ARUP

2017

# Annual Report

We use new ideas and technologies to inspire creativity, strive for quality in what we do, and are never satisfied with the second-rate. This is how we solve our clients' problems and tackle the big challenges of our age. The result is work that pushes boundaries and shapes a better world.

**GETTING THE MOST OUT OF THIS PDF**

The 2017 report uses multiple page sizes to communicate the rich mix of projects and people we have been involved with this year. In this PDF, these pages are indicated by a small page fold in the bottom corner.

# Contents



**SAN FRANCISCO MUSEUM OF MODERN ART**

*San Francisco, US*

The striking façade is made from 700 fibre-reinforced polymer panels which form rippled patterns that echo the topography and water of San Francisco Bay.

PERFORMANCE SUMMARY

# A year in review

*1 April 2016 – 31 March 2017*

We believe new and better solutions come from sharing expertise and valuing the insights diverse teams can bring. This simple idea shapes the way we work – with our clients, partners and each other. This attitude also enabled us to deliver quality and impact across more than 18,000 projects and 6,700 clients this year.

**35**
Countries with permanent offices

**140**
Countries where we have worked on projects

**6,772**
Clients served

**13,346**
Average number of staff members this year

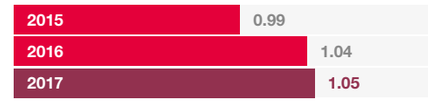


## CLIENTS

Clients in over 140 different countries continue to place their trust in our firm. That trust can be measured by our forward order book which stood at £1.05bn in the year up to March 2017.

Nearly half of our clients are working with us on multiple projects – a clear indication of a further shift to a relationship-based working model.

FORWARD ORDER BOOK (£BN)

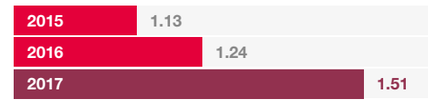



## FINANCIAL

Our revenue grew to £1.51bn in the year to March 2017, an increase of 21.7% from 2016.

Our operating profit margin, before staff profit-sharing for the year, was 11.6%, a sign of our financial health and stability.

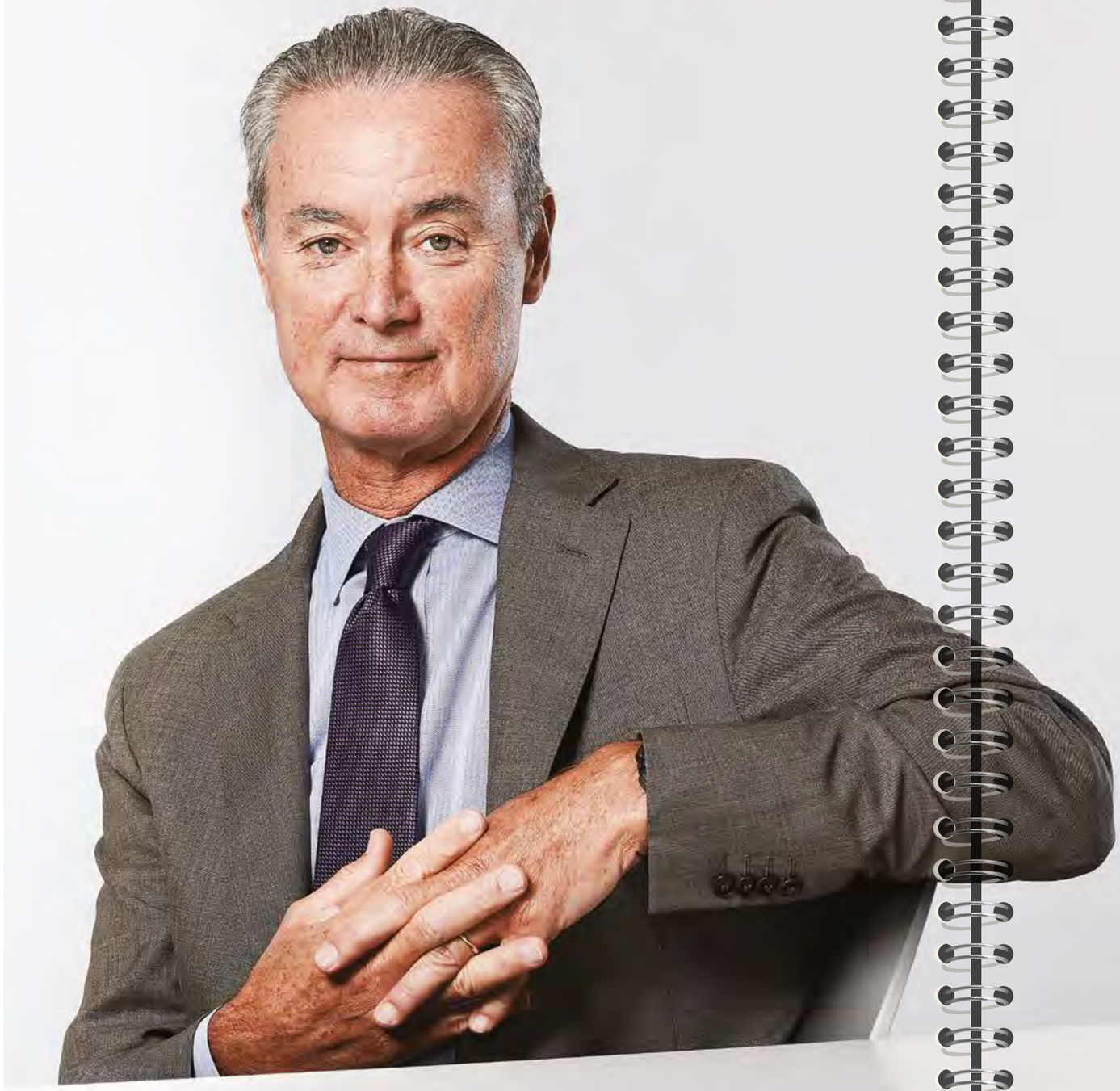
REVENUE (£BN)




## IMPACT

Addressing climate change in a meaningful way and promoting sustainability in everything we do are fundamental to our firm. They are underlined by our membership of the UN Global Compact and by our decision to embed the UN's Sustainable Development Goals across all our operations. This will ensure that our aims translate into tangible progress in 17 important areas.

SUSTAINABLE DEVELOPMENT GOALS



CHAIRMAN'S STATEMENT

# Responding to change

In a year marked by rapid change and new opportunities, Arup has responded with energy and ingenuity. With an ever-broader range of interconnected skills, we have worked with clients around the world to address new challenges in new ways, constantly expanding the impact we make.

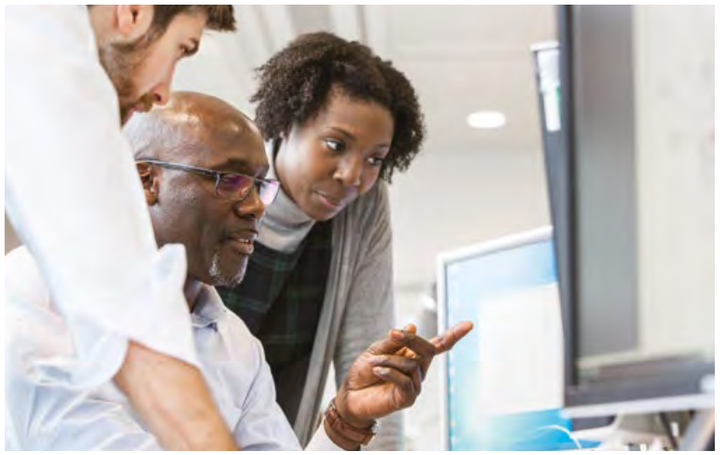
Against this continually evolving backdrop, two unchanging strengths have stood us in good stead: the quality of our people and our distinctive values. Both remain the bedrock of our firm and both ensure we face new challenges with quiet confidence.

## CHANGE

Change comes in many forms. In recent years, the world has been facing new challenges including population growth, rapid urbanisation, resource scarcity, climate change and the exponential rise of digital technology.

For Arup, this change provides both challenge and opportunity.

The challenge comes in finding effective solutions for problems that are very often complex and multi-dimensional. The opportunities arise from our abilities as independent, flexible thinkers with deep technical knowledge and a collective desire to 'shape a better world'.



THE TIMES TOP 100 GRADUATE EMPLOYERS

**EMPLOYER OF CHOICE**

Our position as the sector leader in rankings like The Times Graduate Employers survey demonstrates the strength of our reputation and the quality of work we do.

## PEOPLE

Our people have done terrific work this year. They choose to work here because of the quality of work we do, the calibre of the colleagues they work with and the strong ethos that we all share.

That ethos draws directly from the aims Sir Ove Arup set out for our firm nearly 50 years ago, which are as relevant now as they were then, giving us a set of principles against which we can judge our current actions and progress.

This year, 1,750 new staff members joined our firm in more than 60 countries. They included 550 graduates and were selected from over 41,000 applicants. The number of applications we received and our position as the sector leader in various rankings demonstrates the strength of our reputation – and that is based on the quality of the work we do.

A focus on providing values-driven careers does not stop with graduates. It is something we work hard to achieve across all levels and all parts of the world. The world-class professional development opportunities we offer through *Arup University* (page 14) are just one example of how we put this into practice.

## SKILLS

We continue to seek opportunities in four broad markets – cities, transport, energy and water – and we see increased demand for holistic thinking that draws together diverse strands of our expertise. A notable characteristic of our work this year has been a clear recognition that our different markets are converging.

To meet these demands we continue to broaden our skillset and attract people to the firm who possess a wide spectrum of professional expertise and experience. From my perspective this can only be positive, as the more diverse the thinking we can draw on, the stronger and more dynamic the solutions we can offer our clients.



## ONE FIRM

We operate from 85 offices but focus on a fully integrated service across the world. This gives us the ability to deliver the best of our capabilities wherever our clients need us, without any borders or barriers. Ultimately, we want to be where the challenges are and where there is capacity for us to make a difference.

China and outbound Chinese clients remain an important focus and an exciting place to operate, with a strong need for the leading edge integrated skills that we offer. The demand there for sustainable and resilient development has grown and projects like *Shougang Park* in Beijing – China's first C40 Climate Positive development – typify the type of impact we have been able to make (page 39).

North America is another area where we have seen strong opportunities to expand the scope of our work. The breadth of our activities there offers us a sound base, as does the visibility from successfully completing landmark projects like the first phase of New York's *Second Avenue Subway* (page 56) and the *San Francisco Museum of Modern Art* (page 58).

Finally, South East Asia is a region where we have seen a good deal of opportunity. The *Bangkok Blue Line Extension* (page 38) and the masterplan for *Jurong Lake District* in Singapore (page 35) are two notable examples of the kind of work that is contributing to the rapid development in this dynamic region.

**JURONG LAKE DISTRICT**

*Singapore*

The masterplan for this high-density, mixed-use precinct is built around a high-speed rail terminus and blends new waterways and green spaces with businesses and residential developments.

Climate change is a critical and pressing issue. Our work with the C40 Cities Climate Leadership Group will help cities take practical steps to address it.

## OUR WORLD

In last year's Annual Report, I highlighted our participation at COP21 in Paris and our work with the C40 Cities Climate Leadership Group, which represents 650+ million people and one quarter of the global economy. Both demonstrate our commitment to addressing climate change in a meaningful way.

We have built on this further this year, leading the C40's *Deadline 2020* project, which sets out the steps cities need to take to reduce their $CO_2$ emissions to achieve the COP21 agreement. We have also made a commitment to support the UN's Sustainable Development Goals through the work of our firm (page 23).

This will enable us to play our part in embedding effective sustainable solutions across the built environment, as we know that it will play a central role in driving progress in sustainable development. The good news is that many of the solutions we need are already known or knowable. What is required is the collective will from governments and businesses alike to implement these to the best effect.

The growth in renewable energy and the resulting dramatic shift in its affordability is a strong case in point. The *Solar Capital De Aar 3* project in South Africa (page 48) is one half of the largest photovoltaic solar park in the Southern Hemisphere. It is making a significant contribution to the country's energy needs and is an example of the type of practical, sustainable work we do with our clients.

"This partnership builds upon an existing successful relationship with Arup, which has produced some of the most valuable research and resources on climate change action to date."

Eduardo Paes, C40 Chair and Mayor of Rio de Janeiro

**SOLAR CAPITAL DE AAR 3**
*De Aar, South Africa*
The solar farm covers an area of 274 hectares, almost the size of 40 football fields. It provides electricity to over 35,000 South African homes.



**18,360**
Number of fee-earning projects

**44.6%**
Clients with more than one project

## SELECTED AWARDS

The awards that we have won this year are a tribute to the quality of our people, partners and clients. They recognise our core belief in innovation and commercial excellence.

### AMERICAS

**Fulton Center**
*New York, US*
International Federation of Consulting Engineers
Outstanding Project of the Year Award

**Zuckerberg San Francisco General Hospital and Trauma Center**
*San Francisco, US*
The Structural Engineers Association
Award of Excellence in Structural Engineering

### AUSTRALASIA

*Australia*
Consult Australia Awards for Excellence
Large Firm of the Year

*Singapore*
Institute of Engineers Singapore SC50 Awards
Ten projects named among the top 50 engineering achievements in Singapore

**Downtown Line Stage 3, Contract 937**
*Singapore*
International Tunnelling Awards
Tunnelling Project of the Year
(between €50M and €500M)

### EAST ASIA

**Airport Midfield Concourse Development, Hong Kong International Airport**
*Hong Kong, Greater China*
Engineering News Record ENR
Global Best Projects Awards
Best Airport/Port Project

**Kansai International Airport and Osaka International Airport**
*Osaka, Japan*
IJGlobal Awards
Asia Pacific Airport Deal of the Year

**The Harbour Area Treatment Scheme (HATS) Stage 2A and T·PARK**
*Hong Kong, Greater China*
Global Water Awards
Wastewater Project of the Year – Distinction

### EUROPE

**Stavros Niarchos Foundation Centre**
*Athens, Greece*
Building Awards
International Project of the Year
Institution of Structural Engineers IStructE
Award for Arts or Entertainment Structures
Engineering News Record ENR Global Best Projects Awards
Cultural/Worship Winner

**Stormen**
*Bodø, Norway*
Royal Institute of British Architects RIBA
RIBA Award for International Excellence

### UKMEA

**Jaguar Land Rover Engine Manufacturing Centre (JLR EMC)**
*Wolverhampton, UK*
Chartered Institute of Building Services Engineers CIBSE Building Performance Awards
Project of the Year

**PwC Tower**
*Gauteng, South Africa*
Construction World Magazine Awards
Best Projects Awards – Professional Services

### FIRM WIDE

**Arup**

Management Consultancies Association MCA Awards
Consulting Excellence Award for Ethical Behaviour

NCE100 Companies of the Year
Collaborative Firm of the Year

TARGETJobs National Graduate Recruitment Awards
The Most Popular Graduate Recruiter – Construction, Civil Engineering and Surveying

National Apprenticeship Awards
London Region – BAE Systems Award for Large Employer of the Year – Highly Commended

Lighting Design Awards
Lighting Design Practice of the Year

International Forum Design Awards
Product Design Award for the View Lighting Range

Ecobuild Big Innovation Award
Joint Winner for the Hybrid Fan Coil

Structural Timber Awards
Pioneer Award – Use of Timber in Landmark Projects

American Council of Engineering Companies ACEC
Platinum Award for Engineering Excellence – Studies, Research and Consulting Engineering Services for the Portable Arup Sound Lab

Climate change is a critical and pressing issue. Our work with the C40 Cities Climate Leadership Group will help cities take practical steps to address it.

## STRONG, FAIR-MINDED GOVERNANCE

Our strategy is set by the Group Board, appointed by the firm's Trustees. The Group Board is responsible for Arup's long-term success, financial security, unity, well-being and sustainability.


### GROUP BOARD

Gregory Hodkinson [1]
*Chairman*

Alan Belfield [2]
*Deputy Chairman & COO*

Tristram Carfrae [3]
*Deputy Chairman*

Peter Bailey [4]

Peter Chamley [5]

Fiona Cousins [6]

Jerome Frost [7]

Michael Kwok [8]

Dervilla Mitchell [9]

Matthew Tweedie [10]

Fergal Whyte [11]

Genevieve Shore [12]
*Non-Executive Director*

Tim Stone [13]
*Non-Executive Director*

### OFFICERS OF THE BOARD

Martin Ansley-Young [14]

Karim Klaus Emara [15]

Clare B Marshall [16]

Paul Robinson [17]

**18,360**
Number of fee-earning projects

**44.6%**
Clients with more than one project

If we grow, it is because of our desire to better meet our clients' needs and our continuing ambition to bring about positive change.

### GROWTH

Growth for Arup is not an objective. As a trust-owned firm with no individual shareholders or external investors, we set our own priorities. If we grow, it is a result of better meeting our clients' needs and our continuing ambition to bring about positive change – not as a result of the ever more common financial engineering in our industry.

Our revenue grew to £1.51bn, an increase of 21.7% from 2016 (with approximately 9.5% of the increase attributed to changes in exchange rates). Our operating profit margin, before staff profit-sharing for the year, was 11.6%, a sign of our financial health and stability.

Looking ahead, our forward order book stands at £1.05bn, in line with the position 12 months ago and a strong measure of the trust that our clients continue to place in us. Similarly, we are seeing a trend of more clients working with us on multiple projects. This is a clear indication of a further shift to a relationship-based working model, giving us an opportunity to partner with our clients to help them realise their long-term ambitions.

### THINKING AHEAD

Change in all its forms is a growing feature in all our lives. It is easy to view the scale and speed of it as unsettling and in some respects it is. For a firm like ours, with so many bright, imaginative and energetic people, it presents exciting opportunities we are eager to seize.

We will continue to focus on the needs of our clients and society as a whole, stretch our thinking to stay at the cutting-edge of our industry, collaborate with enthusiasm at every opportunity and concentrate above all on 'quality'.

If we do all this we can achieve a great deal – seizing the opportunities to truly 'shape a better world.'

**GREGORY HODKINSON**
*Chairman*

OUR PEOPLE

# The brightest and the best

One of the main aims of our firm is being a ‘humane organisation’. This reflects our attitudes to everyone who works at Arup and our interactions with the wider world.

OUR PEOPLE
AT WORK

## GRADUATE INDUCTION

All our regions offer a comprehensive induction to graduates. A rich mix of key note speakers and practical challenges including Skills Days ensure that new graduates can build networks and understand Arup's culture and core values.

## COLLABORATING ACROSS BOUNDARIES

Our culture focuses on creating an environment where a diverse mix of talented people can flourish, undertaking work that's both challenging and fulfilling. Providing this 'Membership of Quality' is the bedrock of our firm.

Recruitment is one priority. 1,750 people from more than 60 different nations joined Arup this year. This included 550 entrants into our graduate programme.

Our clients increasingly need us to integrate a wide range of capabilities, so these new colleagues inevitably bring a huge spread of skills to our team. But skills alone aren't enough. We also look for people who share our desire to collaborate at every opportunity. As Sir Ove Arup himself said, to deliver work of quality: "what we must aim at is to make 'we' include as many as possible as often as possible."

**1,750**
New staff members

**550**
Entrants into our graduate programme

"A very good programme for new joiners. It generates team building and acts as a platform to meet and make friends from all disciplines."

Priyanka Tibdewal
Mumbai



## RECOGNITION HIGHLIGHTS

A key measure of the quality and achievements of our people are the awards they have won. Some reflect a lifetime of outstanding work. Others, the promise and enterprise of younger members of our team.

### CAROLINA BARTRAM
**Engineer of the Year Building/Services**
*Women in Construction Awards 2016 (WICE)*

### JOHN COLLINS
**Royal Academy of Engineering (RAEng)**
*RaEng Trust Young Engineer of the Year 2016*

### JAMES DUFF
**Emerging Talent Award**
*Irish Independent Property Industry Excellence Awards*

### MARK FLETCHER
**Leadership Award for Outstanding Contribution to Water Efficiency**
*World Water Leadership Congress Awards 2016*

### JACO KEMP
**Established Green Star of the Year Award, Green Star SA Leadership Awards 2016**
*Green Building Council of South Africa*

### CLARE LAVELLE
**Karen Burt Award**
*Women's Engineering Society*

### DERVILLA MITCHELL
**Daily Telegraph Top 50 Women in Engineering 2016**

### MASAKI TOKUBUCHI
**Structural Award**
*Japan Structural Consultants Association (JSCA)*

### LOUISE ELLIS
### JAMES HOLLOWAY
**Industry category**
*Forbes 30 Under 30 in Europe 2016*

Louise Ellis and James Holloway have been named in Forbes' inaugural 30 under 30 Europe list for Industry. Arup was the only company to have more than one individual recognised.

The list features 300 innovators, entrepreneurs and leaders who are transforming business, technology, finance, media and culture and is selected by a panel of experts in their respective fields.

James, 28, is an engineer in the Scotland Infrastructure Group. He has been helping lead Arup's work on the *Queensferry Crossing* where he oversees design and construction of the bridge's three 200m tall towers. Louise, 26, was selected for her work weatherproofing massive infrastructure works including the New York subway system.

"We are honoured and delighted to be included on the inaugural Forbes list. It's an honour to be alongside so many talented individuals, and we would like to thank our Arup colleagues for their support in the UK and US."

Louise Ellis, James Holloway

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Priyanka Tibd
Mumbai

**JULIE WOOD**
**Honorary Fellowship**
*Association for Project Management (APM), UK*

*Australia's Most Innovative Engineers – Engineers Australia 2016*

**DANYA MULLINS**
**Consulting**
**MARIANNE FOLEY**
**Consulting**
**BEN COOPER-WOOLLEY**
**Consulting**
**KYM BURGEMEISTER**
**Community**
**DANIEL LAMBERT**
**Utilities**
**TIM MOTE**
**ICT**
**MIKE KING**
**Building and Construction**

*ACES Young Consulting Engineer of the Year 2016, Singapore's Association of Consulting Engineers*

**SEBASTIAN LEE**
**Civil**
**JOE LAM**
**Structural**

*Rising Stars in Structural Engineering 2017 Civil and Structural Engineer Magazine, US*

**IBRAHIM ALMUFTI**
**JOHN HAND**
**MURAT MELEK**

200+

Number of awards won by Arup

**SHIGERU HIKONE**
**Gengo Matsui Special Award**
*Japan Structural Designers Club*

Shigeru Hikone, former Leader of our Tokyo office, has received the prestigious Gengo Matsui Special Award from the Japan Structural Designers Club. The award, given to one outstanding structural engineer every year, recognises Shigeru's ongoing leadership and contribution to design, plus his work in collaboration with architects and engineers from various disciplines.

At the ceremony, held on 2 September 2016 at the Tokyo Design Centre in Gotanda, Tokyo, Shigeru shared stories behind some key projects and his passion for structural design, offering a glimpse into our culture of sharing and collaboration.

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# Arup University

## *Investing in our capability*

**308**

Research projects through Arup University

**£3.8m**

Spent globally on our research projects

Beyond a rich mix of talent and a desire to share and collaborate, a third trait of our people is a willingness to constantly improve and push new boundaries. This doesn't happen by itself, it needs to be fed and nurtured. *Arup University* is how we do that.

At its core, Arup University promotes knowledge development and knowledge sharing – ultimately informing the thinking we apply to client work.

### KNOWLEDGE DEVELOPMENT

Knowledge development sees us making significant investments in new research – often in strategic partnerships with academia and industry.

This collaboration creates technical innovation, thought-leadership and diverse applications for new technology that has an impact on both our clients and our firm.

Foresight is invaluable for our clients and we share our tools and research widely.

Our *Drivers for Change* app is a good example of the kind of practical outputs we've developed this year. It features our exclusive research on ten forces shaping the built and natural environments, ranging from climate change to water. Each of these topics can be explored through five lenses (social, technological, economic, environmental, and political) providing the user with a rich source of insights.

### KNOWLEDGE SHARING

Knowledge sharing at Arup takes a number of forms. We offer learning opportunities ranging from online modules on specific technical topics to more immersive academic-led programmes in subjects of strategic importance to the firm. These have included Business Economics, Energy Futures and Transitions and Smart Cities.

Our diverse skills networks enable us to share knowledge and promote new thinking across disciplines and geographies. An ever greater focus on the expanding impact of digital technology has been a notable feature this year.

"Arup University is a very important part of our strategy. We use it to keep our skills at the cutting-edge in learning and development for all our people. What's more, it's a vehicle for our research and foresight activity. We use it to look over the hill to see what might be coming next."

Gregory Hodkinson
Chairman

### DESIGN SCHOOL

*Sydney, Australia*

Masi Latinara, Habitat for Humanity, Fiji, participating in our Sydney Design School

Finally, our annual *Design Schools* provide an opportunity for our people to learn more about our principles of quality and excellence in an engaging way.

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Amongst a host of interesting outcomes was the work undertaken in Sydney which saw us partner with Habitat for Humanity to address this year's theme of Human Centred Design.

Throughout the event, participants were equipped with tools, knowledge and skills which they used to address challenges Habitat for Humanity face in places like Fiji. These include building shelters in rural communities, preparing for cyclones and improving access to clean water.

Challenging, intense and ultimately rewarding, this kind of real-world assignment is a great example of the value our Design Schools continue to have.

**@CYBERTECTURE** · 2016

Discussing the direction of the world – thank you for having me @Arup #arupuniversity topic 'crossing boundaries'.

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Chairman

**@MISSKIMSHERWIN** · 2016

'Why Human Centred Design matters' – challenging thinking at the @arupaustralasia #designschools2016 #arupuniversity

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*Sydney, Australia*

Masi Latinara, Habitat for Humanity, Fiji, participating in our Sydney Design School.

Finally, our annual *Design Schools* provide an opportunity for our people to learn more about our principles of quality and excellence in an engaging way.

This year, programmes were held in Leavenworth (US), Sydney (Australia), Shenzhen and Hong Kong (China), Berlin (Germany) and Manchester and Liverpool (UK).

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"Arup's Design School gave Habitat for Humanity the opportunity to understand the principles and application of Human Centred Design in relation to its home-building programs . We hope to take the solutions which participants identified and apply them into our work of improving shelter in Fiji."

John Lamerton
Head of Partnerships & Organisational Development
Habitat for Humanity

# Making more of a difference

"Humanitarianism implies a social conscience, a wish to do socially useful work, and to join hands with others fighting for the same values."
*– Sir Ove Arup*

**9,300**
Hours volunteered by our staff members

**155**
Major projects undertaken around the world

**£5m**
Global Challenge Fund commitment to larger scale projects over the next five years

## MAKING A MEANINGFUL CONTRIBUTION

This year Arup undertook 155 community engagement projects around the world. These projects have one thing in common: they are driven by our employees' desire to do more with their expertise than just advance their careers or grow our business. They reflect a collective desire to make a meaningful contribution to communities and genuinely 'shape a better world'.

We committed £2.4m to these causes, with our people willingly giving their own time as well, spending more than 9,300 hours working unpaid on a wide variety of community engagement projects. The following four projects are a small selection of the impact our people have made.

In April 2016 a major earthquake hit three regions in Ecuador. We sent a team to undertake urgent structural assessments. Taking direction from the emergency coordination centre, 150 buildings – including 22 schools – were formally assessed in 10 days. Francisco Pavia, Senior Civil Engineer on the Ecuador earthquake response team showed how the skills our people possess can be vital in helping affected communities respond and recover, "We worked with the local responders to help balance the need to demolish unsafe buildings with the need to recover things for the community."

According to the UN Refugee Agency last year the global figure for 'forcibly displaced people' stood at over 65 million. These unprecedented numbers create large housing issues, which our design teams in Europe were eager to address.

Partnering with Netherlands-based design platform 'What Design Can Do', we developed *AGRIshelter* as a practical and sustainable housing solution. The shelter is built from biodegradable, local materials which are durable, provide good insulation and are readily available in and around every city. The whole 35m$^2$ unit can be erected in one day by people with minimum skills and is equally quick to dismantle.

A full-scale prototype was built in Milan in February 2017 with Arup volunteers from European offices working alongside a community of political refugees. Further development of this bold and innovative solution is currently in progress.


**EARTHQUAKE STRUCTURAL ASSESSMENTS**
*Pedernales, Ecuador*

Arup engineers Anna Pavan (right) and Francisco Pavia (centre), discussing post-earthquake building assessments.

# Making more of a difference

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This year Arup undertook 155 community engagement projects around the world. These projects have one thing in common: they are driven by our employees' desire to do more with their expertise than just advance their careers or grow our business. They reflect a collective desire to make a

"We worked with the local responders to help balance the need to demolish unsafe buildings with the need to recover things for the community."

According to the UN Refugee Agency last year the global figure for 'forcibly

## JACKET DONATION

*Butuo, Greater China*

Staff members in Hong Kong and mainland China offices joined a donation drive to provide jackets for the underprivileged children in Butuo, Sichuan province. The temperature there can drop to -20°C in winter.




20+20 Mentorship Programme

"My mentor shared many engineering ideas which inspired me a lot. Now I have a clearer idea of what I want to be in the future."

Leung Hei-Tung
Arup 20+20 Mentee

## HONG KONG 20+20 MENTORSHIP PROGRAMME

*Hong Kong, Greater China*

In Hong Kong, where this year we celebrated our 40th anniversary, our staff members raised the bar with the charity work and fundraising they carried out, from coastal cleanups to hikes, and blood donation to rice sales. Throughout the year, they demonstrated how a culture of community engagement is fundamental and driven from the grassroots. Among the highlights was their work with young students on the *20+20 Mentorship Programme*.

For a year, 20 Arup staff members were mentors to 20 underprivileged secondary school students, giving advice and guidance on their education and careers. Outstanding students received scholarships from Arup to continue onto higher education.

## SUPPORTING OUR COMMUNITIES

We tend to operate on an intimate and local scale where our input can make a big difference to individual lives.

At the *LauraLynn Children's Hospice* in Ireland, our engineers built a specially designed extension in response to a fundamental patient need. This extension will allow parents to sleep alongside their children when they stay at the Hospice – providing comfort at a time when it's needed most.

In Australia, a long-term strategic partnership with Smith Family is enabling our teams to support the most disadvantaged communities with a wide range of initiatives.

The charity helps disadvantaged young Australians to make the most of their education.

Finally, across the world more than ten Arup offices have been contributing to a major mapping initiative that aims to increase vital access to some of the remotest regions. Prompted by the likes of Medicines Sans Frontier (MSF), staff across Arup worked on the *Missing Maps* initiative. When complete, this resource will allow charities like MSF to improve the way they deliver programmes like malaria eradication schemes in communities that until now were literally 'off the map'.

Missing Maps

### MISSING MAPS

Arup volunteers digitally trace satellite imagery, setting down the first layer of map data such as roads, rivers and buildings. This is then used to create usable maps for some of the world's most vulnerable regions.

"Arup talk about resilience in cities, about physical infrastructure and space and the importance of that in people's lives. So providing information about that space as part of Missing Maps makes sense to people at Arup."

Claire Fram
Geographic Information System specialist



OUR PEOPLE

# Meeting our own targets

Another area where our people make a critical contribution is our own environmental performance.

To manage this we have a set of 15 key performance indicators (KPIs) covering factors like energy use, transport and use of materials and resources.

This year we have achieved a 5% annual reduction in carbon emissions per employee, improving on the previous two years. A programme of staff awareness has been critical to this success. So is the concerted effort we've made to ensure that our own offices are a model of best-practice.

Many of our offices are in BREEAM or LEED-rated buildings, but we aspire to do even better. Our new office in Boston, Massachusetts is a case in point. It is the first building in New England (and the first of our global offices) to receive a WELL Certified Gold award and aims to foster a sustainable healthy environment where employees can thrive.

"Arup's WELL Certified Gold award demonstrates outstanding 'healthy building' leadership. IWBI's mission is to bring human health and wellness to the forefront of building practices globally, and it is leaders in the [illegible] that are [illegible]ovement."


### TIME TO READ

*Dublin and Cork, Ireland*

The Business in the Community *Time to Read* programme sees volunteers from Arup working with children from disadvantaged backgrounds to improve their confidence and foster a love of reading.

Drawings by Calum from 2nd Class in Sundays Well Boys' National School, Cork.

## SUPPORTING OUR COMMUNITIES

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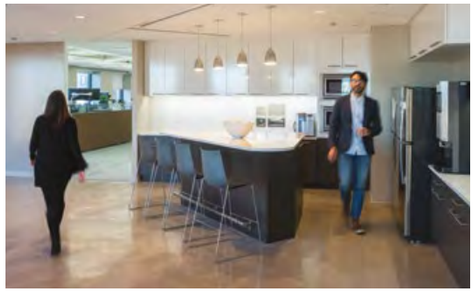


"Arup's WELL Certified Gold award demonstrates outstanding 'healthy building' leadership. IWBI's mission is to bring human health and wellness to the forefront of building practices globally, and it is leaders in the building industry like Arup that are helping to advance this movement."

Rick Fedrizzi
Chairman and CEO, IWBI

**5%**

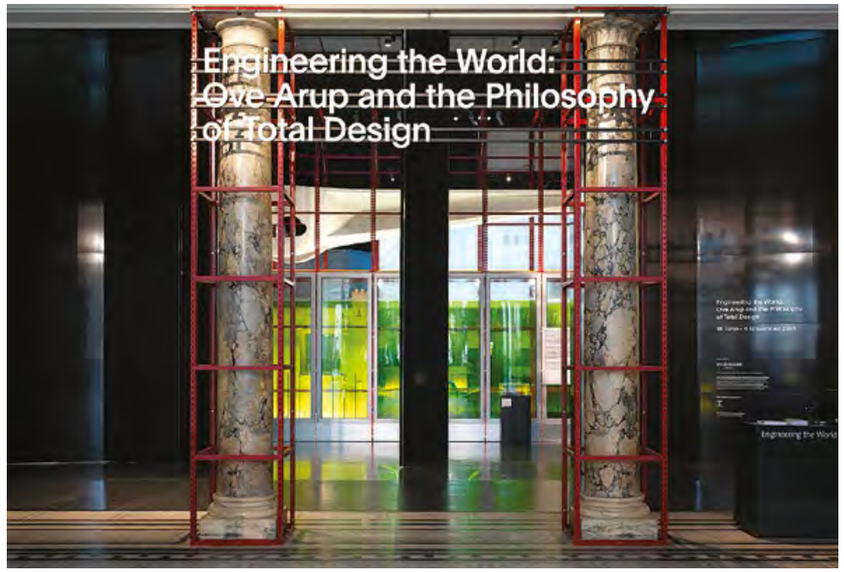
Carbon emissions reduction per employee from previous year

**25%**

Increase of sustainability training per employee

**99.8%**

Staff in offices certified to ISO 14001 Environmental Management System




V&A

# Celebrating Arup's history

## *Engineering the World: Ove Arup and the Philosophy of Total Design*

2016's exhibition at London's Victoria & Albert Museum (V&A) showcased our founder's outstanding work and the enduring strength of his design philosophy.

*Engineering the World: Ove Arup and the Philosophy of Total Design* opened in June 2016 at the V&A, London.

It was described by the V&A as "painting a picture of the man whose ideas led to the creation of one of the most innovative and influential engineering consultancies working today."

Part of the V&A's Engineering Season, the exhibition mixed archival materials with immersive digital displays to bring a lifetime of creativity and engineering excellence to life.

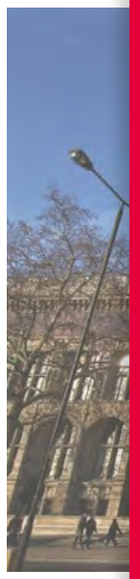
Key features included our work on groundbreaking projects like the *Sydney Opera House* and collaborations with leading architects like Berthold Lubetkin, Renzo Piano, Richard Rogers and Norman Foster.

The exhibition also featured some of Arup's current work including major infrastructure projects like *Crossrail* and innovative technology like *SolarLeaf*, an experimental bio-reactive façade system.

We were delighted that 75,000 people visited the exhibition. They gained a clear insight into Ove Arup's progressive approach and a wider understanding of the role engineering and design plays in driving human progress.

**ENGINEERING THE WORLD**
*London, UK*

The V&A Museum and the exhibition entrance showing the *SolarLeaf* panels in the background.





"Arup's legacy lives on, through his ongoing, world famous engineering firm. Displays take the visitor through early works, such as the London Zoo's Penguin Pool. Exhibits also touch upon key later projects such as the Centre Pompidou in Paris and the Menil Collection. Contemporary and ongoing work by the office offers a fitting ending to the show, hinting towards the future; façades using algae? You name it – Arup is probably working on it."

Ellie Stathaki
Architecture Editor, Wallpaper Magazine

"Ove Arup was the greatest engineer of the 20th century. Unconventional and playful in his approach, his collaborative working style revolutionised building design during his lifetime and influenced how buildings are made today."

Maria Nicanor and Zofia Trafas White
Co-curators of the exhibition, V&A


A sketch by Ove Arup capturing the essence of an engineer


Exhibition overview

Ove Arup (centre) with colleagues Michael Lewis and Jack Zunz on the site of the Sydney Opera House, 1964

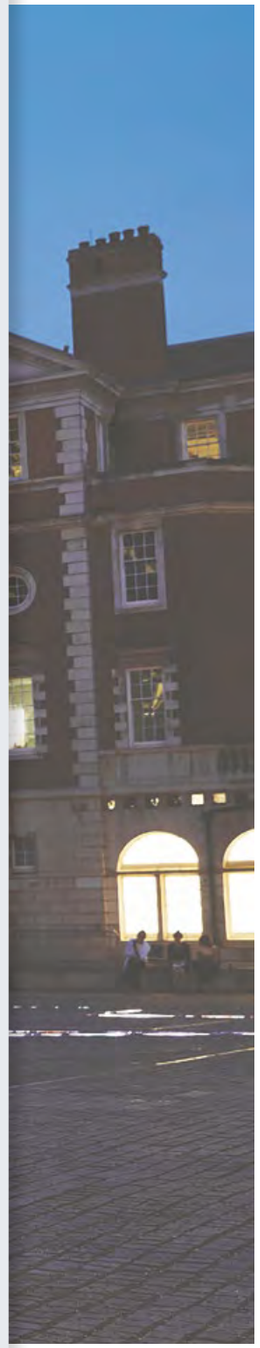
Model of the *Sydney Opera House*

*Centre Pompidou* in Paris with all of the building's services on its exterior

*The Penguin Pool* at London Zoo completed by Ove Arup in 1934

# Finding a better way

Our work around the world is shaped by the belief in doing everything ‘as well as it can be done’. As ideas and technology evolve, that means constantly finding new and better ways to address many of the big issues of our age.

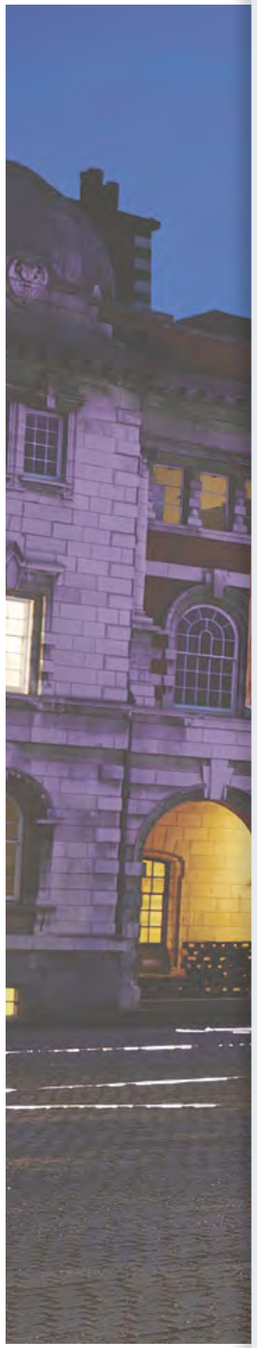


**THE SMILE**

*London, UK*

*The Smile* aims to transform the way architects and engineers approach timber construction. Built from 12 of the largest panels of hardwood, cross-laminated timber ever made, the project is the culmination of 15 years of research between Arup and the American Hardwood Export Council.

Designed in collaboration with architect Alison Brooks, The Smile is not just an experimental structure. Turned on end, it resembles the stabilising core of a five-storey building and sets new benchmarks in terms of its slender form. More importantly, it shows that American tulipwood, an abundant, lightweight and strong hardwood, has great potential as a structural material.



▲

**THE SMILE**

*London, UK*

*The Smile* aims to transform the way architects and engineers approach timber construction. Built from 12 of the largest



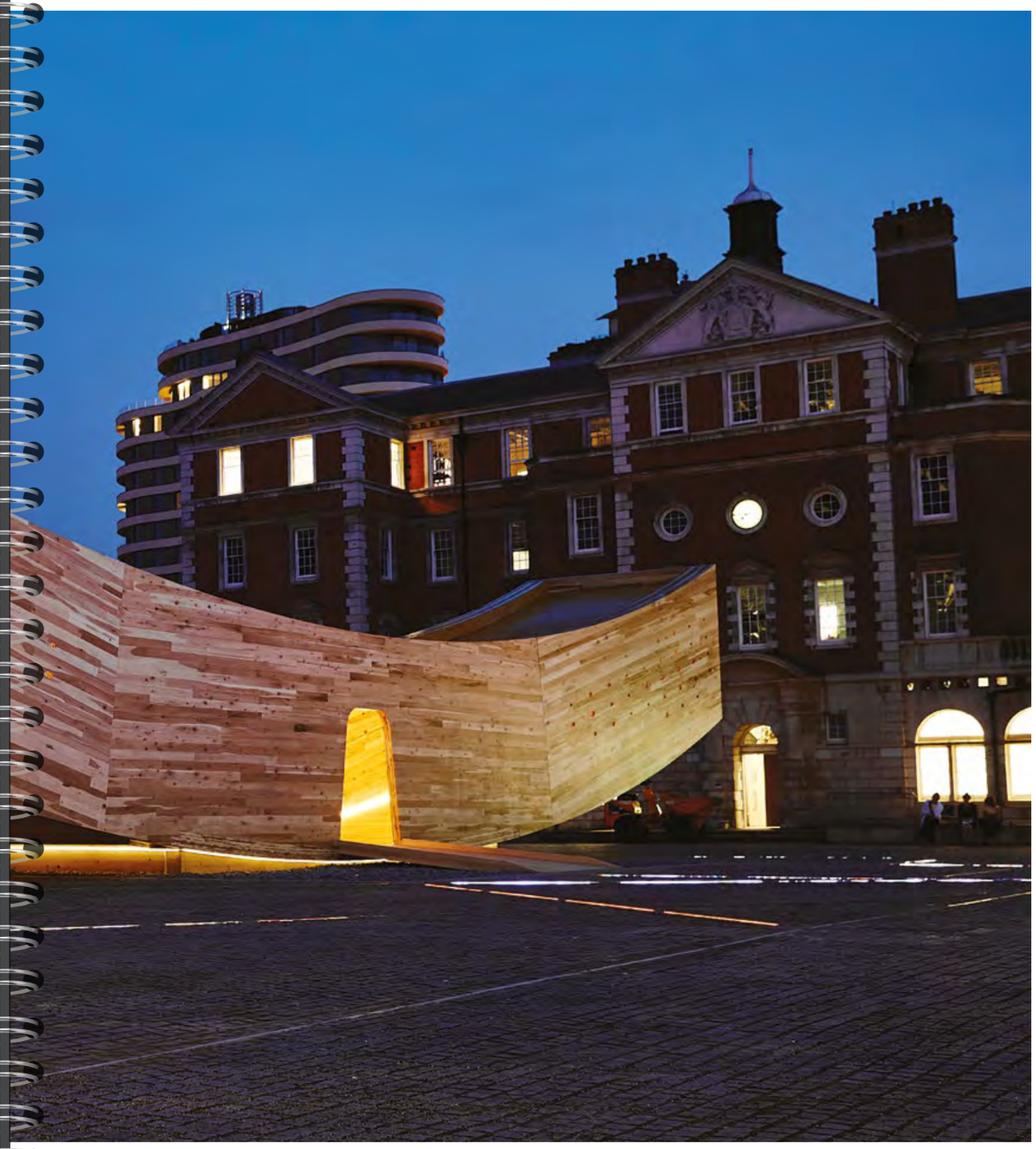
"We have made a commitment to integrate the UN's Sustainable Development Goals across our firm."

Gregory Hodkinson
Chairman

## LEADING THINKING ON CRITICAL RESOURCES

Arup is a firm based on strong values and a clear ethos. When these were set out by Ove Arup in the early 1970s, sustainability wasn't yet part of common vocabulary. Almost 50 years on, it's clear his ideas about 'a humane organisation', 'straight and honourable dealings' and 'social usefulness' align with current priorities, including the principles set out in the UN's Sustainable Development Goals.

We are using these Goals as a framework against which to set project aspirations and targets for the most important aspects of social, economic and environmental sustainability. In particular, we have seen them as a focus for innovation and new thinking, and a bridge to driving progress across all areas of the built environment.

### DEADLINE 2020

Practical and results driven, the report includes a comprehensive roadmap setting out specific steps a city can take. These all align with the overall aim of reducing annual $CO_2$ output per city resident from 5.0 tonnes now to 2.9 in 2030.

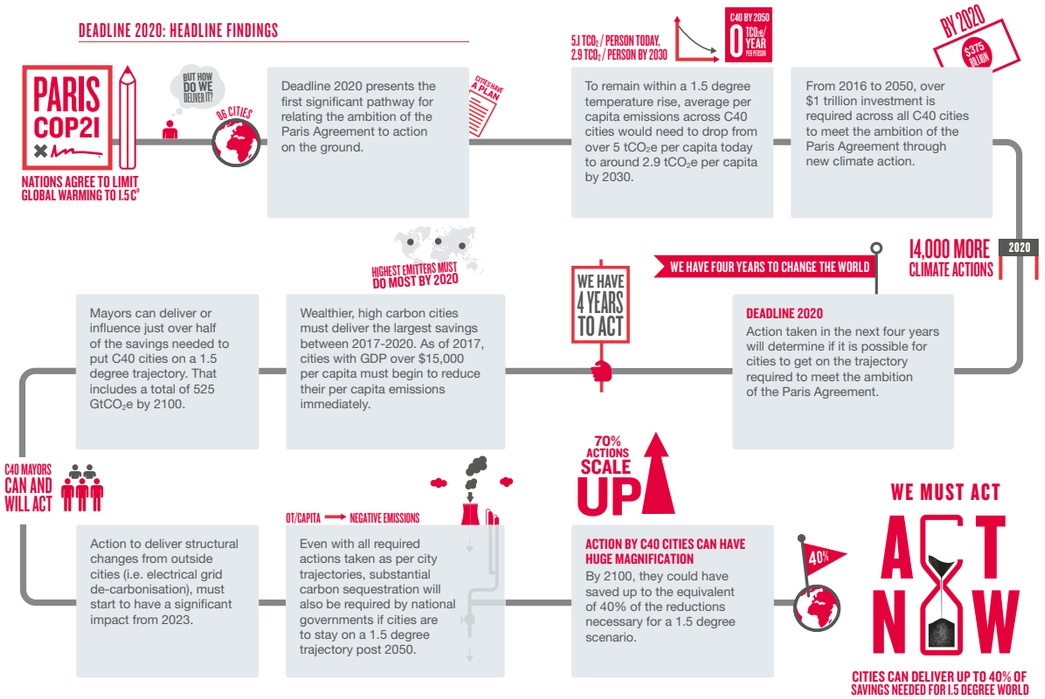
The graphic below summarises content from the full report, *Deadline 2020: How cities will get the job done,* available on arup.com.

## CREATING MORE SUSTAINABLE AND RESILIENT CITIES

With two thirds of the world's population expected to live in urban areas by 2050, innovative thinking in cities will be critical if the sustainability goals set out by the UN are to be met. Our work this year with the C40 Cities Climate Leadership Group is a significant contribution towards turning this thinking into meaningful actions.

Match funding the C40's £1million investment, Arup has developed *Deadline 2020*. This is a detailed report setting out the steps cities need to take to limit average global temperature rises to 1.5 degrees as agreed at last year's COP21 Summit in Paris.

Arup and C40 are united in our view that the next four years are critical if we want to halt the growth of emissions. Cities need to be bold and make decisions now, but they cannot do it alone. Taking action will require approximately $375 billion in investment by national governments and the private sector over the next four years. If we do that we have the opportunity to deliver a new era of climate-ready cities that are efficient, resilient and liveable.




### MINI LIVING

*Milan, Italy*

MINI Living is a prototype housing concept first showcased at the Salone del Mobile in Milan.

Another aspect of sustainable cities is a focus on new forms of housing. Providing affordable and attractive places to live is a key challenge for cities around the world. Ensuring that they also align with the energy and sustainability targets set by bodies like the UN makes this challenge even greater.

Our work on *MINI Living* – a collaboration with Japanese architects ON and carmaker MINI – explored ideas around the development of micro-neighbourhoods, where each apartment is comprised of a mix of private and shared space. Combining a bold vision with careful design consideration, it's a good example of the kind of thinking cities around the world urgently need.

In a similar vein, the *Berlinovo* project has seen us exploring a new concept for micro-apartments to meet the need for affordable student accommodation in the German capital.

The first development at Storkower Straße, will be made up of 129 apartments each optimising 16m² of space.

Air quality is a further challenge for global cities. Our report, *Cities Alive: Green Building Envelopes* looks at ways of addressing this major issue. Specifically the impact on local air quality of elements like living walls, green roofs, roof gardens and vertical farming. Collectively described as 'green envelopes' the report concluded that these elements can improve air quality by up to 20%. Combined with added benefits like temperature control and soundproofing, the report made a strong case for the meaningful role green spaces can make to a better urban landscape.

## HAUT

*Amsterdam, The Netherlands*

Due to its large $CO_2$ storage capacity, building in wood is one of the most talked about innovations in sustainable construction. The use of wood in HAUT is helping in the Municipality of Amsterdam's quest for $CO_2$ neutrality.

## MAKING A MATERIAL DIFFERENCE

Materials is another area where we have applied innovation to deliver tangible progress against the UN's Sustainable Development Goals.

Timber is perhaps the world's oldest building material. Produced and used in the right way, it's also sustainable and adaptable. Three projects this year have explored how it can be used in new and better ways.

In London, Arup collaborated with architect Alison Brooks to create *The Smile*, a gravity defying 34m-long wooden arc. Showcased at the London Design Festival, it's designed to demonstrate the structural possibilities that come from using cross-laminated hardwood.

In Amsterdam we have taken the use of timber up a level. The 73m high, 21-storey *HAUT* will include 55 apartments and will be the tallest timber structure in the Netherlands. It carefully balances robust fire safety standards with clear sustainability benefits, including the embedded storage of more than three million kilograms of $CO_2$.

On the other side of the world, we have teamed up with the Australian Government, the University of Queensland, Lendlease and Hyne Timber to form the *Centre for Future Timber Structures*. This centre will research ways to use timber to meet the challenges of safe and sustainable high-rise construction.

## THE MOST ADVANCED REUSABLE BUILDING YET

*London, UK*

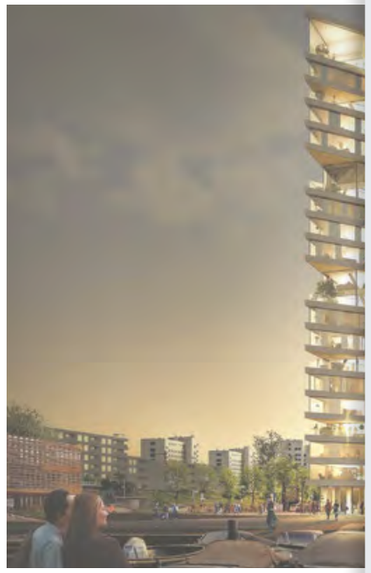
Whilst timber can be a sound and sustainable material, a building that's built around a zero waste ethos goes even further. *The Circular Building* seeks to showcase how this can work in practice. Developed in conjunction with Frener & Reifer, BAM Construction and The Built Environment Trust, the design of this prototype building is fully aligned to circular economy principles developed through our work with the Ellen MacArthur Foundation. In practice, this means that all components are tagged and logged on a 'Materials Database', allowing them to later be removed and reused, not wasted in landfill.

Application of a different type of technology led to us creating *Pedesta*, a new glass-fibre reinforced polymer modular bridge developed with construction expert Mabey.

The bridge is modular, made up of 1m sections that can be bolted together to form a complete bridge. This means the bridge can be delivered to sites where heavy equipment can't reach. Its construction means it is 70% lighter than steel, with up to 30 modules able to be connected in series.

Associate, Rebecca Stewart says, "We are focused on engineering solutions to make bridges more resilient and simpler to construct. This modular bridge is quick and easy to install, minimises disruption to the surrounding communities and significantly reduces ongoing maintenance costs. We can see this bridge being used in many ways – from rail footbridges to road and river spans."

The development of Pedesta was part funded by *Arup Ventures*, which provides support to employees developing products, exploring new business models and taking innovative solutions to market.



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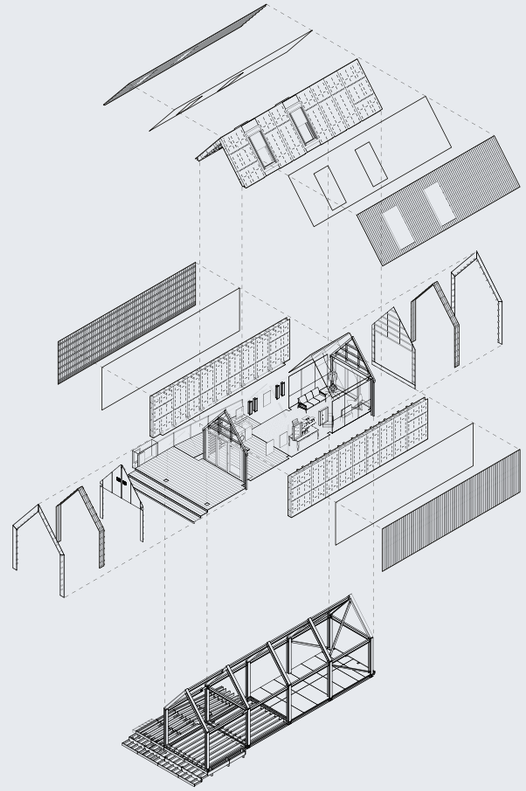
"The Circular Building shows that through collaboration and digital technology, we can design buildings where the materials can be re-used. As an industry, we should aim to eliminate waste and design for re-use."

Stuart Smith
Director




▲ **FOOTFALL**

Arup's Footfall app was launched in 2016. It can be used for preliminary on-site vibration testing in buildings, floors, stairs and footbridges.

▶ **PEDESTA**

A new, glass-fibre reinforced, polymer modular bridge. Each module is 1m long and can be bolted together to form a complete bridge.

## WORKING IN NEW WAYS

Meeting the kinds of ambitious goals set out in the UN's Sustainable Development Goals means working in new ways too.

A great example of this is our US team's answer to the problem of easily measuring vibrations.

Accurate measurement typically requires highly calibrated (and very expensive) equipment, but from time to time it is useful to take a quick vibration reading before embarking on a full investigation.

Recognising that most smartphones now include serviceable accelerometers – a type of sensor used to measure vibration – Arup developed *Footfall*, an app that can take measurements when the phone is placed on a vibrating surface.

The app is intended to be a handy tool for preliminary vibration measurements – helping everyone understand potential problems quickly and easily. Free to download from Apple's AppStore, it also includes background information explaining the basics of vibration measurement to help non-engineers interpret what they're seeing.

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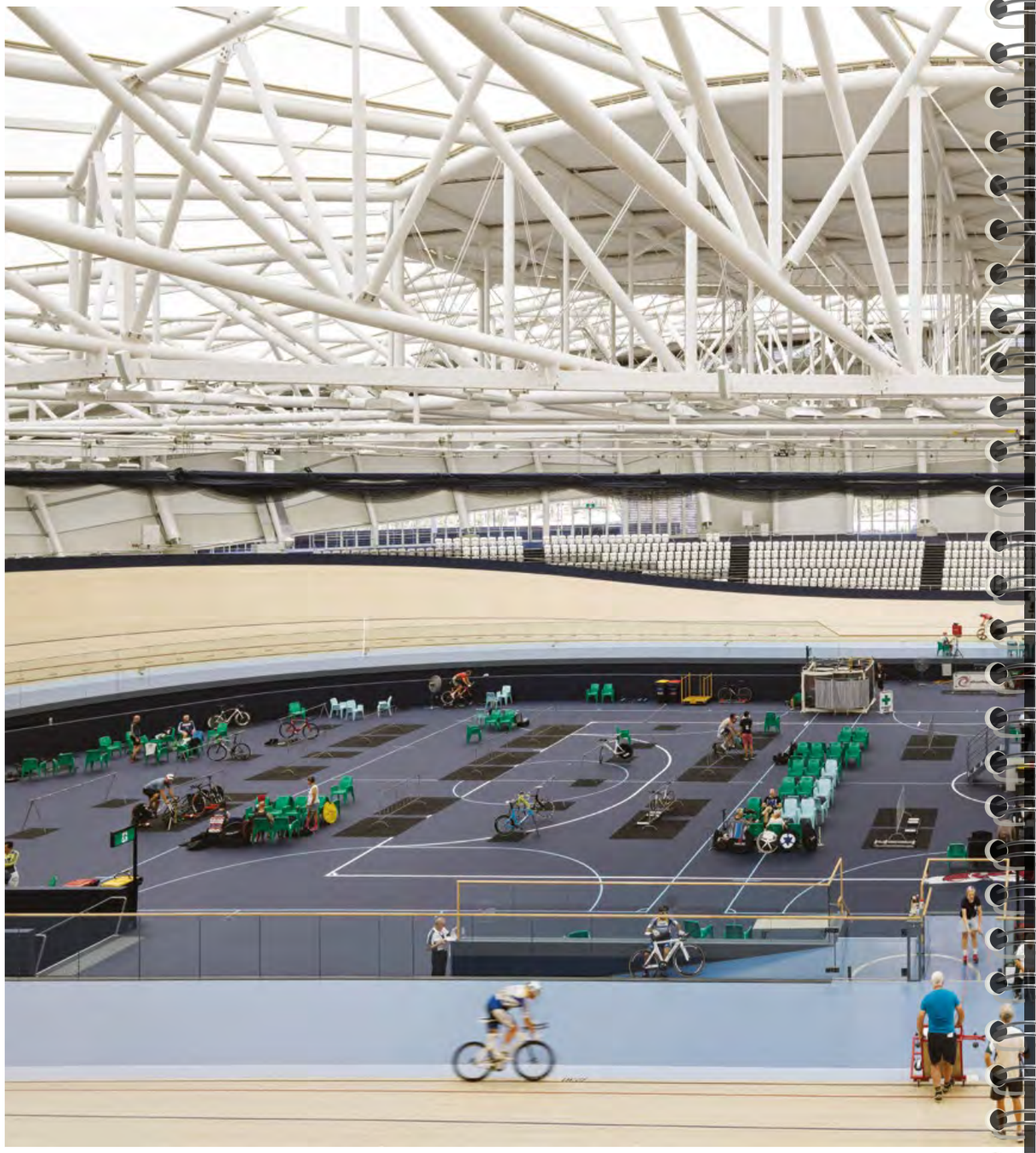
# Shaping a better world

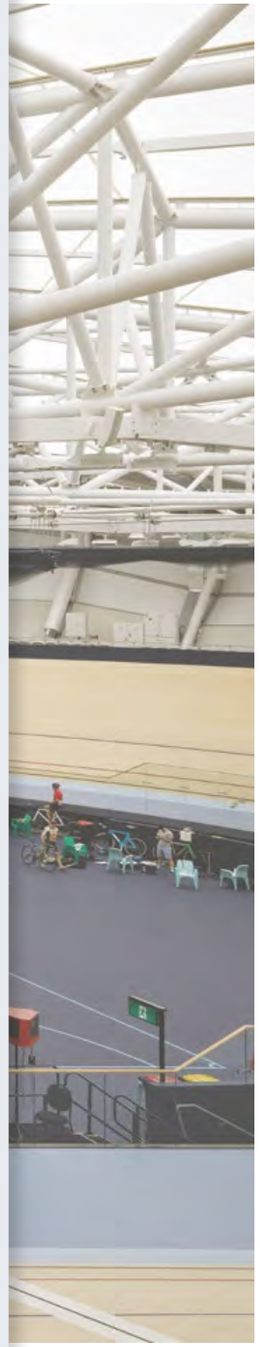
Arup operates as one firm. That means much more to us than a network of offices. It means a shared and defining philosophy that underlies everything we do.

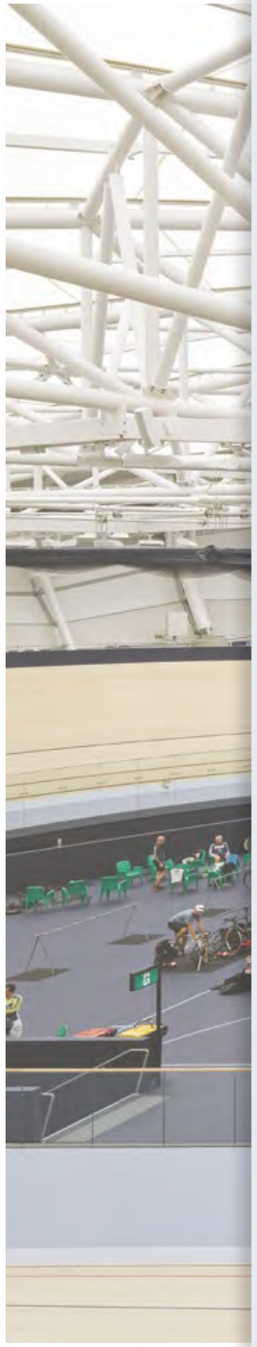
From Sydney to San Francisco, Berlin to Beijing, our work this year has seen us develop innovative ways to drive progress and meet human needs. The benefits from both are clear, as is the direct alignment with the core principles Sir Ove Arup set for our firm.



**ANNA MEARES VELODROME**
*Brisbane, Australia*

Built to provide cycling fans the best possible view of the action, the *Anna Meares Velodrome* is based around a column-free design featuring a 118m-span parabolic roof.





## OFFICE LOCATIONS

**AUSTRALIA**
Adelaide
Brisbane
Cairns
Canberra
Melbourne
Perth
Sydney
Townsville

**BRUNEI**
Bandar Seri Begawan

**CAMBODIA**
Phnom Penh

**CANADA**
Montreal
Toronto

**COLOMBIA**
Bogota

**DENMARK**
Copenhagen

**GERMANY**
Berlin
Düsseldorf
Frankfurt

**GREATER CHINA**
Beijing
Chongqing
Guangzhou
Hong Kong
Macau
Shanghai
Shenzhen
Taipei
Wuhan

**INDIA**
Hyderabad
Mumbai

**INDONESIA**
Jakarta

**IRELAND**
Cork
Dublin
Galway
Limerick

**ITALY**
Milan

**JAPAN**
Tokyo

**MALAYSIA**
Kota Kinabalu
Kuala Lumpur
Penang

**MAURITIUS**
Bagatelle

**NETHERLANDS**
Amsterdam

**NEW ZEALAND**
Auckland

**NIGERIA**
Abuja
Lagos

**PHILIPPINES**
Manila

**POLAND**
Krakow
Warsaw

**QATAR**
Doha

**RUSSIA**
Moscow

**SERBIA**
Belgrade

**SINGAPORE**
Singapore

**SOUTH AFRICA**
Cape Town
Durban
Johannesburg

**SOUTH KOREA**
Seoul

**SPAIN**
Madrid

**THAILAND**
Bangkok

**TURKEY**
Ankara
Istanbul

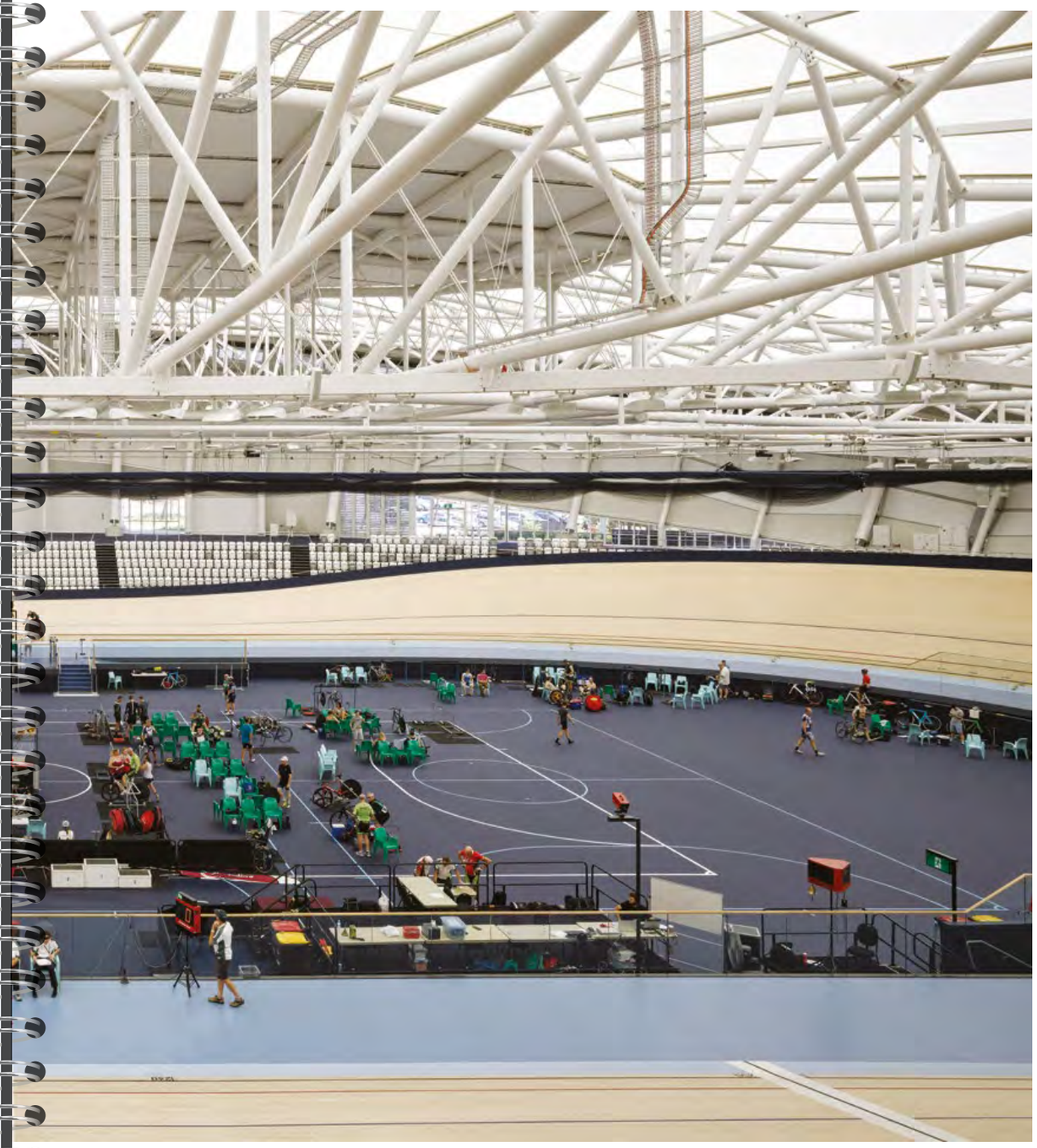
**UNITED ARAB EMIRATES**
Abu Dhabi
Dubai

**UNITED KINGDOM**
Belfast
Bristol
Cardiff
Edinburgh
Glasgow
Leeds
Liverpool
London
Manchester
Newcastle
Nottingham
Sheffield
Solihull
Winchester

**UNITED STATES**
Boston
Chicago
Houston
Los Angeles
New Jersey
New York
San Francisco
Seattle
Washington DC

**VIETNAM**
Ho Chi Minh City

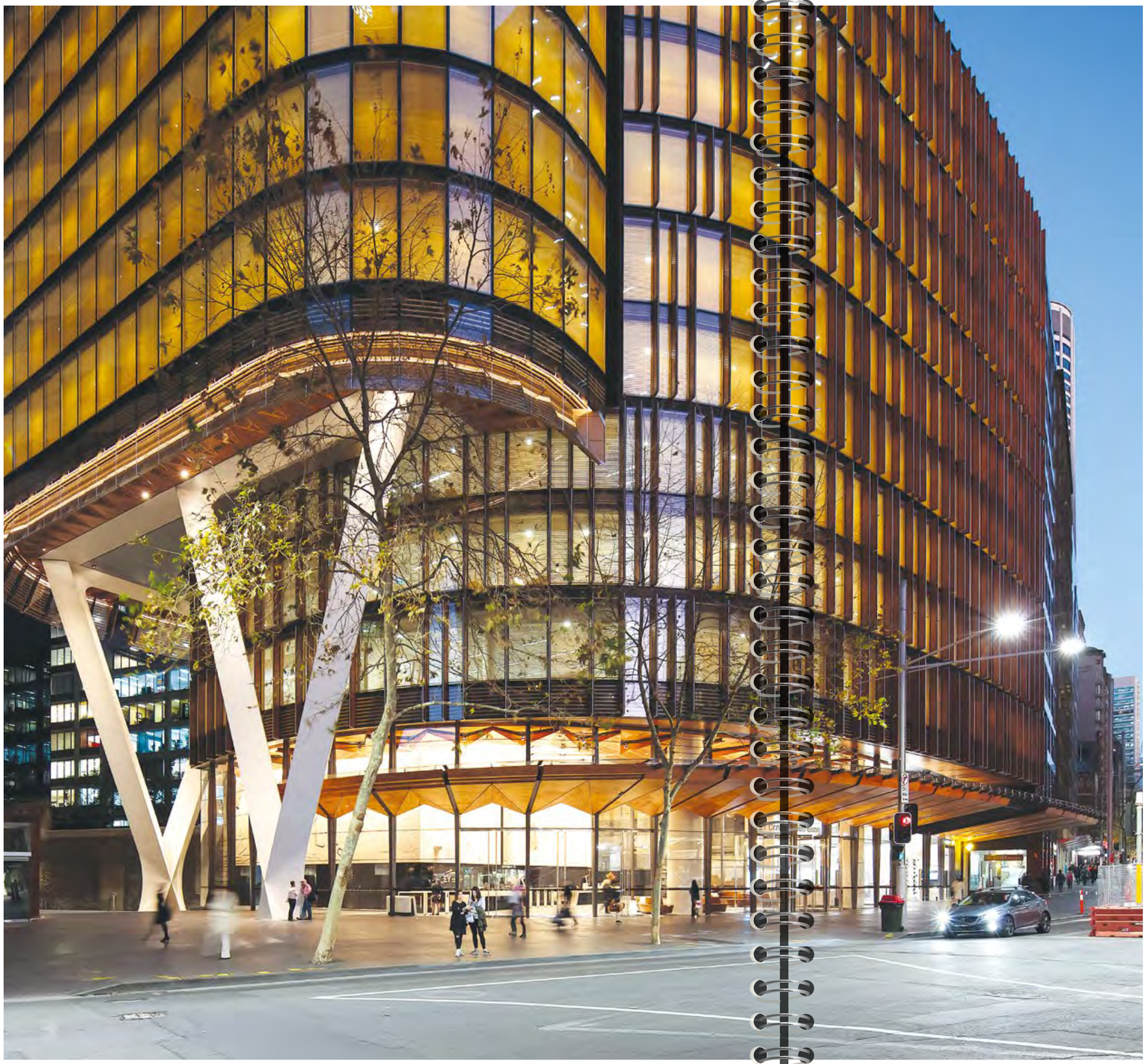
**ZIMBABWE**
Harare



**ANNA MEARES VELODROME**
*Brisbane, Australia*

**118m**
Span of parabolic roof

**4,000**
Number of people the velodrome can expand to accommodate



Our work in Australia and South East Asia continues to have people at its heart. From world-class sports stadia where ‘fans come first’, to urban developments and transport networks carefully planned to optimise quality of life, the needs of individuals have constantly been front-of-mind.

**200 GEORGE STREET**

*Sydney, Australia*

The gold, timber façade of *200 George Street*, also known as the *EY Centre*, is much more than a design feature. It’s a core part of a comprehensive sustainability strategy that has helped achieve award-winning energy and environmental performance.

### HARNESSING NEW TECHNOLOGY

The latest landmark on the Sydney skyline is remarkable, not only for its unique golden wood façade, but also because it's one of the first 'smart' buildings in Australia – setting a benchmark for sustainable performance.

*200 George Street,* also known as the *EY Centre*, utilises a network of digital sensors that respond to occupancy and environmental conditions. These sensors control automated timber shading-blinds applied across the building's closed-cavity façade. Combined with high levels of air tightness, these features significantly reduce costs for heating and cooling. They also ensure optimum working conditions. A further innovation is a smart tenancy app developed by the client, Mirvac. This allows the building's managers to access live data from the sensor network regarding ongoing operational and sustainability performance.

These measures, alongside full LED lighting (a first in Australia), grey water recycling, the latest in energy and water efficient fixtures and space for 300 bicycles have all contributed to the building's exemplary environmental credentials. These have been acknowledged through a six-star Green Star design rating from the Green Building Council of Australia, a WELL Certified Gold award and a five and four star NABERS rating for energy and water respectively.

Use of new technology played an equally important role in a very different project – this time in Victoria.

As lead consultant on the *Hoddle Street Initiative*, Arup was eager to maximise the use of advanced technology to improve one of Melbourne's key arterial routes – balancing the competing needs of pedestrians, cyclists, buses, trams, freight and private vehicles.

We proposed groundbreaking smart technology features, such as real-time public transport priority and enhanced customer information which were then combined with innovative intersection designs to optimise efficiency and minimise delays along what is one of the busiest transport corridors in Australia. Innovations of this kind will increase public transport priority, improve walking and cycling conditions, and create safer, more reliable journeys for private and commercial vehicles alike.

### IMPROVING EXPERIENCES

Listening and responding to our clients' needs is second nature to Arup and across the firm we are aware that the views of end-users are just as important. The new multi-purpose *Optus Stadium* in Western Australia is a case in point.

Using information gathered by the State project team from sports fan user groups, we've helped create a 'fans first' design that delivers an exceptional atmosphere and experience – whether supporters are watching cricket, Australian football, rugby, soccer, or concerts.

Key 'fans first' features include the largest digital scoreboards in the southern hemisphere, a lightweight fabric roof that responds to Perth's climatic conditions for increased comfort and future-proof stadium technology that delivers full 4G and Wi-Fi coverage across the stadium and the surrounding sports precinct. A distinctive added touch is provided by the bronze façade and fabric roof. These reflect LED lighting in the home team's colours at night – creating an even stronger sense of place for every fan.

Keeping with the sporting theme, our work on the new *Anna Meares Velodrome* was also shaped by spectator needs.

No sports fan wants their view obstructed, so designs for the velodrome were column free. Making this a practical reality involved the design and construction of a 118m-span parabolic roof.

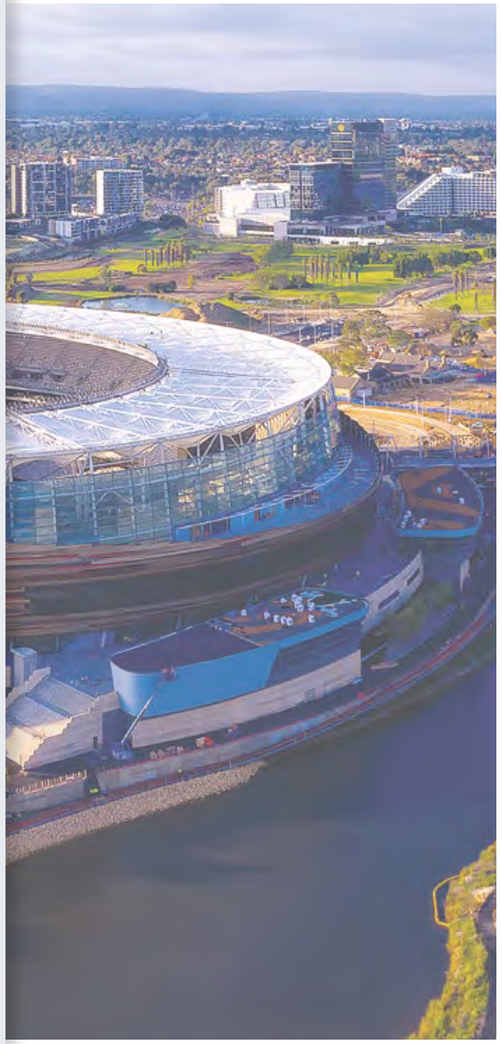
With no columns to support it, this roof needed to be extremely efficient and lightweight. We achieved this by applying advanced digital design techniques, creating a roof with a steel weight of just 50kg/m$^2$. Both elegant and functional, it's a critical feature of a world-class facility optimised for cycling fans and worthy of events like the Commonwealth Games.

"People will be blown away when they go there. People use words like 'awesome' and 'world-class' and this will live up to that."

Ron Alexander
Co-chair, Optus Stadium Steering Committee

## 60,000+

The new world-class venue will accommodate 60,000 sports fans, with the option to increase to 70,000 if required. It can be readily reconfigured to accommodate athletics, allowing it to stage major international events like the Commonwealth Games.



**OPTUS STADIUM**
*Perth, Australia*

When the stadium opens in 2018, three sports teams will play their home games there: Perth's two Australian Football League (AFL) teams, Fremantle Football Club and the West Coast Eagles, and Perth's Twenty20 cricket team, the Perth Scorchers.

## HARNESSING NEW TECHNOLOGY

The latest landmark on the Sydney skyline is remarkable, not only for its unique golden wood façade, but also because it's one of the first 'smart' buildings in Australia – setting a benchmark for sustainable performance.

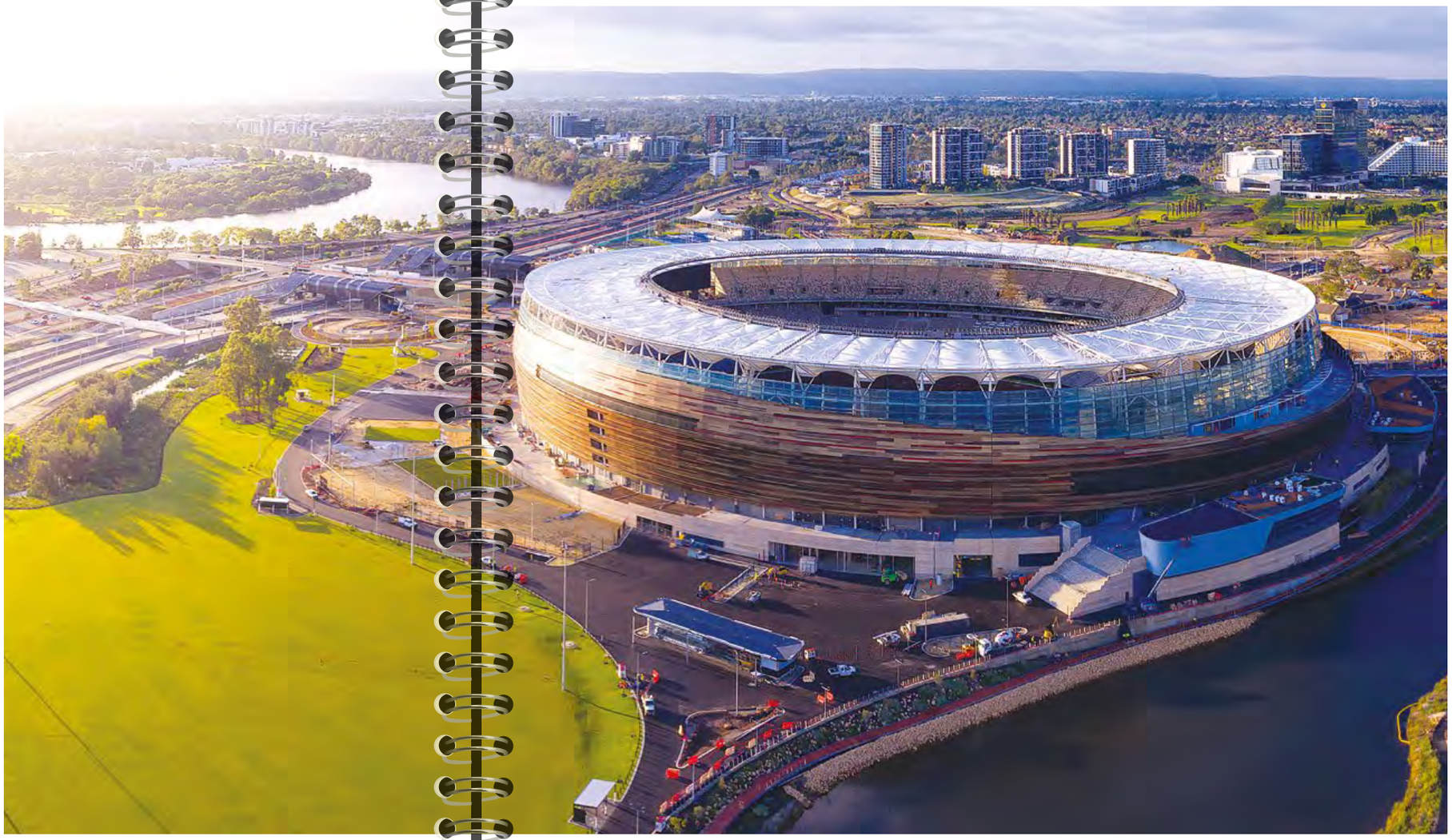
*200 George Street,* also known as the *EY Cen* utilises a network of digital sensors that resp to occupancy and environmental conditions. These sensors control automated timber shadi blinds applied across the building's closed-ca façade. Combined with high levels of air tightn these features significantly reduce costs for hea and cooling. They also ensure optimum work conditions. A further innovation is a smart tenancy app developed by the client, Mirvac. This allows the building's managers to access data from the sensor network regarding ongo operational and sustainability performance.

These measures, alongside full LED lighting (a first in Australia), grey water recycling, th latest in energy and water efficient fixtures a space for 300 bicycles have all contributed t building's exemplary environmental credent These have been acknowledged through a si star Green Star design rating from the Green Building Council of Australia, a WELL Cert Gold award and a five and four star NABER rating for energy and water respectively.

Use of new technology played an equally important role in a very different project – this time in Victoria.

As lead consultant on the *Hoddle Street Initiative*, Arup was eager to maximise the use of advanced technology to improve one Melbourne's key arterial routes – balancing t competing needs of pedestrians, cyclists, bus trams, freight and private vehicles.

We proposed groundbreaking smart technol features, such as real-time public transport priority and enhanced customer information which were then combined with innovative intersection designs to optimise efficiency a minimise delays along what is one of the bus transport corridors in Australia. Innovations this kind will increase public transport priori improve walking and cycling conditions, an create safer, more reliable journeys for priva and commercial vehicles alike.



x9

Engineered to be as inclusive as possible for all fans, the stadium has wheelchair positions on all levels and nine times more permanent ACROD (Australian Council for Rehabilitation of Disabled) parking bays than required by the National Construction Code

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Another example of our focus on the user was demonstrated through our multi-disciplinary design work on a very different project at *South Beach* in Singapore.

Combining state-of-the-art offices with a wave-inspired roof, sunken courtyards and tropical planting, this ‘city in a garden’ creates an inspiring natural haven within a busy metropolis, and a benchmark for a more human, sustainable approach to large-scale commercial development.

Built on a former army camp, this new commercial development had to preserve and integrate four buildings of historical interest. Sweeping above them is a new lightweight canopy that filters sunlight and solar glare and channels breezes through public areas.

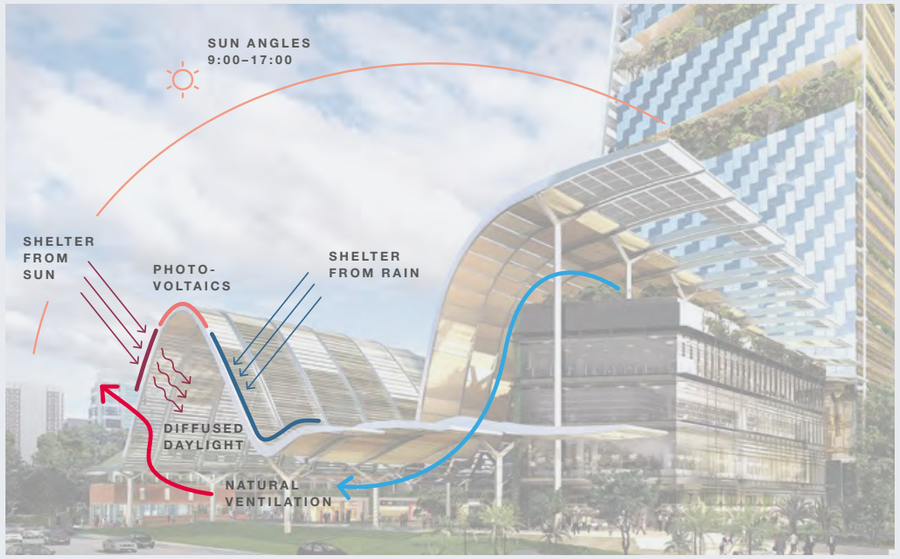
The striking canopy delivers other benefits too. Providing shade and collecting rainwater, it’s part of a comprehensive sustainability strategy

## REALISING A CITY’S FULL POTENTIAL

When Walter Burley Griffin and his wife, Marion Mahony Griffin, originally designed Australia’s capital Canberra, an effective light rail system was a core part of their plans. Sadly that part of their plan never materialised.

Over 100 years later and the impacts of this are still being felt. Car use in Australia’s capital is the highest in the country whilst use of public transport is the second lowest. This imbalance creates congestion and inefficiency. It’s also unsustainable.

Our goal as lead consultant on the *Canberra Light Rail* project was to bring the Griffins’ original light rail vision to life in a form fit for a twenty-first century city. Coordinating over 20 separate technical disciplines, we have taken the ambitious scheme from feasibility and scoping through to enhanced definition design, procurement and construction tendering.




**SOUTH BEACH**
*Singapore*
The striking canopy provides shade and collects rainwater as part of a sustainability strategy that will result in yearly savings of 14,913MW of electricity and 173,000m³ of water.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**CANBERRA LIGHT RAIL**
*Canberra, Australia*

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Staying in Singapore, our reputation for integrating heritage with nature saw Arup as part of the winning team appointed to develop a masterplan for *Jurong Lake District*. This high-density, mixed-use precinct is built around a high-speed rail terminus and blends new waterways and green spaces with businesses and residential developments. It's another great example of putting people's needs at the heart of urban design.

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Phase one of the scheme is now in construction with the 12km, 13-stop line opening in 2018. On completion the scheme will be genuinely transformative – allowing Canberra to finally realise the Griffins' ambition.

**15,000**

Estimated daily trips in Canberra that will switch from car to light rail, creating a city that's more efficient and sustainable

**$1bn**

Estimated uplift to the local economy

**RAFFLES CITY**
*Hangzhou, China*

Moving west, Asia is a region defined by constant change. Our work this year reflects that dynamism, helping cities thrive, transport networks grow and businesses and communities operate more efficiently and sustainably than ever before.

## DESIGN AND ENGINEERING

An uncompromising design approach, combined with a demanding sustainability target presented interesting challenges for our work at *Raffles City* in Hangzhou, China.

From a design perspective, the complex form of the development needed careful consideration by our multi-disciplinary team. Comprised of an unusual, twisting 250m, two-tower structure and undulating 10-storey retail podium, the project required extensive use of digital modelling and simulation tools to accommodate a series of constantly changing floor layouts. Applying a genuinely 'total design' solution across structural and services engineering, and specialist fire and sustainability consultancy, we were able to realise the complex design in a way that was both practical and cost-effective.

This focus on economic value also applied to the development's sustainability strategy. Following comprehensive energy consumption simulations, we recommended the adoption of energy and cost-saving systems including chilled water storage, natural ventilation, optimised daylighting, heat recovery technology and $CO_2$ sensors. The result is a building that achieved LEED (Leaders in Energy and Environmental Design) Gold certification and exceeds its design and sustainability ambitions.

## SOUTH ISLAND LINE

*Hong Kong, Greater China*

At Admiralty Station, we added the South Island Line station plus the enabling works for the future Shatin to Central Link – underneath and adjacent to an operational station.

**45m**

Depth of the cut and cover box for the main connectivity between the new and existing lines for the South Island Line

**24m**

Span of the rock cavern for the South Island Line platform

## SHAPING BETTER CITIES

Hong Kong is a high-density city with a confined and challenging terrain, and limited scope to expand. This means new railway infrastructure solutions must be innovative, integrated and spatially clever. This was exactly the approach we took on the city's Mass Transit Railway (MTR) system.

The *Kwun Tong Line Extension* and *South Island Line* are among the most complex projects ever undertaken by the MTR Corporation. They saw Arup drawing together a wide range of multi-disciplinary skills to deliver stations, tunnels, and a depot, along with preparatory works for high-end residential property developments. Particular challenges included the location, topography and ground conditions – the latter requiring complex excavation and heavy underpinning work.

The *Bangkok Blue Line Extension* in Thailand is a project that will have a major impact in the country's rapidly growing capital.

For the past six years Arup has worked as lead consultant on Wat Mankong and Wang Burapha underground stations, and two intervention shaft structures in the centre of the city's Chinatown district. Our multi-disciplinary services included: civil and structural engineering, geotechnics, architecture, building services, fire engineering, tunnel ventilation and passenger movement analysis. Technical demands included creating structures suitable for difficult geological conditions and a high water table, and working beneath one of the busiest intersections in the city.

We also had to accommodate requirements relating to the extension's location in one of Bangkok's most historic areas.

Work on the whole extension will be finalised by 2019. This will complete Bangkok's first orbital rail network, easing the city's chronic traffic congestion, and improving conditions for Bangkok's 8.3 million residents.



## SHOUGANG PARK

*Beijing, China*

Shougang Park occupies the site of a former steel mill in the west of Beijing. Its prime city centre location offers huge scope for regeneration.

**5,000**

Residents will live at the heart of the regeneration project

**25,000**

Jobs will be based on the site

## ADDRESSING SUSTAINABILITY FROM THE START

*Shougang Park* is a project with an important climate change mission. Located in Beijing, China, it will be the country's first C40 Climate Positive development, designed to regenerate a former industrial area via a radical and far-reaching sustainability and climate-change strategy.

The 34 hectare site is designed as a comprehensive low-carbon urban development. Its scope includes green buildings and transport, clean energy, and sustainable waste and water strategies. We also looked at the provision of green spaces, heritage conservation and rehabilitation of contaminated sites.

An additional outcome from the work is a comprehensive plan covering ecology, sustainability and environmental issues, which has been developed by Arup and Beijing Municipal Institute of City Planning & Design (BICP). The findings of this will inform a national policy framework for the regeneration of other industrial areas.

As part of our mission to 'shape a better world' this award-winning planning project is another example of how we can help modern cities address sustainability and climate change from the very beginning.

**AMOREPACIFIC**
*Seoul, South Korea*

### MEETING OUR CLIENTS' COMPLEX CHALLENGES

In Seoul, South Korea, the new headquarters for Korea's largest cosmetics company, *Amorepacific*, is an important landmark in an area of the city that is regenerating. It saw us realising the building's technically complex design, while meeting demanding sustainability standards.

Working alongside architects David Chipperfield, our team sought to create a building that was both visually arresting and highly efficient. The design of the building is a contemporary take on traditional Korean cultural references, with a curtain façade made up of different sized aluminium fins the most obvious and dramatic expression.

Beyond its exterior design, the project takes a holistic approach to sustainability, integrating a wide range of features to reduce consumption and improve efficiency. Notable elements include water conservation systems, sustainable material selection, natural ventilation and daylighting, and integration with carefully considered exterior spaces. The building's sustainability credentials were recognised through the award of the highest rating from the Korean Green Building Code and LEED Gold certification.

Our work on *Coca Cola's* new regional headquarters in Tokyo, Japan saw us helping the company advance its commitment to sustainability in a number of interesting ways.

Façades resembling the classic glass Coke bottles work as wind-catchers and alongside the building's open-air staircase act as a solar chimney to maximise natural ventilation. For lighting systems, a careful balance between comfort and energy-saving was achieved through the use of an automatic LED lighting system incorporating daylight and occupancy sensors. 25kW photovoltaic panels installed on the rooftop effectively utilise natural energy to supply electricity direct to the building, whilst water conservation is promoted through rainwater harvesting that is used for flushing and irrigation.

All told it's an impressive and comprehensive sustainability approach that influenced all aspects of our multi-disciplinary engineering services, and is the first Coca Cola head office in the world to receive LEED Platinum rating.

Turning an ambitious architectural design into an elegant engineering solution is the kind of challenge we relish. Our work on Thailand's tallest building is a perfect example of us doing just that.

At 314m tall the *MahaNakhon* tower is a striking addition to Bangkok's Central Business District.

The challenge was designing a structural solution that could achieve the architectural vision from elements that were both repeatable and economic to produce. Working in close collaboration with the architects Büro Ole Scheeren to develop the tower's form, we achieved a solution that made use of locally available building materials without compromising on the key features of the original concept. These include the distinctive cantilevered glass 'skyboxes' and terraces that form the pixelated design and provide unparalleled views of the city below.

As well as full structural and services engineering, Arup provided skills in the areas of advanced technology and research, geotechnics, seismic design and wind engineering. The end result is a stunning mixed-used development that justifies its prominent place on the Bangkok skyline.

**MAHANAKHON**
*Bangkok, Thailand*

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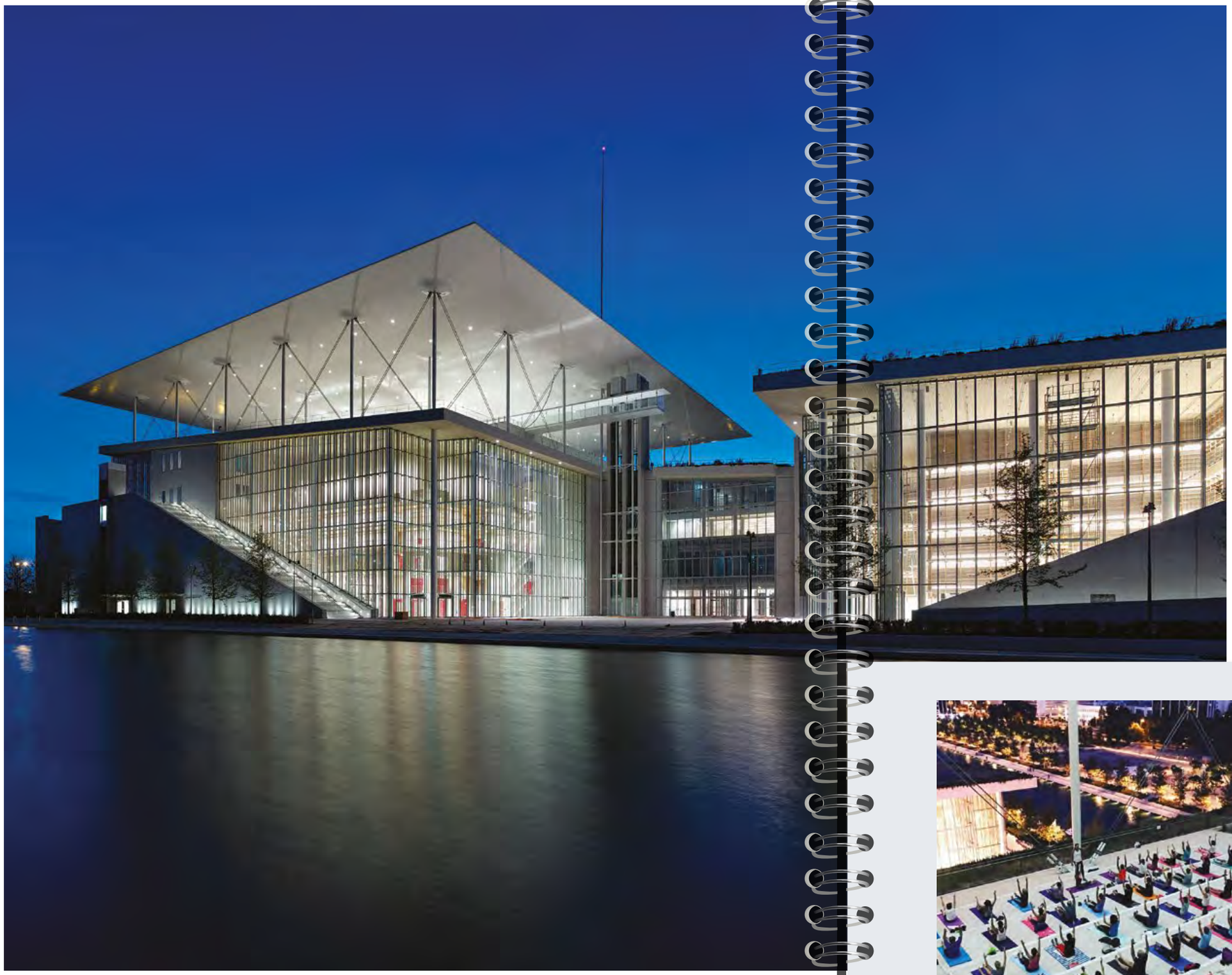
314m

The tallest building in Bangkok

**MAHANAKHON**
*Bangkok, Thailand*



Our work in Europe and Africa has seen us meeting genuinely ambitious goals. From buildings that set new standards in sustainable design to plans for the world's longest sub-sea tunnel for road and rail, we have helped clients go further and achieve more.

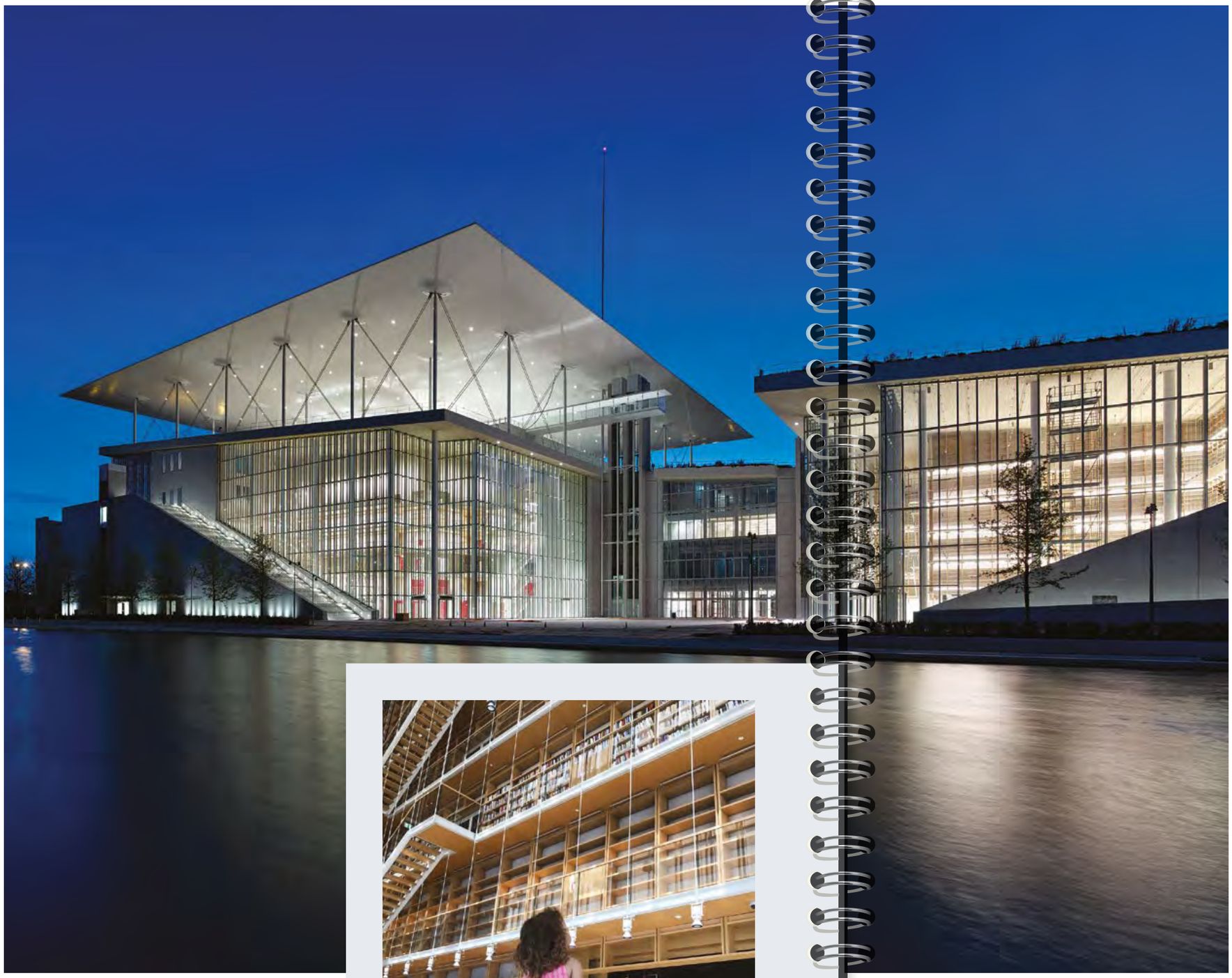


**@PILATESFORWO_MEN** · 2017
at Stavros Niarchos Foundation Cultural Centre.

**STAVROS NIARCHOS FOUNDATION CULTURAL CENTRE**

*Athens, Greece*

Comprised of the National Library of Greece, the Greek National Opera, and a 170,000m² green space, the Stavros Niarchos Foundation Cultural Centre is a world-class cultural venue and prime example of sustainable best practice.





**@ALEXANDER_SOURBATIS** · 2017

And you shall be amazed at the world of books, the gate of knowledge @snfcc #snfcc #Athens

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**MUSEUM VOORLINDEN**

*Wassenaar, The Netherlands*

Each calm, quiet room is naturally lit, with no sunlight shining directly on any of the art installations.

## EXPANDING THE ART OF THE POSSIBLE

In Athens, Arup worked with the Stavros Niarchos Foundation on a project that's firmly focused on the future.

The ambitious *Stavros Niarchos Foundation Cultural Centre* encompasses the National Library of Greece, the Greek National Opera and a 170,000m$^2$ green space where cultural events can be held.

The centrepiece of the development is the new Opera House with a 1,400 capacity auditorium, inspired by ancient Greek amphitheatres and designed using sophisticated 3D modelling techniques.

Our expert knowledge is also an unseen but critical feature of the National Library. Here, our skills in precise environmental control enable a vast collection of fragile books and rare manuscripts to be stored and managed safely.

As well as being a cultural beacon, the Centre is a benchmark for environmental best practice. A stunning 10,000m$^2$ canopy of photovoltaic cells provides both shading and an estimated 2GWhrs of energy per annum – enough to power 650 homes. Elsewhere, a range of passive design solutions optimise use of energy and water, creating a development worthy of Greece's first LEED (Leadership in Energy and Environmental Design) Platinum award.

Further north in Europe, we've been helping a different cultural client address a more specific challenge. Optimising natural daylight was the defining technical challenge for *Museum Voorlinden* – a serene new pavilion housing the largest private art collection in the Netherlands.

Daylight can be both enemy and friend in the art and conservation world – improving viewing experiences but potentially damaging priceless works of art.

To address this challenge we applied our expertise in natural lighting to provide an innovative solution where daylight falls indirectly through 115,000 angled tubes, spread across the pavilion roof. Combined with other features like a canopy and an external sun-shading grid, this approach ensures all of the building's rooms are naturally lit, with no direct sunlight on any of the art installations.

**ENERGY ACADEMY EUROPE**

*Groningen, The Netherlands*

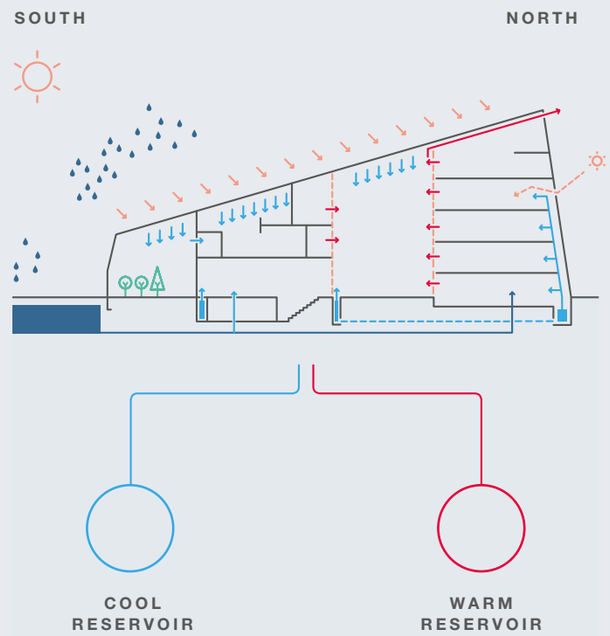
Providing space for 1,600 people, the building includes research facilities, education rooms, labs and offices. Here researchers, students and entrepreneurs can come together to develop inspiring solutions for tomorrow's energy needs.

**ENERGY ACADEMY EUROPE SUSTAINABLE DESIGN FEATURES**

A rainwater recycling system irrigates the gardens and flushes the toilets.

The sloping roof and solar panels are designed to collect solar energy and naturally light the building.

A natural ventilation system allows the internal air temperature to adjust to changes in the seasons.




The winter garden forms an intermediate space between indoor and outdoor.

Earth, water and air combine through a system that uses groundwater to cool and heat the building.

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## SETTING NEW SUSTAINABILITY STANDARDS

It stands to reason that an international institute that specialises in energy innovation, education and research would require their new building to be an exemplar of ultra-sustainable design.

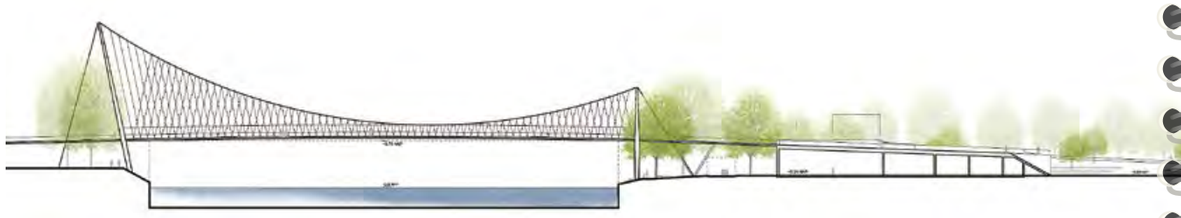
The *Energy Academy Europe* at the University of Groningen in the Netherlands uses a range of innovative approaches focused on the natural potential of the sun, earth, water and air.

The impact of the sun is reflected through the shape and structure of the building. This optimises the amount of daylight penetrating the interior and onto a huge bank of photovoltaic roof panels. The result is a building that is not only naturally lit but energy neutral – creating as much electricity as it consumes.

Earth, water and air combine through a system that uses groundwater to cool and heat the building, whilst a rainwater recycling system irrigates the gardens and flushes the toilets.

Finally, the interior environment is carefully controlled through a system of natural ventilation and the use of a 'winter garden' that connects the inside and outside of the building and allows the internal air temperature to adjust to changes in the seasons.

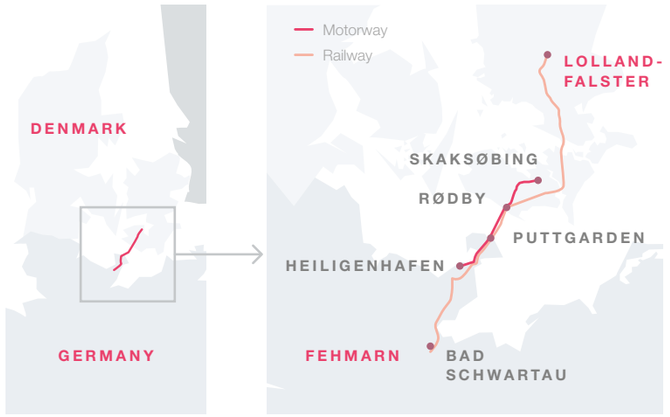
The building represents the best in sustainable building design. This was recognised through the award of a five star BREEAM outstanding rating – the highest available from the internationally recognised environmental assessment scheme – and the award of 'Mixed-use Building of the Year' at the prestigious BREEAM Awards.



**DAFNE SCHIPPERS BRIDGE**

*Utrecht, The Netherlands*

Connecting the historic city of Utrecht with the new residential area of Leidsche Rijn, the bridge will serve 11,000 cyclists and pedestrians every day.




**FEHMARN BELT FIXED LINK**

*Denmark – Germany*

At 18km long and 40m deep, the planned tunnel will be the world's longest sub-sea tunnel for road and rail, and a unique engineering challenge.

**@LRINBEELD** · 2017

Residents from Oog in Al and Leidsche Rijn meet each other and have lunch at the #DafneSchippersbrug #utrecht

**MEETING LOCAL NEEDS**

The *Dafne Schippers Bridge* in the Netherlands provides an important new connection for pedestrians and cyclists – linking the City's historic centre with the new residential area of Leidsche Rijn.

The 110m-suspension bridge fits elegantly into its environment. On the Leidsche Rijn side, a single pylon forms a powerful landmark, whilst on the Utrecht side the bridge seamlessly curves around ublic garden.

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nless static, dynamic ls. This r the bridge get, creating a ate a stronger ection across

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A different kind of local need defined our work in Florence. Here our goal was to create the best possible experience for fans visiting the new football stadium and to contribute more widely to the appropriate development of the city.

The venue will host the home matches of AFC Fiorentina and is part of the wider redevelopment of a 48 hectare area which includes public spaces, an interchange carpark and a shopping mall.

The new stadium, developed by our architecture and engineering team in Milan, with support from several other European offices, is a prime example of our expertise in designing sports projects across the world.

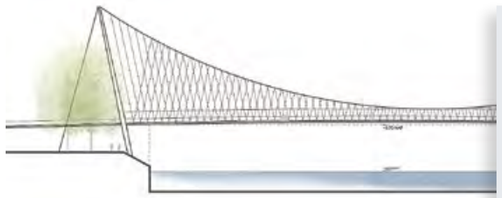
Its design is based on a 'fans first' approach where digital technology and tools have been integral. This has seen us using virtual reality techniques to ensure the best possible sight lines from every seat and simulate the real-time fan experience.

The end result is a 40,000 seater stadium that reflects local history and landscape in a modern way, and provides a best-in-class home for the team and its fans.

At the turn of the twenty-first century Arup played a key role in the design of the *Øresund Bridge*, the longest combined road and rail bridge in Europe, which connects Denmark and Sweden.

Now Arup is working on a scheme that aims to connect Denmark with Germany through the Baltic Sea's *Fehmarn Belt Fixed Link* – an undersea tunnel that will provide an easier and speedier route from Germany to Denmark, Sweden and Norway.

Working alongside Ramboll and TEC, we are providing a full range of multi-disciplinary design services for a project that will have a huge impact on the economy of this region – cutting journey times from Denmark to Germany to ten minutes by car and seven minutes by rail.



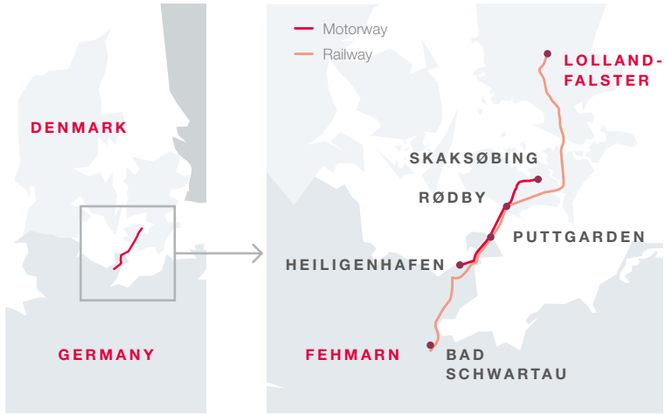
**DAFNE SCHIPPERS BRIDGE**

*Utrecht, The Netherlands*

Connecting the historic city of Utrecht with the new residential area of Leidsche Rijn, the bridge will serve 11,000 cyclists and pedestrians every day.

**@MODACITYLIFE** · 2017

How do the Dutch get bike traffic up onto a bridge connecting two #Utrecht neighbourhoods? By integrating the cycle path into a school roof!




**FEHMARN BELT FIXED LINK**

*Denmark – Germany*

At 18km long and 40m deep, the planned tunnel will be the world's longest sub-sea tunnel for road and rail, and a unique engineering challenge.

## MEETING LOCAL NEEDS

The *Dafne Schippers Bridge* in the Netherlands provides an important new connection for pedestrians and cyclists – linking the City's historic centre with the new residential area of Leidsche Rijn.

The 110m-suspension bridge fits elegantly into its environment. On the Leidsche Rijn side, a single pylon forms a powerful landmark, whilst on the Utrecht side the bridge seamlessly curves around an existing school into a public garden.

Working in close collaboration with Next Architects, Arup provided structural, civil and geotechnical engineering services for the project as well as dynamic assessments, cost estimates and lighting design.

A key feature was the seamless combination of advanced static, dynamic and foundation design skills. This enabled the team to deliver the bridge efficiently and within budget, creating a public facility that will create a stronger and more sustainable connection across the community.

To add to its sense of place, the bridge is named after the world-class athlete Dafne Schippers, who grew up in Utrecht and went to school in Leidsche Rijn. Nearly 2,000 inhabitants of Utrecht voted for the winning bridge name.

A different kind of local need defined our work in Florence. Here our goal was to create the best possible experience for fans visiting the new football stadium and to contribute more widely to the appropriate development of the city.

The venue will host the home matches of AFC Fiorentina and is part of the wider redevelopment of a 48 hectare area which includes public spaces, an interchange carpark and a shopping mall.

The new stadium, developed by our architecture and engineering team in Milan, with support from several other European offices, is a prime example of our expertise in designing sports projects across the world.

Its design is based on a 'fans first' approach where digital technology and tools have been integral. This has seen us using virtual reality techniques to ensure the best possible sight lines from every seat and simulate the real-time fan experience.

The end result is a 40,000 seater stadium that reflects local history and landscape in a modern way, and provides a best-in-class home for the team and its fans.

At the turn of the twenty-first century Arup played a key role in the design of the *Øresund Bridge*, the longest combined road and rail bridge in Europe, which connects Denmark and Sweden.

Now Arup is working on a scheme that aims to connect Denmark with Germany through the Baltic Sea's *Fehmarn Belt Fixed Link* – an undersea tunnel that will provide an easier and speedier route from Germany to Denmark, Sweden and Norway.

Working alongside Ramboll and TEC, we are providing a full range of multi-disciplinary design services for a project that will have a huge impact on the economy of this region – cutting journey times from Denmark to Germany to ten minutes by car and seven minutes by rail.

## PROVIDING SPECIALIST EXPERTISE

Working with our client Price Waterhouse Coopers (PwC), the *Twisty Tower* at Waterfall City presented major design and structural challenges for our multi-disciplinary team.

To make the twisting design a reality we deployed our industry-leading skills in Building Information Modelling (BIM) and parametric modelling to develop an innovative structural approach that fulfils PwC's bold vision.

When complete in 2018, it will house 3,500 employees and be a significant addition to the Johannesburg skyline.

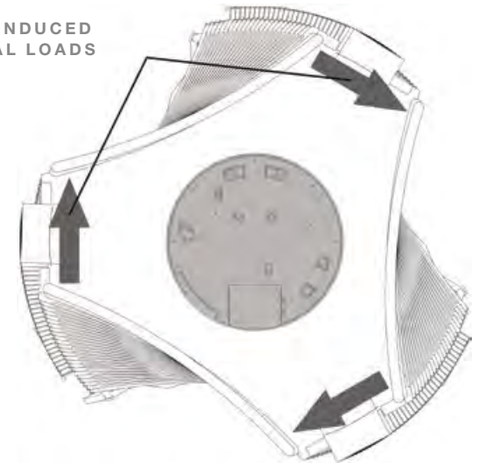
Arup's specialist advice has played an equally important role on another South African project, this time in the energy sector.

Following the award of a 20 year power purchase agreement with utility provider Eskom, renewable energy investment company, Solar Capital commissioned a 75MW photovoltaic (PV) facility – *Solar Capital De Aar 3*. Alongside its sister facility De Aar 1, it will form the biggest operational solar farm in the Southern Hemisphere.

**PWC 'TWISTY TOWER'**
*Johannesburg, South Africa*

The tower's unusual design saw each floor of the 28-storey office block rotate 1.2 degrees relative to the floor below, giving a striking twisting appearance.

**GRAVITY-INDUCED TORSIONAL LOADS**



Arup's role has seen us working directly alongside the client, providing technical oversight across the whole project. Specific tasks have included design reviews, construction and commission supervision, performance guarantee verification and operations monitoring.

For a project of this scale, this role is critical, ensuring build quality, construction efficiency and total return on investment.

## TRANSFORMING A UNIQUE SPACE

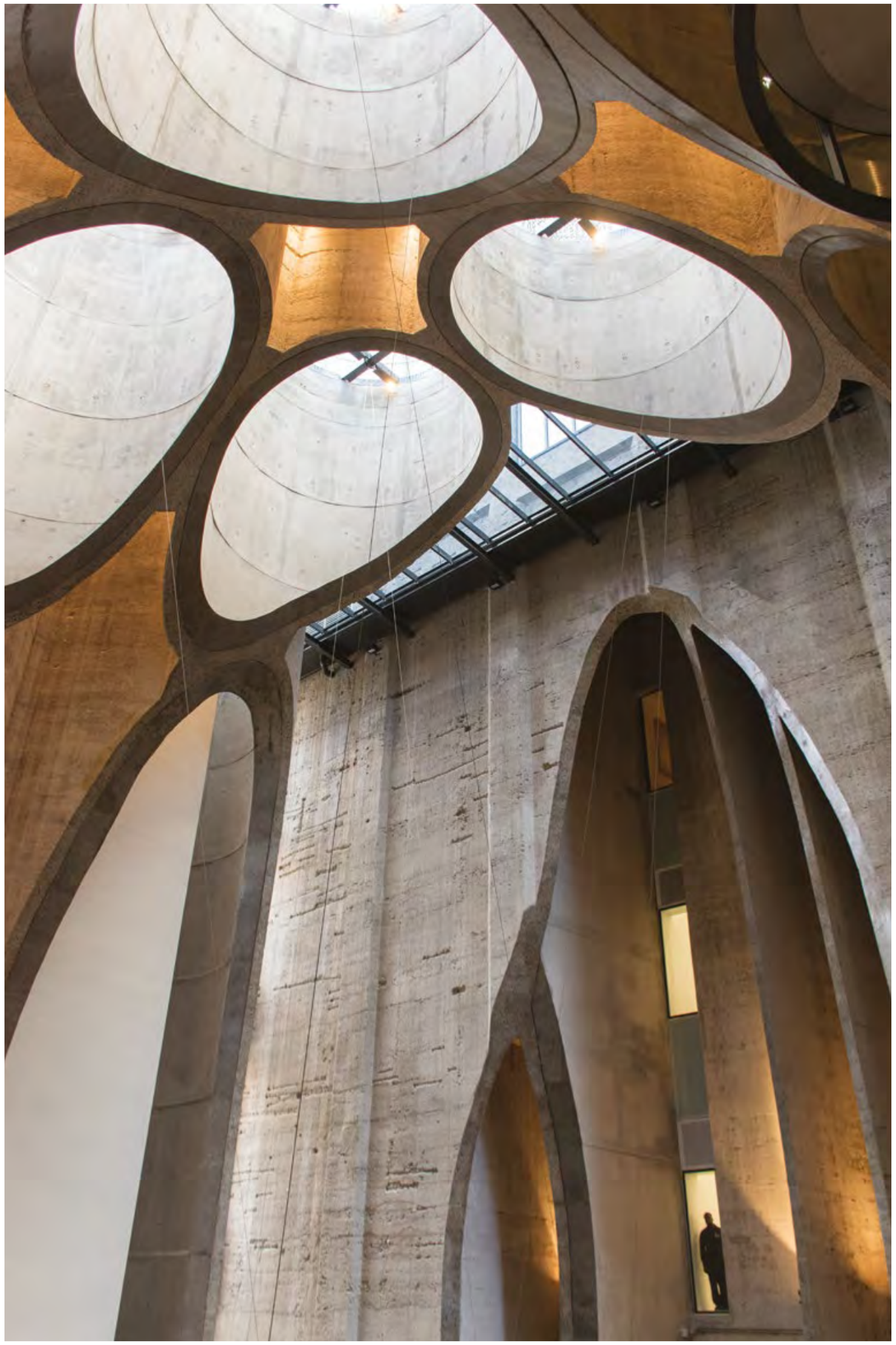
Cape Town's prominent grain silo was once used to store and grade maize from all over South Africa. But with the advent of containerised shipping, the huge piece of concrete infrastructure was decommissioned and in need of a new purpose.

Working in close collaboration with architects Heatherwick Studio, Arup's structural engineering team helped to transform the silos from redundant industrial space into an inspiring cultural centre housing the *Zeitz Museum of Contemporary African Art (MOCAA)*.

The original building was composed of two main elements – a grading tower and a block of 42 tightly-packed silos. Rather than resorting to wholesale demolition, the design team took on the challenge to convert the multitude of concrete tubes into spaces to display art while retaining the silo's industrial character. The result is stunning – providing a suitably inspiring home for an important cultural asset.

**ZEITZ MOCCA**
*Cape Town, South Africa*

The atrium is the heart of the museum – an organically shaped void carved out of the concrete tubes that formerly stored grain.



Deep specialist expertise has been a key feature of our work in the UK. It's seen us solving complex technical challenges, vastly improving user experiences and finding smart ways to make ambitious infrastructure plans a practical reality.

**QUEENSFERRY CROSSING**

*Edinburgh, UK*

At over 1.7miles in length, *Queensferry Crossing* is the longest three-tower, cable-stayed bridge in the world. At the heart of the scheme is a new Bridge Control Room and the Traffic Scotland National Control Centre (TSNCC), a strategic hub which controls and manages Scotland's motorway and trunk network.

## EFFICIENCY AND EFFECTIVENESS

The new *Queensferry Crossing* is a major project by any standards. Specifically, the new bridge spanning the Firth of Forth is the largest infrastructure project in Scotland in a generation and the longest three-tower, cable-stayed bridge in the world.

Getting a project of this scale built is a major undertaking requiring world-class expertise. But for our client Transport Scotland, our advice made a key difference to the project's total affordability.

Initial estimates suggested a total project budget of approximately £4bn. Our team, working together with our joint venture partner Jacobs, evaluated the whole approach and responded with efficiency savings that reduced the budget to £2bn.

For a scheme of this scale, that saving was critical to the total viability of the project.

"…the bridge has been designed to be sympathetic to its unique setting within the dramatic Scottish landscape and sit next to the iconic railway and road bridges that cross the River Forth."

Mike Glover OBE
Arup Fellow

**£2bn**

Amount saved on total project budget as a result of efficiency savings recommended by Arup

With funding and approvals in place, our services for the three-tower, cable-stayed bridge were extensive, spanning civil and structural design, geotechnics, engineering, environmental consultancy, project management, procurement, programming and construction services.

A particular feature was use of smart infrastructure and intelligent transport systems. This digital technology will keep traffic on the move, improve safety, reduce emissions and enhance the driving experience for every bridge user.

## EXPANDING THE ART OF THE POSSIBLE

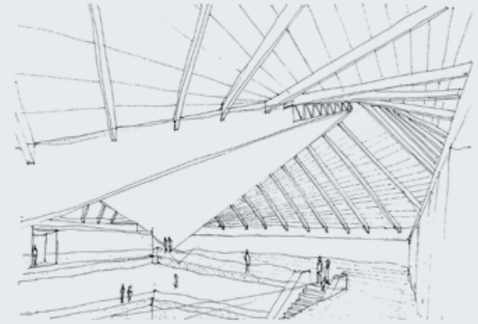
Our ethos sees us constantly pushing boundaries and looking for new and better ways to meet complex challenges.

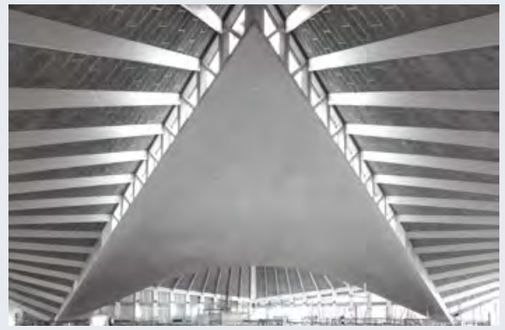
Moving London's *Design Museum* to its new Grade II listed home at the former Commonwealth Institute in Kensington was not an easy task. Specifically, the goal we were set was to find a way of retaining the building's unique hyperbolic/parabolic roof, whilst the space beneath was completely remodelled.

Our answer was ambitious.

We raised the 1,500 tonne roof 20m above ground level to a tolerance of just 5mm. This enabled the removal of the internal structural frame and the redevelopment of 10,000m² of gallery space – triple the size of the Museum's old home.

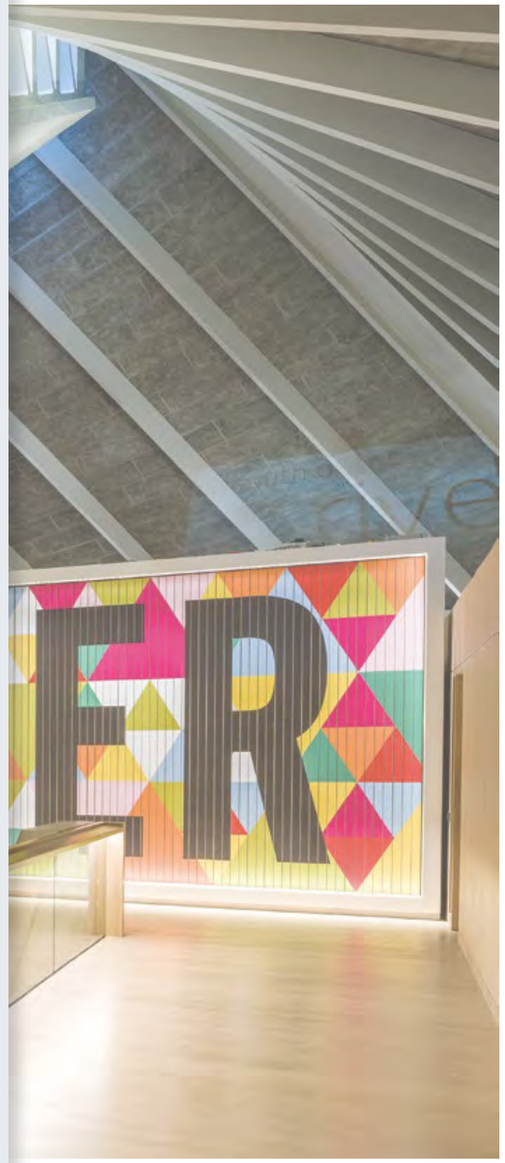
The extensively refurbished copper-covered roof is now back in situ, forming the centrepiece of an outstanding building. Thanks to our creative thinking, it's also a fine example of the type of design and engineering ingenuity the Design Museum is all about.





**1,500 tonnes**

The Design Museum roof, weighing 1,500 tonnes and only 75mm thick at its centre, was raised 20m above ground level



**DESIGN MUSEUM**
*London, UK*

**EFFICIENCY**
**EFFECTIVEN**

The new *Quee*
a major project
Specifically, th
Firth of Forth i
project in Scot
the longest thre
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Getting a proje
a major underta
class expertise
Transport Scot
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affordability.

Initial estimate
budget of appr
team, working
venture partner
whole approac
efficiency savi
budget to £2bn

For a scheme o
critical to the t

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## £2bn

Amount saved on total project budget as a result of efficiency savings recommended by Arup


"The feat of engineering accomplished by Arup to refurbish this spectacular roof is almost miraculous. It is a fitting example of how design, allied to engineering, can create amazing spaces and enduring legacies."

Alice Black
Deputy Director, Design Museum

**DESIGN MUSEUM**
*London, UK*

“Patients have been consulted at every stage and no decision has been made without us. Our views have been welcomed, listened to and acted on.”

Diana Crawshaw, London Guy’s and St Thomas’ Hospitals Chair of the Patient Reference Group

## IMPROVING LIVES

Cancer treatment is a difficult experience for any patient. Those undergoing treatment at *London Guy’s* and *St Thomas’ Hospitals* faced the added difficulty of negotiating facilities at 13 different locations in eight separate buildings. Our goal was to change that.

Providing multi-disciplinary design services in close collaboration with architects Rogers Stirk Harbour + Partners, specialist healthcare architects Stantec and main contractor Laing O’Rourke, our approach was to make patient consultation a key feature of the design process.

This invaluable input informed the development of a single Cancer Centre that brings most treatments together under one roof – organising them as four, easy to navigate ‘villages’. The Radiotherapy Village, for example, is located over three consecutive levels, with each level corresponding to a particular stage of a patient’s treatment.

**6,500**

Number of cancer patients treated each year at London Guy’s Hospital

More radically, the Centre is the first in Europe to locate its radiotherapy facilities above ground. This request came directly from the patient consultation process. It involved adhering to the strict radiation equipment safety standards whilst giving patients access to natural light and landscaped external spaces.

Overall, it’s a transformative result, improving every patient’s experience at the time when they and their families need it most.

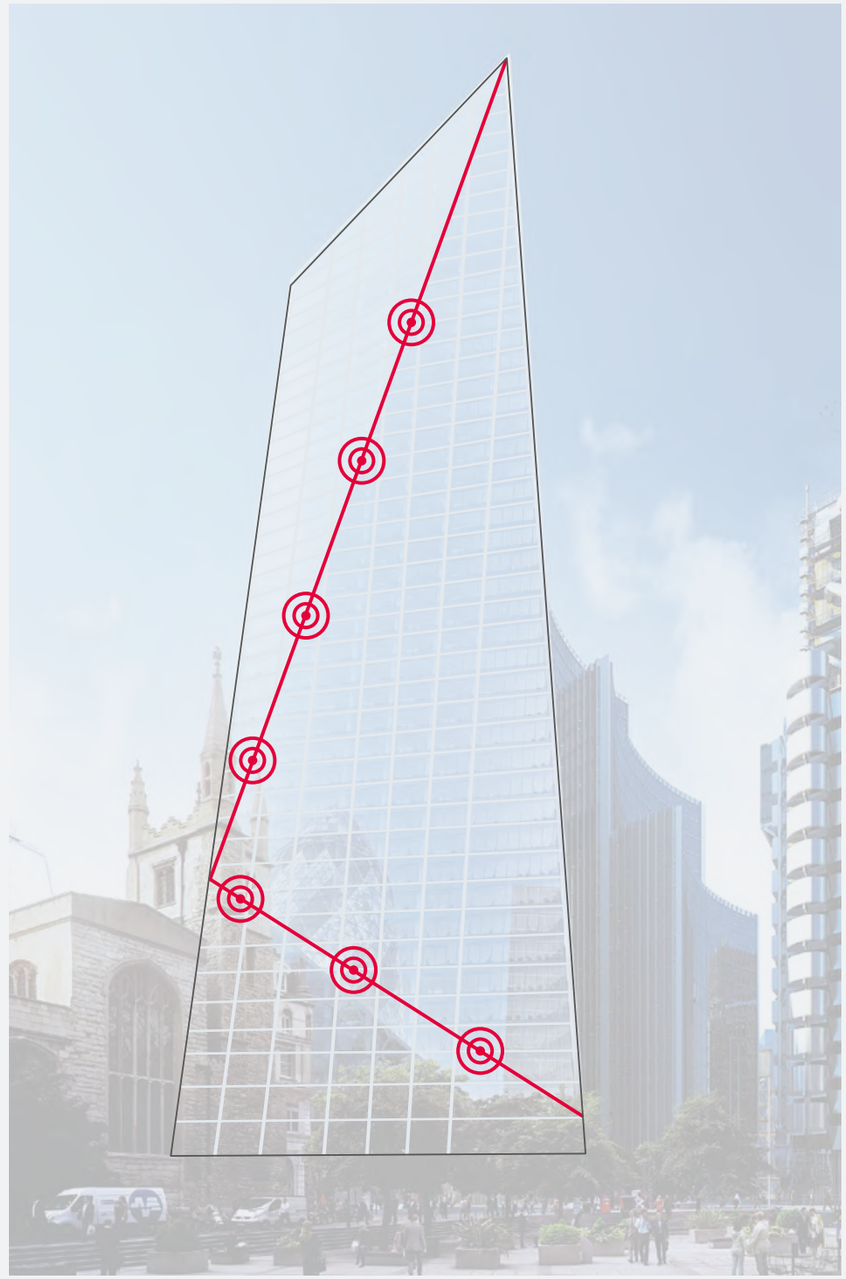
A different human need shaped our work in Wales. At a point when our water supply is more susceptible to shocks and stresses, a pioneering resilience strategy for *Welsh Water* will enable the business to anticipate, respond and recover from extreme events of any kind – climatic, social, political or economic.

We began by identifying around 60 shocks and stresses that Welsh Water might be vulnerable to. Drawing on our global experience of resilience planning for cities and infrastructure, we then developed a resilience framework that identifies best practice and areas for improvement within Welsh Water. From the application of the framework, we arrived at a series of initiatives that will embed resilience into all aspects of Welsh Water’s operations over the next 30 years. These include people, infrastructure, use of natural resources, finances, leadership and strategy.



### LATERAL STABILITY SYSTEM

Seven viscous damper units absorb the energy of motion, so that even in high winds, people working inside will be comfortable as lateral accelerations will be limited.



### 52 LIME STREET

*London, UK*

*52 Lime Street,* also known as *‘The Scalpel’,* is a 35-floor tower in The City of London. Featuring a narrowing, glass-fronted, angular design, it joins past Arup projects like the Lloyds Building and the ‘Gherkin’ as another striking addition to the City’s ever-changing skyline.

The incisive form of the building – created in collaboration with architects Kohn Pedersen Fox – required an engineering approach combining both stability and efficiency.

Stability came from 52 Lime Street’s lateral stability system. Seven viscous damper units are built into the system and absorb the energy of motion – whatever the weather conditions.

To achieve efficiency, we created a script that enabled every beam in the building to be uniquely engineered, and used BIM modelling to deliver data directly to the steel fabricators. Use of this technology saved 700 tonnes of steel compared with a traditional approach – reducing costs by more than £1.4 million and removing 1,300 tonnes of embodied $CO_2$.

Operational efficiency is delivered through a creative approach to building services and façade engineering. This produced a 25% saving in carbon use and enabled the building to receive an Excellent rating from BREEAM, the internationally recognised environmental assessment scheme.

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**SECOND AVENUE SUBWAY**
*New York, US*

Our work in the Americas has expanded in both scale and scope this year. It's seen us address some of the big issues of our age, set new benchmarks for sustainable performance and contribute to the vitality of some of the world's great cities.

## CREATING LANDMARKS

It's rare that Arup joins a project whose genesis can be traced back for almost 100 years. But the opportunity to see phase 1 of New York's *Second Avenue Subway* finally completed was not to be missed.

First proposed in 1919, multiple versions of the line were started and abandoned several times without ever being finished.

Our challenge was to change that.

Working with our joint venture partner, complex engineering was required to tie into the existing subway network, open up old abandoned tunnels and build new ones.

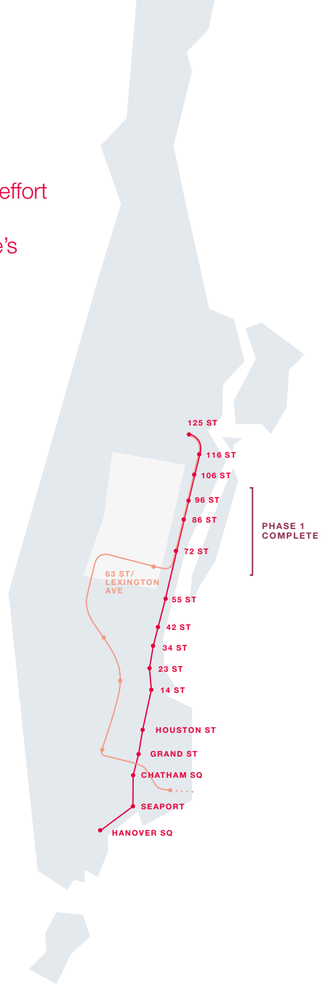
Our expertise in tunnelling, geotechnics, ventilation and acoustics wasn't all that was required. We also led the multi-disciplinary design of four new underground stations that set a benchmark for world-class transport infrastructure.

Phase 1 of the Subway opened in January 2017. It's already carrying 200,000 passengers a day and relieving congestion by as much as 40%. It will make a major contribution to Governor Cuomo's ambitious transportation vision – enhancing the lives of New Yorkers and underpinning the strength of one of the world's great cities.


**SECOND AVENUE SUBWAY**
*New York, US*

"There was a super human effort to get this done on time... This is New York, and there's nothing we can't do when we put our mind to it."

Governor Andrew Cuomo
New York




**8.5**
Miles the project will eventually run

**16**
Stations on the subway line

**2.4**
Miles of twin-track tunnels

On the US West Coast, we've worked in close collaboration with architects Snøhetta on the extension of the *San Francisco Museum of Modern Art* (SFMOMA).

Our work has focused on optimising the visitor experience. Combining acoustic, audio-visual and theatre consulting with lighting design and pedestrian modelling, we've created a space with the flexibility to respond to diverse curatorial needs.

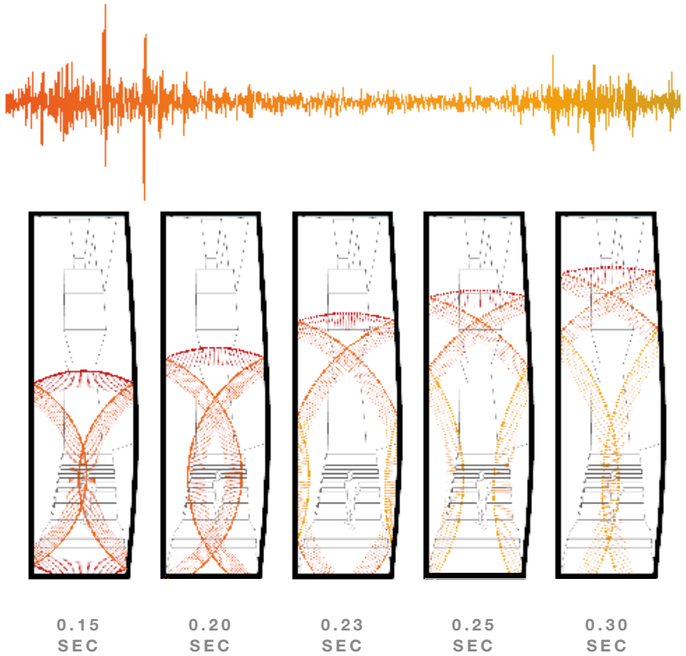
This visitor-centred approach also applies to our work on the building's striking façade.

700 fibre-reinforced polymer panels form rippled patterns that echo the topography and water of San Francisco Bay. But the impacts aren't just skin-deep. Drawing on our multidisciplinary skills, our façade engineering team ensured that the building's unique exterior also enhanced the museum's daylighting, acoustic, and audio-visual strategies.

Another much loved feature of the building is the Living Wall, a green, leafy contrast to the interior gallery spaces.

The end result is a building that's as functional as it is beautiful.

**WAVEFORM OF RECORDED FLUTTER ECHO**




**SAN FRANCISCO MUSEUM OF MODERN ART**

*San Francisco, US*

The long stairs connecting the galleries exhibit a natural 'flutter echo' giving each stair a unique acoustic signature, which is activated by the sounds made by visitors: footsteps and whispers, for example.

In essence, each sound creates a unique sonic artwork. This acoustic signature can be specifically activated by artists should they choose.



**@NATASHA_AD** · 2017

Appreciating the MoMament #moma #sfmoma

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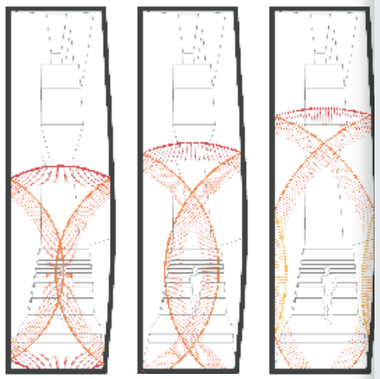

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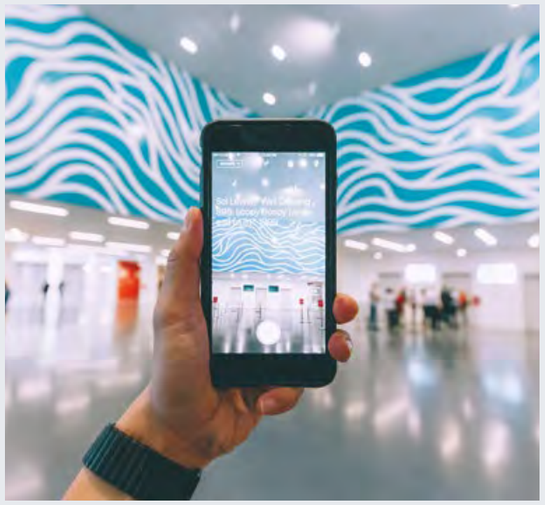


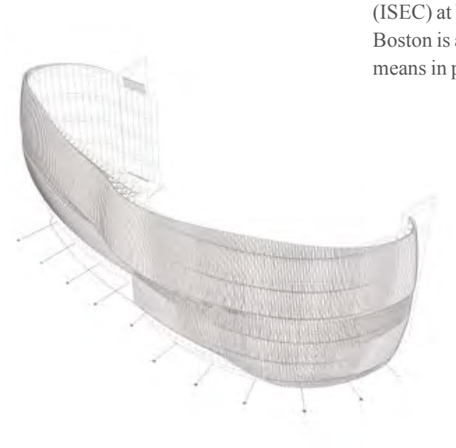
**@50DMA** · 2017

I've seen beautiful art on the sides of buildings. I've seen beautiful art in museums. I've seen beautiful art in galleries. Beautiful art is everywhere. – John Mellencamp

**ISEC AT NORTHEASTERN UNIVERSITY**

*Boston, US*

Our design for the curtain wall balances openness and aesthetics with enhanced thermal performance.



## PUTTING SUSTAINABILITY AT THE CORE

Across Arup, we recognise the contribution the built environment needs to make in creating a more sustainable and resource-efficient world.

The new 234,000ft² *Interdisciplinary Science and Engineering Complex* (ISEC) at Northeastern University in Boston is a great example of what this means in practice.

By using advanced modelling software early in the design process, we were able to provide insights around energy use and building performance, plus an understanding of the 3D space. Bi-weekly meetings with the whole project team enabled the client to make better, more informed design decisions, fully aligned with their ambitious sustainability goals.

We then applied this mindset across the whole project – making sustainability a core element to mechanical, electrical, plumbing, fire engineering services and consultancy in lighting, and façades. In total this allowed ISEC to deliver energy savings 75% above a typical laboratory.

Outstanding environmental performance was also a primary feature for another buildings project.

Non-profit, health plan and care provider Kaiser Permanente's new state-of-the-art *San Diego Medical Center* is an expansion of their acute care services and a template for future healthcare facilities.

A clear reduction in both carbon use and operational costs were key drivers for the project – aligning to Kaiser Permanente's goal of providing quality, affordable care to their members. Arup provided a broad range of engineering, design and consultancy services where sustainability was a constant fundamental. The result is a hospital that's the first in California to use active chilled beam technology in clinical areas and the first in the world with 100% LED lighting. These features, combined with a high-performance façade, on-site power generation and a water saving strategy that cuts consumption by five million gallons a year, make the San Diego Medical Center the largest LEED (Leadership in Energy and Environmental Design) Healthcare Platinum rated project in the world.

## MAKING CHALLENGING ENVIRONMENTS WORK

Our clients consistently look to us to provide inventive solutions to engineering challenges.

One example is *181 Fremont Tower* in San Francisco. This 802ft mixed-use tower will be the city's second tallest building, as well as one of the most resilient tall buildings on the West Coast.

That resilience relies on our expertise in structural, geoseismic and geotechnical engineering.

Constructed in compliance with REDi Gold – the Arup-developed design and planning guidelines – the tower sits on an innovative damped megaframe and utilises improved egress and recovery plans so that post-disaster continuity is literally built-in. It's a fine example of our industry-leading expertise shaping the practical answers we provide to a client's specific technical questions.

Exacting challenges were also a feature of the Scott Hall project at the *Carnegie Mellon University* in Pittsburgh, Pennsylvania.

A difficult site presented structural engineering complexities, whilst internally there were demanding performance requirements to accommodate. Budgetary and schedule constraints were also a factor, making this high profile project a significant challenge for our multi-disciplinary team. One they met in full.

The external issues were addressed through a structural design approach that allows the building to sit elegantly on a narrow sloping site. Internally we delivered state-of-the art clean rooms and laboratories – many with stringent performance requirements. These included vibration minimisation, tight humidity and temperature controls, plus safe management of highly combustible gases.

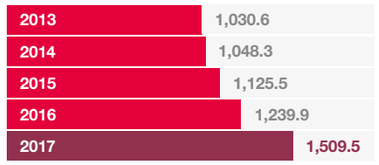
Getting these requirements right was critical, allowing a university at the forefront of progress in areas like biomedicine and nanotechnology to remain a leader in their field.

FINANCIAL SUMMARY

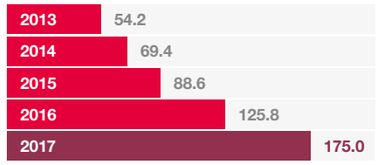
# A robust financial performance

During the year to March 2017, Arup delivered a robust financial performance, generating an operating profit before staff-profit sharing of 11.6% on revenue of £1.51bn. This represents a strong result for our staff members, our clients and for the long-term prospects of the firm.

**REVENUE (£M)**




**OPERATING PROFIT (£M)**
*Before staff profit-sharing*




**21.7%**
Revenue growth

**11.6%**
Operating profit before staff profit-sharing as a percentage of revenue

Our results this year show growth of 21.7% in revenue, with approximately 9.5% of this increase attributed to the weakening of Sterling against many of our major operating currencies.

Our profit has continually improved over the last five years, with this year's figure in line with our strategy. This result reflects our position as a strong, stable firm with the right balance of strategic focus and consistent execution.

Achieving our target allows us to continue investing in the research, innovation and staff development activities that enable us to provide world-leading advice in all our markets.

Profit-sharing distributed to staff as a percentage of total employment costs is 11.8%. Distributing profit in this way ensures that everyone in the firm benefits from our success – helping us to attract and retain the brightest and best people across our diverse disciplines.

The end of this financial year also saw us with a strong forward order book – a key measure of sustained client satisfaction and trust. At the end of March, forward orders stood at £1.05bn, in line with the position 12 months ago.

Our five regions have all performed well compared to plan.

Growth in the Americas (particularly North America) is a key strategic focus for the firm and has seen positive progress over the past year. The Australasia region has likewise performed well, with strong growth in Australia.

Greater China (mainland and Hong Kong) has suffered a slow-down in property and infrastructure investment which has led to a reduction in the overall size of the business. Europe has been stable with a continued strong performance in the Netherlands. The UK performed well, despite the uncertainty of Brexit, and remains a cornerstone of our business.

In total our financial performance offers a strong platform for future success. For our clients it demonstrates that we have the strength and stability to provide the world-leading resources they need.

For our staff it confirms that they are part of a progressive firm – attracting and investing in the best talent to produce work of real quality.

**MATTHEW TWEEDIE**
*Group Finance Director*

**181 FREMONT TOWER**

*San Francisco, US*

At 56 storeys high, 181 Fremont Tower is one of the tallest and most resilient buildings on the US west coast (page 61).

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