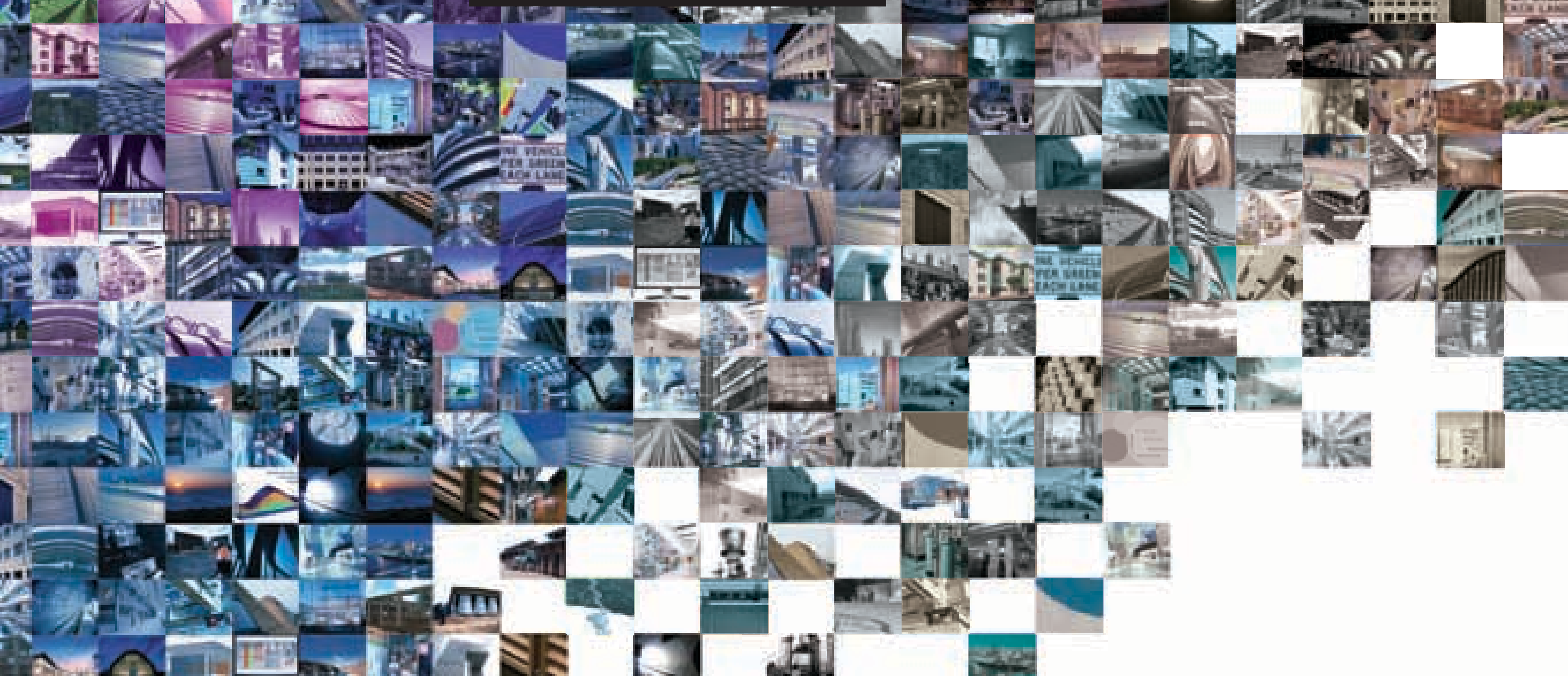
Foreword

■ Design is more than simply the creation of a project. Design is an active, evolving, and increasingly inclusive process. And more than ever, the design process carries with it a responsibility. Good design has the power to transform an idea into something useful.

Our fifth Design Yearbook takes another glimpse into Arup's creative world, where responsible design is at the core of what we do. We work hard to ensure that our creativity, innovation and technical excellence are relevant to the marketplace, to its current physical, social and economic context, and to the future.

Our design ideas push all kinds of boundaries. But in the end, our clients measure the value of those ideas only by the positive difference they make to their businesses and to the communities they work in. This edition of the Yearbook gives you a taste of the richness and diversity of Arup's design work in the last year, and how it helped our clients to succeed and to connect communities in a rapidly changing world.

Working responsibly across the built environment, we help to create a better place in which we all can live. □



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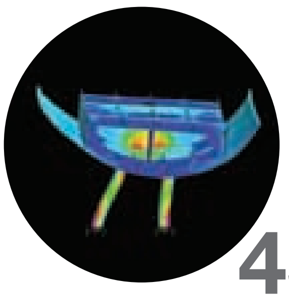
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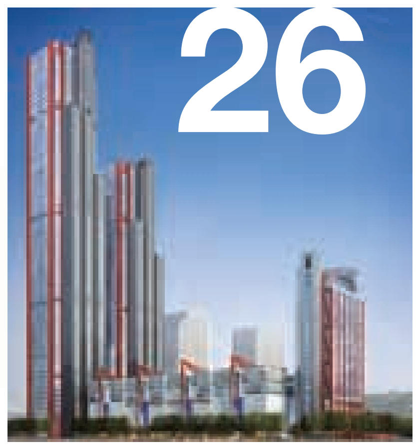
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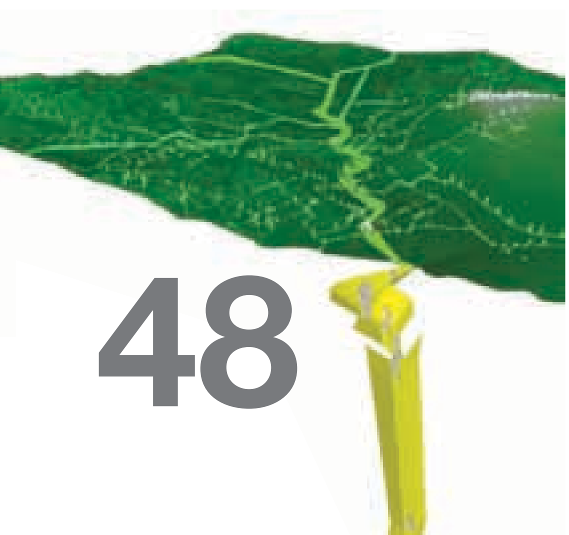
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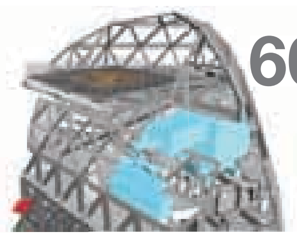
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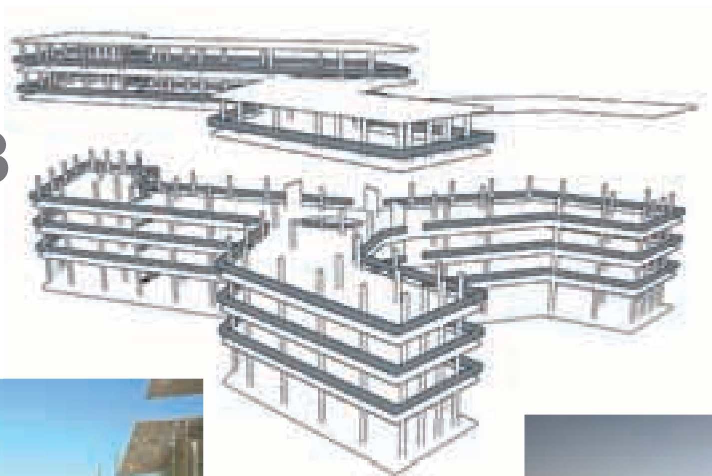

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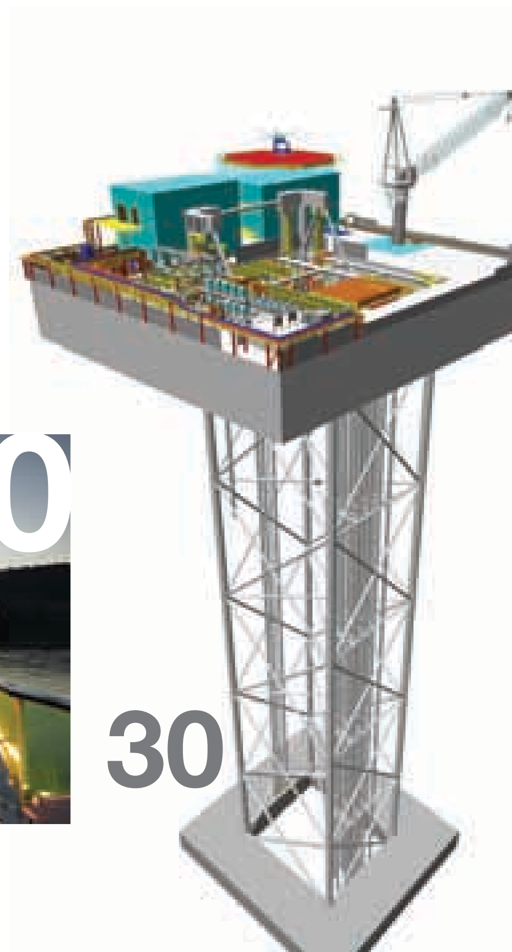

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In safe hands

A new intake tunnel for a Nevada reservoir required masterful planning

After nearly ten years of drought, Lake Mead, the reservoir behind the Hoover Dam, is dangerously low. A further drop could render existing intake tunnels inoperable. A new, deeper intake tunnel will secure the supply of water to nearly two million people in the Las Vegas area.

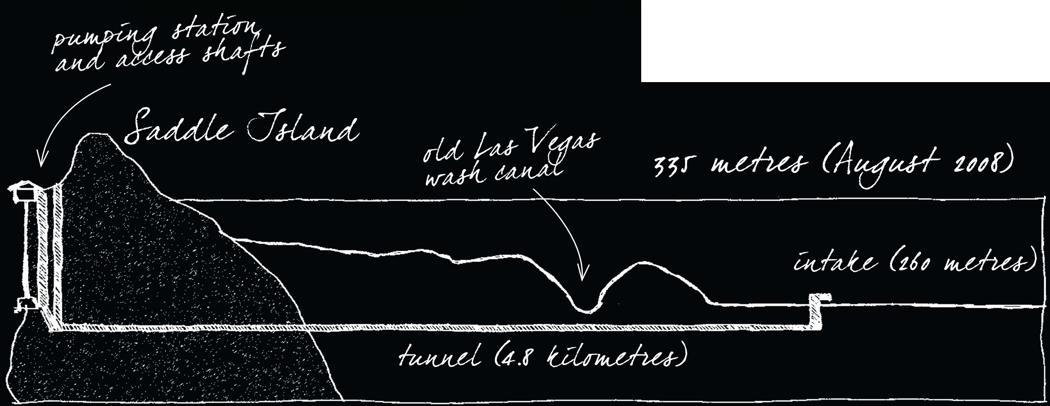
■ It's May 2009, and Lake Mead is less than half full. With the Las Vegas area relying on it as its primary source of water, the white mineral deposits which reveal the 1983 high-water mark are a stark reminder that this metropolitan area (in the middle of the Mojave desert) is under pressure. Nine years of drought has taken its toll, and a further drop in water level of 30.4 metres – since 1983 it has already dropped 38 metres and has been dropping by up to seven metres a year – will restrict the water supply, as the existing Intake No.1 will find itself above water for the first time since the Hoover Dam was built in 1936.

The new intake tunnel will be sited at 262 metres above sea level – approximately 45 metres deeper than the current deepest tunnel. Constructing it is a huge undertaking and involves digging of underground caverns, installation of a surface pumping station and various surface pipelines to link the new intake to the existing treatment facility.

The task facing the Vegas Tunnel Constructors, with Arup as its designer, is to construct a shaft at the lakeside, bore a new tunnel under the lake and make the connection between the tunnel and the water – the intake structure itself.

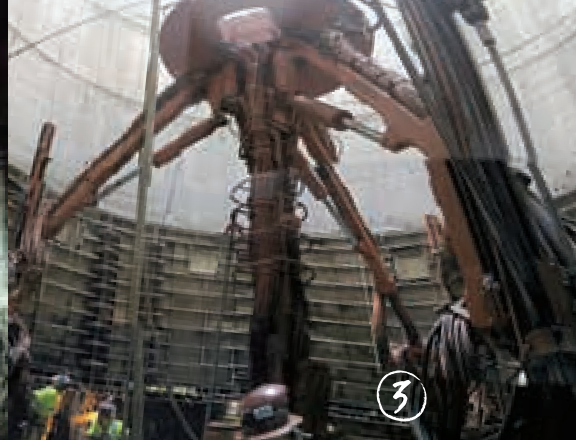
Conceptually, the task is simple enough: a shaft is sunk down into the volcanic rock at the lakeside. From the bottom of the shaft, a tunnel boring machine cuts horizontally out under the lake bed, erecting a lining as it goes to support the ground. The end of the tunnel is connected through the lake bed to an inlet and the water can start flowing.

In practice, though, each of the stages is a challenging construction project in its own right. The whole is a project that few firms have the expertise to manage.



The proposed intake system in cross section.

 Project Name Lake Mead Intake No 3 Shafts and Tunnels **Location** Las Vegas, Nevada, USA **Client** Vegas Tunnel Constructors (Impregilo/SA Healy)



1. A model of the tunnel and intake system.

2. Workers will have over 120 metres of rock and water above them.

3. The intake structure provides a docking station for the tunnel boring machine.

4. A model shows the relative depth of intake no 3.

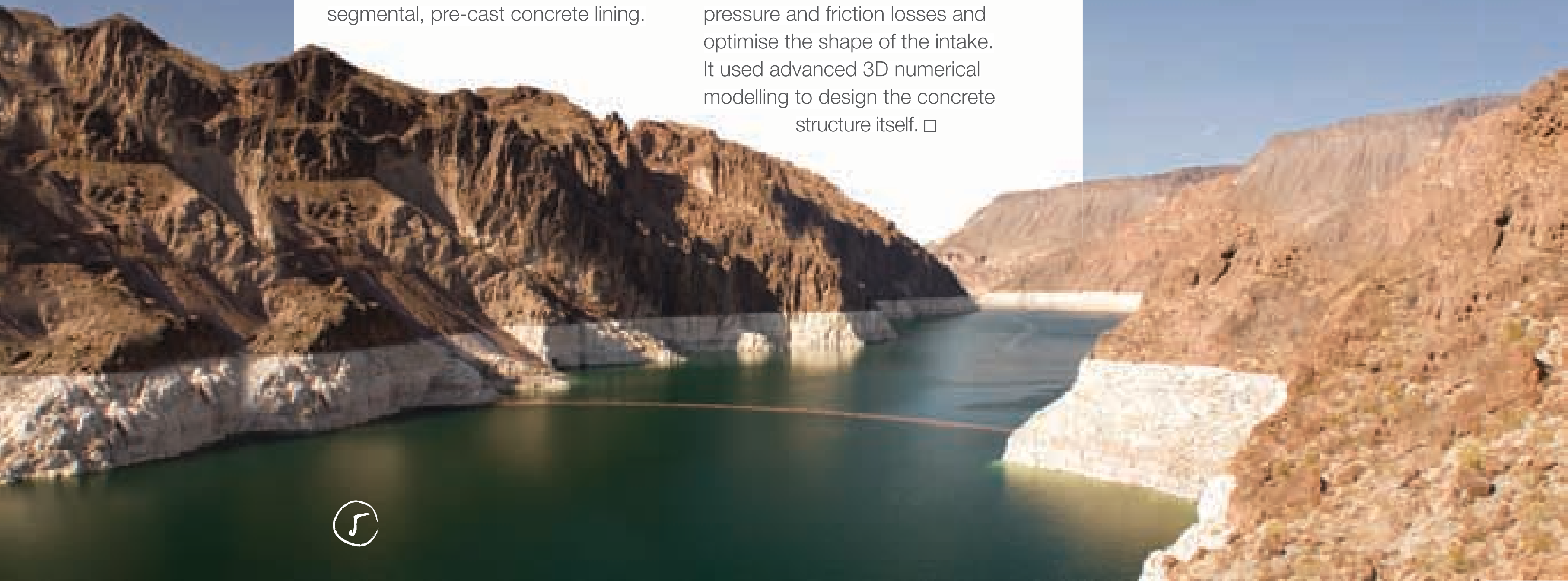
5. White mineral deposits reveal the 38 metre drop in water levels since 1983.

The 182 metre deep shaft is carved out of the rock by blasting the hard volcanic rock with dynamite. Because groundwater seeps through the rock fissures, cement grout is pumped into the fissures to fill gaps and reduce the water inflows. To allow efficient construction, the entire shaft is lined with unreinforced concrete. A couple of 'stub' tunnels are needed to house drainage equipment and Arup has designed an underground cavern at the base of the shaft, where the tunnel boring machine (TBM) will be assembled.

The TBM required for the project will operate under high pressure – in fact, its pressure rating is the highest ever used. The tunnel must be safe for a workforce with over 121 metres of rock and water above them. As it is bored, the tunnel will be lined with a segmental, pre-cast concrete lining.

Making the connection between the tunnel and the water is the tricky part. Originally, the plan had been to drill into the lake bed from the surface within a vertical pipe and to break out of the tunnel to make a connection, but the sheer scale of the operation and the extreme water pressure made it risky. Instead, Arup suggested placing a concrete structure – much like a socket – onto the lake bed. This would be fabricated onshore before being floated out and sunk into position. Once fixed in place, this intake structure would provide a docking station for the TBM. Once the connection was made, the tunnel would be flooded from the shore side, allowing the bulkhead that separates the lake from the tunnel to be removed.

The team used computational fluid dynamics to model the water flow, pressure and friction losses and optimise the shape of the intake. It used advanced 3D numerical modelling to design the concrete structure itself. □



Visitors to Athens' New Acropolis Museum gain an entirely new perspective of the history of the Acropolis and its treasures. Engineered to make inspired use of natural light, the museum's Parthenon Gallery shows the artefacts in conditions that mimic the original site.

Trick of the light

Athens' New Acropolis Museum showcases the Parthenon's ancient splendours

From a distance

The six caryatids that held up the Caryatid Porch of the Erechtheion temple at the Acropolis are displayed so that, from certain vantage points, they appear to hold up the gallery roof. Stage lighting techniques make them stand out from their background, accentuating the effect.

Close up

Arup's lighting designers positioned and focused the spotlights to ensure that visitors can fully appreciate the detail of the Caryatids' hair braiding, recently revealed by laser cleaning.

Project Name New Acropolis Museum **Location** Athens, Greece **Client** Organisation for the Construction of the New Acropolis Museum/Bernard Tschumi Architects

1. The metopes are raised several metres above the gallery floor.

2. Skylights allow natural light to graze the sculptures, emphasising their relief.

3. Ceiling-mounted spotlights enhance the sculptures' beauty.

4. Windows are screen-printed with graduated black dots to filter the harsh sun.

■ The capital of Greece, named after Athena, the goddess of wisdom, is famed for its many gifts to modern civilisation. Among the most spectacular is the Parthenon, Athena's temple.

In the New Acropolis Museum, which opened in June 2009, Athens has, at last, a museum with a purpose-designed gallery fit to unite, protect and display the Parthenon Marbles alongside the rest of the site's artefacts. The museum received over 90,000 visitors in its first seven days. Its treasures could be viewed in similar light and spatial relationships as would have been found in their original locations.

The architectural ornamentation on the upper section of the Parthenon comprises three distinct elements. The frieze portraying the Panathenaic procession is a continuous band of marble relief sculpture that adorned the upper surrounds of the inside of the Parthenon's cella. Over 160 metres of the original survives.

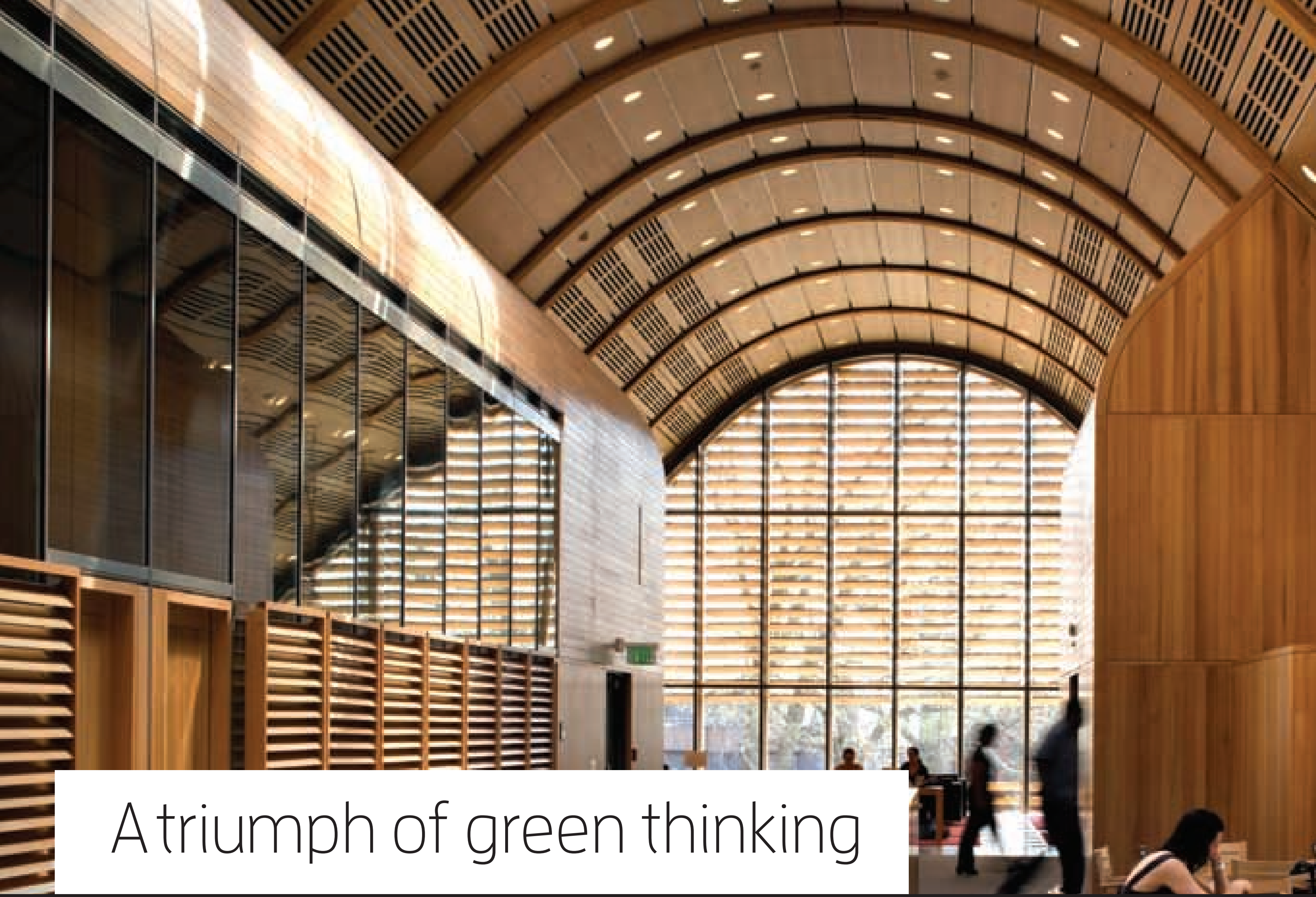
The metopes are the 92 marble slabs that form part of the decorative band around the top of the Parthenon's columns. Each element features superbly sculpted relief. Together they recount the battle between the mythical Centaurs, half-man and half-horse, and the legendary Lapith people of Thessaly. Within the new museum's Parthenon gallery, these metopes are displayed in precisely the same spatial relationship as they were on the building itself. Freshly cast sandstone reproductions stand in place of the missing statues.

The pediments are the eastern and western ends of the Parthenon temple, comprising a series of statues beautifully sculpted and arranged within the 3.3 metre high pedimental triangles located in the centre.

Arup worked closely with Bernard Tschumi Architects and local engineers ADK to realise the gallery's five metre high glass walls, made possible in this seismic area by base isolators, which minimised the need for heavy structure. Arup's mechanical and electrical engineers designed the ventilated facades and displacement ventilation to protect sculptures and visitors alike from the sun's heat. The Parthenon Gallery's glass windows maintain the visual connection with the Parthenon.

Both the metopes and the frieze show a procession which tells a complete story or series of stories. Each statue is a masterpiece. Adopting theatrical lighting principles, Arup's lighting designers configured skylights to allow daylight from above to graze the sculptures. This adds dramatic effect to the otherwise flat light from the side windows, enhancing the display by day.

As dusk falls, the lighting becomes more theatrical. Different techniques were used both to reveal the beauty and character of the relief surfaces of the exhibits, and to subtly distinguish the surviving collection from the missing pieces. The glass museum's exterior is, in effect, transformed into a giant display case. Through the glass, passersby can glimpse the architectural wonders within. Athens has the museum it has been waiting for. □



A triumph of green thinking

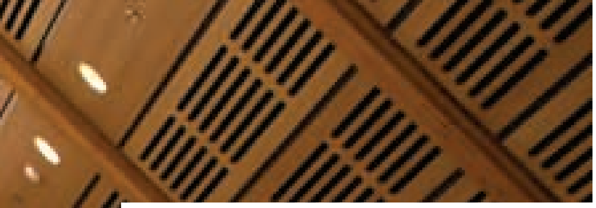
Yale's newest building reflects a tradition of innovative thinking

Yale University's new, cathedral-like Kroon Hall is the epitome of green design. Built to accommodate the Yale School of Forestry & Environmental Studies, it transforms Science Hill, an industrial corner of the Yale campus. A gas-fired power plant has given way to a light and airy building, which is operationally carbon neutral and whose heating and cooling systems efficiently extract energy from groundwater.

■ It costs very little to think ahead, as Yale did when it decided a decade ago to design a carbon-neutral building. The architect and Arup set the direction early, making key decisions on location, orientation, shape and choosing concrete for its thermal properties long before they got down to details. Here, design and systems work together and complement each other.

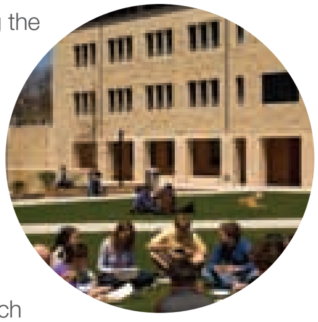
The form of the building itself is designed for passive, low-energy systems. It is orientated east-west along the sun's path, with exposed thermal mass, deep-set windows and external shading to control solar gain.

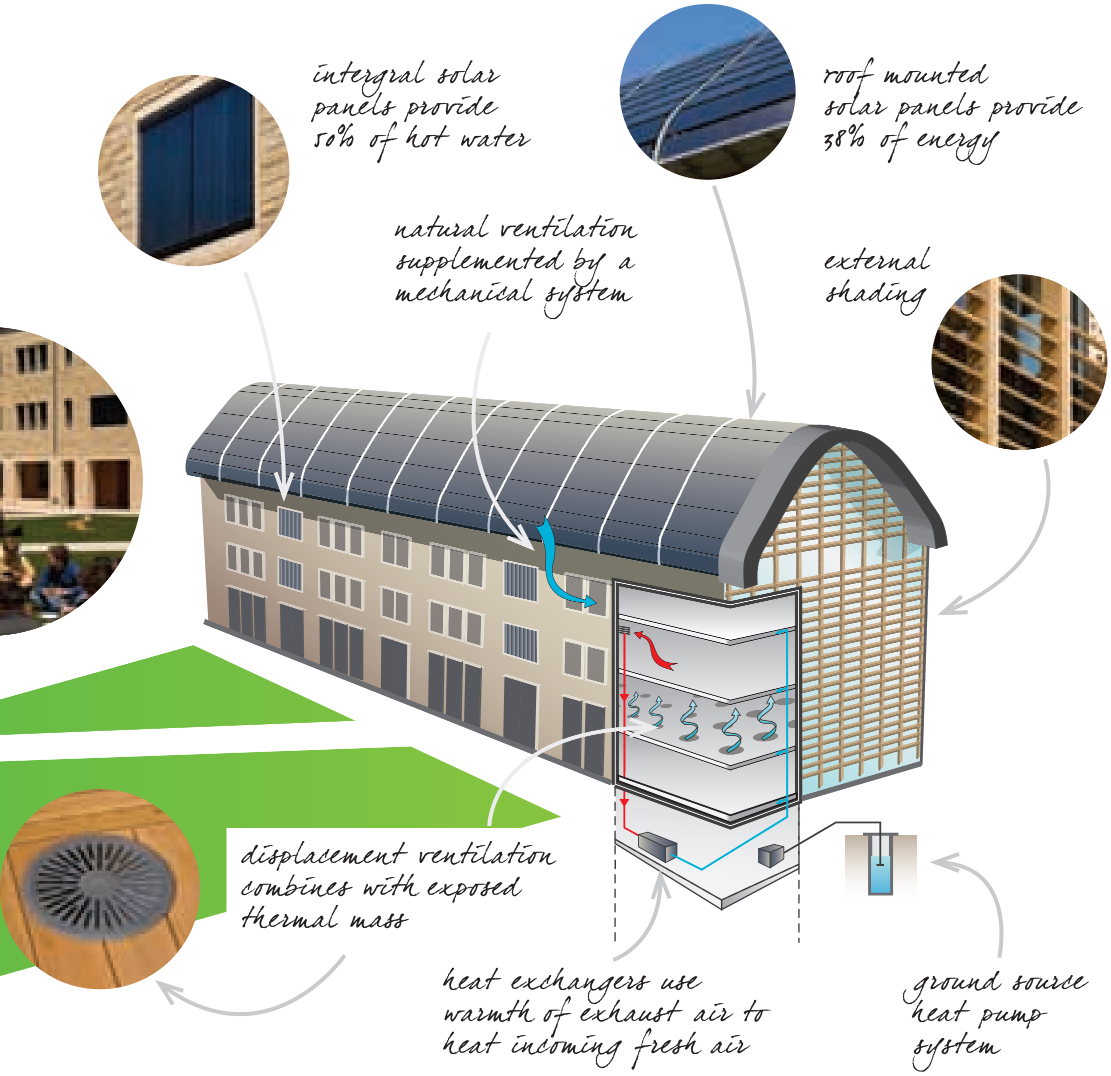
Project Name School of Forestry & Environmental Studies **Location** New Haven, Connecticut, USA **Client** Yale University



A modern twist on Yale's courtyard tradition

Grassy enclosed courtyards are a much-loved feature of college life at Yale. The south courtyard at Kroon Hall is far more than an attractive place to linger after lectures. Raising the ground level has lessened the intrusiveness of the neighbouring buildings and improved their view. Landscaped with native species, the courtyard's water feature doubles as a natural reed bed filtration system for stormwater, which removes 80% of suspended solids – as required under LEED® regulations – before the water enters underground tanks. After further treatment, the water is used for toilets and irrigation, saving around 2m litres of water each year and reducing the burden on city sewers at a stroke. In a final twist, the south courtyard is also a green roof for the service area below, masking the waste and delivery services in this corner of Science Hill.





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The mixed-mode system means that when external conditions are suitable for natural ventilation, indicator lights remind occupants to open windows.

The building is heated and cooled by four geothermal wells, although conventional utility power is on hand as an emergency back-up. While the technology behind geothermal systems is mature, a system on this scale is unusual, not least because of the capital investment required. Four 500 metre 'standing column' wells were bored into the bedrock, where water temperatures hover around 13°C. Groundwater is pumped up and its thermal energy is extracted and intensified by ground source heat pumps, much like a refrigerator in reverse. Once the water has performed its heating function (or, in summer, its cooling function), it is returned to the same wells, circulating in a loop.

In winter, efficient air-handling units extract heat from exhaust air, and use it to pre-heat incoming air. In summer, the indirect evaporative cooling system sprays water into the exhaust air, lowering its temperature. Incoming air is passed over the cool exhaust ducts, maintaining comfortable temperatures. Yale calculated that many seemingly expensive green technologies would in fact rapidly pay for themselves through energy savings and might also pre-empt future global warming legislation. There was another benefit: although the air handlers chosen cost twice as much as a conventional system, they allowed designers to build a smaller basement, saving around $2m.

Of paramount importance was the need to be consistent with the ethos of the School of Forestry & Environmental Studies itself. This was an ethical imperative of which the team never lost sight. □

Dujiangyan was a thriving city before the Sichuan earthquake reduced it to rubble. In the aftermath of the tragedy, Arup recognised there was an opportunity for change that could lead to a better future for the people of Dujiangyan. The reconstruction plans looked beyond the early stages of emergency response and temporary recovery to long-term socio-economic resurgence for the area.

Opportunity out of tragedy

Reconstruction plans for Dujiangyan help build a better future

Arup's strategic decision-making framework gave the reconstruction process both structure and flexibility.

■ Post-disaster planning differs from ordinary masterplanning: the massive destruction imposes extreme conditions and creates a lot of constraints – not least that severe and complex problems need to be addressed in a relatively short space of time.

In spite of this, Arup's reconstruction plans recognised the importance of addressing not only the immediate needs of Dujiangyan, but also looking beyond these to the city's future. To achieve this balance it was vital that the reconstruction planning was approached in a holistic and integrated way.

As a starting point, Arup proposed a strategic decision-making framework that gave the reconstruction process adequate structure to enable the formulation of policies, but enough flexibility to allow decisions to be reevaluated as new information became available. Circumstances changed rapidly as implementation progressed, making this dynamic approach essential.

Arup also proposed that an independent authority be appointed as the key entity to oversee the post-disaster reconstruction process. Central to this role was coordinating with local communities and ensuring that local residents received all the assistance they sought; people were, after all, the central consideration for the plans.

Prioritising the remedial work was done through extensive use of Geographic Information Systems (GIS), remote sensing techniques and satellite images. Areas of likely risk of earthquake, landslide, or flooding were identified and the findings used to determine if existing infrastructure – existing towns, access roads, and heritage sites – should be relocated. The initial priority was the resettlement of some 170,000 residents in areas that were safe.

Following the disaster, the city has been rethought as a first-class tourist destination, with six distinct types of tourist interest identified including cultural and heritage, as well as spa and wellbeing opportunities. Both nearby Qing Cheng Mountain, an important religious site, and the Qing Cheng ecological reserve, home to a panda conservation area, attract many visitors. The goal is to generate greater interest in tourism to bring a better quality of life to the region's 200,000 urban residents.

In the aftermath of the earthquake, it became clear that rescue efforts were being severely hampered by inadequate access to the city. As a result, an urban disaster evacuation system was a key element of the conceptual city reconstruction plan Arup proposed.

The new Dujiangyan is also built on sustainable principles that significantly improve on pre-earthquake conditions. Water conservation, renewable energy sources, integrated waste management and recycling targets have all been addressed within the plan.

Reconstruction by the Municipal Government has been remarkably swift. Residents have been moved efficiently into new housing, hotels and heritage sites have been restored, and visitor numbers are already at 60% of their pre-earthquake levels. Arup's holistic package of reconstruction strategies went far beyond what was expected for a pro-bono project and is helping to create an enhanced and safer city. □

Project Name Dujiangyan Post-disaster Reconstruction Conceptual Planning

Location Dujiangyan City, Sichuan Province, China

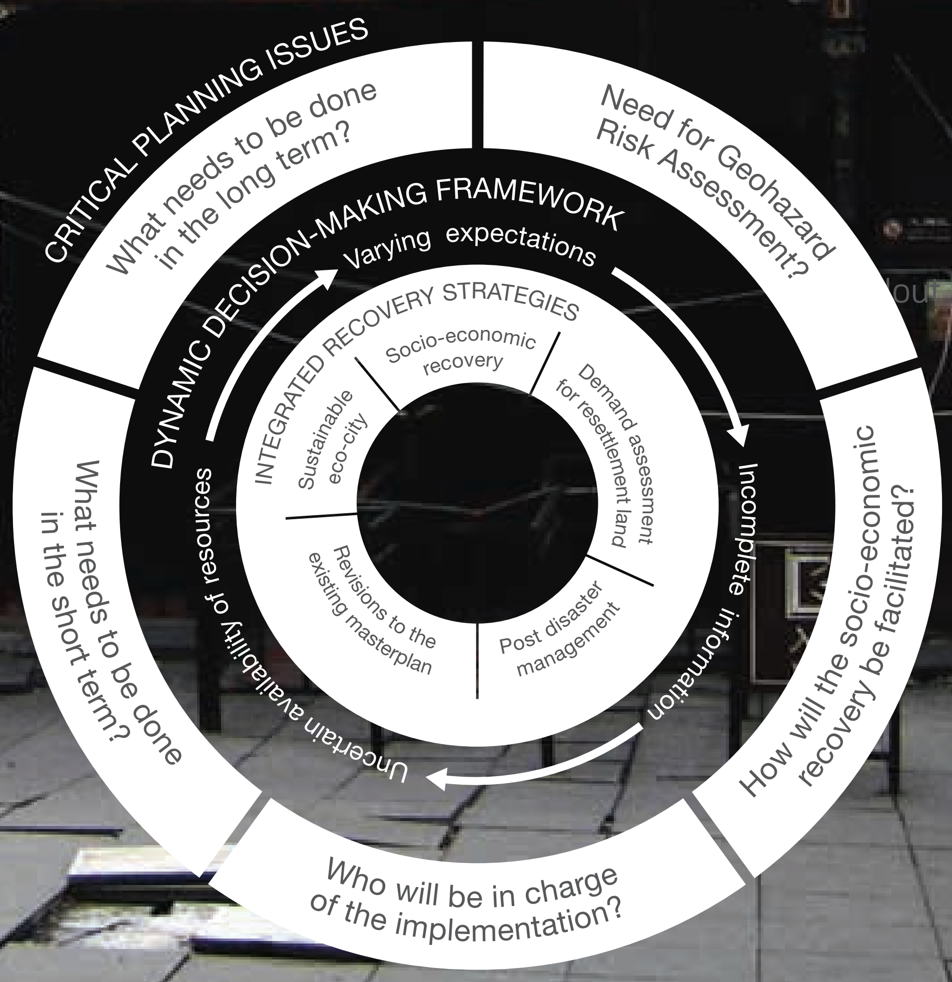
Client Chengdu Planning & Management Bureau, Dujiangyan Municipal Government

Urban disaster evacuation system

A city's evacuation strategy can mean the difference between life and death when disaster strikes. The reconstruction strategies proposed by Arup ensure that Dujiangyan City has exactly this lifeline.

The evacuation system has a dual approach. First, it ensures emergency vehicle access by setting buildings farther back from the street line and creating multiple vehicle access routes. Second, it creates open spaces linked to hazard resilient parks where people can congregate safely. Such measures are now a routine consideration for town planning in China, creating a new standard for urban design.

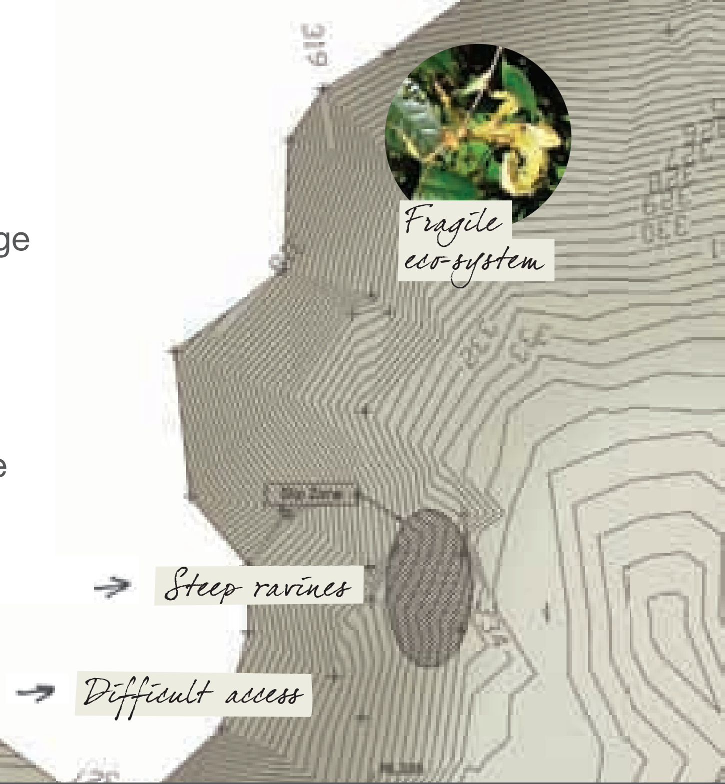
Challenges faced and strategies proposed



Geo-hazard Risk Assessment by GIS

GIS data helped determine the most appropriate sites for resettlement.

The Mamu Rainforest walkway is in a UNESCO World Heritage site in Far North Queensland, Australia. The new Canopy Walkway creates a way for visitors to experience this unique area without disturbing the fragile ecosystem. Arup needed to ensure that the design and engineering of the walkway supported the difficult construction process to such a degree that it would also leave the area undisturbed.



Leave no trace

An elevated walkway gives access to the Mamu Rainforest

The modular design employs lightweight but durable materials that require minimal maintenance. Recycled plastic, Replas, has been used for the walkway decking, and galvanised steel, for its long lifespan, for the walkways and towers.

The 28 circular towers each follow the same design, but vary in height, and their bases follow three standard designs. Adjacent tower tops are connected by a series of ten-metre bridges also uniform in design and with standard fittings.

This simple approach minimised the chance of error during construction in the challenging conditions.

Project Name Mamu Rainforest Canopy Walkway

Location Far North Queensland, Australia

Client Department of Environment and Resource Management – Queensland Parks and Wildlife

The Canopy Walkway allows visitors to experience the rainforest from a unique vantage point, moving from ground-level observations to the expansiveness of being above the treetops. A 37 metre high viewing platform offers sweeping views.

To enhance the rainforest experience yet further, a cantilever tower was created with a platform which projects eight metres beyond the tower's observation deck and hovers 16 metres above the forest floor, with the North Johnstone rapids in view.

■ Cyclone Larry left behind a trail of destruction when it hit the north Queensland coastal area in March 2006, with extensive damage to infrastructure and crops. But as devastating as it was, it also cleared the way for the Mamu Rainforest Canopy Walkway project.

The walkway, which had been discussed for some years, finally received the necessary funding to turn the project into a reality. As a result of the disaster, the state government wanted to find ways to regenerate the area.

The Mamu Rainforest is located in the Wooroonooran National Park and is home to many protected species. It contains some of the oldest surviving rainforest in the world and the whole area is important ecologically. It was vital that construction and the subsequent use of the walkway caused minimal disturbance.

The continuing presence of a family of cassowaries throughout the construction and beyond is testament to the fact that this has been achieved successfully.

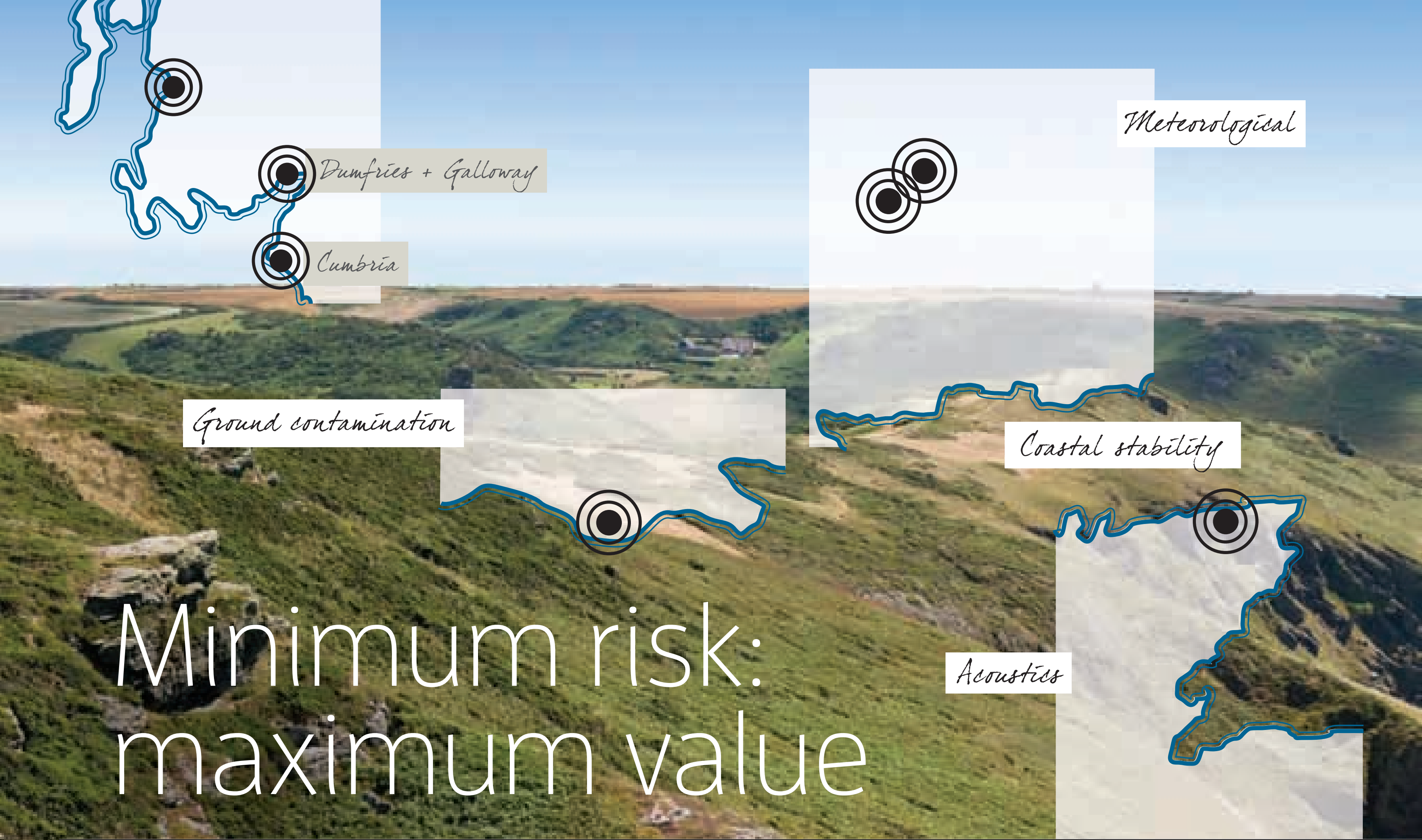
Difficult access created two constraints for the concept design: a mobile crane with limited reach and lifting capacity had to be used throughout the construction, and all materials had to be transported into the forest by small vehicles.

The elevated steel walkway is poised over a steep ravine with areas of unstable ground. The tower bases therefore made use of concrete piles and ground anchors to stitch the steep slope together, minimising the risk of landslides. The piles were installed using a small excavator with an auger attachment, enabling access to the bases and limiting the need to cut down trees.

Entry to the walkway is provided at four points from an adjacent ridge, which allows for repairs to be made to discrete sections without closing the entire tourist site. Use of standard parts and materials permits quick and efficient repair.

The site is culturally significant. Traditionally the land belonged to the Mamu indigenous people and the development has been carried out in close collaboration with their representatives. Visitors gain an insight into the Mamu culture and history through a series of interpretative signs located along the Walkway.

The Canopy Walkway brings the Mamu Rainforest to life in a unique and accessible way. Visitors come away with an understanding and appreciation of this beautiful landscape, but without disturbing its fragile balance. □



Minimum risk: maximum value

Arup minimises risk and maximises value for site asset disposal

The lifecycle of a nuclear power plant, from construction through operation and decommissioning, is typically more than 100 years. How then do you determine with certainty the suitability of a particular site for the development of a nuclear plant? Working for the UK's Nuclear Decommissioning Authority (NDA), Arup analysed complex site issues to help minimise the risk for potential investors and maximise the value of the sites in the NDA's portfolio.

■ The NDA has strategic responsibility for the UK's nuclear legacy – managing the nuclear decommissioning and waste process. But with renewed government enthusiasm for new nuclear power, the NDA is now in the process of selling some of its sites to the private sector for development of new nuclear power plants.

Arup was able to give a calculated view of the future environmental context of the sites, offer design solutions to address anticipated site challenges, and assess a site's potential suitability for a nuclear power plant over a full lifecycle. This created greater certainty for investors, and by reducing perceived risk, the value and desirability of the sites were enhanced.

Project Name NDA Asset Evaluation and Technical Support

Location Sites across the UK

Client Nuclear Decommissioning Authority

The NDA engaged Arup as technical adviser to assess sites and assist in determining the commercial value of assets through technical evaluation and design. Arup's status at the forefront of policy development on nuclear siting, flooding, and climate change adaptation was an important factor in making Arup NDA's preferred choice. Most of the sites in question are in coastal zones and part of Arup's work for the NDA looked at predicting how climate change – including predicted sea level rise – will impact the sites.

Arup's detailed analysis generated large amounts of data. To make the analysis easier to grasp and present it transparently, Arup used spatial processes such as Geographical Information Systems to display layers of data graphically. This type of presentation made key information readily accessible, enabling the NDA to make complex decisions quickly. It also gave the NDA a valuable marketing tool for presenting sites to potential buyers. Arup's work made it possible to gauge the viability of a particular site by simply referring to a site map highlighting the outcome of its assessment. This helped give potential buyers the confidence to invest.

The NDA recently conducted auctions to dispose of three sites: Wylfa on Anglesey, Bradwell in Essex, and Oldbury in South Gloucestershire. In support, Arup provided information underpinning a website portal that was accessible to interested parties. Team members also made themselves available to answer questions on due diligence. The auctions drew substantial interest and provoked, as it turned out, something of a bidding frenzy. Arup's work contributed to the heightened level of interest and investor confidence in the sites, and consequently their increased commercial value. The sites eventually sold for a combined value in excess of £380m.

The ancillary benefits of Arup's work are substantial. The project safeguards nuclear power within the UK energy portfolio and lays the foundation for what will be among the largest infrastructure programmes the UK has ever seen. □

Arup's work included technical evaluation and assessment of a site's potential suitability for a nuclear power plant over a full lifecycle.

Most of the NDA's sites are in coastal zones and part of this assessment included identifying how climate change – including predicted sea level rise – will impact the sites.

An eye to the future

... TRANSFERRING UP TO **30** GIGALITRES OF WATER EACH YEAR

Construction of a new bulk water supply is ready to start at a moment's notice

A far-sighted Australian regional water board has moved to secure water supplies against future challenges of climate change and drought. Once approved by the regulatory authorities, water supplies could be up and running within 24 months. This outcome is down to the collaborative relationship forged between the water board and Arup's water specialists.

■ Queensland is not often associated with a lack of water but in recent years the Gladstone area of the state has experienced increasingly severe periods of drought.

The Gladstone Area Water Board is acutely aware of the needs of its customers, the largest of which include two power stations, an aluminium smelter and alumina refinery, and concrete and chemicals manufacturers. These companies are major employers and exporters and the power plants are a vital part of state power supply. Together they use 80% of the Board's water supply. Just one more industrial customer could put demand beyond the available capacity.

With little rainfall since Cyclone Beni hit in 2003, the Board became increasingly concerned about diminishing water levels in the Lake Awoonga reservoir. Although the dam is the fourth biggest in Queensland, its catchment area – the watershed that drains into it – is small. The Board therefore asked Arup to start preparatory work for a new treatment plant, a large diameter pipeline, pump stations and storage reservoirs to transfer up to 30 gigalitres of water each year from the Fitzroy River to Gladstone.

A combined Arup and Gladstone Area Water Board team worked very closely together during the project, evaluating many alternative options which included a desalination plant. The Board had to develop a concept and procure detailed design and a constructor for a major new water supply – which could be put on hold or fast-tracked, subject to rainfall or the investment decisions of its customers. The challenge was to give the Board certainty over programme and cost. Arup proposed an 'early contractor involvement' approach, which brings in contractors at the design stage. This encourages innovation and commitment, improving certainty and results, while maintaining flexibility and competitive tension.

In contrast to many water authorities that have been forced to respond urgently to crisis conditions, the Board will be able to trigger the project construction whenever it is needed. The new water supply could be on tap just two years later. □

Project Name Gladstone Contingent Water Supply Strategy

Location Central Queensland, Australia

Client Gladstone Area Water Board

Making the invisible visible

Use of the new State Library of Queensland's Wi-Fi facility has far exceeded expectations. Arup's post-occupancy evaluation is helping the State Library to understand the impact of the service and how it influences its plans for the future.

■ Arup is working with the State Library of Queensland in Australia to gauge the impact of their highly successful Wi-Fi service and how this shapes its broader strategy. Information and communications technology is typically seen as a support service, but Arup's work is revealing how Wi-Fi needs to be a fundamental consideration for organisations.

Arup created a 3D model of the Wi-Fi signal strength and combined this with sketches of how users occupy the space. With this analysis, the State Library is reconsidering its spatial organisation and looking at ways to make the Wi-Fi service 'visible' to users through signage and installations, and through appropriate design of furniture and fixtures.

The digital age is redefining the role of libraries to encompass far more than the physical resources contained within their walls. To ensure the State Library's relevance over time, data on webpage access is analysed to identify patterns of user behaviour. This allows it to keep in touch with user needs; it also gives them the opportunity to direct users to their other digital and non-digital services.

Arup's findings are informing the design of the State Library's latest project, a new digital culture facility known as The Edge. A key element being explored is the integration of displays into the architecture of the building, which will enable real-time installations.

Understanding the influence of invisible phenomena such as heat and sound has long been integral to good building and urban design. Now, Wi-Fi and other real-time digital activity are destined for similar consideration. □

Wi-Fi is being used almost
24 HOURS PER DAY

A 3D model maps the Wi-Fi signal's peaks and troughs, enabling Wi-Fi to be perceived as a physical phenomenon.

Project Name Post-occupancy evaluation of Wi-Fi **Location** Brisbane, Australia **Client** State Library of Queensland

A building that breathes

© Arup/Giles Rocholl Photography

The University of Sheffield's new Arts and Humanities faculty at Jessop West shows how it is possible to create a naturally-ventilated interior in a noisy location, using a double-skin acoustic façade. It also proves that low-carbon buildings can succeed in an urban environment.

■ The story of Jessop West is as much about what is left out of the building as it is about what is included. From the earliest stages, the Arup design team, in collaboration with Sauerbruch Hutton Architects and RMJM, explored ways to make the building as lean as possible, and in doing so to produce a model of affordable sustainability. At the same time it was important to create a comfortable environment that gave the UK university a high-quality, creative learning space.

Natural ventilation in a noisy location

Central to the design was the desire to forgo mechanical air conditioning and eliminate the need for a conventional 'sealed' building. Jessop West fronts onto Sheffield's busy inner-city ring road. The need for good acoustic insulation was vital to eliminate the noise from traffic along the west face of the new building.

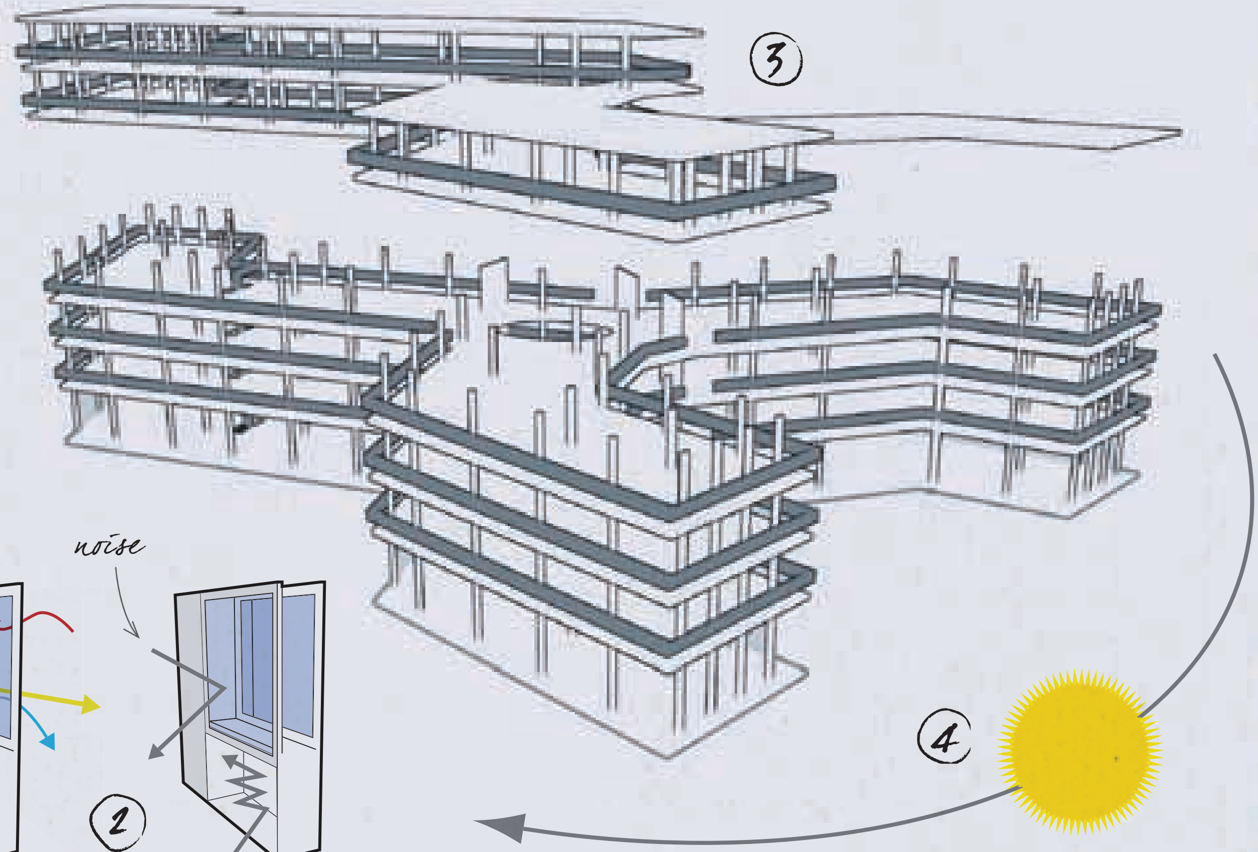
Computational fluid dynamics testing was carried out to verify air movement within the façade cavity and the flue, thereby ensuring that the building would perform as expected.

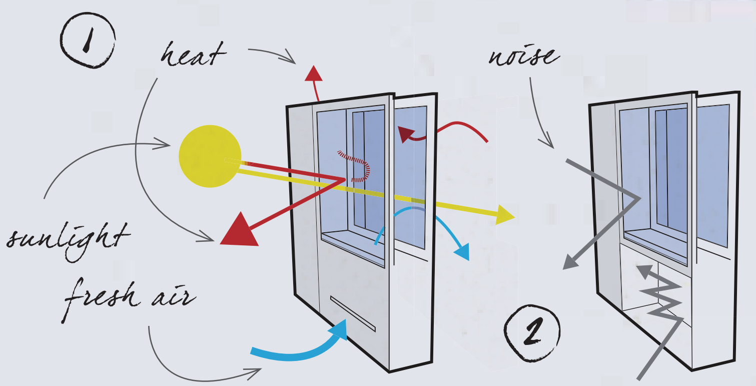
Project Name University of Sheffield, Jessop West

Location Sheffield, UK

Client University of Sheffield, and Bowmer & Kirkland Ltd

1. Solar-performing glass in the external pane reflects 30% of the heat.
2. Air enters the façade through an acoustic labyrinth that ventilates while blocking noise.
3. The façade changes as it wraps around the building to respond to varying site conditions.
4. The size of the windows is optimised for the orientation of each façade, helping to ensure that light, and not heat, is brought into the building.





Arup explored the option of a double-skin acoustic façade in great detail. This would allow effective natural ventilation despite the close proximity to the busy road. This is the first such use of a double-skin acoustic façade in the UK.

The double-skin west façade

The west façade incorporates internal and external opening windows, with a narrow cavity running between the two. When the internal window is opened it allows outside air to enter the room via the acoustically-lined cavity within the double-skin façade, and to exit the room via a thermal flue. This flue runs the full height of the façade and draws stale air up and out of the building using the natural stack or chimney effect.

Manually adjustable blinds, sandwiched between the windows in the ventilated cavity, trap solar heat gain within the façade before it enters the building. This heat is passively removed via the thermal flue whether the windows are open or closed.

Arup modelled the thermal performance of the west façade and assessed the expected internal conditions against agreed comfort criteria. These tests were supplemented by computational fluid dynamics analysis and a physical test using a full-scale mock-up of one module of the west façade and a typical academic office. The results were used to optimise the size of ventilation openings, which are different on each floor due to the change in flue height.

Natural daylight and an even temperature

To complement the natural ventilation scheme, exposed concrete is used throughout the interior of the building. As well as creating a design feature, concrete absorbs heat during hot weather and it radiates stored heat during cooler weather, thereby tempering the internal environment.

The shallow depth of the building, combined with solar-control glass and window sizing optimised for the orientation of each façade, also helps to ensure that light, and not heat, is brought into the building.

Jessop West was consciously designed to allow gradual changes in daylight, temperature, air quality, and noise levels to stimulate the senses and enhance creative thinking.

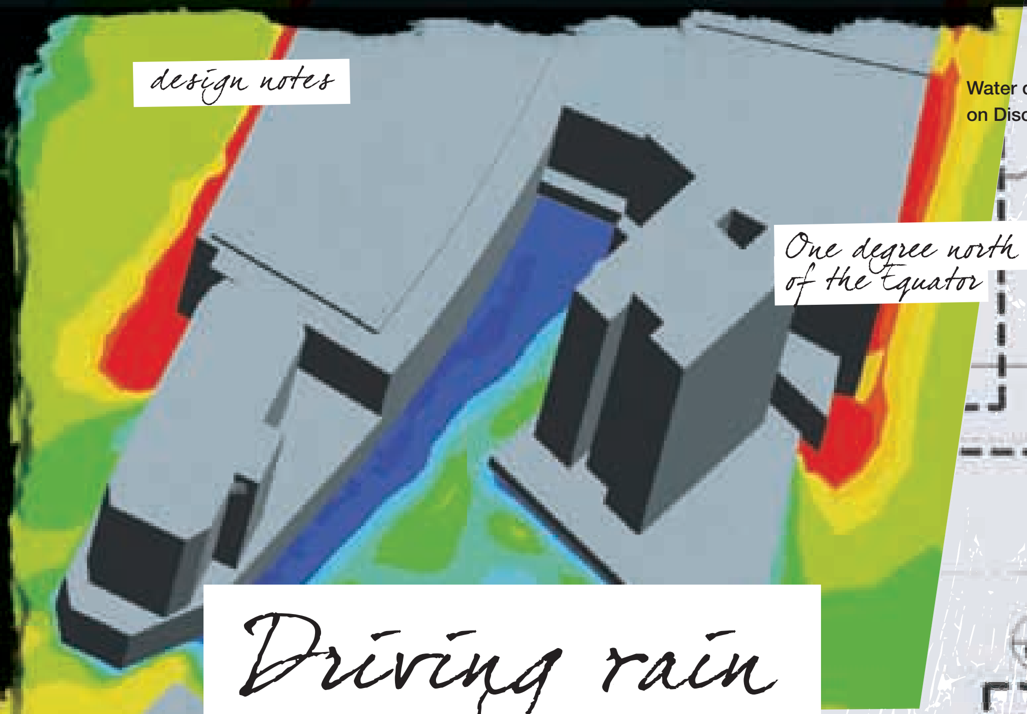
Occupant comfort

The building has been occupied since the beginning of 2009 and the double-skin façade is exceeding the expected acoustic performance. Occupants are finding the internal conditions comfortable even in the warmest weeks of the year.

Environmental credentials: low-energy design

Annual CO_2 emissions are predicted to be as low as 40% of emissions for a comparable air-conditioned building built to current standards on a similar site. Jessop West leads the way towards the UK Government's target to reduce CO_2 emissions by 80% by 2050. □

design notes

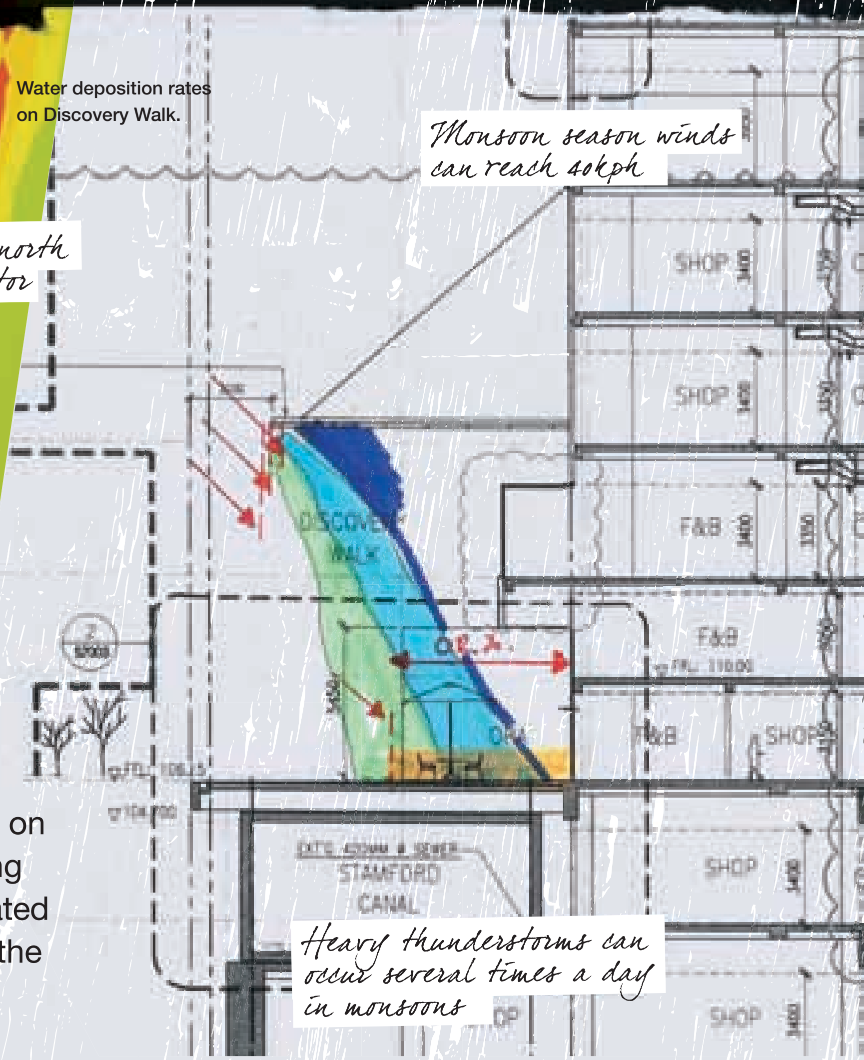


Water deposition rates on Discovery Walk.

One degree north of the Equator

Driving rain

Arup's approach to modelling air and liquid flows has made it possible to quantify the effect of monsoon rain on customer comfort – and lettability – of an outdoor dining area in Singapore. It could help to make naturally ventilated outdoor space a common feature of urban planning in the tropics, where over half of the world's population live.



Monsoon season winds can reach 40kph

Heavy thunderstorms can occur several times a day in monsoons

Cross section of Discovery Walk, part of 313@somerset, a new retail development.

Wet seats

■ Potential tenants for the outdoor Discovery Walk, part of a new retail development in Singapore, were concerned about the effect of wind-driven rain on their dining trade. The glass canopy roof protects customers from vertical rain. During the monsoon seasons, however, high winds drive the rain at an angle. Worse, high humidity levels means that, once wet, tables and chairs are slow to dry, rendering them unusable.

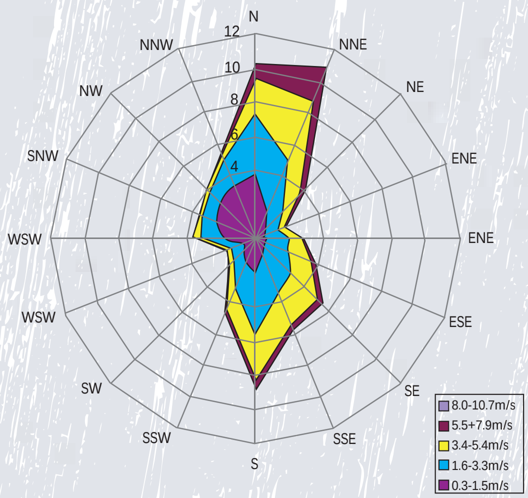
Analyse this

Traditional fluid dynamics computer models can simulate air or liquid movement – but normally not both. Arup created a new hybrid model to represent wind-driven rain. It programmed-in the city's topology – tall buildings affect wind movement – and added a statistical analysis of historical data on Singapore's tropical weather. The team could then model probable and extreme wind/rain scenarios for Discovery Walk.

The human factor

Computer models work with quantifiable values. The client wanted the values related to comfort levels of customers – a subjective measure. Once the team successfully modelled the driving rain, it ran simulations with varying sizes of rain droplets from drizzle to deluge.

Using terms used by the UK's Meteorological Society, Arup mapped customer comfort, looking at droplet size and moisture content. When moisture levels reached a certain level, customers would be deterred and trade affected. This helped the team to find suitable and effective solutions for the tennant. The team also suggested several adjustments to the canopy roof design and vertical blinds to reduce the vulnerability of the dining areas to driving rain. □



Distribution of wind patterns between 1975 and 2007.

Project Name Wind-driven Rain Study: 313 @ Somerset Discovery Walk **Location** Singapore **Client** Bovis Lend Lease Pte Ltd

Education packs make roll-out of the session easy.

Bringing water into the classroom

Students get to grips with global water issues

A new interactive classroom session, Water for the World, is helping schoolchildren understand global water sustainability issues and is adding an important element to the UK school curriculum.

■ With world water resources becoming increasingly stressed and potable supplies more precious, it is critical that future generations understand the importance of these resources early on and become inspired to protect them. Education is a vital aspect of this effort. One programme that aims to do this is Water for the World, a collaborative project with the non-profit organisation Engineers Without Borders UK (EWB-UK). A team of volunteers from Arup developed the technical and communications component of the programme.

Careful research ensured that the programme, which is divided into three age-specific modules, is appropriate for each group's level of technical understanding as well as their unique learning style. The content addresses water issues faced by both the developed and the developing world.

A key part of the 90-minute session is a 'hands-on' workshop that demonstrates the challenges people in developing countries go through to obtain safe drinking water. It quickly becomes apparent to students that without technical know-how, dependable communications and access to other resources that people in the developed world take for granted, creating and sustaining a healthy living environment is far more difficult. The message hits home through the experiential nature of the exercise.

The self-explanatory education packs have, to date, been used to run the sessions in the UK by Arup volunteers and EWB-UK students. However, the content is being developed so that Water for the World can be conducted by schoolteachers who otherwise might not be familiar with the subject matter. This will bring the issues that surround global water sustainability to a much wider school audience. □

Project Name Water for the World **Location** UK **Client** Engineers Without Borders UK

The award-winning Barratt Green House meets the stringent Level Six of the UK's Code for Sustainable Homes and sets a new standard in sustainable design. The three-bedroom house shows that a net-zero-carbon house can be both affordable and desirable. A triumph in itself, it also offers a blueprint for sustainable development on a larger scale.

32 square metre solar PV array on its south-facing roof

© Barratt Developments PLC

A green prototype

Testing the performance of sustainable technologies

■ When the Barratt Green House opened in May 2008 at the UK's BRE Innovation Park, it was the first foray by a major house-builder into sustainable design. By aiming to produce a net-zero-carbon domestic house, Barratt Developments PLC was pushing the boundaries of sustainable design to create its prototype.

From the start, Arup and the architect Gaunt Francis aimed to achieve Level Six under the UK's Code for Sustainable Homes. The house had to clock up a certain number of credits for sustainable practice and features at all stages, from design to operation. Vegetation and 32 square metres of photovoltaic solar panels cover the roof. Solar energy powers the domestic electrical appliances and solar thermal panels provide hot water for the house.

Designing for Level Six is a tricky balancing act. The team wanted to use smaller windows to minimise heat loss in winter and excess heat gains in summer but also to maximise daylight to specific rooms. So it specified triple-glazed windows and powered external solar shading. Concrete was chosen for the walls and floors for its thermal mass properties, which reduce the need for energy-hungry climate control.

Unlike conventionally-built houses, which have space within walls, under floors and in lofts to hide essential cabling and pipes, the Barratt Green House had even less space in which to conceal the increased amount of wiring needed for its computerised lighting, solar shades, temperature controls – and even an integrated iPod player control. Here, the concrete posed a practical problem – its all-important thermal stability and structural strength would be compromised if it were punched full of voids or covered with void forming materials. The team decided on a containment system of pipework similar to that used in commercial buildings.

The Barratt Green House provides a test bed which continues to provide data on the performance of materials and technology over time. The results are no mere intellectual exercise and are already informing Barratt's approach to its next, more ambitious project, an entire community of sustainable homes. □

Three storeys, three bedrooms

Eco-friendly copper cladding contrasts with white rendered walls

© Barratt Developments PLC

A prototype for domestic housing

 Project Name Green House **Location** BRE Innovation Park, Watford, UK **Client** Barratt Developments plc

The same developer who used new sustainable techniques and technologies tested on the eco-friendly Barratt Green House is now applying them on a commercial scale. Hanham Hall will show how a zero carbon development fares in a realistic commercial setting: the UK's housing market.

Green community

A new community shows that green can be profitable

■ The developer has two inter-linked challenges. The first is to design the 195-home Hanham Hall eco-community to achieve a Code Level Six on the UK's Code for Sustainable Homes. The second is for it to succeed as a commercial venture. This is the first project on such a scale and the first of its kind from a major housebuilder in the UK. Arup, Barratt and HTA architects jointly developed the scheme in response to the UK Government's Carbon Challenge Programme, run by the Homes and Communities Agency.

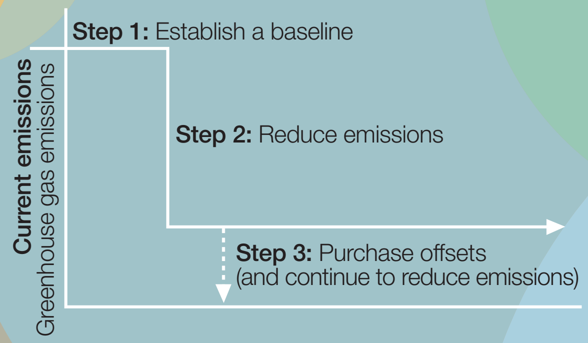
The original Hanham Hall was built in 1665 in the middle of farmland. It has been used as a psychiatric hospital for decades but has slowly fallen into disrepair following its closure in 2000. The new scheme refurbishes the original building – which is Grade II listed by the UK's Department of Heritage – and brings it back into commercial and community use. The new homes have been designed to encourage a new way of living, one that is more sustainable. Much of the rich, original landscaping has been retained, including the orchard and walled gardens. Some has been enhanced and now features allotments and pasture. The result is a development which stays true to the site's heritage and sense of place, while securing its ecology and wildlife, which includes slowworms and badgers. Hanham Hall showcases leading sustainable technologies. Visitors will see at first hand the community's combined heat and power plant in the sustainable living centre at the heart of the scheme. The plant will burn locally produced biomass to meet the development's modest energy requirements.

Hanham Hall is on the outskirts of Bristol, surrounded by suburban development and within a 10-minute walk of local shops and schools. At the heart of the development are offices, a community hall and a café.

The chance to live a green lifestyle seems to hold considerable appeal to residents and recent open days at the site have been overwhelmed with interested parties. Hanham Hall will show that a carbon-neutral lifestyle is within the grasp of ordinary house-buyers in the UK. □

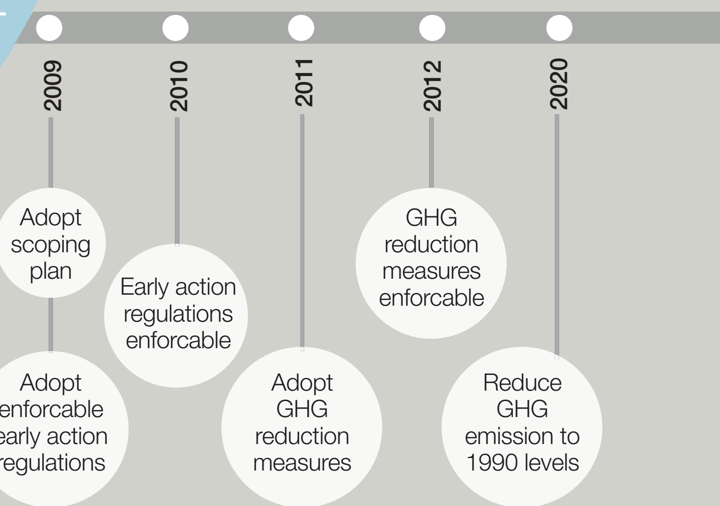
1/3
AFFORDABLE HOUSING

-30% *by 2020*



Stepping down the Carbon Ladder

Policy process timeline



In 2012, Californian businesses will be operating within a new 'cap and trade' carbon emissions regime. A guide written by Arup offers businesses the practical help they need to come to grips with reducing their emissions.

Carbon emission reductions made easy

Helping California to make carbon compliance good business

■ California's Global Warming Solutions Act, known as AB32, was enacted in 2006. It requires the state to reduce greenhouse gas emissions by 30% by 2020. It also provides for a new system with strict carbon emission limits for businesses.

With only three years to finalise the details before the act takes effect in 2012, the state government has its work cut out, setting emission limits across sectors and devising a trading system. Businesses, meanwhile, are concerned about how AB32 will affect their bottom line and what they can do to prepare for it.

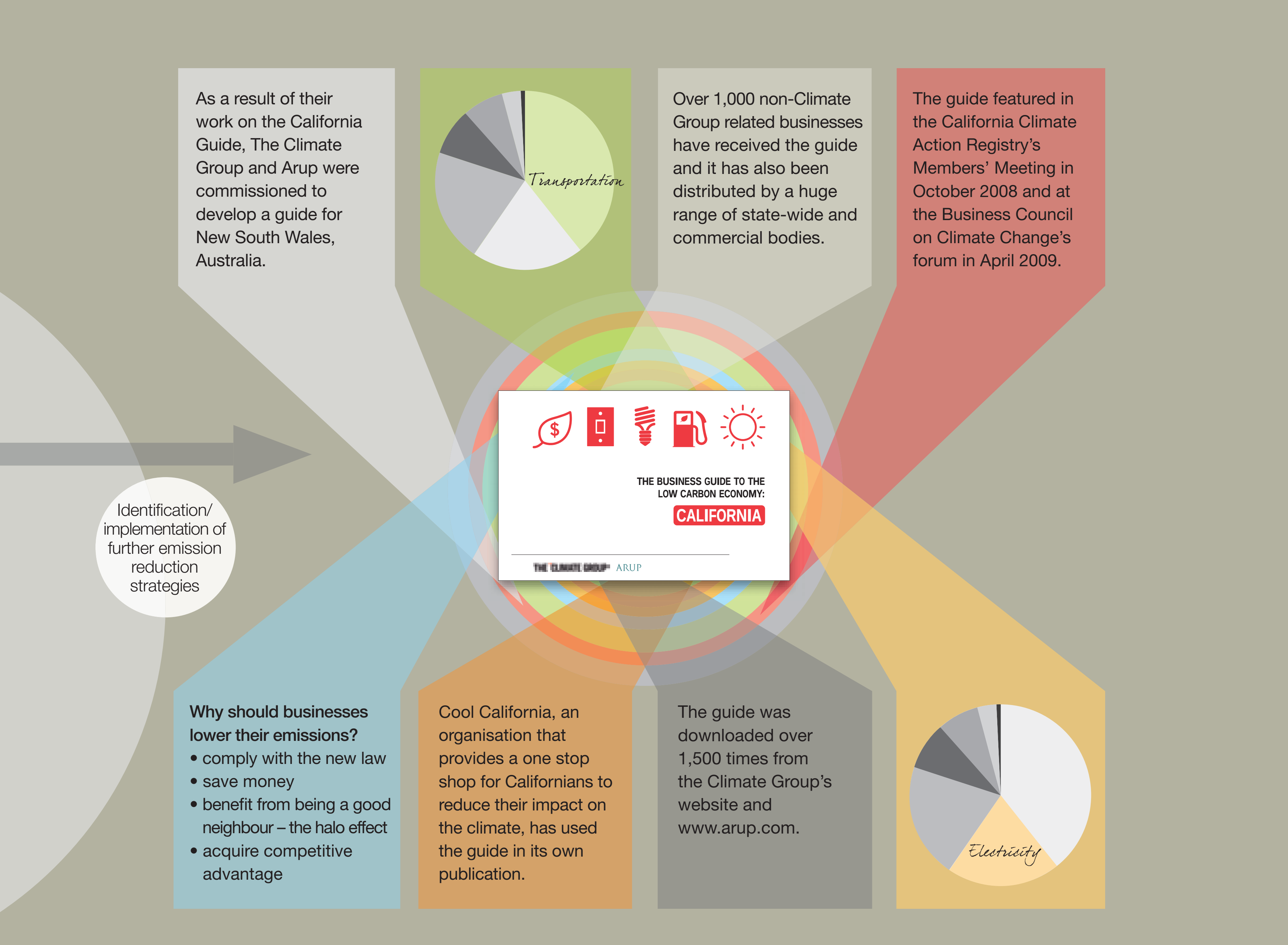
California encourages entrepreneurship with a range of incentives, including tax breaks. As a result, small and medium enterprises form a significant part of the state's economic activity. These companies often lack the resources to employ in-house lawyers or sustainability experts to deal with the carbon emission challenge.

A key source of practical advice is the *Business Guide to the Low Carbon Economy: California*, a publication jointly produced by Arup and the international non-profit organisation, The Climate Group. The publication introduces the state's emissions reduction policies and offers practical guidelines for businesses – both in complying with reduction goals and in pursuing business opportunities created by the new regime. Straight forward and easy to follow, it offers

Project Name The Climate Group/ The California Air Resources Board

Location Business Guide to the Low Carbon Economy

Client California, USA



businesses a starter's guide to measuring their carbon emissions – the first step towards actually reducing them.

The practical tenor of the guide owes much to the experience of Arup's team. Working for San Francisco's Bay Area Rapid Transit (BART) system, for example, Arup devised a normalised measure of emissions – CO_2 per passenger mile – to develop a baseline for carbon emissions. This method of measurement was necessary because the very philosophy of mass public transportation is paradoxically at odds with reducing carbon emissions overall. Getting people out of private vehicles and onto trains seems fundamentally sound, highly desirable and a vital aim for cities. Yet if a transportation company carries more people, it could increase its emissions beyond its permitted level. Working on similar issues with clients such as the New York Power Authority and the San Francisco Public Utilities Commission, Arup's experience extends across key sectors. Arup drew on its experience analysing carbon footprints to formulate the method set out in the state business guide. It is this streak of practical know-how that is striking a chord with California's business community. The guide is short on moralising and long on simple how-to advice. It assumes at the outset that companies already understand the ethical, commercial and legal case for reducing emissions and simply want to get it done. □

Decoding carbon emissions

A new statistical tool helps policymakers to reduce carbon emissions

Reducing a nation's carbon emissions is an enormous undertaking, but one that has to start somewhere. Charged with accelerating the UK's move towards a low-carbon economy, The Carbon Trust asked Arup to help analyse the best way for the UK to achieve a low-carbon non-domestic building stock by 2050.

THE UK'S CLIMATE CHANGE ACT 2008 COMMITTED THE UK TO REDUCING ITS GREENHOUSE GASES TO AT LEAST **80% BELOW** 1990 LEVELS BY 2050

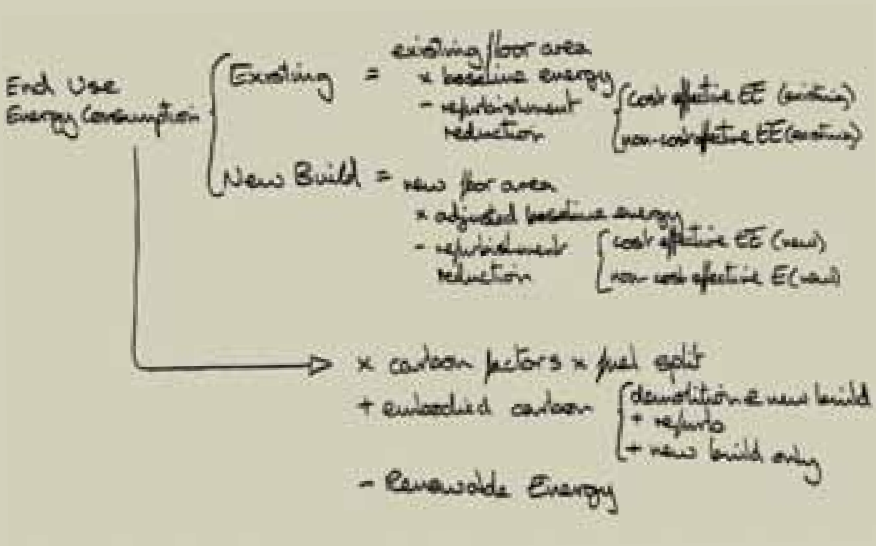
IF RECOMMENDED ENERGY EFFICIENCY MEASURES IN PUBLIC BUILDINGS ALONE WERE IMPLEMENTED, THEY COULD CREATE **13,000 JOBS BY 2020**

[UK BUSINESS COULD **SAVE £2.5bn** A YEAR THROUGH CARBON REDUCTION MEASURES SUCH AS REPLACING OLD BOILERS OR INSTALLING NEW LIGHTING] decode©

determining **c**arbon **o**pportunities in the **d**evelopment **e**nvironment

Where to start

DeCODE gives the government a point of departure. The challenge is not choosing some measures over others – with a target of 80% reduction in emissions, virtually all are needed. The task is to prioritise them. DeCODE offers a tool to help policymakers do just that, at the same time ensuring that effort and resources are deployed where they will make the most difference. Although created for policymakers, DeCODE could easily be adapted to suit any organisation with a property portfolio, from a commercial landlord to the UK's National Health Service.



In 2008, the UK Government set the country's carbon budgets up to the year 2022. Taking into account the latest climate change science, the Climate Change Act set a goal of 80% reduction in carbon emissions by 2050 to minimise the impact of climate change.

The UK Government had many policy options at its disposal, from subsidising insulation to redefining how 'zero-carbon' can be achieved in the built environment. What it lacked was a means of comparing the relative effectiveness of carbon reduction policy interventions. The Carbon Trust asked Arup to invent one.

Demystified

The result was DeCODE, a statistical model that shows how carbon savings accrue from different carbon reduction measures, the rate at which they can be implemented, and potential barriers to their adoption. Developed using a standard spreadsheet, its sophistication lies in how the carbon saving measures, implementation rates and barriers are linked, ultimately, to output the sought-after 80% reduction in emissions.

DeCODE helps property owners to meet – and even exceed – the targets that will be set under the Carbon Reduction Commitment, the system of carbon compliance that will be effective from 2010 in the UK.

Carbon-saving measures

- energy efficiency
- renewable energy
- demolition rates
- new build rates
- grid carbon intensity

80%

Understanding the baseline

The first step is to calculate what total emissions of non-domestic housing stock would be in 2050 if no policy were implemented. This baseline can then be compared with a variety of different, emission-reducing policy scenarios.

The baseline takes into account factors like current rates of demolition, refurbishment and new construction as well as predicted growth in individual non-domestic building sectors and associated increased floor areas. The model shows that, in the absence of policy changes, carbon emissions will show a net increase of about five percent by 2050.

Building up a picture

The Carbon Trust wanted the DeCODE tool to be externally verifiable, so Arup only used data that is already in the public domain. Owners of buildings are organised by standard industry sectors used by central government and energy use (based on fuel supply); changes in floor area are input as historical data from existing records.

The Carbon Trust had previously surveyed landlords, tenants, funders, developers and lawyers to identify barriers to implementing different carbon-reduction measures. Some of these are legal or regulatory and some are practical, such as the capital cost of retrofitting. Arup identified the most effective carbon-reduction measures and linked them with policies that might change carbon emission levels.

Next, Arup identified factors that might be affected by policy, such as rates of demolition or refurbishment. The firm added carbon saving measures – these values can be changed to model different scenarios.

The rates at which energy efficiency measures are implemented can also vary. Data, for example, showed that only about 40% of buildings can be prompted to use any given energy efficiency measure because so many buildings already have it in some form or because landlords refuse to pay for it.

DeCODE =

Determining Carbon Opportunities in the Development Environment

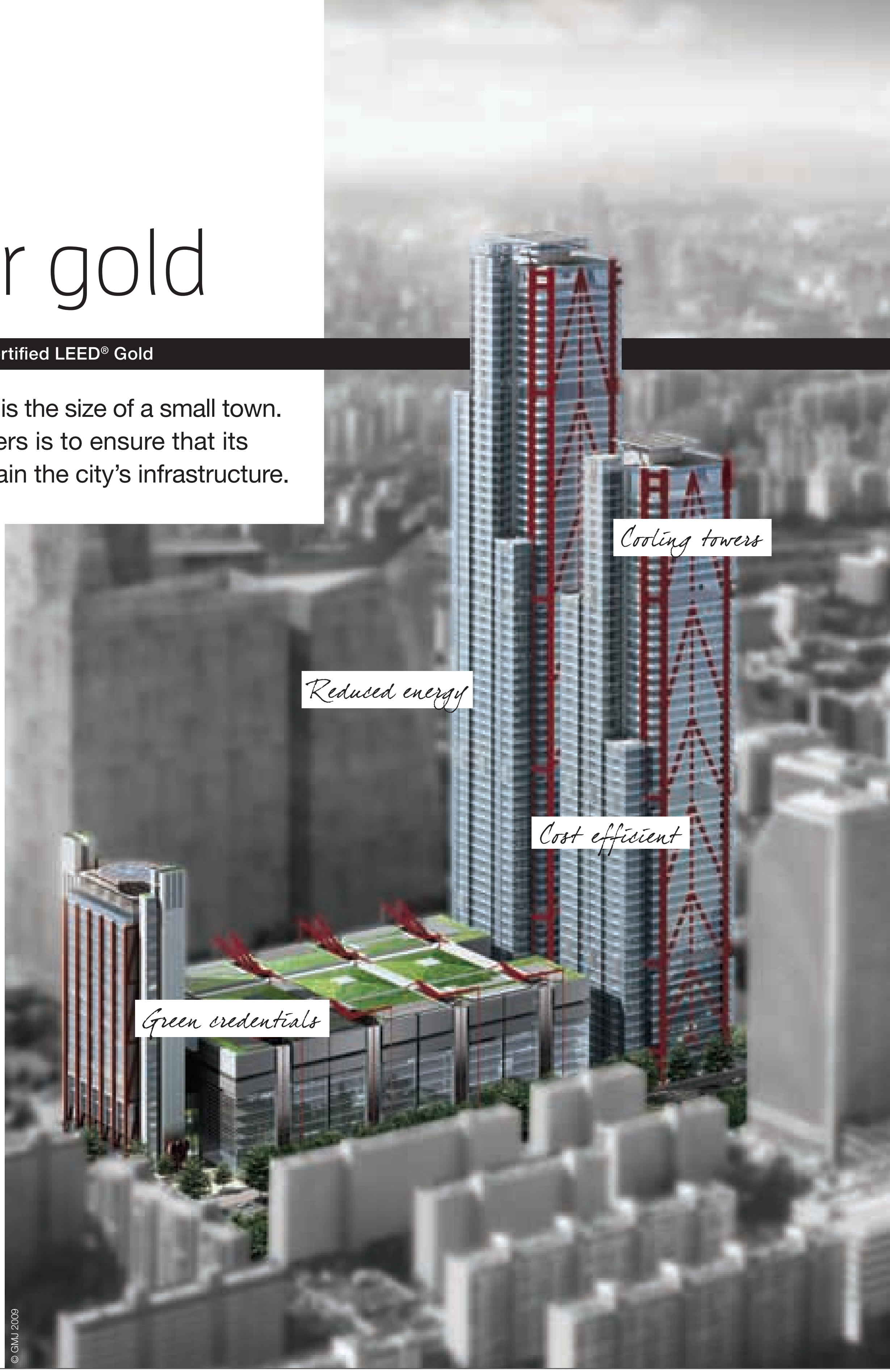
Location UK

Client The Carbon Trust

Going for gold

Seoul's largest development is pre-certified LEED® Gold

Seoul's newest development is the size of a small town. The challenge for its designers is to ensure that its energy demand does not strain the city's infrastructure.



© GMJ 2009

■ Parc 1's distinctive glass towers are unlike anything else in Seoul: the architect Rogers Stirk Harbour and Partners has created a prestigious signature building for corporate tenants. Parc 1 is also a green icon: the towers are the first buildings in the city to achieve pre-certified Leadership in Energy and Environmental Design (LEED®) Gold status, thanks in large measure to Arup's expertise in designing energy-efficient systems.

Named Parc 1 for its proximity to Yeouido Park, Seoul's new hotel-office-shopping complex is all about size. When completed, the 72-floor and 54-floor glass towers – alone 50% of the development – will accommodate more than 20,000 workers. The taller tower will be the tallest in South Korea when completed. The development includes a 300-room hotel and a nine-level shopping complex with space for 400 shops. One floor of the shopping complex is given over entirely to a miniature park. The sheer scale of the development means that energy efficiency measures have a significant impact on carbon emissions and the bottom line.

Project Name Parc 1 **Location** Seoul, South Korea **Client** Y22 Project Financing Investment

Like any modern office building full of people and computers generating heat, the big issue for Parc 1's towers is cooling, even in winter, when the temperature can drop to -11ºC. Arup wanted to harness the cold outside air. The firm therefore designed a variable air ventilation system for the two towers to do just this, creating a cost-effective and highly energy-efficient system.

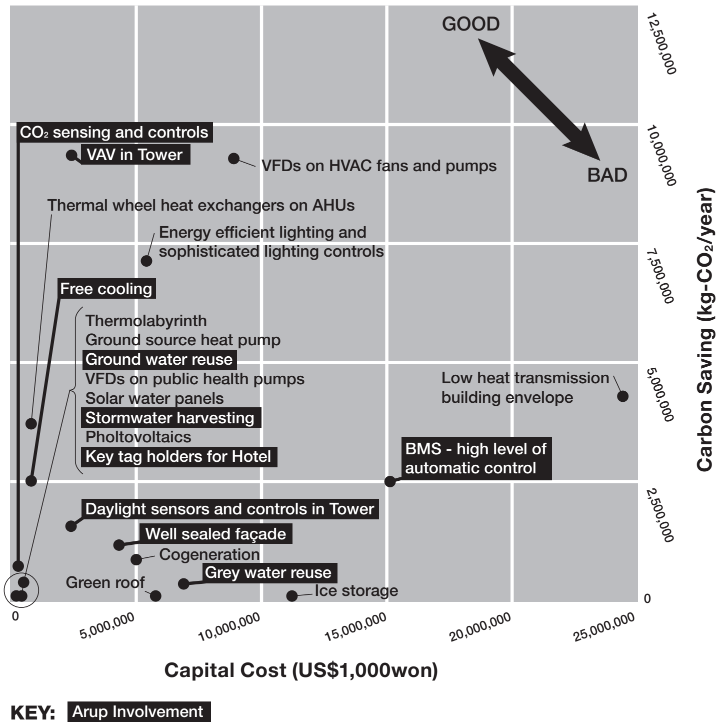
The cold winter temperatures inspired another Arup idea. Normally, cooling towers work with chillers to provide chilled water to cool the buildings and regulate the internal air. The unwanted heat is rejected from the cooling towers into the open air. The team designed the Parc 1 chilled water system to have an alternative connection directly to the cooling towers, such that in winter it could bypass the energy-hungry chillers. This provided a free cooling system which will save energy during the winter months.

When fully occupied, Parc 1's demand for cooling and other services will peak during the day, when 14,000 or more people are at work in the towers. The team decided to chill huge ice tanks at night, when energy is cheaper. The ice tanks are depleted during the day to provide cooling to the buildings, opposite to the way night-time storage heaters operate. In this way, the peaks and troughs of energy use are reduced, with the energy to create the ice taken during the night, and all other office needs during the day. This is cost efficient for the client and reduces the burden on the city's infrastructure.

Achieving a high LEED rating was expected to add around three percent to the building cost. In fact, it added nothing, thanks to the inherent energy-efficiency of Arup's design. Parc 1's energy-efficient towers have not only achieved LEED Gold pre-certification but are also the first buildings in South Korea to do so. ◻

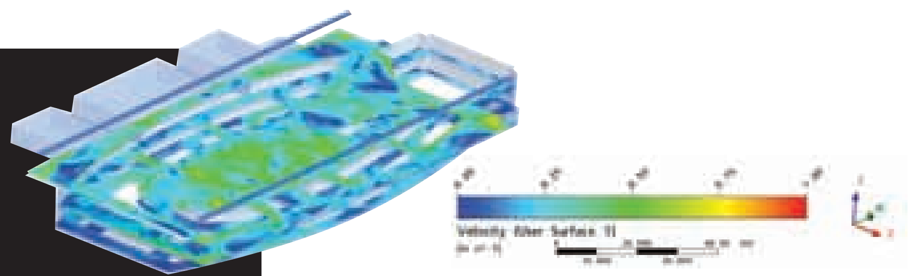
Carbon-saving technologies

Technologies such as thermolabyrinths are mandatory in Korea, yet for Parc 1 their value would be negligible. Arup analysed technologies for carbon savings and capital cost. Some of the measures introduced by Arup highlighted below are, by contrast, highly cost effective.



630,000 SQUARE METRES OF NEW BUILDING

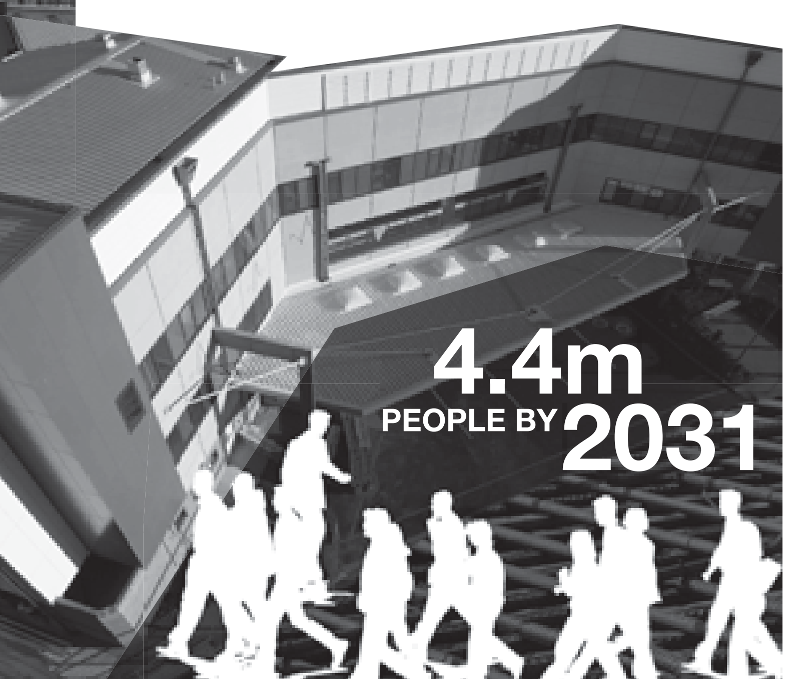
The team used 3D advanced computer modeling techniques to explore and compare the options for the building and to optimise the design, thereby maximising lettable building area. This diagram shows velocity distribution modeling for the rooftop park area in summer.



A truly coordinated approach

Meeting Queensland's infrastructure challenge

Australia's largest infrastructure programme encompasses over 378 identifiable projects, ranging from road tunnels and railways to hospitals and prisons. A truly coordinated approach to managing the programme is ensuring that Queensland's taxpayers are getting maximum value for money.



■ Colloquially known as the Sunshine State, Queensland is home to Australia's fasted-growing metropolitan region: South East Queensland. With such an enviable reputation, the region's job opportunities, sub-tropical climate and sought-after lifestyle prompt more than 1,000 people to move there each week. Projections show a rise in the regional population of 1m to 4.4m by 2031. The state capital, Brisbane, may play on its country-town charm, but is in reality a city on the rise. The state government has planned for the necessary infrastructure to support sustainable growth through the South East Queensland Infrastructure Plan and Programme (SEQIPP). Worth AUS$124bn over 20 years, and including some 378 projects, it is a substantial investment, most of which comes from taxpayers.

The traditional approach would be simply to plan and approve the individual projects on a case-by-case basis and let the delivery agencies get on with it. But state leaders took a more sophisticated approach, turning to Arup and the Peron Group to bring reform to the coordination of SEQIPP. Essentially, they asked the team to build programme management expertise within the government, and to, in effect, work its way out of a job over the course of 30 months. Government staff were left with new systems and skills to coordinate the programme. When Arup started work in January 2006, the Programme Management Office (PMO) had two government staff and ten consultants. By July 2008, there were no consultant personnel embedded within the PMO, emphasising the success of the commission.

The global economic downturn is seeing construction projects all over the world deferred or cancelled. While South East Queensland is not immune from global forces, the state government's commitment to infrastructure remains strong, with a focus on ensuring that infrastructure investment provides the best value for money in a tight fiscal environment. The PMO's role is key to ensuring that the government makes the right investments at the right time, providing South East Queensland with the services it needs to manage its unprecedented growth. SEQIPP has brought a disciplined programme management ethos to the state coordination of funding, to the benefit of all. □

“Excellent idea, innovative concept, desperately required and has been well received by the infrastructure community”

Paul Clauson
Chief Executive Officer
Infrastructure Association of Queensland

All images provided courtesy of the Queensland Government

SEQIPP includes 378 identifiable projects across a range of asset classes – including roads, rail, public transport, ports, water, energy transmission and distribution, hospitals and health facilities, schools and tertiary education facilities, correctional and justice facilities, sporting and recreational facilities. Of the projects, more than 80 are over AUS $100m in value and a further 35 are over AUS $1bn in value.

A new oil drilling platform in one of the world's remotest offshore oilfields was engineered to cope with extreme weather conditions and 20 metre high waves. The platform is designed to 'self install' at sea without the need for expensive marine cranes. At the end of its useful life the installation sequence can be reversed, and the platform can be recycled or reused elsewhere.

Second life

An oil drilling platform that can be used more than once

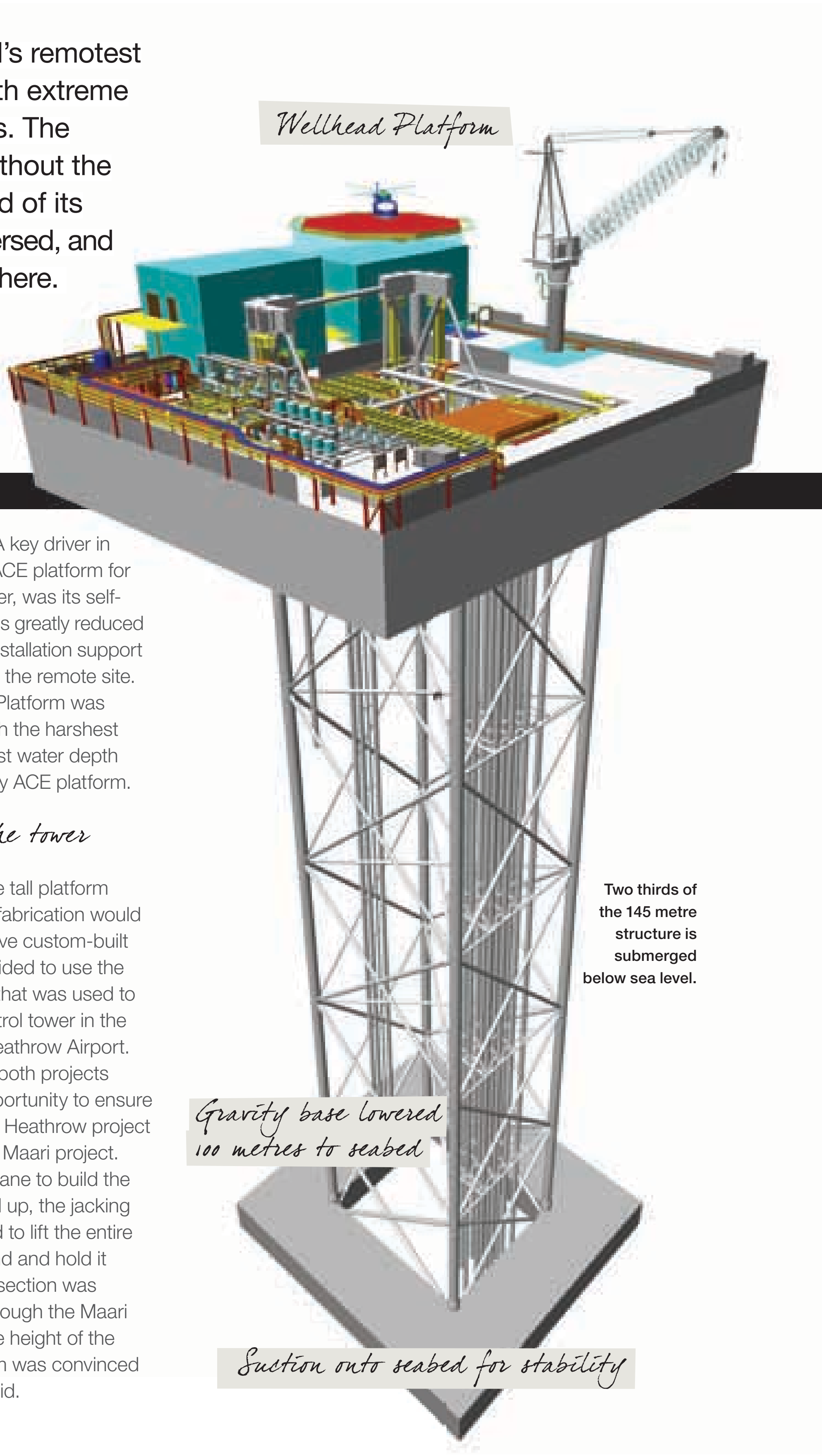
■ The Maari oil field lies 80 kilometres off the New Zealand coast in the Taranaki basin, at the edge of the 'Roaring Forties,' an ocean region swept constantly by powerful westerly winds. For decades its economic viability was considered to be marginal. Arup's DrillACE concept, a member of the ACE (Arup Concept Elevator) range of offshore platform configurations, has changed the economic basis for these remote fields. By adopting the DrillACE concept as preferred platform configuration, our strategic partner, Clough Projects International – also the main contractor on the project – was awarded the engineering, procurement and construction for the platform in 2005. Arup provided detailed design and construction and installation support for the DrillACE substructure. The platform was successfully installed in 2008.

1 Designed for strength

The Maari platform is built to withstand 20 metre high waves and wind gusts in excess of 160kph. A key driver in the choice of the DrillACE platform for the Maari field, however, was its self-installing capability. This greatly reduced the amount of costly installation support equipment required at the remote site. The Maari Well Head Platform was designed for a site with the harshest conditions and greatest water depth yet experienced by any ACE platform.

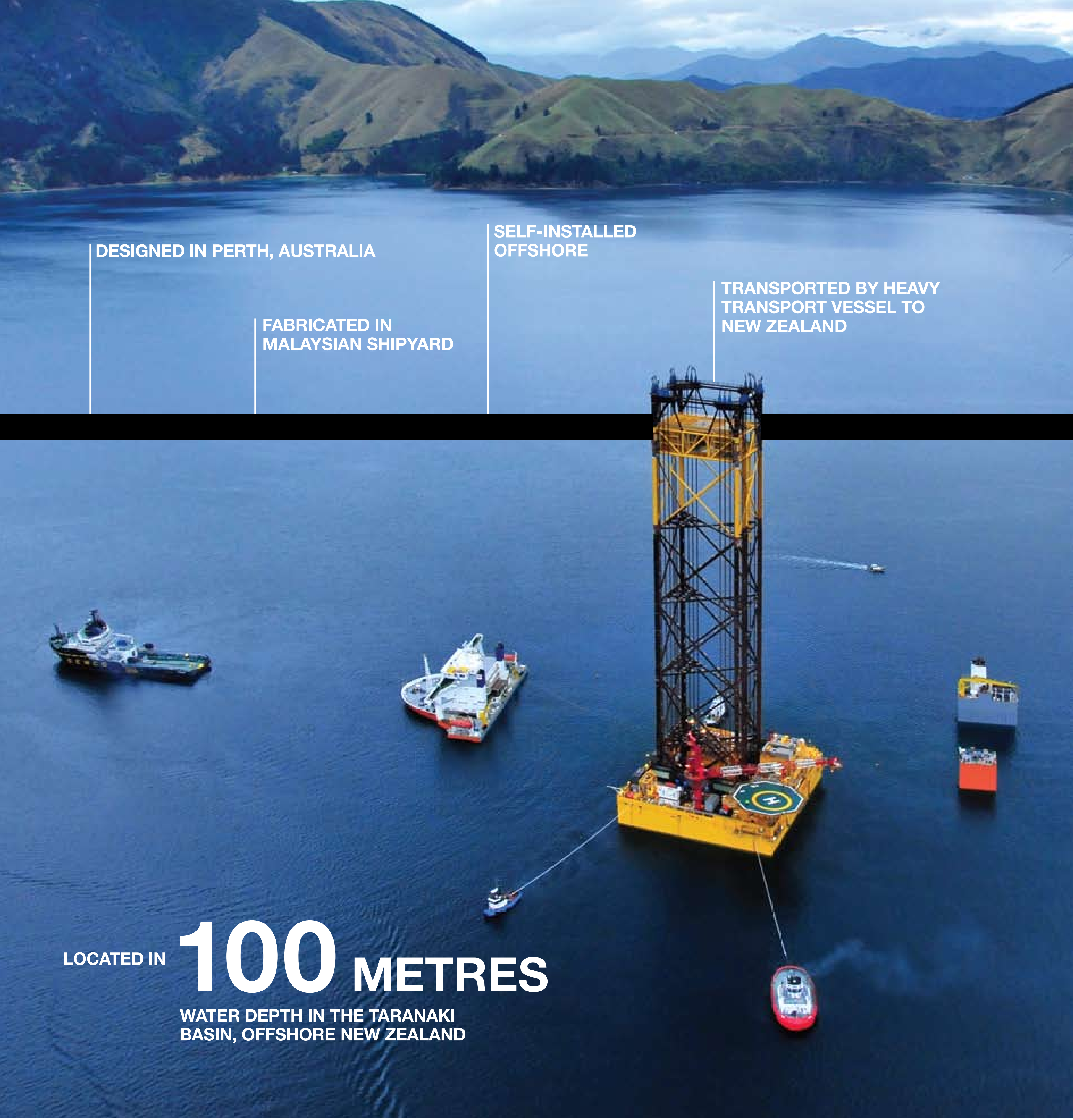
2 Building the tower

Erecting the 145 metre tall platform conventionally during fabrication would have required expensive custom-built cranes. The team decided to use the same jacking system that was used to erect an air traffic control tower in the middle of London's Heathrow Airport. Arup's involvement in both projects provided a unique opportunity to ensure best practice from the Heathrow project was transferred to the Maari project. Rather than using a crane to build the tower from the ground up, the jacking system would be used to lift the entire structure off the ground and hold it steady while the next section was welded on below. Although the Maari was almost double the height of the control tower, the team was convinced that it would work. It did.



Two thirds of the 145 metre structure is submerged below sea level.

Project Name Maari Wellhead Platform **Location** Taranaki Basin, offshore New Zealand **Client** OMV New Zealand Limited


DESIGNED IN PERTH, AUSTRALIA
FABRICATED IN MALAYSIAN SHIPYARD
SELF-INSTALLED OFFSHORE
TRANSPORTED BY HEAVY TRANSPORT VESSEL TO NEW ZEALAND
LOCATED IN 100 METRES
WATER DEPTH IN THE TARANAKI BASIN, OFFSHORE NEW ZEALAND

JACKET ERECTION ONSHORE USING INNOVATIVE JACKING SYSTEM

PRODUCTION CAPACITY OF **35,000** BARRELS OF CRUDE OIL PER DAY

80 KILOMETRES
OFFSHORE NEW ZEALAND

ARUP'S **2ND** SELF-INSTALLING DRILLACE PLATFORM


① Designed for strength
© Clough


③ Taking the platform to Taranaki
© Clough


④ Leaving little trace
© Clough

② Building the tower

© Clough

© Clough

③ Taking the platform to Taranaki

Once constructed, the tower was towed to its location, 80 kilometres offshore New Zealand in the Taranaki Basin.

This year saw the Maari Wellhead Platform, which is unmanned and tied to a Floating Production Storage and Offloading vessel, start to produce oil. The platform's facilities include down hole heating and pumping systems, wellhead control panel, temporary accommodation for visiting service technicians, helideck and pedestal crane.

④ Leaving little trace

Like its counterparts in Arup's ACE platform range, the installation of the Maari platform can be reversed to allow for its removal at the end of its useful life. It can then be reused at another site or taken onshore for demolition. Either way, it is a remarkably tidy affair, leaving behind little trace that the platform was ever there. □

A modern plant science laboratory in the University of Cambridge's Botanic Garden marries the highly serviced technical requirements of a lab with an uncompromising aesthetic vision. It will also house a plant collection that includes specimens brought back by Charles Darwin from the Beagle voyage.

In the footsteps of Darwin

A new plant science laboratory combined with Darwin's prized plant collection

■ Like the University, Cambridge's Botanic Garden is steeped in history. Since 1831 it has been a working research tool for the ordering and cataloguing of the diversity of plant species. In the heart of this historic setting, a new complex represents the modern face of plant science.

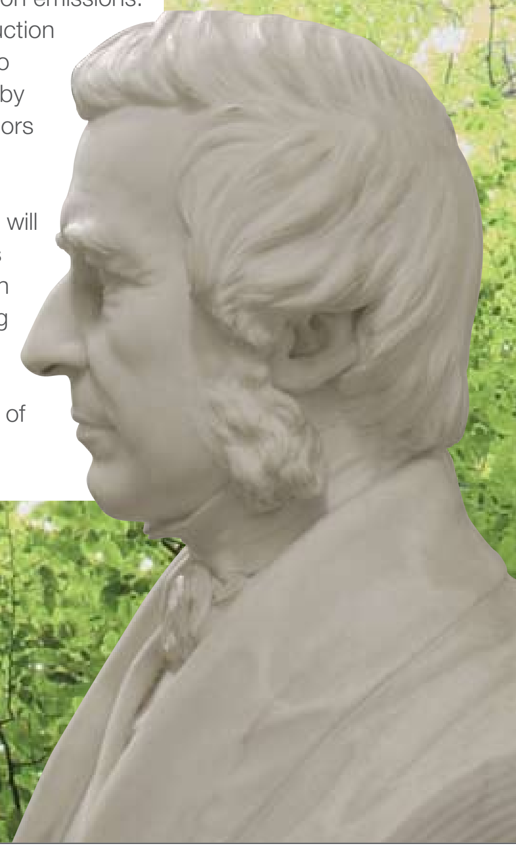
Laboratories are typically designed for function alone, divided into small units for private study and hidden from public view. With extensive equipment, they demand three or four times the power of an office building and are typically serviced from above, with large amounts of ducting and electrical services concealed by suspended ceilings.

The new Sainsbury Laboratory is light and airy thanks to two wholly-glazed walls, one of which overlooks the Botanic Garden. Arup and the architect Stanton Williams collaborated from the start to integrate state-of-the-art services within the strict architectural form. The team defined the mechanical and electrical routing up front – down to the smallest aperture – before the concrete was cast. Serviced from below with natural gas, compressed air, electrical wiring, cabling, chilled water and ventilation, the laboratory itself remains light, open and uncluttered.

To accommodate an advanced transmission electron microscope, only the second of its kind in the UK, the team had to ensure that the laboratory met onerous vibration and air movement criteria for its use. Another key focus was the control of services to the areas housing the 45 plant growth chambers, which scientists can programme for optimum temperature, humidity and light conditions for any plant. The building is equipped for the future; it can accommodate more computer-based research if required. A roof-mounted photovoltaic array offsets the building's carbon emissions. Part-way through construction the building is on target to gain a rating of Excellent by the environmental assessors BREEAM.

The Sainsbury Laboratory will provide 120 of the world's top plant scientists with an extremely modern working environment, one that promotes the exchange of ideas and the evolution of scientific knowledge. □

Professor John Stevens Henslow, Darwin's mentor conceived the Botanic Garden as a working research tool in 1831.



Project Name Sainsbury Laboratory University of Cambridge **Location** Cambridge, UK **Client** Kier Regional

An exhibit in its own right

The new Academy is a living museum

© Tim Griffith

The California Academy of Sciences is one of the ten largest natural history museums in the world, housing a range of phenomenal exhibits – from a four-storey rainforest to the world's deepest living coral reef tank. But the new Academy building is also an exhibit in its own right, demonstrating to visitors how a sustainable approach to its business can have a positive impact on the environment.

Project Name California Academy of Sciences **Location** San Francisco, California. USA **Client** California Academy of Sciences

> The Academy is about answering the question "How did we get here, and what are we going to do to make sure we can stay around?"
>
> **Chris Andrews, Chief of Public Programs, California Academy of Sciences**

■ Founded in 1853, the California Academy of Sciences is the largest cultural institution in the City of San Francisco, one of the ten largest natural history museums in the world, and its mission is to explore, explain and protect the natural world. With the opening of the new Academy in September 2008 – the culmination of a seven-year collaboration between Arup and architects Renzo Piano Building Workshop and Stantec Architecture – this stated mission was broadened to include sustainability. It is now the Academy's central theme.

The vision for the new Academy was to create a structure that embodied nature in both form and function. A series of innovative and sustainable strategies conserve water and energy, reduce pollution and maximise natural ventilation and light. The building is an exhibit in its own right and the Academy aims to help change behaviour by demonstrating how small changes can have a positive impact on the environment.

From the outset, the roof was a key feature of the architectural vision. By essentially lifting a section of the park's green space and sliding the museum underneath, the building successfully blends with the surrounding landscape and enhances rather than disrupts the environment. The roof evolved as an essential part of the sustainable design and its undulating shape helps the naturally-ventilated building 'breathe'. It provides an insulating blanket that moderates the internal temperature and is also a living roof; it makes one hectare of varied habitat available for 1.7m of California's native plants.

The roof also absorbs 98% of the rainwater that hits it, preventing over

A 27.43 metre diameter glazed dome housing the rainforest exhibit

© Tim Griffith

© Tim Griffith

The Water Planet exhibit

13m litres of runoff from flowing needlessly into city storm drains. Its planted surface reduces the 'urban heat island' effect, staying up to 22ºC cooler than a standard roof.

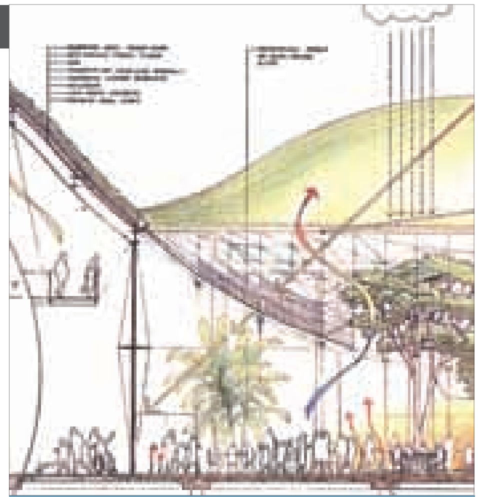
The perimeter of the roof is lined with 60,000 photovoltaic cells, providing both shade and regulated light for visitors. It also provides over 220 kilowatts of energy annually – at least five percent of the building's total energy requirement – and prevents the release of more than 183,700 kilograms of greenhouse gas emissions annually.

By relying on natural daylighting and ventilation, high-efficiency electric lighting, and careful, thorough commissioning of all building systems, the Academy's projected energy use is at least 30% below US federal and state energy use requirements.

The end result of these innovations is a highly sustainable building; the Academy achieved a Platinum rating in Leadership in Energy and Environmental Design (LEED®) from the US Green Building Council.

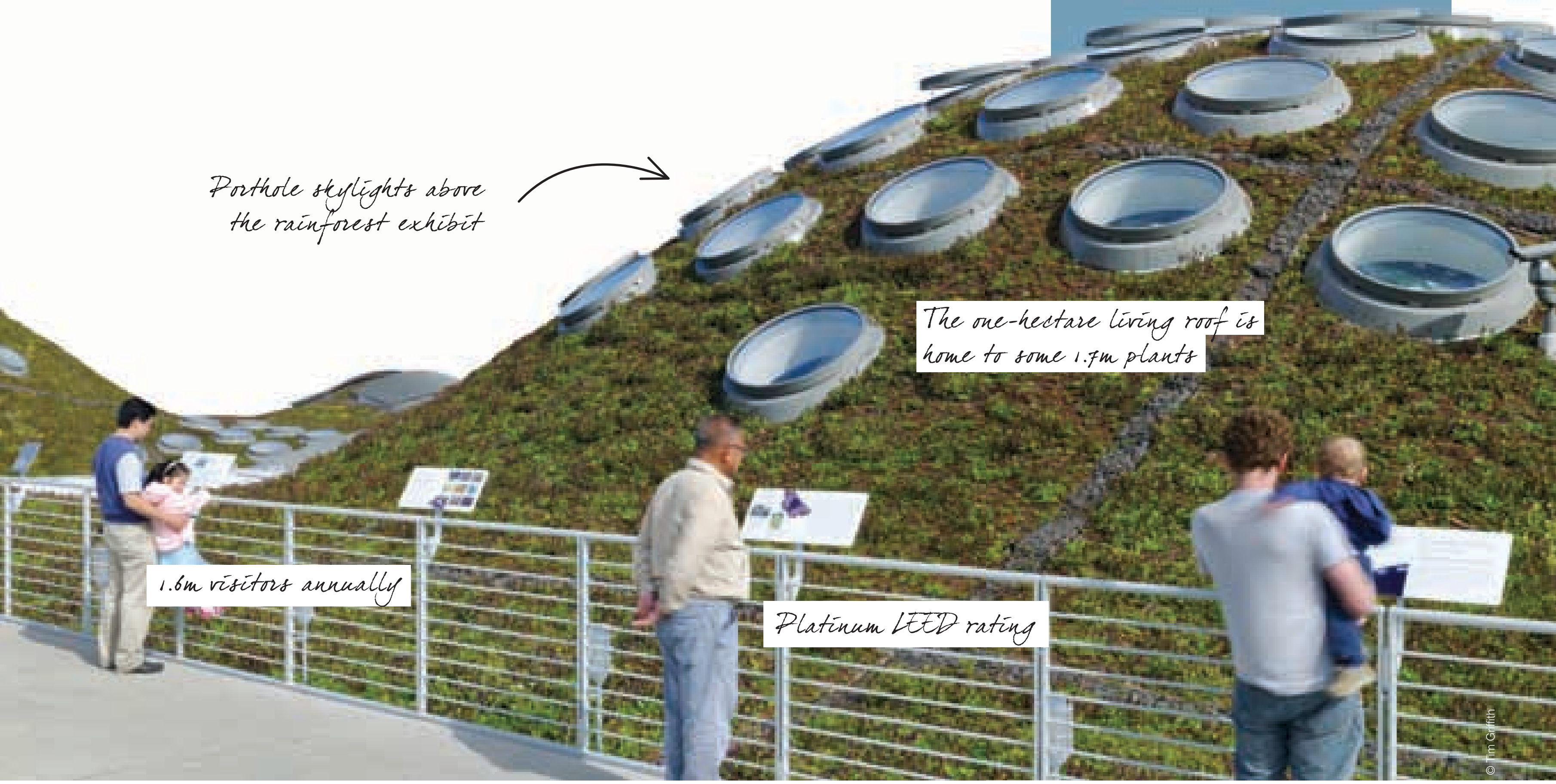
Tours of the building highlight and demonstrate its sustainable features, the materials used, and the performance of conservation approaches. It is itself a living, breathing exhibit for sustainability principles, designed to have a positive impact on the behaviour of all those who visit. □

The vision for the new Academy was to create a structure that embodied nature in both form and function.



© Renzo Piano Building Workshop

The undulating roof shape creates the thermal dynamic required for natural ventilation. On calm days there is stack-driven ventilation, like a chimney expelling hot air. Wind passing over the roof hills generates lift that helps with airflow. Avoiding mechanical ventilation was an important aspect of the low energy design strategy, and the roof enables this.



© Tim Griffith

Breaking the mould

An ingenious structural form combines strength with slenderness

Engineering a multi-layered structure resembling a ring of slender-stalked mushrooms is challenging enough. In an extremely seismic zone such as Japan, with highly conservative building design codes, it took ingenuity to translate the architectural vision into reality.

■ In 2006, architect Riken Yamamoto's daring 'kinoko' – mushroom-shaped – design won a competition for Namics Technocore's new research facility in Niigata, Japan. The subsequent design stage coincided with the rolling out of a new building code and a period of risk aversion on the part of Japan's building authorities, particularly when it came to radical, innovative design.

At first glance, the structural form of the new research and development facility in Niigata seems implausible. Meeting rooms and offices perch on top of slender stalks above the research and development rooms. The vision was of an extraordinary building that symbolised the position of its occupants at the vanguard of technology.

The world over, engineers must consider the forces of gravity and wind. In Niigata, any building must also withstand earthquakes, typhoons and heavy snow loads, making it a uniquely challenging building environment.

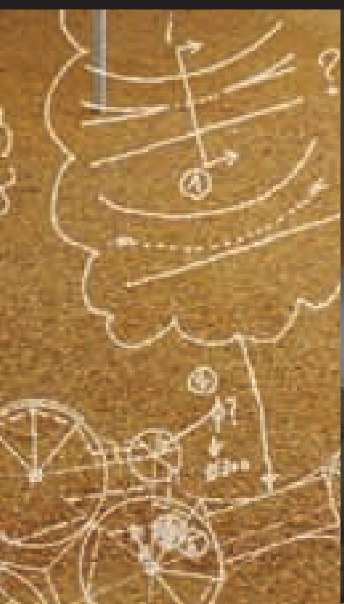
Arup decided to use a combination of existing structural systems that would be familiar to the building authorities. Like many conventional buildings, the structural scheme is a network of moment-resistant frames made from conventional rolled steel. Here, the key difference is the pivot joint, made from cast steel, at the base of the kinoko columns. These special cast steel pivot joints are created by pouring molten steel into sand moulds, which are machined down precisely.

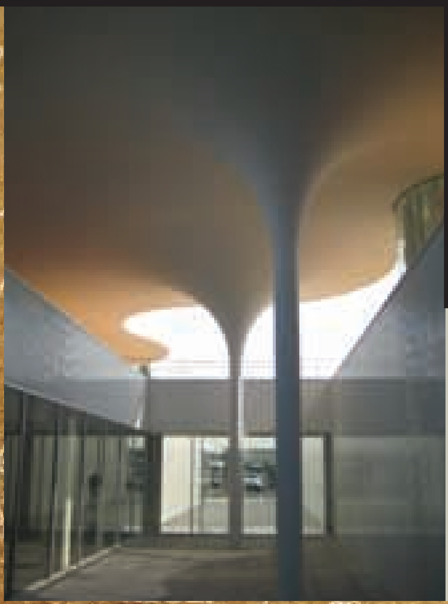
The pivot joint is similar to a ball joint – the top piece is concave and the semi-spherical bottom piece is convex. The perfectly spherical shape allows the joint to rock without resistance. Because the arrangement prevents the forces from building up in the joint, it allows the base of the kinoko columns to taper, achieving the aesthetically desired slenderness.

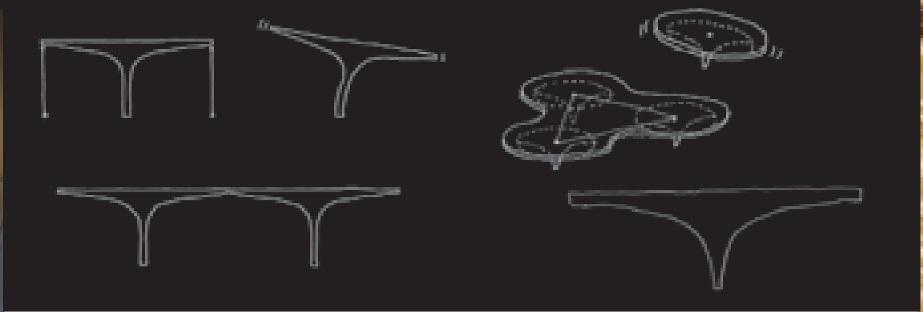
Given the unusual structural form, Arup adduced extra evidence to show the authorities that the acrobatic shapes were based on familiar principles and provided adequate seismic performance.

Although at first glance the final structural form of the building appears surreal with its tapered stalks, it is, in fact, structurally honest. The same amount of structural 'muscle' is required as in a standard rectangular building, but is concentrated in different locations, resulting in an architectural form that reflects the structural needs. □

Project Name Namics Technocore **Location** Niigata, Japan **Client** Riken Yamamoto & Associates, Architects



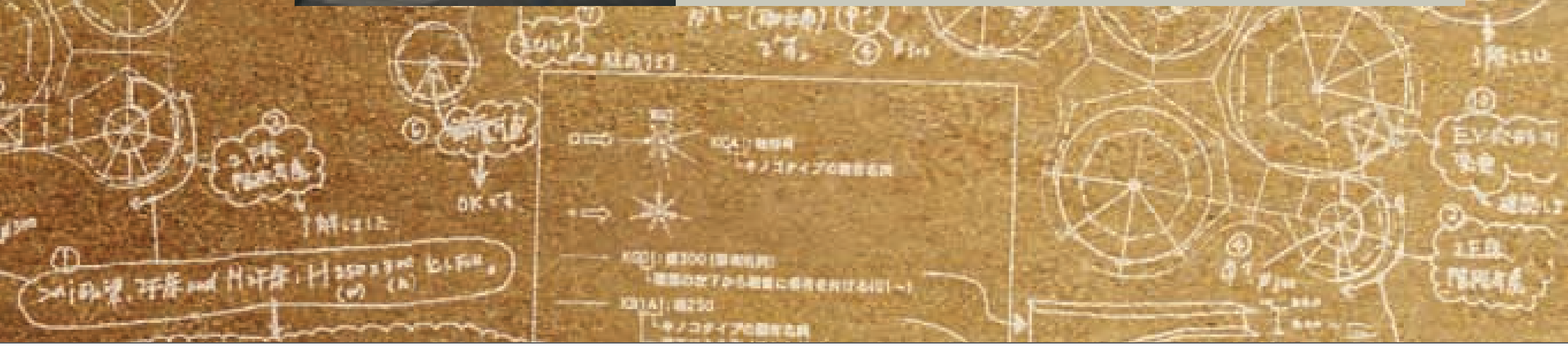




Stability on a stalk

A kinoko structure would need a thick stalk to stand alone. Arup set a rule that kinokos would be in groups of at least three to acquire the requisite stability – just as a table with three legs stands firm.

The building's structural stability is down to the firm connection between the thin vertical stalk and the hefty top, rather than that between the stalk and the ground. This enables the kinoko structure to resist forces from the side – such as those present in an earthquake.



3x
TEMPLATE DESIGN

California's health planners approved the new 174-bed Kaiser Permanente Hospital in just nine months, a fraction of the typical 28-month approval cycle. What's more, the hospital opened early. What made this possible was a building template design that could be customised for multiple locations – and potentially many more.

Precision planning

A template hospital design saves energy, money and time

■ Kaiser Permanente originated in the 1930s as an industrial healthcare programme for construction, shipyard and steel mill workers in California. Today it is the largest managed care organisation in the US, with 8.6m members, operations in nine states, and ambitious expansion plans.

Asked to design three new hospitals in California, Arup and the Stantec/SmithGroup Joint Venture drew on their understanding of California's Office of Statewide Health Planning and Development (OSHPD) permit process to devise instead a single hospital and central utility plant 'template' design that could be used on other, future sites without major redesign, and with an expedited OSHPD permit period. Once the template was approved, subsequent applications would be faster and less expensive, being based on the same approved template design.

In the event, OSHPD took eleven months (compared with its usual 28 months) to review the original template design. For the Vacaville hospital it took only nine, since it was a mirror image of the same design, flipped and slightly customised for the Vacaville site.

Labour costs are a hospital's single biggest operating expense. To help keep costs down, the design team sought to maximise the number of patients each nurse could comfortably manage. Distinctive, triangular towers placed nursing stations at the centre of each floor. Patient rooms, with generous windows and ample natural light, line the building perimeter around the stations.

Hospitals are exempt from California's stringent energy requirements, but Arup nonetheless designed building systems to be as efficient as possible. The central utility plant serves the hospital, the medical office building and its own support areas. The template design offers similar structural and seismic systems for each site regardless of the number of storeys in the patient tower. The template design can also be adapted to various site conditions.

The template is designed to accommodate future expansion. If work starts on a new treatment block or patient tower, it should not disrupt the operation of the hospital, and the mechanical, electrical and other services should be able to be extended easily and efficiently.

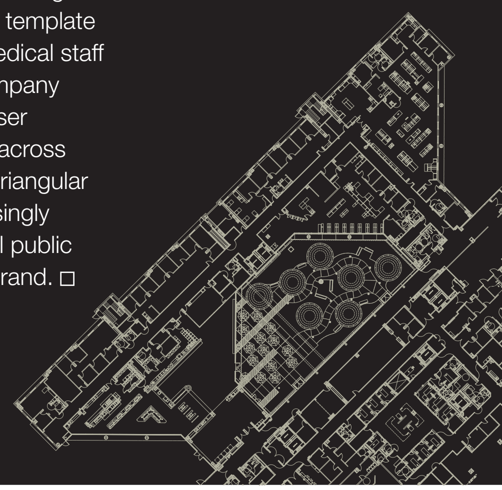
Cost effective, efficient and designed with the future in mind, the template hospital design benefits medical staff and patients alike. The company benefits too: as further Kaiser Permanente hospitals rise across California, their distinctive triangular towers will become increasingly recognisable to the general public as part of the company's brand. □

Typical Approval Cycle
28 MONTHS

2007-8:
Kaiser Permanente Template Hospital approved in
11 MONTHS

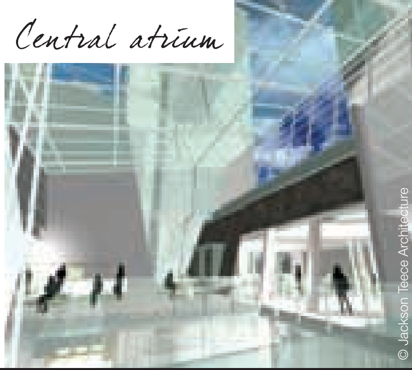
2008:
Kaiser Permanente Vacaville Hospital approved in
9 MONTHS

© Robert Canfield



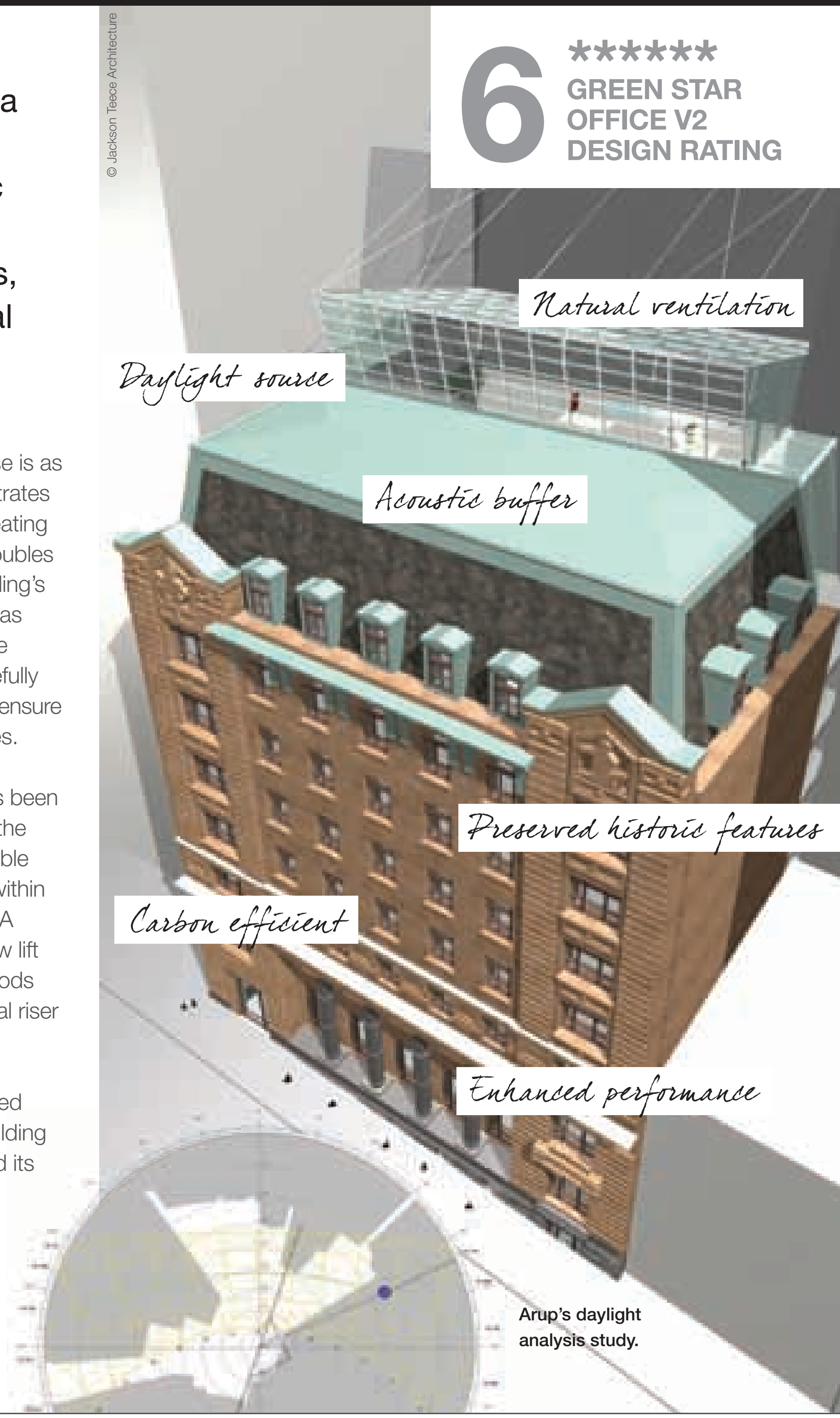
Project Name Kaiser Permanente Vacaville Hospital and Central Utility Plant **Location** Vacaville, California, USA **Client** Stantec

Better than new



Refurbishment restores heritage and enhances performance

As a result of substantial refurbishment, 39 Hunter Street is the first heritage-listed building in Australia to achieve a 6 star Green Star Office version 2 Design rating. Arup worked with the existing fabric of this early twentieth century office building in Sydney to restore and preserve its historic features, while creating state-of-the-art, A grade commercial space with impressive sustainability performance.



Arup's daylight analysis study.

■ When Arup, in conjunction with Jackson Teece architects, began work on the extensive refurbishment project, the old building at 39 Hunter Street was somewhat dark and dingy. Most original decorative features had been either damaged or concealed by extensive renovations in the 1960s. The 7-storey, 6,000 square metre office building, considered high-rise when it was built in 1917, had become dwarfed by the central business district that had grown up around it, and, because of its age, its environmental performance was poor in comparison to its newer neighbours.

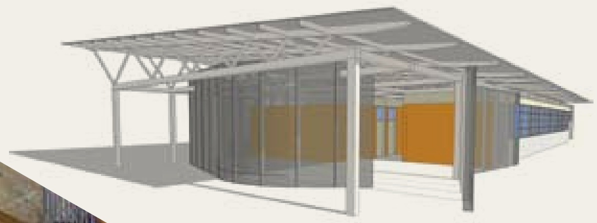
This is all in sharp contrast to the building as it stands today. Now, a central atrium floods the building with natural light and creates an internal focal point that compensates for the lack of access to external views. The removal of oppressive suspended ceilings and the use of displacement air conditioning have brought the intricate plaster ceilings and cornices back into view, all elegantly repaired and accentuated with LED uplighting.

While the atrium's primary purpose is as a daylight source, it also demonstrates the multi-faceted approach to creating sustainable solutions. It quietly doubles as the main air return for the building's ventilation system and would act as a smoke-collecting reservoir in the event of fire. It has also been carefully designed as an acoustic buffer to ensure speech privacy between tenancies.

Central to the design process has been working within the constraints of the present structure, wherever possible adapting existing elements to fit within modern environmental solutions. A lightwell now incorporates the new lift shaft and a de-commissioned goods lift shaft has become a mechanical riser for supply air.

The result of this highly-coordinated approach is a carbon-efficient building that, with its heritage restored and its future sustainable, is a significant asset in the City of Sydney. □

Project Name 39 Hunter Street **Location** Sydney, Australia **Client** Kador Group



Medical centre rendering

1

Timber frames

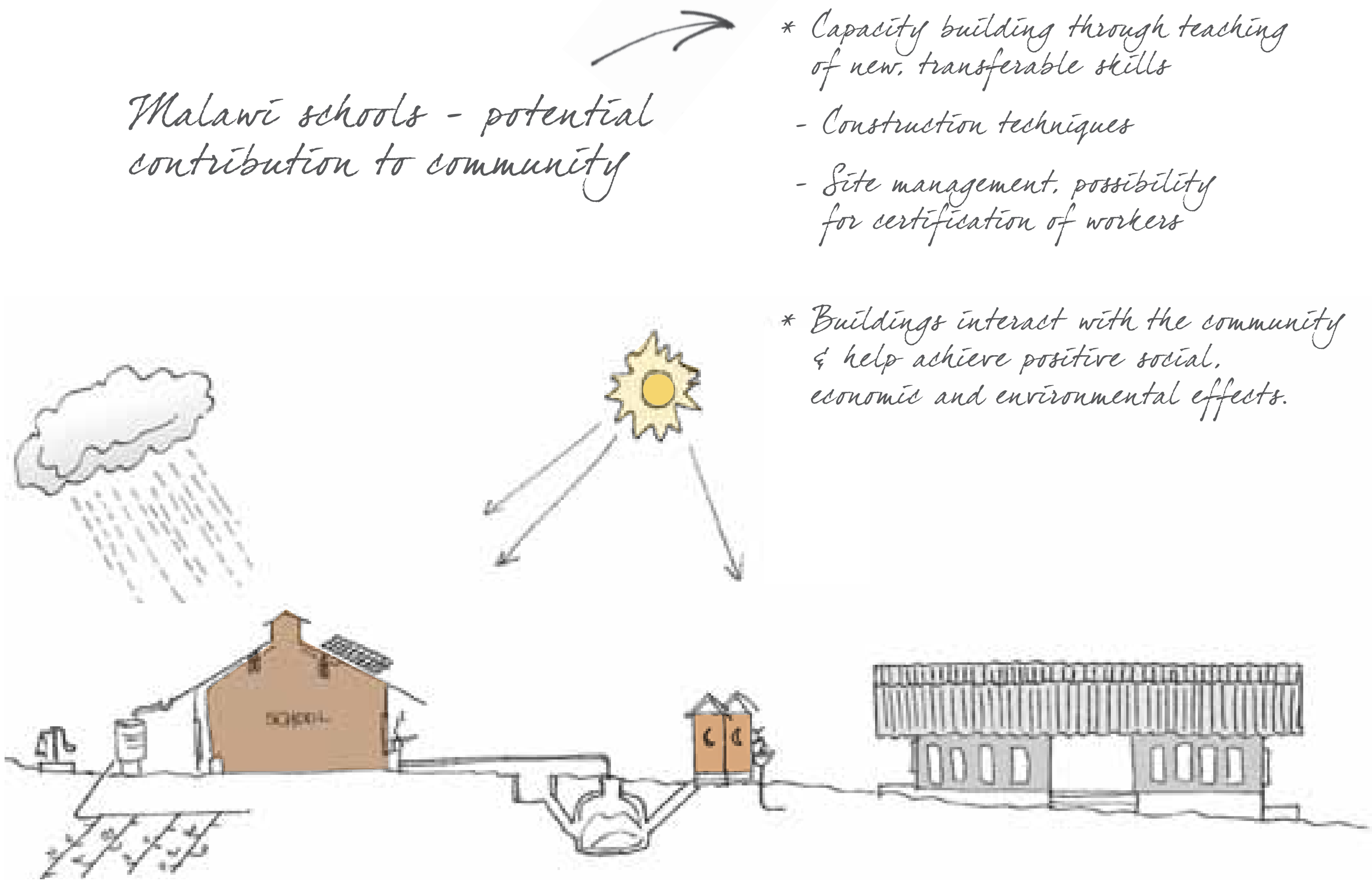
Teaching new skills and construction methods

Project Name Soroti Community Medical Centre **Location** Soroti, Uganda **Client** Saltpeter Trust – Designed and built by EFOD

Reaching out to Africa

Pro-bono work helps local communities in Africa

Pro-bono contributions from Arup have paved the way for a number of projects in Africa that have helped to build local capacity. By combining Arup's global expertise with local knowledge, these projects address critical issues of water and sanitation, healthcare and education. They pass on valuable skills that have a practical impact on communities, and enhance prospects and improve livelihoods.



© Klaas Lingbeek- van Kranen

① Vital medical services

A new community medical centre brings vital services to Soroti, Uganda

■ The Soroti region is home to over 200,000 people. As with many rural communities in Uganda, medical care is not only difficult to come by but also expensive. That's why the new Soroti Community Medical Centre, designed and constructed with the help of Arup engineers, is so vital to Soroti.

Construction of the multi-use centre has been wholly-financed through fund-raising. Scheduled for completion in 2009, it will offer basic medical and dental care, along with nursing and eye care, all in a simple structure of private rooms that run off a central corridor.

A single pitch roof provides natural ventilation, harvested rainwater is used to flush toilets, and the use of compressed earth blocks for the walls creates a building solution that is affordable, functional and appropriate, and one that can easily be replicated throughout the region.

The construction process has been as important as the finished product. Area residents have learned new skills and been introduced to new construction technologies using local materials which will be of lasting benefit to this community.

② Building blocks of education

A prototype school to meet the need for 17,000 centres across Malawi

To come up with a building design suitable for an environment that has no real infrastructure is no mean feat, particularly when the intention is to create a space conducive to learning.

Working within these constraints, and with a no-frills budget, Arup, in collaboration with architects John McAslan and Partners, evaluated a number of different building options. The ideal protoype, intended to be used to meet the need for 17,000 centres across Malawi, had to be determined with absolute certainty.

Maintaining comfort was key. Internal daylight analysis and thermal modelling helped Arup designers determine adequate natural light levels and maximise interior ventilation. Focusing on the building envelope, designers sought to minimise the use of locally-expensive materials, such as concrete, without compromising the finished product. It was also essential to create protected outside space to maintain a connection to the wider community instead of building a 'closed box' largely cut off from it.

The final result speaks for itself – a modern building modest in stature, built with local and low-impact materials, but with high impact in terms of both its presence and the possibilities it represents for the populations it will serve.

Internal daylight analysis and thermal modelling helped Arup designers determine adequate natural light levels and maximise interior ventilation.

Project Name African Schools Prototype **Location** Malawi **Client** Clinton Hunter Development Initiative

Teaching the '3 jar' method of water purification

③ Working for health

A local village water supply and sanitation project brings safe drinking water to Sironko, Uganda

When Arup engineers tested the river water that provides drinking water in Busabulo, the level of harmful bacteria was found to be more than 3,000 times higher than the World Health Organisation's recommended limit. A local village water supply and sanitation project is set to change this for good.

Busabulo lies in the Sironko District of Uganda and is reached only by a dirt track. The villagers live simply, in keeping with their long traditions. Arup's client has a long established connection with the area, and she commissioned Arup to assist her with a plan to bring safe water to the village. Engineers on an initial fact-finding tour recommended broadening the programme to look at water-related health issues. As a result, sanitation, hygiene and health education form the core of the project, enhancing its long-term value to the community.

Arup engineers have spent much time forging links with important organisations at local, district, national and international levels, as well as simply talking with the locals. Such relationships are key to the ongoing success of the project.

Now that fact-finding is complete, health and hygiene education can begin, followed by design and construction of latrines and household rainwater harvesting. In 2010 it is hoped that a simple, hand-pumped borehole well will be drilled to provide a safe, reliable and convenient main water supply to Busabulo. □

The level of harmful bacteria was found to be more than 3,000 times higher than the recommended limit.

Household water treatment

As an interim measure and a first step to improving the drinking water, the Busabulo villagers were taught the '3 jar' method of water purification. A rudimentary system, it is easy to apply and effectively removes sediment and some harmful bacteria.

River water poured through cloth filter and left covered for 24 hours.

Water from jar 1 poured into jar 2 and left covered for 24 hours. Jar 1 refilled to ensure ongoing water supply.

Water from jar 2 poured into jar 3 and left covered for 24 hours.

Water from jar 3 removed with ladle and used for household drinking.

Project Name Sironko VillageWater Supply **Location** Sironko District, Uganda **Client** Belinda Swift

Down to earth

A modern winery is built from the earth on which it stands

The winery is almost complete and is scheduled to open in late 2009.

Looking at Australia's newest winery, one would never guess that it is constructed from humble rammed earth. This supremely modern building mixes ancient and modern to powerful effect, setting new standards of design in Australia's wine valley.

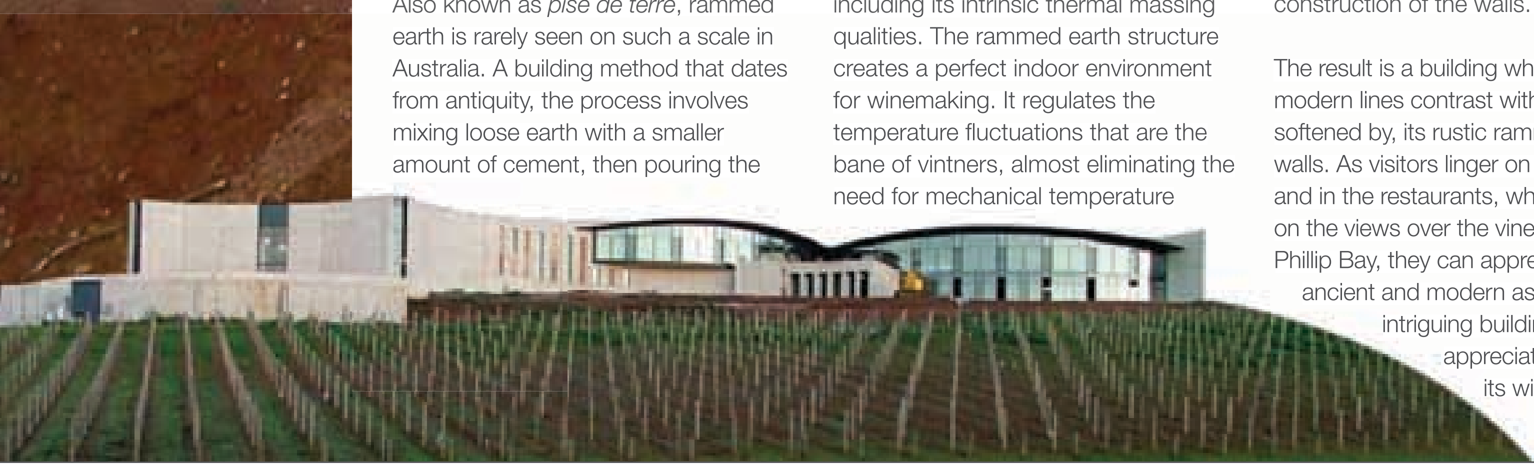
■ Port Phillip Estate's new winery is blessed with commanding views over the Australian wine lands. The pale curved building, glazed to the east and overlooking western port bay, looks every inch the modern winery. From a distance, one might assume that the pale walls are concrete. Look closer and they appear to have a grain texture, like wood, silk or cloth. They lack the coldness, rigidity and smoothness of concrete.

The winery is built into the hillside and constructed of 'rammed' earth. Also known as *pisé de terre*, rammed earth is rarely seen on such a scale in Australia. A building method that dates from antiquity, the process involves mixing loose earth with a smaller amount of cement, then pouring the mixture into four metre-long forms. It is compressed by a pneumatic ram and built up in layers to create basic building blocks. Rammed earth hardens over time and when fully 'cured', becomes a rigid and robust building material.

Inside, the building's texture and acoustics give it the solidity and warmth that you would expect of a centuries-old building. Rammed earth is full of surface irregularities and imperfections, which give it its distinctive texture. WoodMarsh Architecture selected the material with Arup for its many benefits including its intrinsic thermal massing qualities. The rammed earth structure creates a perfect indoor environment for winemaking. It regulates the temperature fluctuations that are the bane of vintners, almost eliminating the need for mechanical temperature control. Deep-set windows block out the summer sun but allow in winter sunlight when the sun is low in the sky, making the winery an exceptionally energy-efficient building.

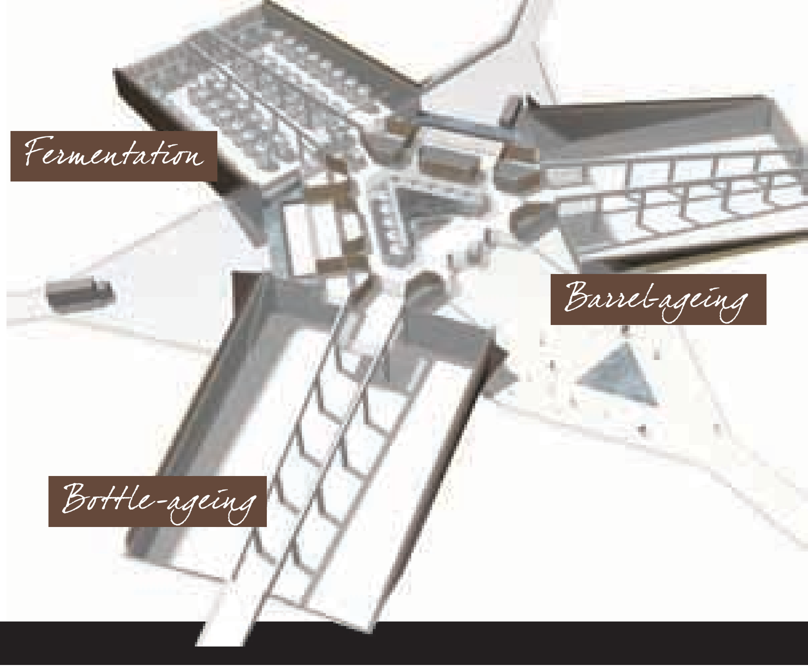
It is also visually arresting. The undulating walls follow the curves of its contemporary roof. The building's complex shape is formed from deceptively simple geometries. WoodMarsh defined the wall geometries utilising intersecting circles and arcs and with Arup used 3D modelling to detail the design and construction of the walls.

The result is a building whose ultra-modern lines contrast with, and are softened by, its rustic rammed earth walls. As visitors linger on the terraces and in the restaurants, which capitalise on the views over the vineyards and Port Phillip Bay, they can appreciate both ancient and modern aspects of this intriguing building, just as they appreciate the quality of its wine. □



Project Name Port Phillip Estate Winery **Location** Red Hill, Australia **Client** Port Phillip Estate

The ambition that has earned the Faustino Group its enviable reputation as one of Spain's premier wine producers is just as evident in its new Bodegas Portia winery in the Ribera Del Duero region. The building is conceived and designed to provide and display to visitors the perfect environment for wine, from grape to bottle.



A winemaker's delight

Designing the perfect environment for fine wine-making

■ One of Spain's legendary winemaking regions, Ribera Del Duero produces some of the world's finest and most exclusive red wines. Bodegas Portia, Grupo Faustino's new winery in the region, will give visitors new insight into the wine making process.

For Arup and architect Foster + Partners, the need for high-quality winemaking and a coherent visitor experience drove their development scheme. The functional requirements of the building for winemaking set by Faustino's master winemakers were key to the evolution of the building – from the arrangement of the fermentation and ageing cellars set around a central hub, to the delivery of grapes from the roof of the building to minimise pumping, which crushes the grapes. Integrated into the winemaking process is a visitor centre which overcomes the often disjointed series of processes experienced at many other wineries.

Viewed from the air, the winery is a distinctive three-armed shape, which both symbolises and accommodates the needs of the wine at three stages: fermentation, barrel-ageing, and bottle-ageing.

The temperature and humidity at which wine is kept throughout the process affects its ultimate quality. Therefore the new winery is designed to minimise daily and seasonal variations within the ageing cellars. The team optimised the building's environmental performance by designing the building to restrict thermal gain from sunlight. Partly buried in the landscape to avoid the harsh summer sun, the building capitalises on the thermal mass of exposed concrete internally. As a result, for much of the time the wine can be left to sleep undisturbed while its flavour matures.

The design of the structural systems was also informed by their role. The massive scale concrete structure supports the road structure above the ageing cellars. The roof areas to each side are supported by finer-scale pre-cast bespoke units. These units are also used to form the external walls and to articulate the junction between above- and below-ground in the half-buried structure.

The entire design process expressed and reflected the building's function and scale – an approach made possible by an exceptionally close collaboration between architect and engineer. The result is a building whose design enhances and lays bare the wine making process that takes place within. □

The structure's geometry is a complex arrangement of inclined planes.

The ultra-thin Nichols Bridgeway spans 200 metres with little visible means of support. It forges an eye-catching link between Chicago's two civic hubs, Millennium Park and the Art Institute of Chicago.

Zero gravity bridge

An impossibly-slender bridge opens Chicago's museum to the park

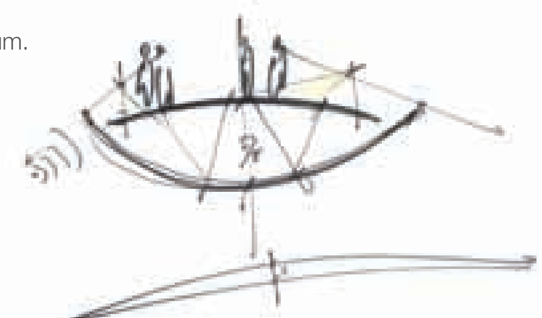
■ In May 2009, the Art Institute of Chicago opened its Modern Wing, complete with an apparently gravity-defying new footbridge. Architect Renzo Piano conceived of a slender, minimalist structure to link the Modern Wing with the nearby Millennium Park. The bridge makes the museum's new rooftop restaurant and outdoor sculpture terrace directly accessible from the park.

Over 190 metres long and weighing in at 400 tonnes, the footbridge itself is less than 1.3 metres deep in section. For the maximum unsupported span of over 60 metres, the span-to-depth ratio is 44. It soars above Monroe Street to the third floor of the museum. Passersby have been overheard to wonder how the bridge stays up.

Part of the answer lies in its steel construction. Steel is both strong and light, which allows the bridge to rest on existing structures, including an underground car park and the museum itself.

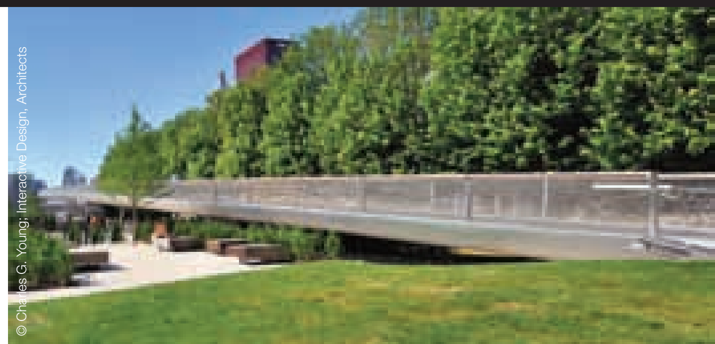
Arup detailed the thin curved steel shell with the help of advanced software typically used in the automotive industry. This helped to determine how to eliminate vertical supports from over half of the bridge's length.

Essentially, the bridge structure is a long beam. Like a ruler leaning against a step, the structure's very proportions make it inclined to bend in response to movement. Analysis techniques developed in-house enabled the design of the bridge to be thinner and lighter than could be achieved using conventional methods. □



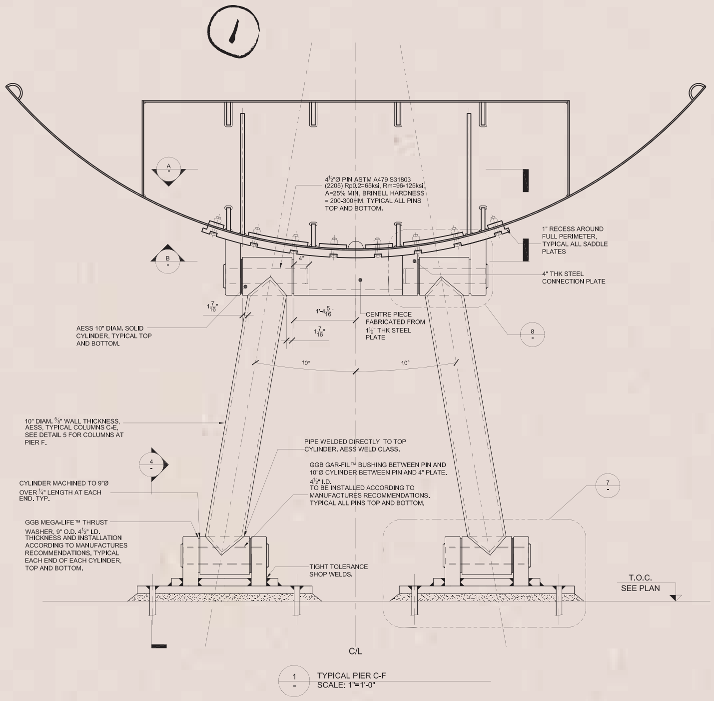
Early sketch by Renzo Piano

© Renzo Piano Building Workshop



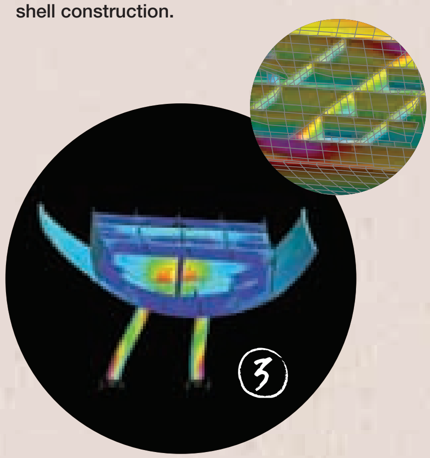
 Project Name Nichols Bridgeway **Location** Chicago, Illinois, USA **Client** Art Institute of Chicago

Forecasting footfalls



1. Expansion and contraction of the bridge in Chicago's extreme climate is accommodated by rocking of the columns.

2. A structural analysis model of the whole bridge, comprising over 90,000 elements, was used as part of the design justification of the complex, thin curved shell construction.



3. Analysis of the bridge support structure under lateral sway motion. Advanced analysis was used during the design process to help achieve the architectural aspirations.

Arup's vibration experts used advanced modelling to ensure that the natural movement of the Nichols Bridgeway stayed within acceptable limits. They looked at crowd behaviour as well as the structure itself to predict vibration levels on the footbridge.

■ As people walk along a footbridge, their footfalls apply a small horizontal force on the surface. The forces cause initial vibrations that are insignificant. However, in slender and flexible bridges, small vibrations can grow into large movements. The blade-like aspirations for the Nichols Bridgeway very much fell into the slender category, making design against lateral wobble a key focus.

Arup knew from experience that it needed to consider human subconscious behaviour: crowds of people move randomly, but tend to involuntarily fall into step if lateral movements become noticeable. The result is 'lateral synchronous excitation' – the bridge's structural response to a large number of people walking in step. The movement can be dispensed with entirely if the bridge tries to sway faster than people can walk.

From the start, the design of the Nichols Bridgeway was developed to minimise lateral vibrations. Like a golfer standing with his legs spaced out to stay more stable, the bridge's support columns are splayed to maximise lateral stiffness. The gutters on the bridge form wide wings that are used to increase width of the section, generating the rigidity needed to prevent build-up of lateral sway movement. □

Managed flow

INSTALLATION AND COORDINATION OF

64

RAMP METERING SITES

Traffic congestion affects cities worldwide and Melbourne is no exception. The AUS$1bn Monash-CityLink-West Gate upgrade project is putting in place a Freeway Management System (FMS), designed to help manage the flow of traffic. Arup's work on the delivery strategy and technical specifications of the new FMS has set the precedent for similar projects in other Australian states.

■ The AUS $1bn Monash-CityLink-West Gate project involves upgrades to the main 75 kilometre east-west arterial network through Melbourne and will increase capacity by up to 55%. This will be achieved by adding an additional lane in either direction on the most congested section of the freeway and by using Intelligent Transport Systems (ITS) as part of a new Freeway Management System (FMS). By adding information and communication technology to the existing transport infrastructure, ITS provides a cost-effective solution to help keep traffic flowing.

The aim of the FMS is to improve the safety and efficiency of the Monash and West Gate freeways by reducing travel times and managing congestion, in particular congestion where the freeways meet the privately operated tolled tunnels.

Arup was contracted to develop the delivery strategy and produce the technical specifications for all FMS elements including the central control system at the Melbourne VicRoads Traffic Management Centre.

Delivering an integrated system

The size and scope of the upgrade project posed considerable challenges for the Arup project team, not least the large number of stakeholders. Arup actively engaged with these stakeholders to consider their needs from both an operations and maintenance perspective in order to ensure the FMS works seamlessly and, from the user's perspective, invisibly.

Two agencies operate the freeway corridor: CityLink, the private toll road operator, and VicRoads. A centre-to-centre interface is therefore vital to the successful implementation of the project, as this will enable efficient, reliable and coordinated operations between the two agencies. For example, if a collision occurs on a section of freeway managed by VicRoads, CityLink operations will be notified automatically so their systems can respond accordingly.

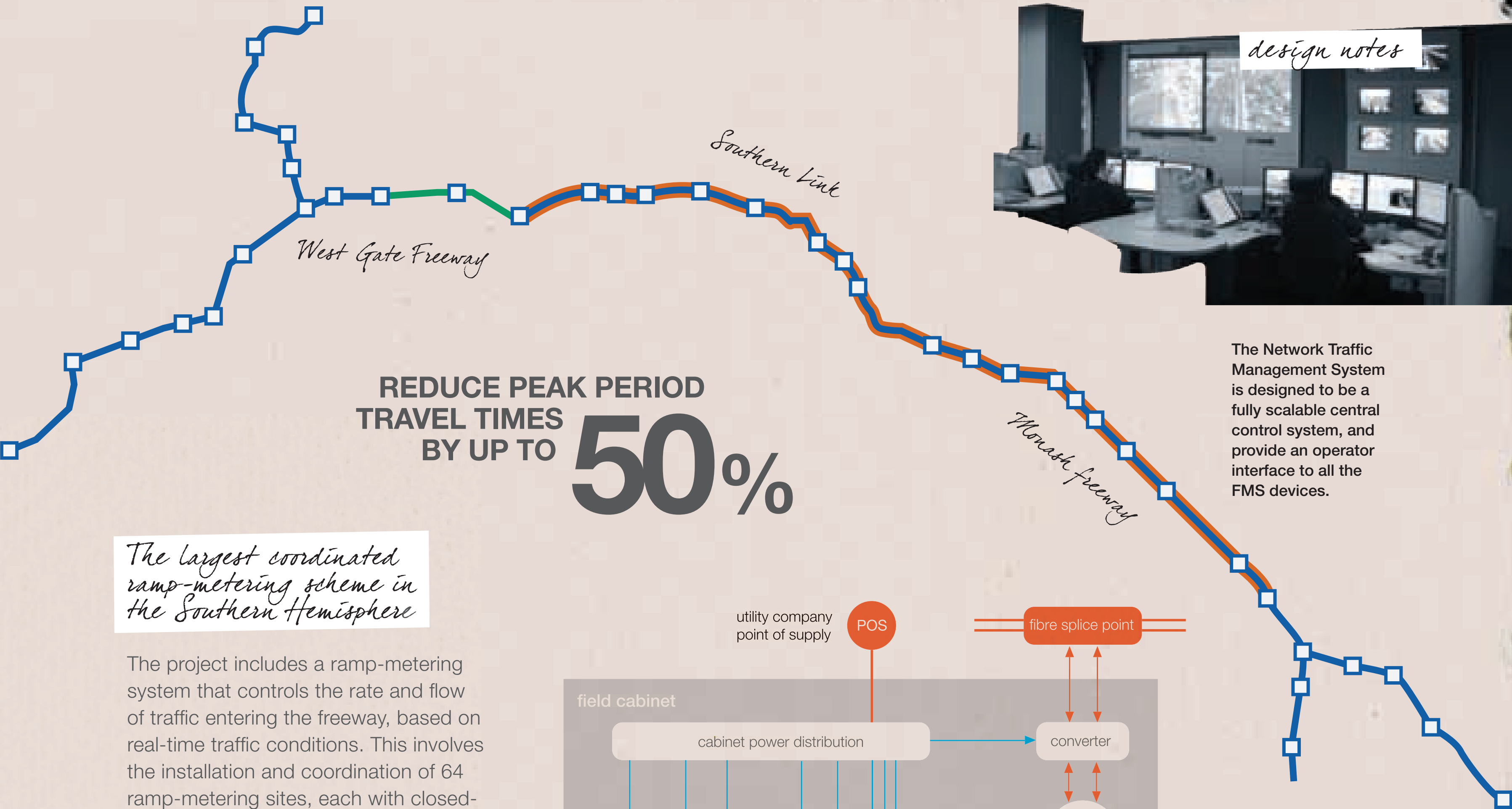
Timely delivery of the project has been a key consideration. By reducing congestion and increasing the traffic throughput to the freeways and privately operated CityLink tollroads – the benefits of the FMS, in conjunction with the upgrade works – will outweigh the initial capital expenditure over time.

Arup's technical specifications have become part of the client's standard for procuring ITS devices and Arup's work has set the precedent for similar projects in other Australian states.

Project Name Monash–City Link–West Gate Upgrade Project

Location Melbourne, Australia

Client VicRoads



The Network Traffic Management System is designed to be a fully scalable central control system, and provide an operator interface to all the FMS devices.

REDUCE PEAK PERIOD TRAVEL TIMES BY UP TO 50%

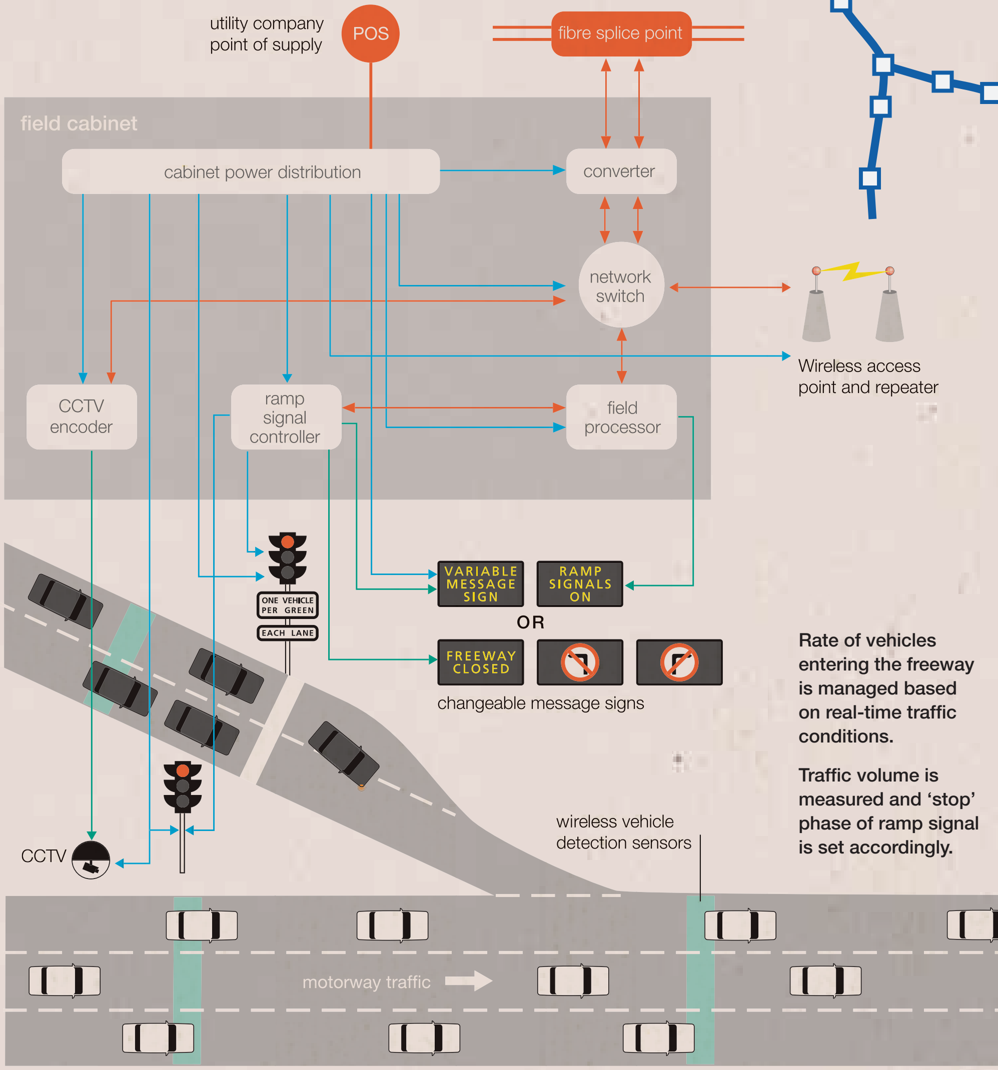
The largest coordinated ramp-metering scheme in the Southern Hemisphere

The project includes a ramp-metering system that controls the rate and flow of traffic entering the freeway, based on real-time traffic conditions. This involves the installation and coordination of 64 ramp-metering sites, each with closed-circuit television, traffic signals and signal controllers, wireless vehicle detection systems and variable message signs, as well as the associated infrastructure.

Detection devices along the freeway monitor the flow and volume of traffic and send information to control systems; traffic signals positioned on the on-ramps adjust the red 'stop' phase accordingly. Significantly, coordinated ramp metering, operating with other ramps rather than in isolation, can better prevent traffic-flow breakdown.

A hybrid communication system

To accommodate the varying requirements for ITS devices along the freeway, Arup proposed a hybrid communication system. A fixed, internet-based fibre-optic network will be used as the base transmission medium, with wireless communications used to extend the fixed network into areas where investing in long runs of cable is not cost effective. □



Rate of vehicles entering the freeway is managed based on real-time traffic conditions.

Traffic volume is measured and 'stop' phase of ramp signal is set accordingly.

Averting flood risk

Significant changes to the landscape, such as a new housing development, can make an area susceptible to flooding. Arup's integrated hydraulic simulation model accurately predicts flood risk for any given area based on new or changing conditions. The model can be used in a number of ways and is a powerful decision-making tool for planners.

■ Following severe flooding in the UK in 2007, surface water management has become a pressing issue for the government. Arup's integrated water catchment model analyses flood risk by looking at an urban area as an interlinked and interconnected model. It does this in great detail and with great flexibility, simultaneously allowing for multi-directional water flows.

Arup used the model to study a new development project in Mullingar, west of Dublin, Ireland. The area has a history of flooding and the Westmeath County Council wanted to understand the impact of a proposed new housing development to the north of the town.

Arup's findings will help the Council make critical decisions about how to move the development forward. As an adjunct to the modelling work, the team was able to propose a sustainable drainage system upstream of the existing town that they were confident would avert any downstream flood risk.

The model can be used to run 'what if' scenarios. Arup analysed the flood risk of a number of proposed development options and determined appropriate solutions to potential surface water issues. In the case of Mullingar, they also determined that extreme weather events would inundate some of the access roads to the regional hospital, prompting the need to look at contingency plans.

Arup plans to use this model to look at increasingly larger areas. It can be used, for example, to measure the impact of climate change on flood risk. With surface water management high on the UK Government's agenda, interest is also high in such a flexible, scalable model. □

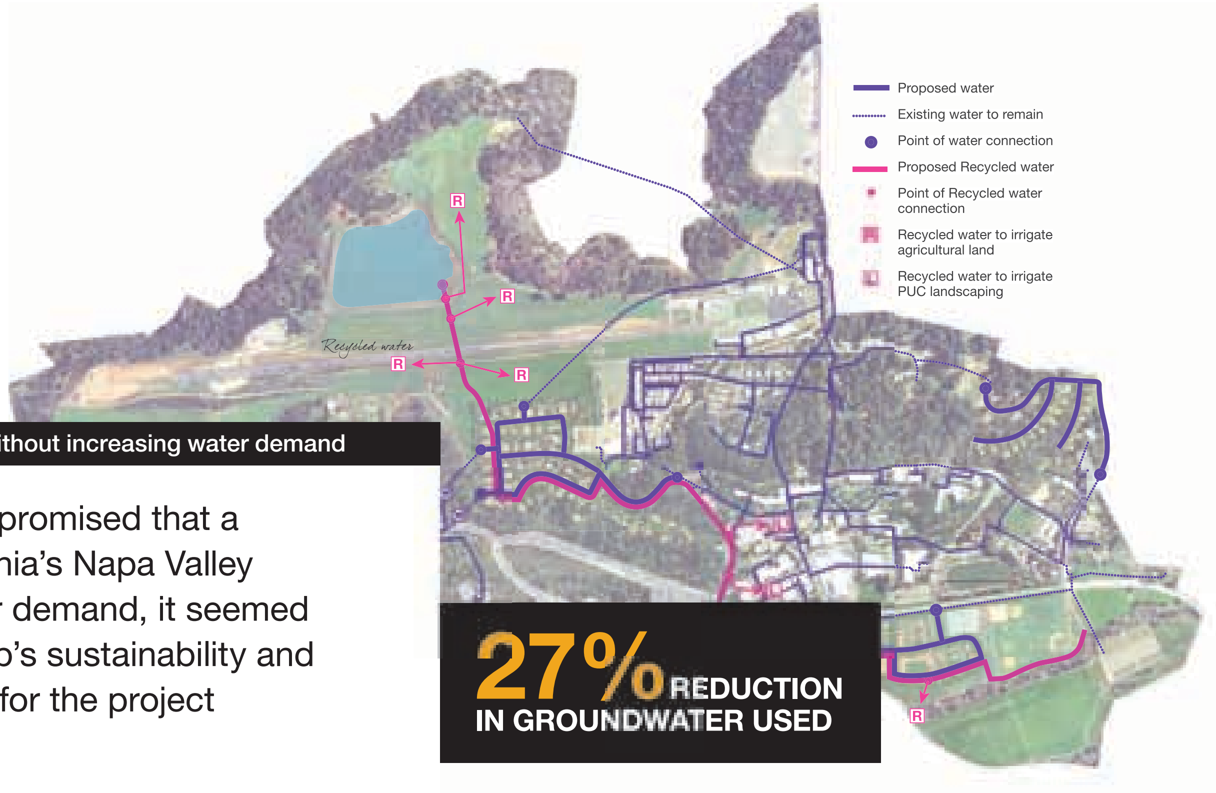
Composite model showing combined one- and two-dimensional elements including a fully interactive river model (shown in yellow).

Project Name Robinstown Surface Water Management Plan

Location Mullingar, Ireland

Client Westmeath County Council

Every drop counts



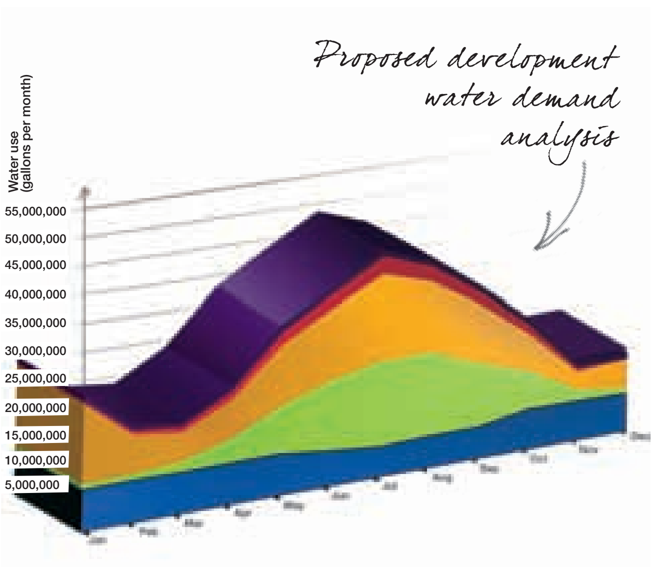
A development provides more homes without increasing water demand

27% REDUCTION IN GROUNDWATER USED

When Pacific Union College promised that a small development in California's Napa Valley would not increase net water demand, it seemed too good to be true. But Arup's sustainability and water management strategy for the project achieves just this.

Key

- Reservoir percolation
- Reservoir evaporation losses
- Agricultural irrigation
- Landscape irrigation
- Potable water demand



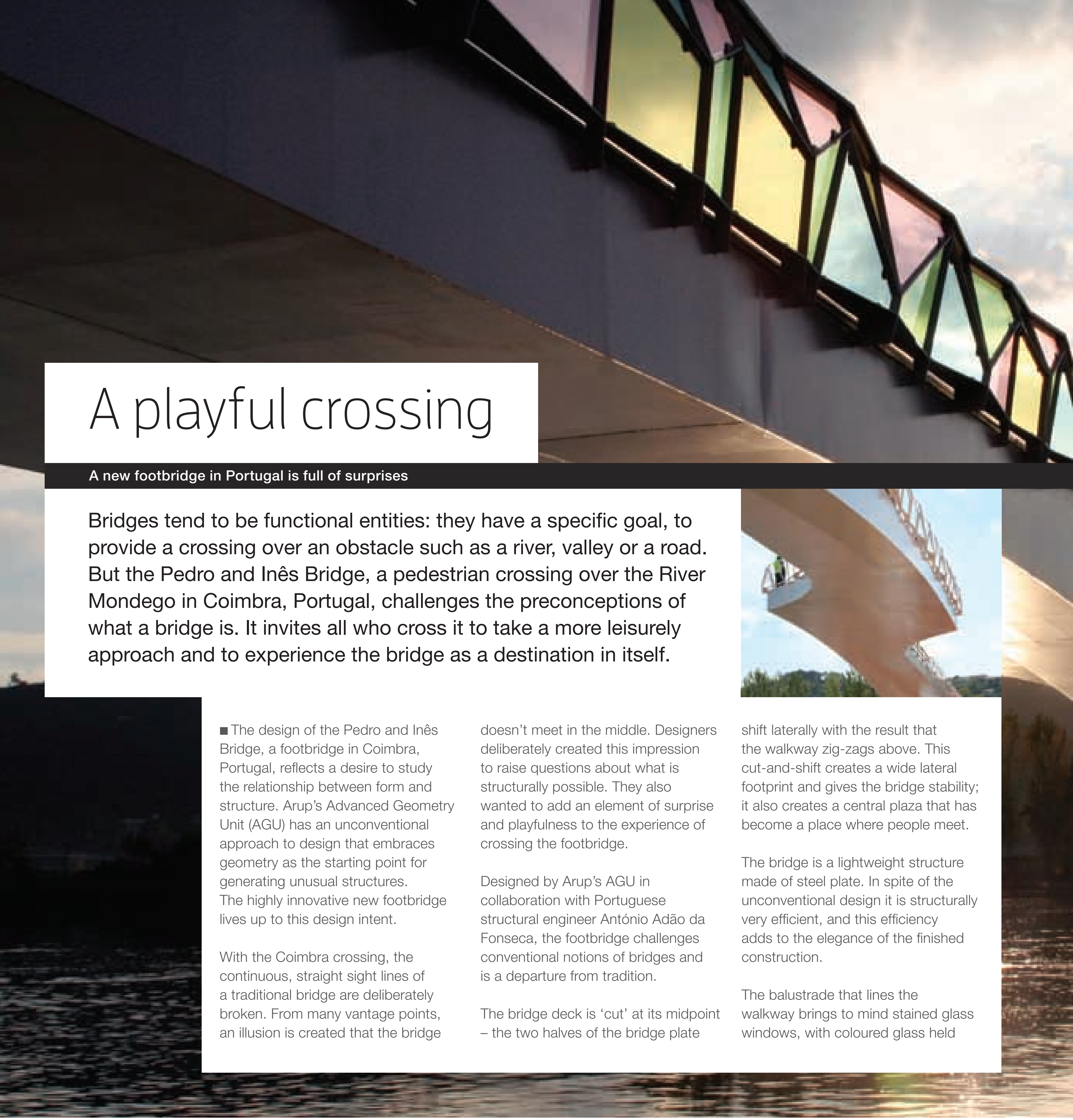
■ California's Napa Valley is home to many of the best known wineries in the USA. Viticulture has shaped the landscape, which from the air is a patchwork of vineyards stitched together by a smattering of small towns. Highly susceptible to water shortages, the state is currently suffering a three-year drought. Governor Arnold Schwarzenegger issued sanctions on water use in February 2009, making the Napa Valley's water supply, derived exclusively from groundwater, a major issue for wineries, municipalities and residents alike. A proposed new development immediately prompted concerns among the local business community about water demand.

Angwin Ecovillage, however, embodies smart development. It is a community that brings a range of environmental, social and economic benefits with few of the attendant disadvantages of a conventional development. Indeed, the projected water demands of the village are just 17% of current water demand. Arup's analysis and projections show that even this additional demand can be met easily through more water conservation strategies and efficiencies in the community. The result is more homes for local workers, college staff and students without any net increase in water use for the area overall.

Arup's ingenuity is on display in the harmony between the water and energy systems. The thermal properties of an existing nearby reservoir will be used to heat and cool buildings on the site via a recycled water pipe network. The proposed development introduces alternative water sources such as spring water, recycled wastewater and rainwater harvesting. When combined with water reduction measures, conventional residential potable usage is halved. Wastewater gets a second chance – 100% of it is used in outdoor landscaping and irrigation.

The bigger picture is impressive too. The compact development sits on just 24 hectares of land, only a quarter of which is new development. It offers residents the opportunity to enjoy a highly sustainable lifestyle with shuttles to surrounding towns and extensive cycle-path networks. As part of the agreement, it will virtually eliminate the possibility of future housing development outside the university campus and permanently preserve approximately 605 hectares of agricultural and prime forest land for the enjoyment of all. ◻

Project Name Angwin Ecovillage **Location** Angwin (Napa Valley), California, USA **Client** Pacific Union College and Triad Communities



A playful crossing

A new footbridge in Portugal is full of surprises

Bridges tend to be functional entities: they have a specific goal, to provide a crossing over an obstacle such as a river, valley or a road. But the Pedro and Inês Bridge, a pedestrian crossing over the River Mondego in Coimbra, Portugal, challenges the preconceptions of what a bridge is. It invites all who cross it to take a more leisurely approach and to experience the bridge as a destination in itself.

■ The design of the Pedro and Inês Bridge, a footbridge in Coimbra, Portugal, reflects a desire to study the relationship between form and structure. Arup's Advanced Geometry Unit (AGU) has an unconventional approach to design that embraces geometry as the starting point for generating unusual structures. The highly innovative new footbridge lives up to this design intent.

With the Coimbra crossing, the continuous, straight sight lines of a traditional bridge are deliberately broken. From many vantage points, an illusion is created that the bridge doesn't meet in the middle. Designers deliberately created this impression to raise questions about what is structurally possible. They also wanted to add an element of surprise and playfulness to the experience of crossing the footbridge.

Designed by Arup's AGU in collaboration with Portuguese structural engineer António Adão da Fonseca, the footbridge challenges conventional notions of bridges and is a departure from tradition.

The bridge deck is 'cut' at its midpoint – the two halves of the bridge plate shift laterally with the result that the walkway zig-zags above. This cut-and-shift creates a wide lateral footprint and gives the bridge stability; it also creates a central plaza that has become a place where people meet.

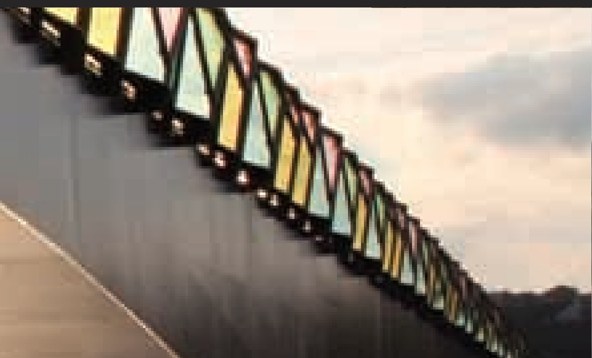
The bridge is a lightweight structure made of steel plate. In spite of the unconventional design it is structurally very efficient, and this efficiency adds to the elegance of the finished construction.

The balustrade that lines the walkway brings to mind stained glass windows, with coloured glass held

Project Name Coimbra **Location** Portugal **Client** AFA Consultores De Engenharialda

"A completely new and interesting experience of the river and the surrounding landscapes"

António Adão da Fonseca of AFA

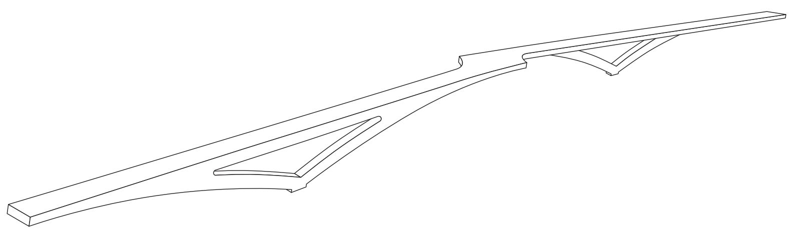


From many vantage points, an illusion is created that the bridge doesn't meet in the middle. Designers deliberately created this impression to raise questions about what is structurally possible.

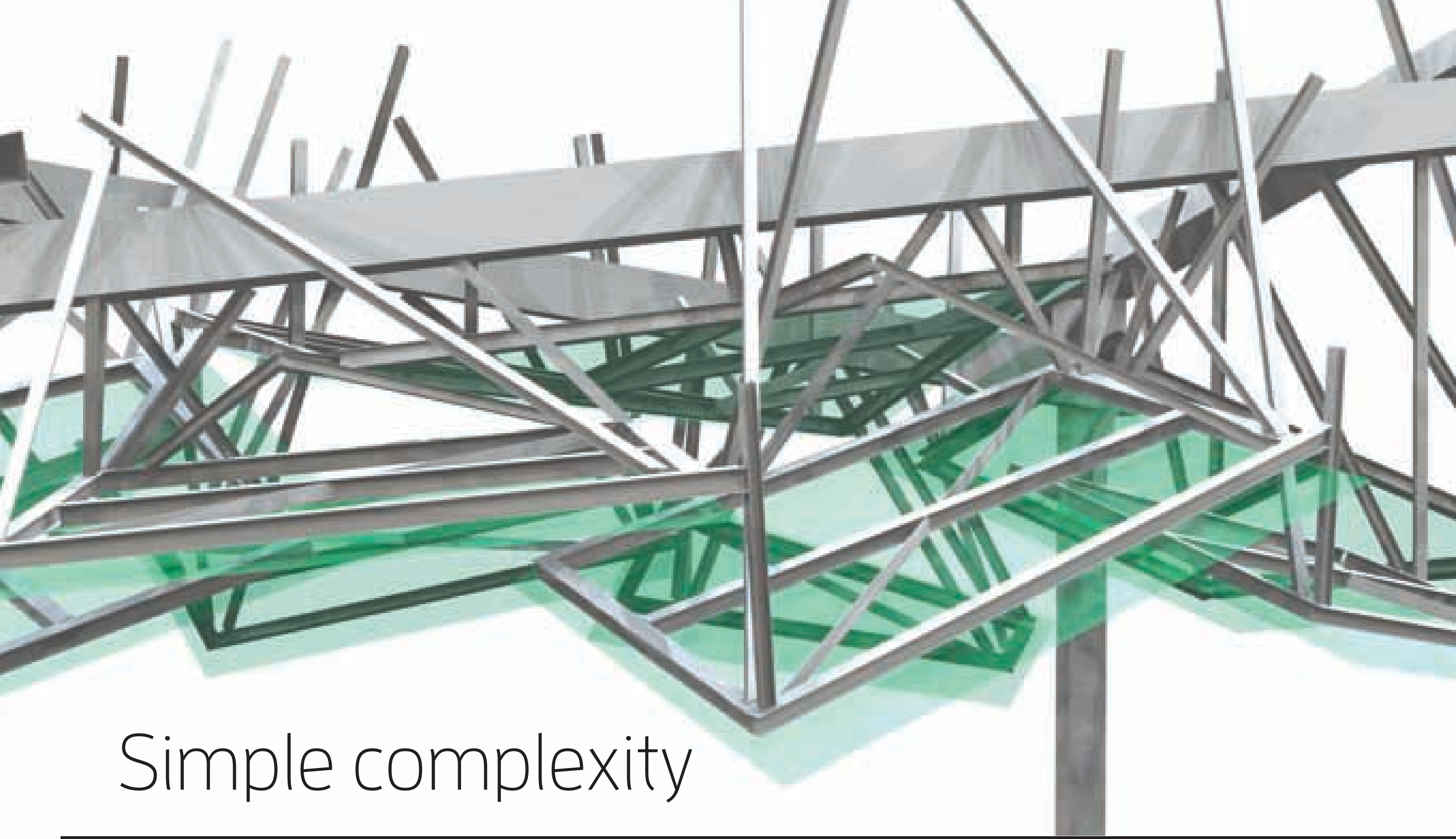
together within a steel framework. Each segment catches and diffracts sunlight, creating a multi-coloured pattern on the wooden decking. The balustrade also folds on itself and becomes three-dimensional; this provides structural stiffness while creating a sense of movement. The pattern in the balustrade is actually very simple, as it contains just four distinct shapes, but the random repetition of these and the use of four different colours for the glass make the end result visually rich, in spite of its simplicity.

The bridge extends beyond the riverbank and roots itself into the landscape of the parks that front along both sides of the river, so the pedestrian's experience of the bridge begins before the actual river crossing and continues beyond its end.

But the real achievement of the bridge is that it moves beyond functional architecture to become an experience and a destination in itself. □



The bridge is not purely functional, but intended as an experience.



Simple complexity

Overcoming complex challenges to create a dramatic structure

The Serpentine Gallery Summer Pavilion installation sets an ambitious schedule: conception to completion in just six months. The technical complexity of the 2008 Pavilion, by renowned architect Frank Gehry, required a seamless and unified approach from the Arup team to meet the stringent deadline.

■ The Summer Pavilion is an annual commission organised by the Serpentine Gallery to bring the work of a renowned architect – one who has not yet built in England – to London's Kensington Gardens. The Pavilion is in built form and stands for just three months. The 2008 Pavilion marked Arup's seventh year of design collaboration, one that continues in 2009 with the Japanese architects, SANAA.

With just six months from concept to completed construction, the design process for the Summer Pavilion is always a challenge. Within this tight timeframe Arup needed to create a structural form that was true to Gehry's aesthetic vision, while creating an efficient and stable solution.

Arup evaluated design strategies, choice of materials and structural typology of the Pavilion as well as providing engineering and specialist design. The choice of materials was an intrinsic part of the interpretation of the design with a strong emphasis on the massive timber frames because of their rustic quality. From a structural perspective, however, these raw timber sections were unable to support the weight of the building. To resolve this, the timber concealed a steel frame that provided the necessary support without compromising the desired aesthetic.

The roof comprised nine timber-and-glass canopies set at different heights and angles, giving the Pavilion a dynamic appearance. They posed the biggest design challenge because of their natural tendency to sway under their own weight. To remedy this, the canopies were

The building was pieced together on site like a complex 3D jigsaw puzzle.

braced together in key locations, creating sufficient stiffness to prevent movement. This and the organisation of the supporting hangers kept the elements in the structure stable: In reality the elements that look random in the finished structure are actually positioned very strategically based on Maxwell's equation, a simple engineering principle.

The complex network of overlapping glass canopies created a fragmented view of the sky and at night gave the effect of a lantern glowing – this was an important part of the Gehry concept and this effect was interpreted and orchestrated by Arup's lighting team.

The central walkway, which led to the Gallery itself, also served as a performance space, with tiered seating on either side. The Summer Pavilion has a practical purpose, so the building had to be a fully accessible public space and provide protection from the elements. Acoustically, it was imperative that it performed well as a number of live events and performances were planned for its three-month stay in Kensington Gardens.

The Pavilion teams were widely dispersed: the architects were based in the United States, the fabricators in Europe, and the Arup team in London. This made accurate communication and coordinated design essential in order to meet the strict deadline. This was accomplished via the exchange of 3D design models. In addition, a Light Detection And Ranging survey gave the architectural designers a true spatial picture of the site.

The design had very tight tolerances and accuracy of construction was vital to guarantee that the building would behave as expected. The structure was fabricated in Switzerland and Germany directly from the computer models – this ensured that the modular components of the building fitted together perfectly on site.

The Pavilion called upon many areas of expertise within Arup. The firm worked with the Serpentine Gallery to secure planning permission; addressed health and safety, and access issues; solved fire engineering, acoustic and lighting challenges; and overcame structural and technical engineering issues. The project also required rigorous management by the Serpentine Gallery project leader to meet the timescales, but it was delivered on time and the result was an impressive and dramatic structure. □

Massive timber frames give the seemingly random structure a rustic quality.

Feast for the senses

A 1,000-seat recital hall with an intimate feel

The success of a new building is often determined by how well the public takes to its external aesthetic. Performance halls, by contrast, are often judged from within. Since its opening in February 2009, the new Melbourne Recital Centre, with its 1,000-seat Elisabeth Murdoch Hall, has delighted audiences, musicians and performers alike and put the city firmly on the map for touring top performers.

The recital hall has accommodated a wide range of musical performance styles in its opening season.

© Bovis Lend Lease

■ From the start, the Elisabeth Murdoch Hall was conceived as an acoustically stunning building. Designers passed over various geometric options in favour of an entirely contemporary interpretation of the classic shoe-box shape of traditionally-successful concert hall interiors. From the outside, the building's white concrete façade evokes a packing case, with polystyrene cladding protecting something precious within.

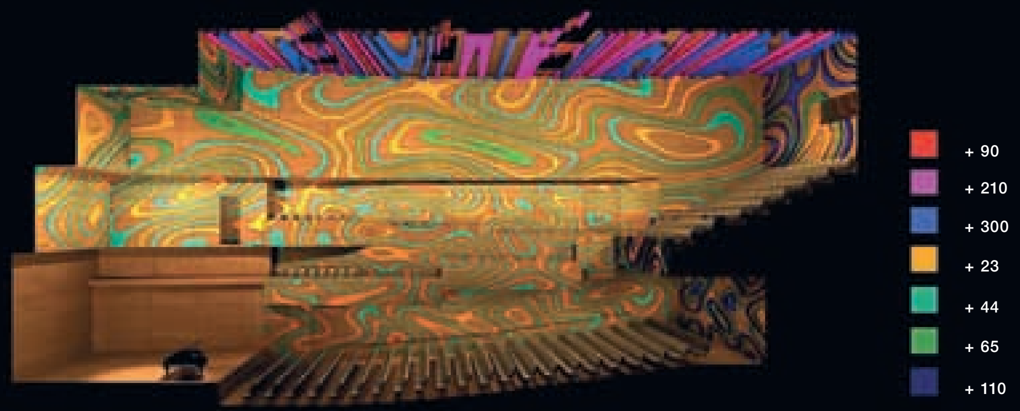
The shape of the performance space itself maximises the depth of sound. Arup used its SoundLab, a room in which the acoustic performance of any building can be experienced before it is built, to demonstrate what string quartets, chamber orchestras and solo instruments would sound like in the space long before it was built. This gave the design team and the client confidence in the design even as it was being developed. Visually arresting, the swirling design that is etched into the hoop pine cladding of the walls and ceiling has a vital acoustic function, diffusing and directing sound evenly throughout the space. The effect is an acoustic and architectural experience that has been likened by concert-goers to "being inside a Stradivarius".

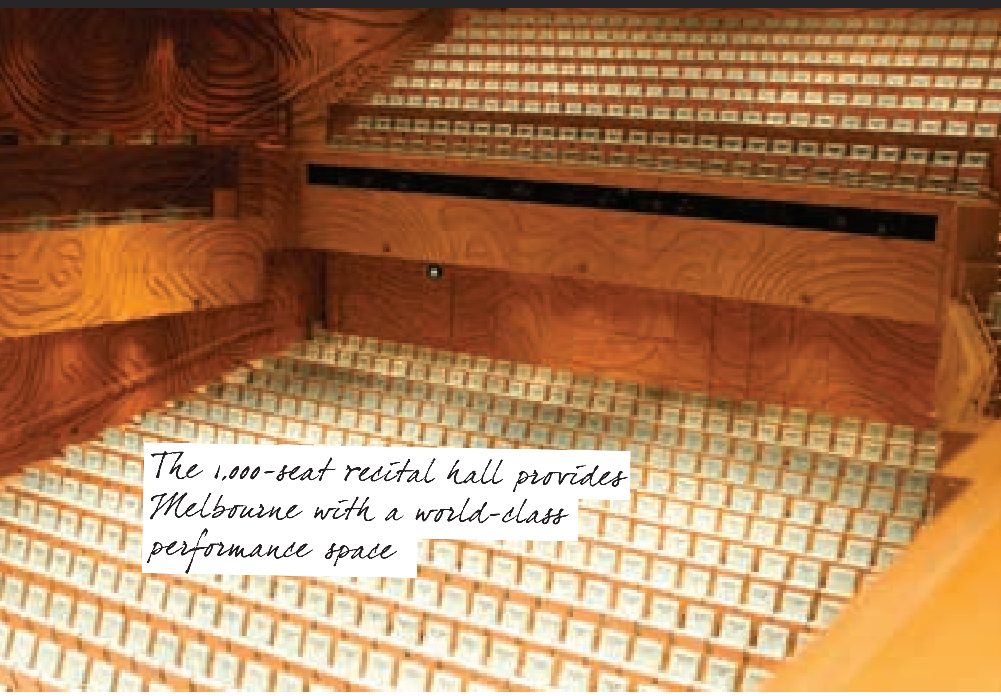
A challenge for any performance space is to accommodate music from different eras and with different performance characteristics. The delicate pizzicato that characterises early chamber music for the harpsichord or clavichord is lost if the listener cannot hear each individual note. Music from the romantic period reflects the soaring cathedral spaces for which it was composed; individual notes blend together and are enhanced by the spectacular reverberation and resonance. Much contemporary music, by contrast, is written for electric guitar or percussion and requires amplification,

Any recital hall, in its pure form, is purpose-built for small ensemble music. However the team created a suite of low-tech but effective tools to customise the space, including a set of fabric banners that can be lowered to manipulate sound absorption and reverberation levels to accommodate a range of other music styles. With several musicians on the team, Arup's acousticians shared an easy rapport with the performers, whose feedback informed the design process.

Project Name Melbourne Recital Centre **Location** Melbourne, Australia **Client** Major Projects Victoria

The colours represent the differing depths of sound diffusion in Arup's swirling design.





The 1,000-seat recital hall provides Melbourne with a world-class performance space

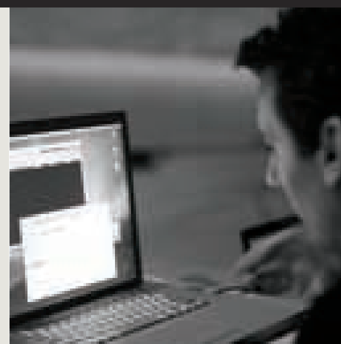
The opening season of Elisabeth Murdoch Hall featured opera and chamber music. It also boasted a traditional Chinese mouth organist, and an unusual, meditative glass percussion performance. No other space could have done justice to this broad range of musical styles. That the Elisabeth Murdoch Hall did so is testament to its acoustic design. □

The swirling design serves a vital acoustic function, diffusing and directing sound evenly throughout the space.

Quiet by design

Visitors to Melbourne, Australia are often charmed by the city's tram system, which provides efficient and low-carbon transport in the city. Arup's acoustic designers were less enamoured by the vibrations caused; they posed the single biggest challenge to the hall's acoustic integrity. When Arup's geotechnical engineers sank a series of 20-30 metre deep boreholes early on to test soil conditions, Arup's acoustic designers took the chance to measure tram vibrations at bedrock level, on which the building piles would eventually sit. They analysed the vibration levels for their potential to propagate into the building structure.

The team used Arup's SoundLab, a self-contained auralisation studio to demonstrate the effect of tram-induced vibration noise on a musical performance, with and without structural isolation. The analysis and auralisation prompted the decision to isolate the hall structure on giant steel springs that act as shock absorbers to block tram vibrations entirely. This structural isolation – simplified as a 'box' floating within a 'box' – gives the hall its uncanny, characteristic quietness.



Arup's acoustic designers

A coherent vision

A modern homeland rooted in sustainable values

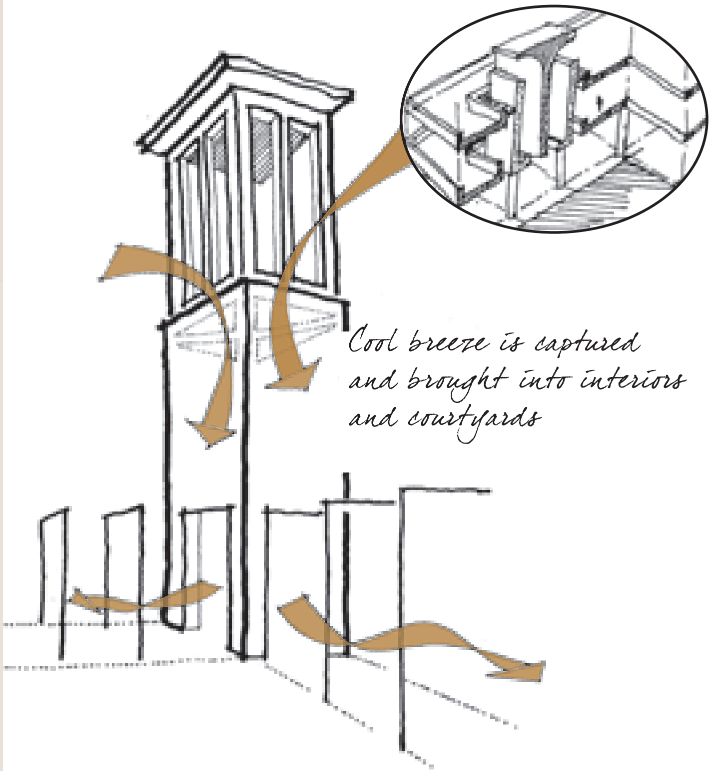
The Heart of Doha development aims to attract Qataris back into their capital city, with an inspiring sustainable urban lifestyle and a renewed sense of community. It will also set a creative new approach to inner-city development in the Gulf region.

■ The Heart of Doha is a unique opportunity to regenerate the core of the city as a place to live and work, and to reflect both the history and growing international importance of Doha. Mixed-use developments are unusual in Qatar as Qataris typically live outside the city centre. By contrast the Heart of Doha development will create a highly desirable urban district of lasting value to the people of Qatar.

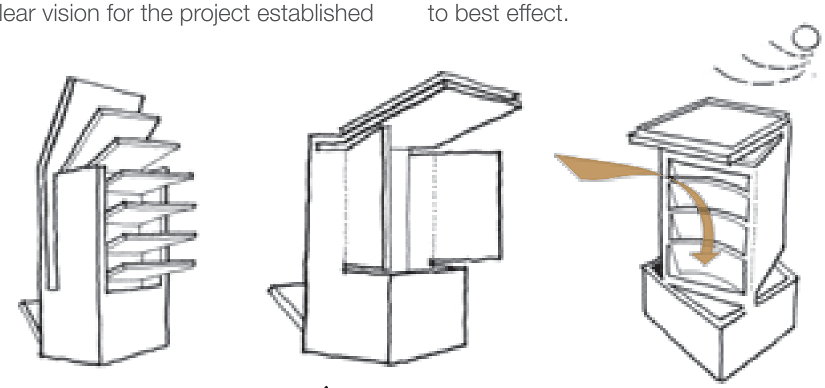
Arup has led the masterplanning and technical concepts for this new 760,000 square metre district, with subconsultants EDAW and Allies and Morrison. Arup took a unique approach by developing a comprehensive set of sustainable development guidelines and an implementation strategy to fully define the project at the outset – to enable both its delivery and the long-term custodianship of the development. These have been underpinned by a clear vision for the project established in conjunction with the client and inspired by a series of sustainable design objectives.

Strategically placed close to the historic origins of Doha, the development will comprise around 200 buildings, which will offer top-quality office accommodation and a range of luxury apartments. It will also offer convenience and high-class shopping, leisure, entertainment and cultural facilities, mosques, and excellent schools, all within easy walking distance.

The plan envisions eight distinct local areas, each with its own defining mix of residential, commercial and community buildings. The areas are further characterised by a shift from low-rise buildings in the north, to high-rise – 20 to 30 storeys – in the south. This design decision also serves a practical purpose; the gradual rise in building height captures the cool sea breezes to best effect.

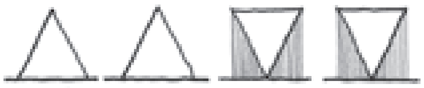


Cool breeze is captured and brought into interiors and courtyards



Modern interpretation of a wind catcher

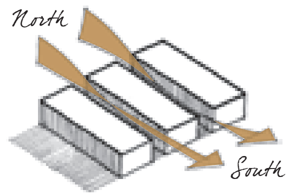
© Allies and Morrison



Orientate urban blocks to channel north-south cool breeze

Closely positioned building blocks to create cool and shaded pathways

Wide top building profile to minimise sun exposure and maximise shade in hot climate



The buildings will incorporate high sustainability performance while elaborating on traditional forms and methods of dealing with the aggressive climate.

The familiar steel and glass of many modern cities is to be set aside in favour of elaborate stonework and beautiful piazzas. The buildings will incorporate high sustainability performance while elaborating on traditional forms and methods of dealing with the aggressive climate in Qatar. In summer, temperatures top 50°C and Qataris tend to head to Europe to escape the intense heat. The Arup team was keen to create a comfortable outdoor environment, and one that could be enjoyed for a greater portion of the year.

Closely spaced structures with internal and external shaded courtyards, as well as colonnades, fountains and other water features, all serve to cool the outside space. In addition, the courtyards are to be built subtly lower than the surrounding buildings to catch the spillover from the air-conditioned space inside the buildings and create a 'cool pool'.

The development applied for outline planning permission as a first stage in the planning process and the result is a coherent vision for the entire district. The merits of this approach have been recognised and it is hoped they will be adopted as the standard in Qatar for planning public projects. In addition, the project introduced sustainable development to Qatar, and the Qatar Green Building Council has now been established.

Arup developed, in parallel with the masterplan, a detailed infrastructure design for the Qatar Foundation. Primary roads, traffic circulation and an underground road system for deliveries and utilities have all have been considered. Subterranean servicing facilities, extensive underground car-parking and smart waste collection will all contribute to the aesthetics of the new district, by making the area above ground less congested.

The ten-year programme of building, which is due to start in 2009, is intended to create a lasting endowment for the city and to give Doha a distinct identity that celebrates its heritage. □

© Mossessian & Partners

Schools for all seasons

Three new schools take pride of place in their local communities

Schools hold a mirror up to the communities they serve. Three of Arup's recent eco-schools while very different from each other, fit perfectly into their localities. A new green primary school campus in Devon epitomises the environmental awareness of its parental and local community. The new Newport High School building in Wales opens its doors to adult learners and local residents and leaves behind a troubled past. A primary school in the Scottish Highlands has been embraced by locals as a green icon for the way it uses occupants' body heat to stay warm.

Dartington Primary School

A new low-energy school in Devon epitomises the environmental awareness and hands-on approach to learning of the community it serves.

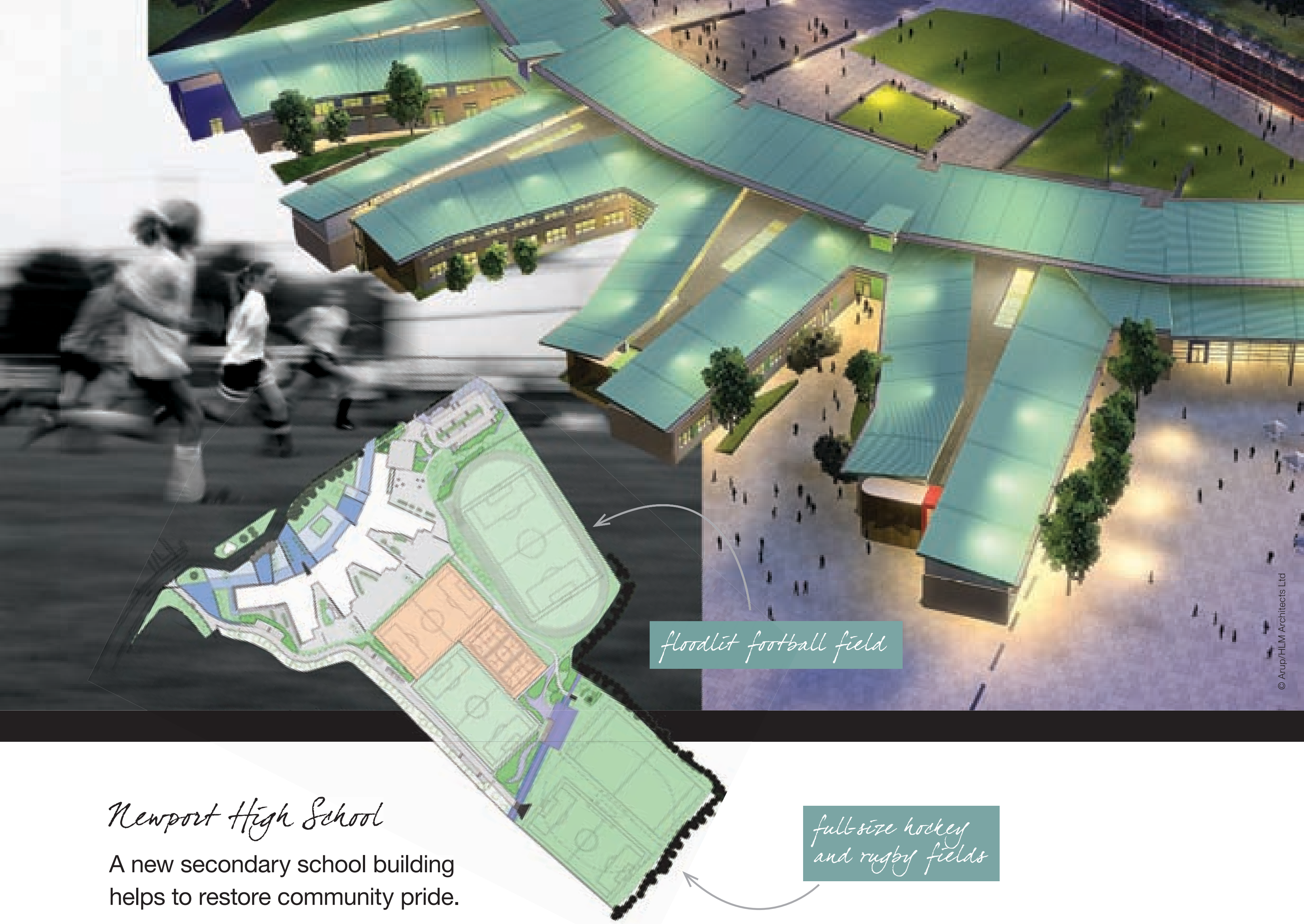
Dartington Primary School is to take ownership of a new building that reflects its forward-looking approach and commitment to sustainability. The school, which is determined to put the environment at its heart, has a building that is a learning tool in itself.

Clusters of wooden classrooms nestle next to a stream in the school's 2.1 hectare rural site. They are not connected by conventional corridors; each classroom opens onto a garden area and outside space. Children must go outside to move between buildings.

The buildings are individual wooden structures that are pre-fabricated offsite and assembled onsite. They are highly insulated to minimise heat loss in winter and are naturally ventilated, reducing the need for energy-hungry climate control. Photovoltaic arrays are mounted on the roofs and the roof pitch itself is calculated to enhance their effectiveness as well as to maximise daylight.

To minimise the use of potable water, Arup developed a novel passive rainwater harvesting system for the classroom roofs. The rainwater system uses gravity, not mechanical pumps, to filter the water from the roof directly into the toilet cisterns. Each cistern features a window so children can easily view and monitor water use. Arup designed a monitoring scheme to oversee and manage water consumption – essential when the ultimate aim is to provide a low energy, sustainable school.

Project Name Dartington Primary School **Location** Dartington, Devon, UK **Client** White Design Associates



Newport High School

A new secondary school building helps to restore community pride.

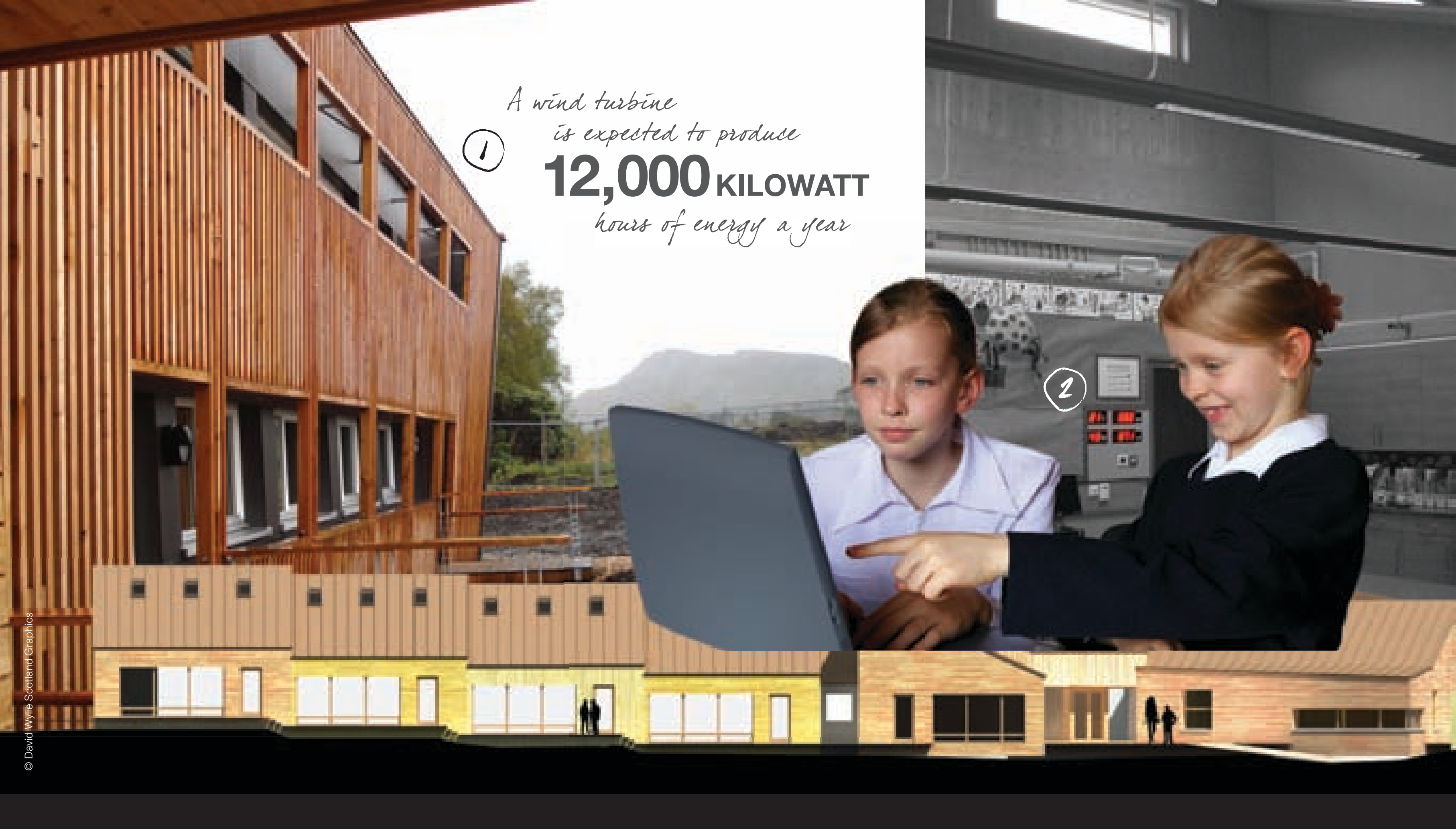
Few will miss the dilapidated old Bettws Secondary School building when it is demolished. Thanks to the best of passive design and modern technologies, the replacement building that will open in October 2009 as Newport High School will use 25% less energy than required by Building Regulations. Its facilities will be enjoyed by the whole community, with adult education classes in the community hall and excellent sporting facilities open to public use outside school hours, including a 25 metre pool and two floodlit outdoor pitches.

This area of Newport, Wales, has a higher than average proportion of students qualifying for free school meals, a traditional indicator of poverty. The old school building was set back from the road, making it easy prey for vandals. By contrast, the new school building is designed to be secure, fronting onto a well lit road, with active security measures in place to the rear.

The school is oriented to capitalise on the sun's heat and to use natural light as much as possible, which also promotes a healthy learning environment for students and teachers. Sensor-controlled lighting, ventilation and heating are programmed to be utilised only when necessary and are simple for teachers and caretakers to use.

Although the economic downturn has tightened budgets, the council has not deviated from its original vision of an energy-efficient, low-maintenance school. Newport High School is the first secondary school in Wales to achieve an Excellent rating from the environmental assessment body BREEAM. With two further replacement schools planned for Newport, the school is a blueprint for future success.

Project Name Newport High School **Location** Bettws, Newport, Gwent, Wales **Client** Newport City Council



Acharacle Primary School

The Highland Council's unwavering commitment to sustainable design for a remote Scottish primary school has paid off.

1. Timber panels with integral insulation are slotted together on site.

2. LED display of environmental performance.

On a cool mid-April day, a Scottish classroom containing four people, one laptop and a PC is checking in at a heady 21ºC on the classroom thermometer. The temperature in the room is maintained only by a combination of body heat and the heat by-product of the computers. This is sustainable design in action at a remote primary school in the Scottish Highlands.

A wind turbine on a nearby hillside is expected to produce around 12,000 kilowatt hours a year of energy – plenty for the school's IT and minimal heating purposes. Arup worked with GAIA Architects to ensure that the school would lose only a fifth of the heat lost by a conventional building.

In fact, the building is the most airtight building ever measured in the UK, thanks to the pre-fabricated mass timber system from Austria, which fits together like giant timber lego. They are held together with wooden dowelling, which is treated to reduce its moisture content to just ten percent. Once slid into place, the dowelling swells as it absorbs moisture from the air and grips the panels together without the need for chemical binding.

Arup used computer modelling to optimise the position of roof lights, windows and key reflective surfaces that make the most of available light. Each classroom has operable windows and doors to allow in more light and air. If the temperature becomes too high, high-level windows open automatically.

The school's green credentials are a source of considerable local pride. Children are keen to point to the LED displays in each classroom that show temperature, relative humidity, light levels and carbon dioxide concentration. Educational in itself, the data presented daily to students will also allow Arup to monitor and fine tune the school's energy efficiency even further.

Project Name Acharacle Primary School **Location** Lochaber, Scotland **Client** The Highland Council

All wrapped up

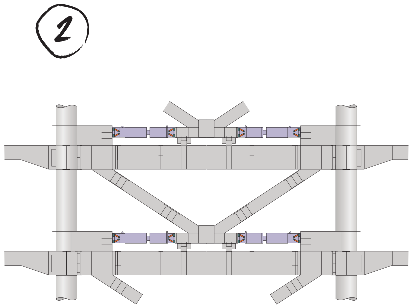
A vertical campus like no other

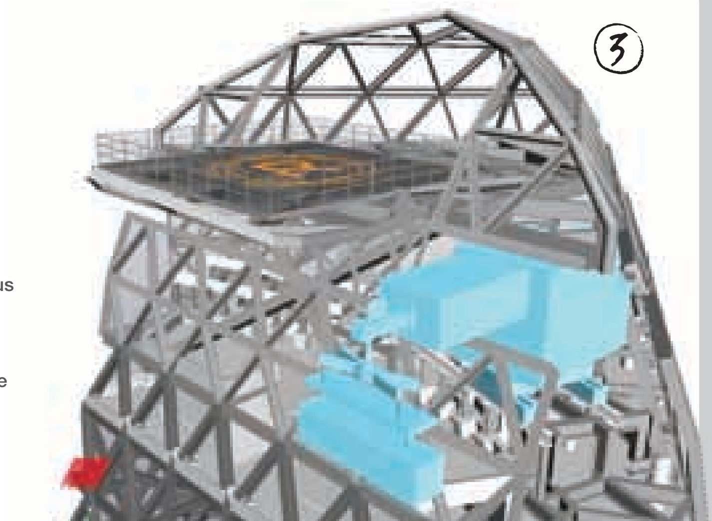
In Tokyo, the only way to give over 10,000 students a spacious campus in which to study was to build skywards. The curvaceous MODE GAKUEN Cocoon Tower is a distinctive addition to the city's skyline and a significant achievement in this highly seismic area.

Project Name Mode Gakuen Cocoon Tower **Location** Tokyo, Japan **Client** Tange Associates

2ND TALLEST EDUCATIONAL BUILDING IN THE WORLD

ACCOMMODATES 10,000 STUDENTS





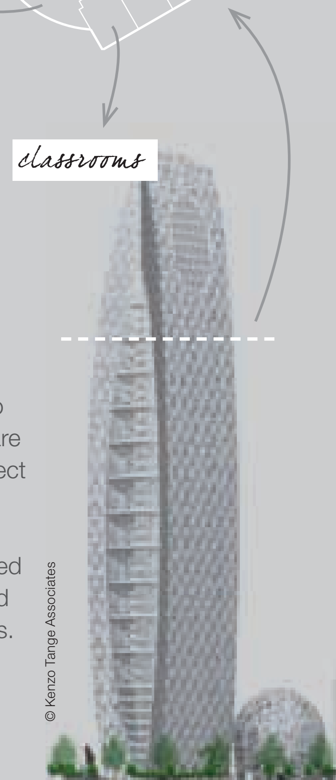
1. The steel diagrid system helps resist side forces.

2. Typical floor section showing location of viscous dampers on vierendeel beam.

3. Hovering space and gondola hanger (showing sliding door mechanism).

An inspiring environment

A typical floor has three classrooms and a triple-height atrium with uninterrupted views across the city for relaxation. The classroom floor beams support the floor loads, and connect the diagrid horizontally with the building's inner core, so providing further stability to the diagrid frames. Double-arched truss beams at each floor level in the atria support the 20 metre-wide glazed panels and help to resist wind pressure. Storey heights are such that the diagrid members intersect at the same angle on each floor. This allows the steel and exterior cladding units to be simplified and manufactured less expensively. The building's diagrid skeleton is exposed in the classrooms. There are no suspended ceilings, just simple and elegant exposed steel beams throughout.



© Kenzo Tange Associates

■ When Tange Associates won an architectural competition with a cocoon-shaped, vertical campus for Mode Gakuen in Tokyo, it was on condition that it found a contractor who would guarantee the scheme within the defined budget.

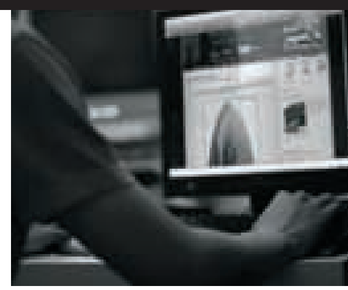
Curved structures have a reputation for being more expensive to construct than classical rectangular buildings. Certainly, Tange found Japanese general contractors reluctant to take responsibility for the building's construction without simplifying the structural system, which would have compromised the design. The curved shape of the tower made structural analysis challenging. The challenge was magnified here, since Japan is a highly seismic zone.

Arup and local contractor Shimizu took up the challenge. As there is no vertical column in the building's perimeter, the team came up with a steel 'diagrid' structure, which helps the structure to resist horizontal forces such as earthquakes or wind. Although conceptually simple, it is geometrically complex. Arup used 3D computer modelling techniques to detail the connections between the steel members – typically seven on each node – which characterise the building.

The team introduced dampers to absorb the seismic energy of an earthquake. By reducing the seismic force entering the structure by 30%, the amount of steel used in the building could also be reduced, with accompanying cost savings.

Tall buildings in Tokyo are required to provide hovering space for a helicopter and an exterior cleaning system. For the tapering tower, a flat space on top was out of the question, so the team designed a retractable roof at the building's apex, which accommodates a helicopter and a floor for a gondola.

MODE GAKUEN Cocoon Tower welcomed its first students in October 2008, by which time it had already acquired cult status. It captured the imagination of people in Tokyo, who photographed its progress through construction and posted it online. The densely developed Nishi-Shinjuku district of Tokyo is home to many high-rise buildings – but none like this. □

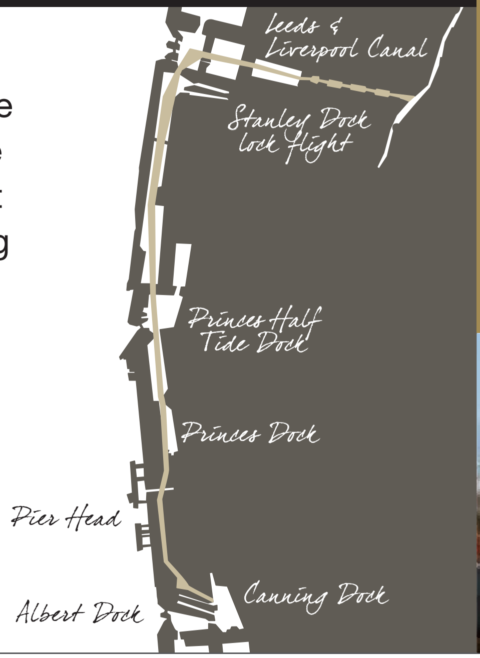


The tower achieved cult status in the blogosphere.

The missing link

A new canal link regenerates the boroughs of Liverpool

The Leeds & Liverpool Canal finally lives up to its name, with a new 2.25 kilometre link that brings boats from Leeds all the way to Liverpool's Pier Head and Albert Dock World Heritage Site. By increasing canal traffic it is helping to regenerate and reenergise the boroughs that run along the canal corridor.



Virtual design

A 3D solid-shape model proved to be a great asset to the project as a communication tool and as a means to save time and money. It was used to explore and present options to the client, to refine the design, to assist with construction on site, to assist with toolbox talks, and to support the briefing process with suppliers.

Detailed 3D models were also included in the brief sent to the China-based granite supplier, and as a result the granite for the canal basins was delivered 'made to fit', considerably reducing material waste.

 Project Name Liverpool Canal Link **Location** Liverpool, UK **Client** British Waterways – National Regeneration Directorate

■ Liverpool's Pier Head and Albert Dock area form part of the city's World Heritage Site and have as its backdrop the iconic Three Graces: the Liver Building, the Cunard Building and the Port of Liverpool Building. It now has a new way to draw more visitors into its midst, but they will arrive in a rather more leisurely fashion – by canal boat.

Arup was involved in the project from its design development stage and provided a range of engineering and specialist services.

The Liverpool Canal Link adds a 2.25 kilometre stretch of inland waterway to the Leeds & Liverpool Canal bringing it into the heart of the city of Liverpool and finally giving boaters a flagship destination and meaningful reason to use it. Now an attractive route choice, the revitalised canal will help to regenerate the boroughs that run along its corridor, injecting life into the local economy in the process. The new waterway threads its way through the publicly accessible area of Pier Head and integrates with it seamlessly. Arup's design creates a balance between the water and the public spaces that line its banks. The granite of the new canal basins is of the highest quality, befitting the site's waterfront World Heritage status. The granite deliberately evokes the size, shape and mass of stone used around the south docks, helping to blend it into the landscape.

The River Mersey is visible from many of the streets that lead down to Pier Head, a vital aspect of a seafaring city that dates back to the days when ship owners needed to know at a glance if their ship had docked or been unloaded. Preserving these unobstructed views created a lot of complex geometry within the canal design. Anything solid – tunnel portals, parapets and balustrades – had to be carefully aligned with the existing street lines.

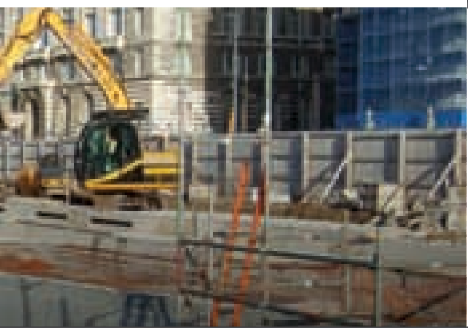
Liverpool is a city steeped in maritime history and the excavation of the site became a journey of discovery. An archaeologist was on hand to record the historical findings, and these records along with photographs and laser scans have captured the story of the craftsmanship that lay behind the construction of the old docks and river walls.

To reduce the cost of the development and its environmental impact, Arup proposed to make the link itself as narrow as practicable, while keeping the canal basins wide. This would limit the amount of construction through the old dock walls and minimise waste to be removed from the site. This involved reviewing and agreeing a new operating strategy with British Waterways.

The Canal Link supports not only the desire of partner organisations to revitalise and restore the Liverpool waterfront and Central Docks but it will also act as a catalyst for the economic regeneration of the canal corridor through Merseyside by dramatically increasing the boat movements on the 40 kilometre section of canal between Liverpool and Wigan. □

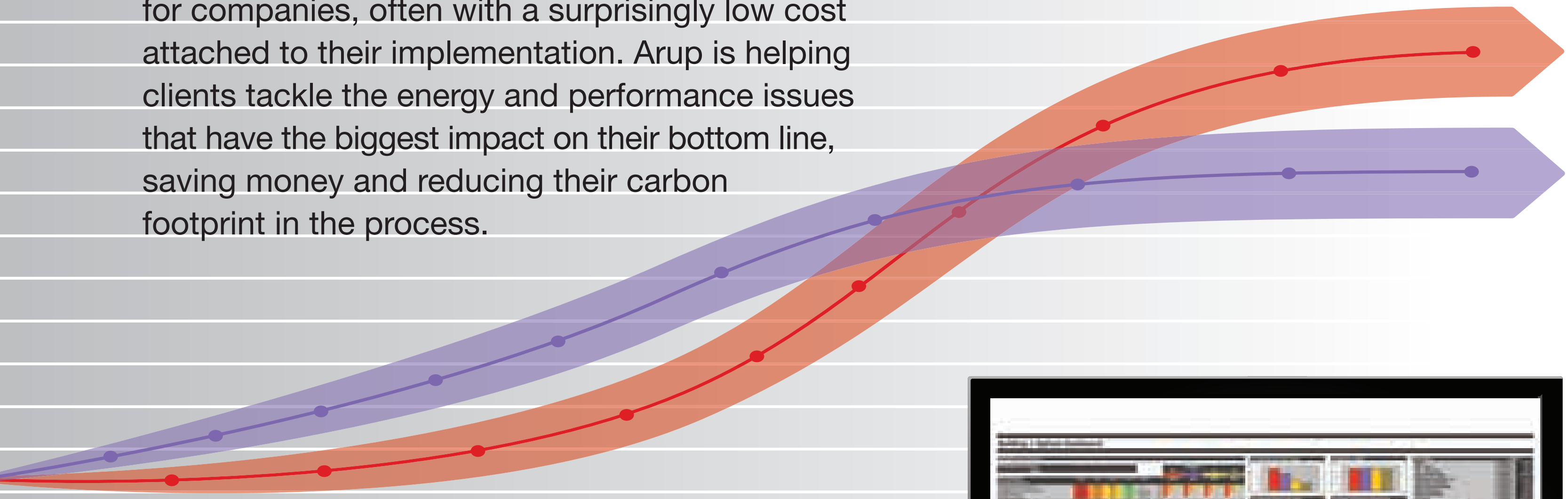
> The new Canal Link will act as a catalyst for regeneration in the surrounding area, bringing increased recreation and amenity resources, and social and community benefits.

£3.3m NET
additional gross value added



Increase in
PROPERTY VALUES
through the canal corridor

Enhancements to the way buildings are used by their occupants can result in significant savings for companies, often with a surprisingly low cost attached to their implementation. Arup is helping clients tackle the energy and performance issues that have the biggest impact on their bottom line, saving money and reducing their carbon footprint in the process.



Peak performance

Arup assists businesses to optimise building performance

■ When Australia Post, the government-owned postal service, approached Arup to improve the sustainability performance of its substantial building portfolio as part of the company's 'Green Building Strategy', it came prepared with several years of environmental data on hand. Energy costs, water usage, and levels of waste had all been diligently recorded.

When the Arup team began to review and consolidate the mass of information they quickly realised that a business tool would greatly assist the processing and analysis of the data and the decision-making that would follow.

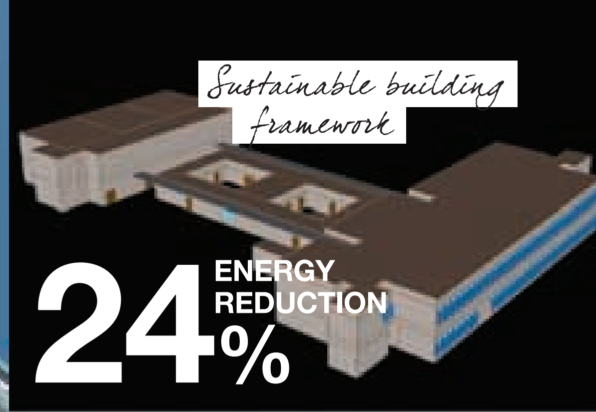
It is out of this work that Arup's Financial Impact Tool (FIT) has been developed. Once a baseline audit has been carried out on a building's performance, and potential remedial measures have been identified, the next natural question is which measures should be implemented?

FIT helps answer this question, but it does so in the context of a company's own objectives. The advantage of FIT is that it is fully customisable. An organisation can decide on its own criteria for evaluating and prioritising efficiency measures, and these factors can be weighted in the decision-making process. As a result, suggested performance strategies are prioritised according to a client's requirements.

Some of the proposed building changes are very inexpensive to put into practice and a cost-benefit analysis enables the optimisation of the bundling and timing of interventions. For an organisation with a large property portfolio to maintain, it enables the identification of buildings that are performing poorly, the financial implication of any proposed changes and the impact of these changes on targets. Buildings can then be targeted appropriately for refurbishment on a rolling basis.

The work with Australia Post has been instrumental in the tool's development, but FIT has now found a broader application: it has already been adapted for use in the UK and has great potential to assist businesses in making their operations more cost-effective and sustainable in a time of constant and increasing financial pressure.

Project Name Financial Impact Tool **Location** Australia and UK **Client** Australia Post



TIME EQUITIES INC.
Arup's energy audit at Time Equities Inc. led to the identification of 13 energy efficiency measures that will save $295,000 in utility costs in the first year, 40% of current annual spend. The measures will reduce site energy intensity by 24% and provide Time Equities Inc. with approximately 17 points towards certification under the Leadership in Energy and Environmental Design (LEED®) for Existing Buildings.

Energy efficiency measures that make sound business sense

Arup has been working with a growing number of clients in the US to help them to understand the energy performance of their portfolio of existing buildings. The work has a clear economic driver: With rising energy costs, any related savings can have a big impact on profitability. And in the current economic climate any measures to help improve profitability can also help recession-proof a business.

Added to this, the shift towards a 'green economy' is prompting new legislation that will require businesses to reassess how they manage their building stock. But the legislation is not just about imposing penalties for poor performance. Financial incentives are now available for organisations to improve their operating efficiencies.

Against this backdrop, Arup uses its knowledge of the built environment – and more specifically, of building mechanical systems, such as HVAC and lighting – to audit a client's operations and recommend measures to improve energy efficiency. A key part of the model is gauging return on investment – measures are only proposed if they make sound business sense.

The work carried out has not been sector-specific either. To date it has encompassed the education, healthcare (which constitutes six percent of all energy use in the USA), banking and entertainment sectors, among others, and Arup is now starting to work with government organisations. The reality is financial and performance improvements are of benefit to any corporation. □

PFIZER
Arup worked with Pfizer to identify and implement energy conservation measures at its California research facility. This has resulted in savings of $1m per year with a simple payback period of less than six months and a reduction in CO_2 of 5,000 tonnes each year.

Sustainable planning in wetlands

Working sensitively with the environment

The planned Destiny development in central Florida will sit between two natural watersheds amid a network of waterways. Arup's masterplan weaves the new development sensitively into the existing environment, preserving important wetland habitat and creating a sustainable landscape for future residents.

■ Destiny is set in 16,700 hectares of central Florida farmland and forest. Planned from the very beginning as an eco-city, it has been designed to co-exist harmoniously with its natural surroundings.

Water is a defining feature of the Destiny site. The development will sit on a raised arc of land that runs northeast to southwest between the watersheds of the Kissimmee and St John rivers, making it a logical choice for the site. Arup's sustainable approach to water management fitted well with the environmental design principles of the development and the clients' commitment to limit the use of groundwater resources. The other design intent was to preserve the existing wetland habitat.

Rainwater harvesting was maximised by the use of engineering and design techniques to channel rainwater into cisterns and reservoirs for use as needed, leaving the natural water flow patterns untouched.

The waterways intersect the site, and working within this layout, Arup proposed the development of 13 separate districts, each one based around a distinct urban watershed and with approximately 6,000 households. The districts will be as self-sufficient as possible with respect to water, waste, and energy infrastructure.

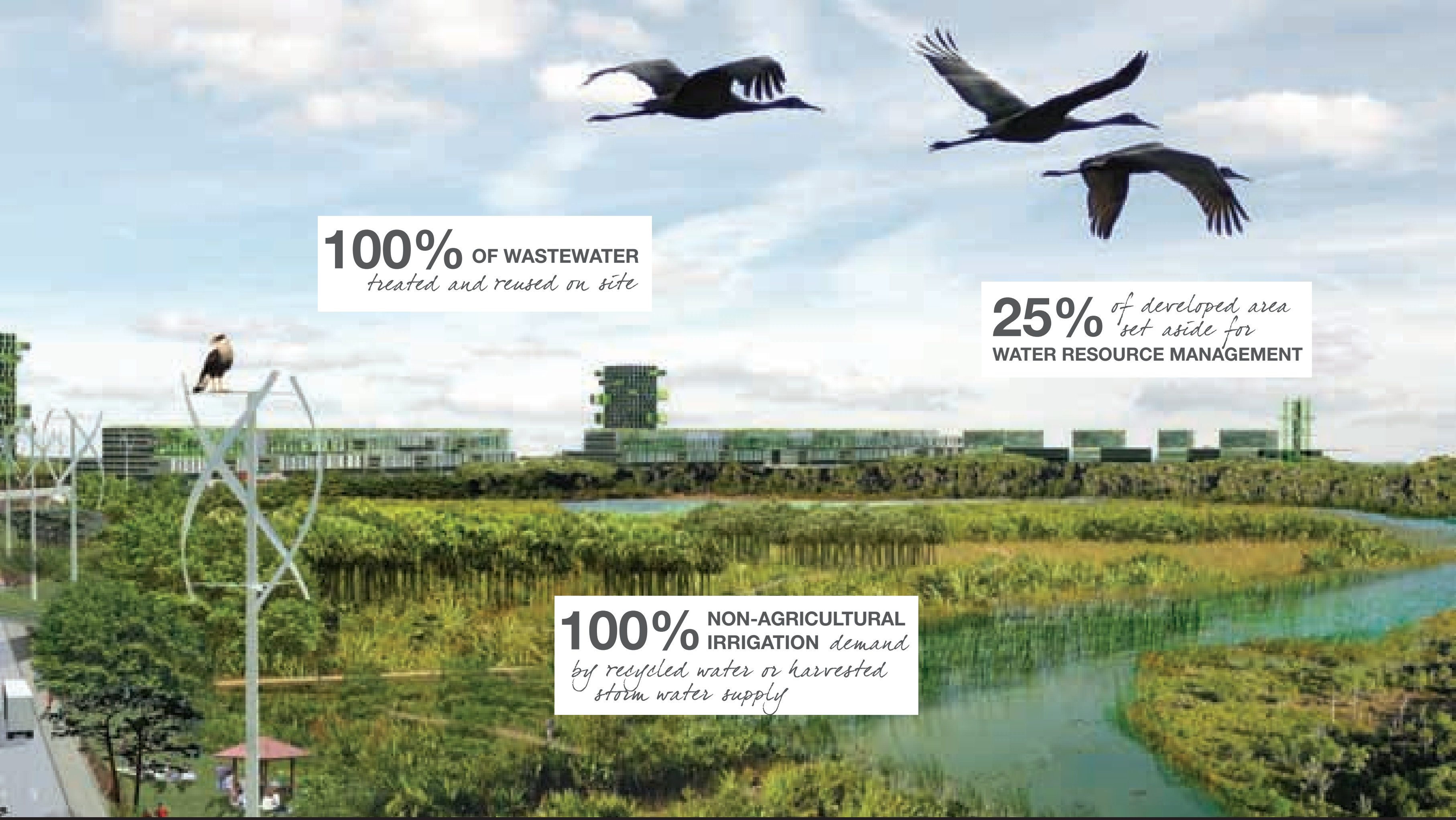
The wetlands are home to many endangered birds such as the bald eagle. They are also a major habitat for deer, tortoise, alligator and wild boar. By leaving most of the land undisturbed, and by working sensitively with the environment, Arup is ensuring that this

Map of Destiny showing planned open space. Over 50 percent of the site will be left undisturbed.

Project Name Destiny Eco-City Conceptual Masterplan

Location Osceola County, Florida, USA

Client Land Company of Osceola County, LLC



"Land is our past, our present and our future... Building all the aspects of an eco and sociological sustainable community is our Destiny."

Anthony Pugliese
CEO, Destiny

important habitat is preserved. On the economic front, Arup's masterplan envisions a pedestrian-friendly community supported by a new and expanding base of clean technology industry and research jobs.

Destiny is a prototype for urban development that seeks to control and contain urban sprawl in high-growth environments. Designed to be operationally carbon-neutral, its site planning, infrastructure and building strategies create a high degree of self-sufficiency with respect to energy, water, waste and transportation, and aim to synthesise urban and conservation strategies.

It is a new type of city, in part because all of its components have been thought out, planned and integrated from the outset.

The Destiny masterplan is already drawing worldwide attention. In May 2009, the Clinton Climate Initiative, founded by the former US President, recognised it as one of 16 worldwide 'founding projects' under its prestigious Climate Positive Development Program. □

Sustainable solutions:

→ Renewable energy systems to provide at least 50% of total on-site energy requirements.

→ A hydrology system that minimises irrigation requirements and integrates district-scale rainwater harvesting, biofiltration, and reuse and recycling solutions.

→ A compact transportation system that relies on mass transit access complemented by a publicly available fleet of electric vehicles.

→ Waste, recycling and logistics activities coordinated through neighbourhood-level utility hubs.

→ Planning to promote climate resilience, with respect to flood mitigation, storm-resistant building and storm recovery planning.

Designed for earthquakes

Arup's seismic expertise ensures a new airport terminal is protected

The new terminal at Sabiha Gökçen International Airport will be the largest seismically-isolated structure in the world. Arup's team of seismic experts carried out extensive real-time earthquake simulation to ensure that the new €3bn terminal will be as well protected as possible should an earthquake strike.

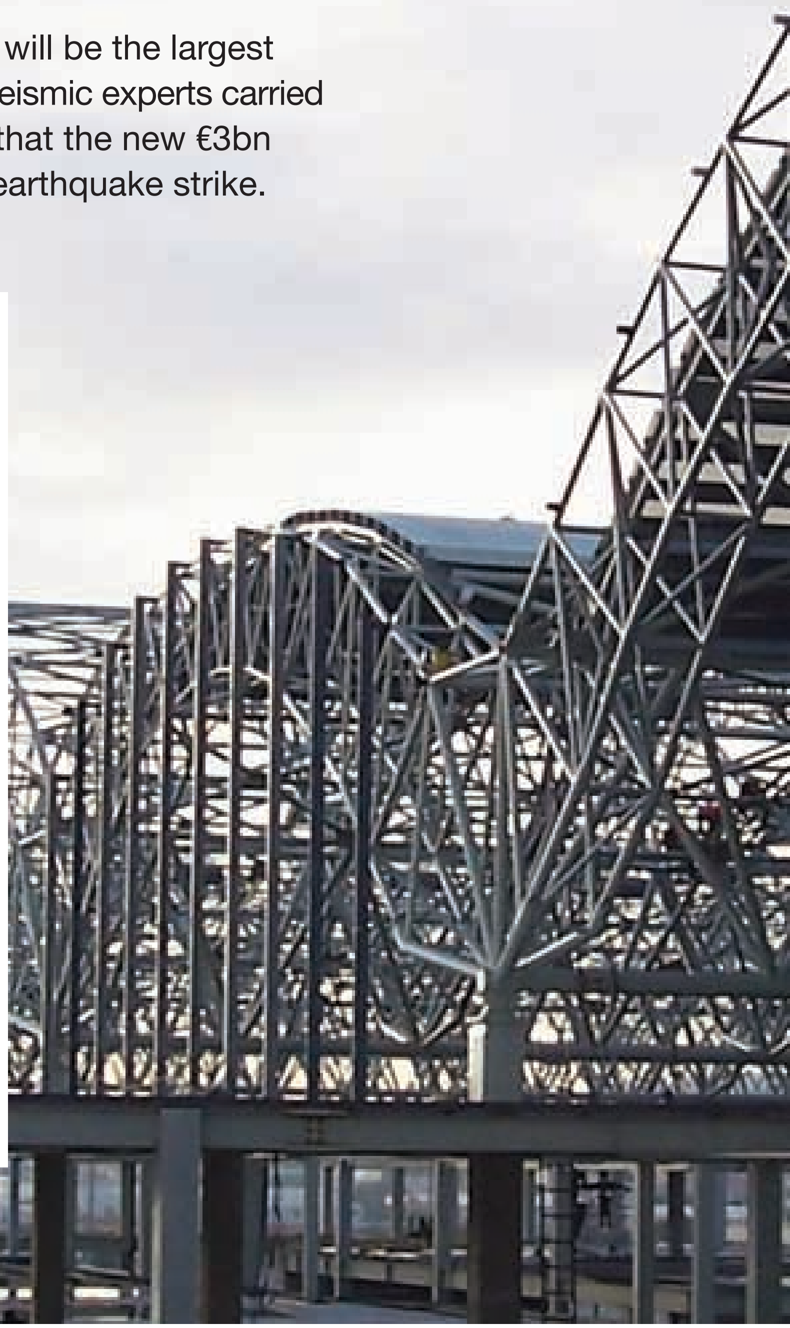
■ Istanbul is no stranger to earthquakes. It lies over the North Anatolian Fault, which runs for 1,500 kilometres between the African and Eurasian tectonic plates. As the African plate continues its move northwest, the Mediterranean is subject to earthquakes on a regular basis.

In order to safeguard the investment made by investors Limak, GMR and MAHB, the design and construction consortium wanted to ensure the best possible protection from disaster for the new terminal at Sabiha Gökçen International Airport. As the consortium will own and operate the building for the next 20 years, it also wanted to build the terminal quickly for a rapid return on its investment.

The schedule for the design and construction of the 200,000 square metre terminal could well be the fastest on record in Europe. Due for completion towards the end of 2009, it will have taken just over 18 months. The Arup structural design team made this possible with a fully-coordinated effort from the firm's Istanbul and Los Angeles offices.

In 2008, the local building codes did not address design requirements for seismically-isolated structures, so Arup adopted US building codes as its baseline, though ultimately the design solutions went far beyond these.

Earthquakes release a tremendous amount of energy in the form of seismic waves. In a conventional, non-isolated building this energy will travel up through the rigid structural elements, which then attempt to absorb and dissipate this energy. But when the structure reaches its energy absorption capacity, it will begin to fracture – and if stretched beyond its deformation limit – it may collapse.



Project Name Sabiha Gökçen International Airport **Location** Istanbul, Turkey **Client** Limak – GMR Joint Venture

Enter seismic isolators. Their purpose is two-fold: to enable the building to move in a controlled manner; and to absorb or dissipate energy from seismic waves. Positioned at ground level at the top of the base columns, seismic isolators are made up of concave steel plates with a bearing sandwiched in the middle.

The plate surfaces slide easily over one another and over the bearing in precisely-engineered fashion. This precision is key: the friction level must be high enough for the building to remain stationary if, for example, there is a strong wind, but allow the building to move in its entirety if there is an earthquake.

Arup's ability to determine the horizontal movements that the isolated building would be able to withstand proved invaluable. Through these predictions, Arup was able to give the client complete confidence about the building's seismic performance.

Arup used real-time earthquake simulation, modelling the effect of various ground motion accelerations coming into the isolator. To ensure the accuracy of the calculations, Arup's seismic experts checked the response of the building at one-hundredth of a second time intervals. This detailed analysis was then repeated for 14 potential earthquake scenarios. The isolator properties used in the earthquake simulations were later verified through rigorous prototype performance testing of each isolator.

All of this work has served to reassure the client that, should a major earthquake strike Istanbul, the Sabiha Gökçen International Airport's new terminal building will perform well. □

Superior seismic performance

1. Seismic isolators are made up of concave steel plates with a bearing sandwiched in the middle. This central bearing takes the gravity load of the concrete columns of the structure, allowing the building to move horizontally if the energy coming into the isolator exceeds a pre-determined limit.

2. The seismic isolators are positioned at ground level at the top of the base columns. Each isolator is 900 millimetres x 900 millimetres and allows a lateral movement of 345 millimetres.

Airside view of the terminal building and gates under construction (March 2009).

Going underground

A new 26 kilometre tunnel brings Hong Kong and mainland China closer together

A new high-speed rail link connecting Hong Kong, Shenzhen and Guangzhou will reduce journey times from over one and a half hours to 48 minutes.

■ The new express rail link between Hong Kong and Guangdong in the heavily industrialised Pearl Delta region is a key infrastructure project for Hong Kong. Though there are many existing road, rail and ferry connections between the two regions, none are especially fast. With the new, 142 kilometre high-speed rail link between Hong Kong and Guangdong's capital, Guangzhou, a journey that before would take over an hour and a half will take as little as 48 minutes.

The best way to build the Hong Kong section of the express link was to go underground. Arup and joint venture partners Atkins were asked to identify and evaluate the route alignment options for a 26 kilometre tunnel between a new terminus in West Kowloon and the Shenzhen boundary at Huanggang. The firm's tunnelling experts needed to balance practicality with environmental and land issues: an underground tunnel of such length needs plenty of land for the construction works, and for ventilation, safety and maintenance access points along the route.

The team soon whittled down a number of route options to just four. It then assessed the relative merits of each, devising a weighted scoring system to gauge ease of construction, cost, land use issues and environmental factors. Given that the express trains will travel at up to 200kph in the tunnelled section, the straighter the route, the better.

The northern half of the Hong Kong section is predominantly rural. Here, the main issue was land purchase. There were also environmental factors to consider, such as the many historic temples in the rural part of Hong Kong.

As if this wasn't enough to consider, the tunnels are required to pass under the 950 metre high Tai Mo Shan Mountain. Arup modified the route to minimise the tunnel length, but even so, the obstacle meant a seven kilometre separation between access points.

The challenges were different in the south where the route passes through the urban areas of Kowloon. The team had to minimise the impact of tunnelling and construction work on existing buildings and other infrastructure, threading the route through obstacles such as existing rail and drainage tunnels, drainage culverts and foundations. It proved easier to identify access points in built-up areas, thanks to the prevalence of government-owned property or available unallocated land. Widespread use of reclaimed land for urban development in recent decades also made route selection easier, thanks to more extensive mapping of foundations and underground services.

Ultimately, only two routes were feasible and one scored better against the relevant criteria. The chosen route had significantly less impact on residential buildings, had more surface land available for construction, and simplified the tunnelling works. The team focused on developing the scheme to bring down construction costs.

As one of the longest railway tunnels in the world, the underground section is an engineering feat in itself. The rail link will help Hong Kong to retain a leading role in the regional economy. □

Project Name Guangzhou-Shenzhen-Hong Kong Express Rail Link

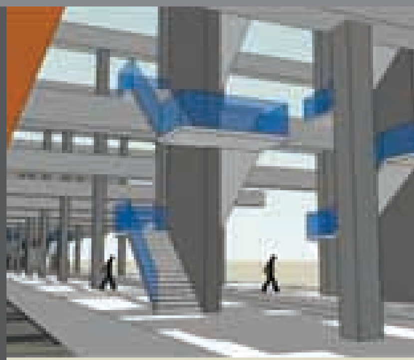
Location Hong Kong, China

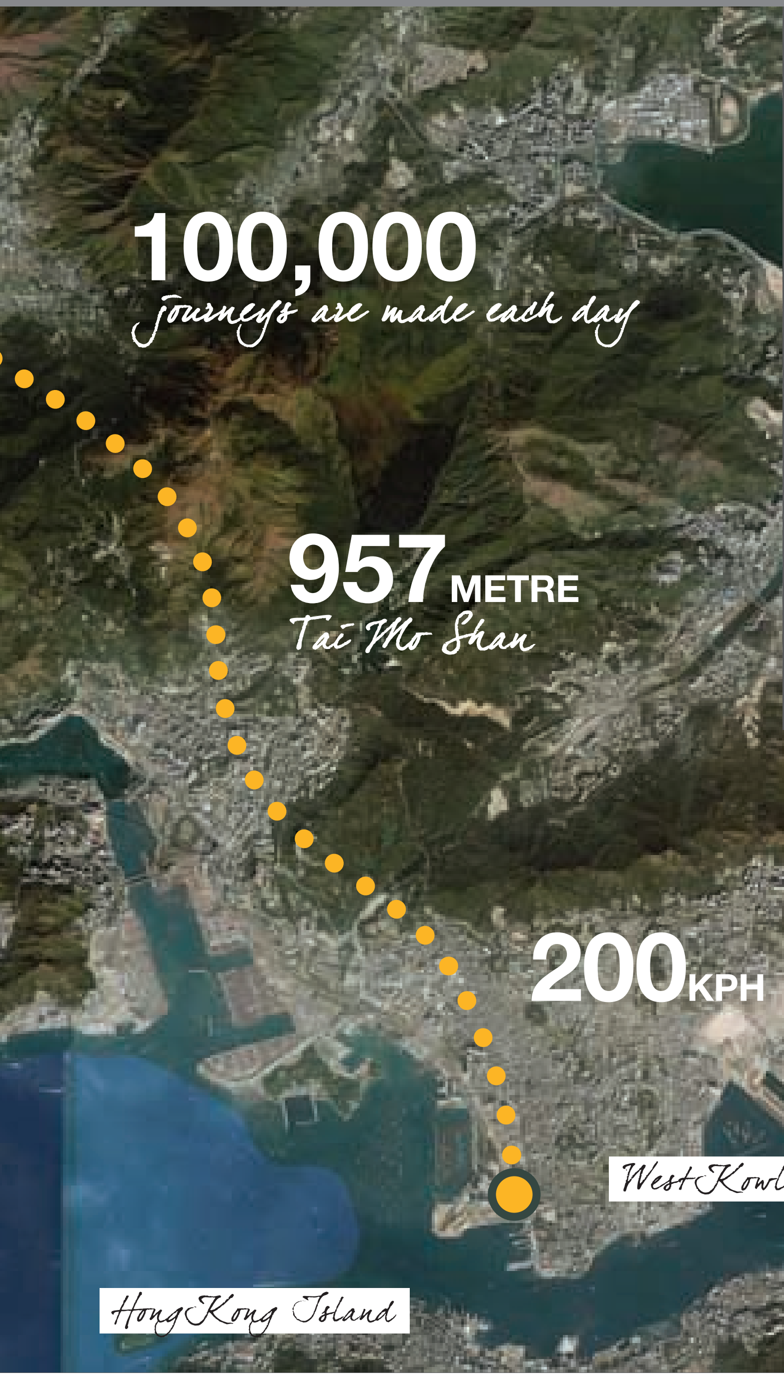
Client MTR Corporation Limited

A sub-terranean fire-fighting cavern

What happens if fire breaks out on board a train? Safety is the paramount consideration for any tunnel, but one so long and deep needed special consideration. Arup's fire experts designed an open-air emergency rescue station, sited roughly halfway between Hong Kong and the first Chinese station. This is used both for evacuation of passengers in the event of an emergency, and for fighting a train-borne fire.

The 500 metre x 25 metre wide and 20 metre deep open-air box gives a fire-stricken train an escape from the main track. Once the train pulls into the rescue station, its passengers can be evacuated and the fire-fighters can deal with the fire in relative safety, away from the tunnel.





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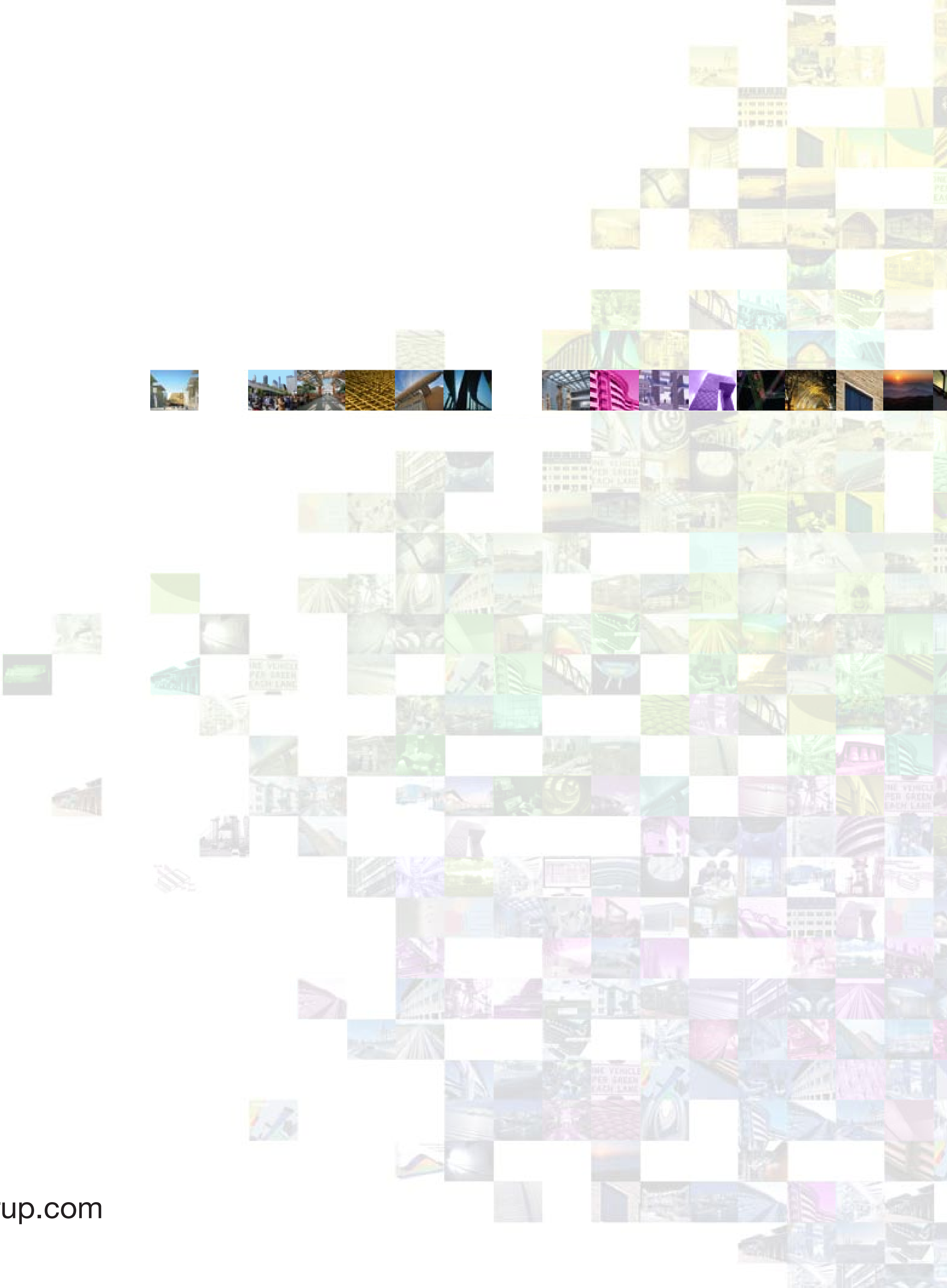

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