ARUP

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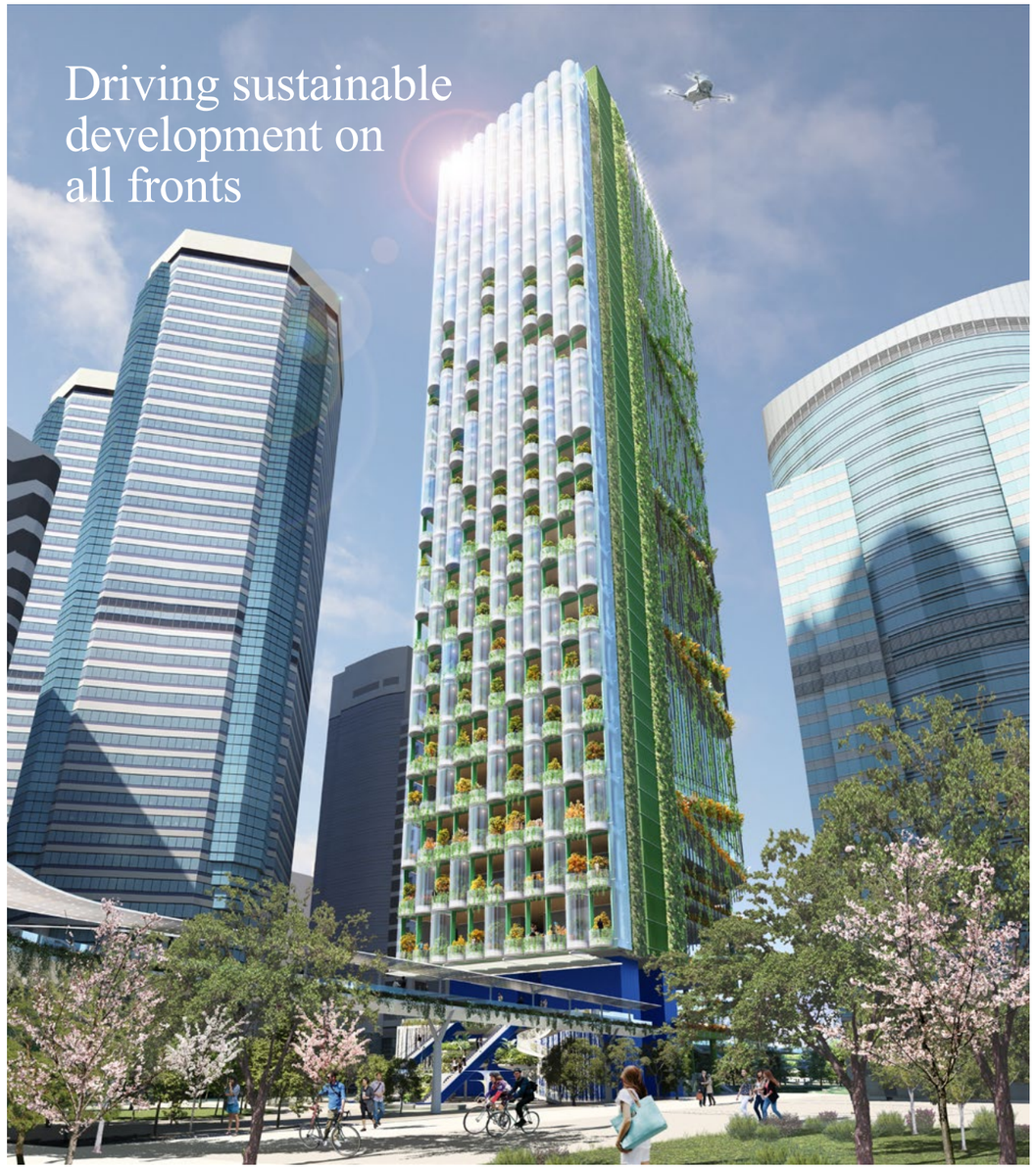

Foreword

2023 is a year of renewal and vibrancy and we are filled with hope and optimism for East Asia. The region has made a remarkable recovery from the COVID-19 pandemic, and Arup is proud to be part of this journey. With our experts and thought leaders working more closely with clients and partners, we are committed to driving sustainable development on all fronts by fostering collaboration and innovation.

Throughout this year, Arup has actively engaged with industry participants on the critical topic of sustainability through various industry events. One notable event was the Shanghai International Carbon Neutrality Expo in Technologies, Products, and Achievements, which took place in June. During the three-day event, our experts shared their knowledge on sustainable practices, research insights and forward-looking solutions.

In May, we had a busy month as we co-hosted the Asia Summit on Green Economy with the Business Environment Council. Besides, we partnered with the Independent Power Producers Forum and the Hong Kong Association of Energy to host a webinar that focused on the feasibility of hydrogen hubs. In March, we co-organised the Asian Knowledge and Innovation Forum with the Hong Kong Polytechnic University. The event brought together over 80 knowledge management experts from both the public and private sectors to share their experiences.

In Southeast Asia, national governments are proactively taking steps to integrate the United Nations Sustainable Development Goals into their policies. There is a particular emphasis on incorporating these goals into urban planning and decarbonization strategies. As a result, we expect to see more opportunities for collaboration between Arup, policymakers and industry participants on the ground.

Earlier this year, our Bangkok colleagues attended the Thailand: The New Chapter of Green Construction Forum 2023, where they had the opportunity to connect with officials and industry experts. In Cambodia, our experts from the UK and Southeast Asia recently joined representatives from the Cambodian and UK governments in Phnom Penh to share their experiences and discuss the opportunities and challenges brought by Cambodia's National Strategic Development Plan.

Moving forward, we are dedicated to maintaining a strong presence in the industry by bolstering our client relationships, actively participating in industry events, and pushing the boundaries of what is possible through ongoing innovation and collaboration.

Arup University (AU), as a unique part of Arup, aims to deliver excellence in everything we do for the benefit of our members, our clients and the communities we serve. We assist our clients in understanding the megatrends that are shaping the future of the built environment, identifying new opportunities and developing innovative ideas. Through partnerships with external organisations and clients, we continuously strive to push the boundaries of our industry and formulate solutions for some of the world's most complex problems. Our goal is to provide exceptional services to our clients.

FIRST is a publication produced by East Asia AU for our clients and partners, exploring design, innovation and technical solutions for the built environment. It takes its name from the unique model of AU: Foresight, Innovation, Research, Sharing, and Training. If you have any thoughts on business and collaboration opportunities, or questions and comments about the content, we would love to hear back from you at ea.arupuniversity@arup.com.

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Driving sustainable development on all fronts

Consolidating expertise and exerting influence with integrated climate and sustainability services

Arup is committed to making a positive impact on society and the environment by integrating the 17 Sustainable Development Goals (SDGs) into all aspects of our work. Following the United Nations General Assembly's adoption of the UN SDGs in 2017, we made a firm commitment to contributing to the common good, and our integrated climate and sustainability services have been leading the way in implementing these goals across the company's projects and initiatives.

By pulling together different domain experts, Arup has positioned itself to better embrace the UN SDGs and exert its influence on project owners, industry participants, policymakers, and the wider public. This integration has enabled the firm to offer a wide range of services that effectively help clients and partners achieve their sustainability goals. These services include reducing carbon emissions, promoting renewable energy, developing green infrastructure, and improving social equity.

Ever since, Arup has achieved significant milestones in supporting clients and partners on their sustainable journey, and this drive is only gaining momentum. To achieve this ambition, we aim to share our innovative solutions with clients and partners, empowering them to address the challenges of climate change, and promoting sustainable practices with our influence.

In fact, we have already incorporated these principles into our work over the years. Now that we have structured these principles into a more cohesive approach, we can better leverage the expertise of our global workforce to formulate innovative and effective solutions.

Pathways to net zero and resilience

Signed during the COP21 meeting in 2015, the Paris Agreement has had a profound impact on the world's sustainable future. Since then, Arup executives have been attending COP meetings, including COP26, which convened in 2021, that has been hailed as the most important meeting since COP21, as it sets four key priorities for tackling climate change:

- Green finance for the net zero economy
- Climate risk disclosure for companies
- Disclosure and transparency for the private sector
- Increasing the pace of implementing the Paris Agreement

After COP26, there has been a growing recognition that the world must take more ambitious and immediate actions to address decarbonisation and adaptation in order to prevent irreversible damage from climate change. As an example, to achieve its carbon neutrality target by 2050, the Hong Kong government has formulated the Hong Kong Climate Action Plan 2050.

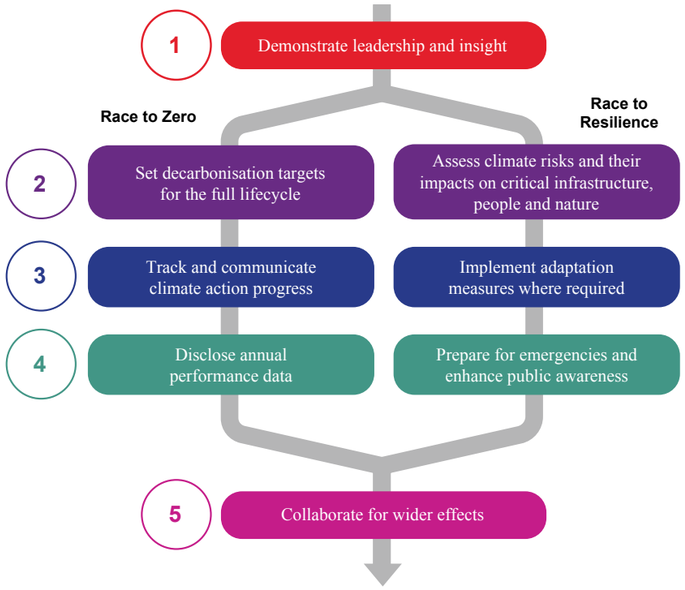
Subsequent to COP26, we published a paper in collaboration with Civic Exchange, the Institution of Civil Engineers Hong Kong Association, the World Business Council for Sustainable Development and World Green Building Council, offering insights into how we can contribute to — and capitalise on — the outcomes of COP26.

Read the Post-COP26 position paper:

The COP27 meeting, held in November 2022 in Sharm El-Sheikh, Egypt, placed a stronger emphasis on adapting to climate change. A significant milestone was achieved with the establishment of a fund dedicated to addressing the loss and damage resulting from extreme weather events.

We believe that partnerships with government agencies, think-tanks, professional bodies, and NGOs are essential in achieving collective wisdom towards a collaborative approach to addressing climate change challenges. Building up to COP27, we had taken proactive steps to foster these partnerships.

One such initiative was the Race to Resilience Asia event series, where we brought together experts,



Source: Post-COP27: Building a more climate-resilient Asia

Arup has identified five crucial steps in its climate action plan designed to achieve both net zero emissions and resilience.

policymakers and stakeholders to discuss strategies for building resilience in various cities across the region, including Ho Chi Minh City, Hong Kong, Jakarta, Kuala Lumpur, Manila and Singapore.

The event series took a comprehensive city systems approach, covering various topics such as energy, water, transport, and inclusive design. Through this approach, we were able to examine the urgent global challenge of climate change from a regional perspective and analyse local insights and solutions.

Race to Resilience Asia event series:

China refines policy framework to give clear directions

As a signatory country of the Paris Agreement, China has committed to decarbonisation goals and has been working diligently towards achieving them since 2020, the year in which the Chinese government made a bold announcement of its dual carbon goals, which include reaching peak CO_2 emissions before 2030 and achieving carbon neutrality by 2060.

In 2022, China also mapped out a strategic plan to enhance its climate resilience, putting emphasis on both adaptation and mitigation in the face of global climate change. The country will seek to build a climate-resilient society by 2035, with significant improvements in its ability to adapt to climate change, according to the national climate change adaptation strategy 2035 jointly released by 17 departments, including the Ministry of Ecology and Environment.

Complementary to each other, adaptation and mitigation are two major strategies for tackling climate change. Mitigation focuses on reducing greenhouse gas emissions and increasing carbon sinks, while adaptation emphasises the prevention and reduction of the impacts and risks of climate change.

In April 2023, the Chinese government released the 'Guidelines for the Construction of the Standard System for Carbon Peaking and Carbon Neutrality' to provide more precise guidance for formulating strategies and policies. The framework identifies four key areas where priorities are placed: (1) emissions monitoring, audit, and reporting, (2) carbon reduction, (3) carbon removal, and (4) market mechanism.

This framework provides a roadmap for decarbonisation efforts in the private sector; promoting the use of clean energy; establishing standards for carbon emissions reduction; and providing financing opportunities to meet these goals.

Emissions monitoring, audit and reporting	Carbon reduction	Carbon removal	Market mechanism
• Terminology, taxonomy, and disclosure standardisation • Monitoring, audit, reporting, and assessment • Low carbon management and evaluation	• Energy efficiency • Non-fossil energy sources • Clean and low-carbon utilisation of fossil energy sources • Production and service procedures • Resource recycling	• Carbon sink • Carbon capture, utilisation and storage (CCUS) • Direct air capture (DAC)	• Green finance • Carbon trading • Ecological product value (EPV) realisation

The Chinese government has released the 'Guidelines for the Construction of the Standard System for Carbon Peaking and Carbon Neutrality' to provide more precise guidance for formulating strategies and policies.

The Guidelines for the Construction of the Standard System for Carbon Peaking and Carbon Neutrality (Chinese version only).

Corporate ESG transformation

Whether it is the public or private sector, achieving environmental, social and governance (ESG) goals has become increasingly critical. Implementing decarbonisation and climate resilience measures are now integral parts of these goals, either required as part of mandatory objectives or pursued as part of a mission. Moreover, meeting these goals has taken on even greater significance in the face of increasingly stringent regulatory environments.

In this issue, we showcase how Arup advisory services can help large organisations and listed companies meet the ever-growing and increasingly stringent ESG compliance standards. Our services go beyond that, as we help them develop and implement decarbonisation strategies and mitigate climate change risks while providing actionable recommendations.

Going beyond green

Buildings are a significant source of carbon emissions, making them a crucial component in achieving decarbonisation goals. Arup has been at the forefront of designing and executing green building projects in the region, contributing to its successful implementation over the years. As highlighted in this issue, the two recently completed projects in Shanghai and Guangzhou — a prime mixed-use development and a smart campus — exemplify Arup's innovative approach to sustainable building and infrastructure design.

It is worth noting that one of our latest concept designs, developed through a competition, envisions a 'future building'. Our design incorporates integrated climate and sustainable design elements into a mixed-use building.

The building design, envisioned as a 230m commercial tower in the heart of Hong Kong, was awarded the top prize in the Future Building category at the inaugural International Advancing Net Zero Ideas Competition organised by the Hong Kong Green Building Council with Swire Properties as the Principal Partner.

Arup's award-winning design goes beyond achieving net zero and carbon neutrality. Our design is driven by both nature and technology, while taking into consideration the UN SDGs.

Offshore wind farm

Sustainable development goes far beyond designing green buildings or infrastructures. A transformational change is needed throughout the entire supply chain, including the energy sector. The planning and development of offshore wind farms in East Asia's clean energy sector is gaining momentum, particularly in regions and countries that have coastal advantages.

To increase their wind energy generation capacity, some countries and regions in East Asia are planning to construct new offshore wind farms or expand their existing ones. Offshore wind farms are more efficient in generating electricity compared to onshore wind farms. In this issue, we showcase our recent research on integrating offshore wind farms into the national energy strategies of certain countries, such as the Philippines. The article also highlights our recent site planning, design and advisory services in Taiwan and Hong Kong.

The design of a future green building envisioned by Arup, which is proposed to be a 230m commercial tower located in the heart of Hong Kong, was honoured with the top prize in the Future Building category at the first-ever International Advancing Net Zero Ideas Competition organised by the Hong Kong Green Building Council.

Hydrogen in transportation

The transportation sector is exploring hydrogen as a potential clean energy option to meet its demands. Researchers are conducting studies to evaluate its technical feasibility, commercial viability, and scalability.

The Aerospace Technology Institute has engaged Arup and other consultants to conduct a comprehensive study, aiming to explore the potential for transforming fuel use in the UK aviation sector. The study evaluates the entire supply chain, including liquefaction, storage, transportation, connectivity, and associated costs. The report was completed in January 2022.

In China, the central government released in March 2022 the country's first-ever long-term plan for hydrogen, covering the period of 2021–2035. The plan outlines a phased approach to developing a domestic hydrogen industry and mastering technologies and manufacturing capabilities. It also emphasises the country's commitment to carbon peaking and neutrality as the driving forces behind these efforts.

To support this long-term plan, we have contributed to a research project led by the Guangzhou Institute of Energy Resources of the Chinese Academy of Sciences, which developed two sets of technical and safety codes for hydrogen generation in hydrogen refuelling stations. This research is vital for advancing research and development and eventually paves the way for the widespread adoption of hydrogen production technology in an urban environment.

The way forward: nature-based solutions

To sustain the progress made in sustainable development, the private sector should be incentivised to reduce carbon emissions. This can be achieved through a combination of carrot-and-stick policies. Strategies for adapting to climate change and developing infrastructure for clean energy are also essential steps. Eventually, nature-based solutions must be put into action.

Nature-based solutions are a viable solution to both climate mitigation and adaptation because they work with nature to address the challenges posed by climate change. By harnessing the power of natural processes and systems, nature-based solutions can reduce greenhouse gas emissions and increase carbon sinks, while also helping to build resilience to the impacts of climate change.

For example, planting trees and restoring degraded landscapes can sequester carbon, reduce the risk of flooding and erosion, and provide other co-benefits such as biodiversity conservation and sustainable livelihoods.

In addition to their climate benefits, nature-based solutions also bring larger benefits to people and the planet. They provide ecosystem services such as clean air and water, food and fibre, and natural resources that support human well-being and economic development. They also help to maintain biodiversity and cultural values and can contribute to poverty reduction and social equity.

Ultimately, integrating nature-based solutions into our decarbonisation, climate mitigation and adaptation strategies will be critical to achieving a more sustainable future for all.

Supporting corporate ESG transformation

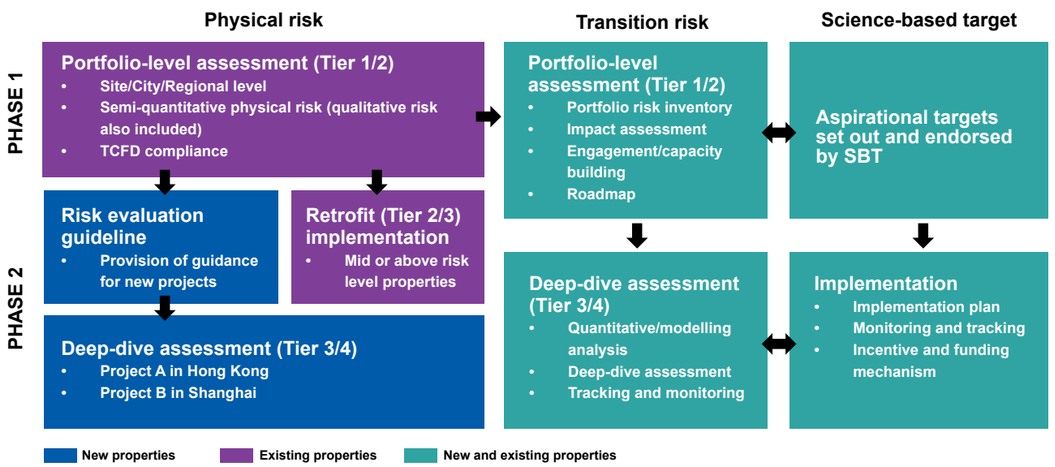
Arup's integrated climate and sustainability services provide clients with a comprehensive analysis of the environmental and economic benefits associated with their actions. With the firm's multi-disciplinary expertise, clients can confidently calculate cost analysis and effectively justify their sustainability measures from an economic perspective.

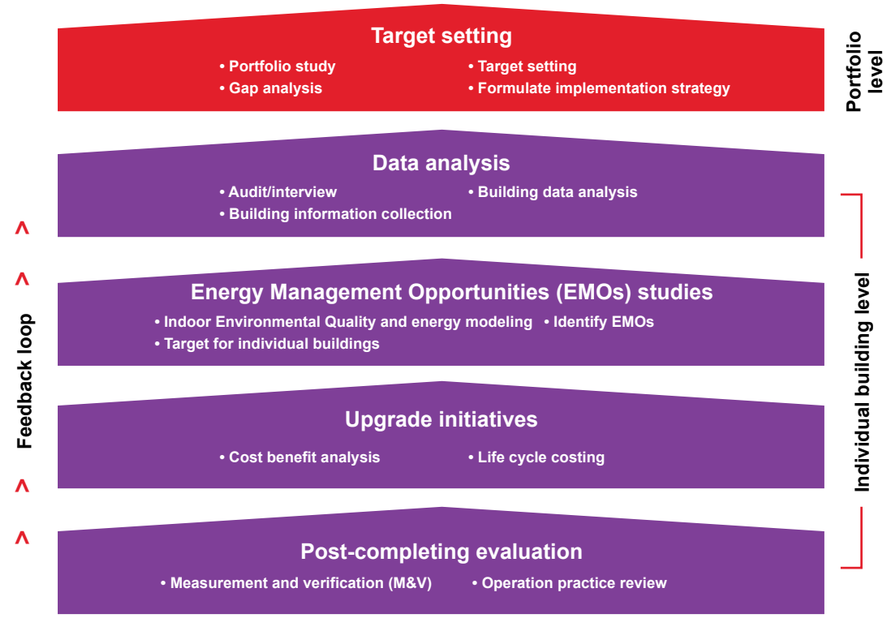
As Hong Kong works towards its Climate Action Plan's net zero goals by 2050, the city's leading property developers have committed to achieving their decarbonisation goals. While it may sound easy to set goals, mapping out action plans, measuring progress, justifying costs, and disclosing relevant information is easier said than done. To address this challenge, many of them have consulted Arup to set realistic targets and strategies.

For large organisations to effectively create and execute successful decarbonisation strategies, minimise their risk of climate change, and create robust environmental, social and governance (ESG) practices, it is critical to involve all stakeholders. This includes setting clear objectives, creating action plans, and enabling implementation.

Arup's integrated climate and sustainability services offer clients a comprehensive analysis of not only the environmental benefits but also the cost-effectiveness and financial advantages. With our engineering expertise, we enable clients to calculate cost analysis and justify their measures or actions, ensuring that they can make informed decisions that align with their goals.

In doing so, Arup engineers from different disciplines collaborate with climate and biodiversity experts, as well as stakeholders within the client organisation, to jointly develop comprehensive solutions, from Smart, Green and Resilient urban planning strategies and building energy-efficient infrastructure, to managing and optimising building energy efficiency and reporting metrics to fulfil compliance requirements.





Task Force on Climate-related Financial Disclosures (TCFD)

Listed property developers face a unique set of challenges when it comes to complying with the listing rules regarding ESG disclosure. In response, the Task Force on Climate-related Financial Disclosures (TCFD) has drafted a set of recommendations to help simplify the process. Our climate service flow is structured in line with TCFD recommendations. This helps ensure that property developers are compliant with major applicable ESG disclosure rules while promoting sustainability practices within their operations.

Meanwhile, regulators are currently assessing the ISSB Climate Standard, which builds on the principles of the TCFD recommendations. If the final ISSB standards meet regulators' expectations, which could lead to major exchanges using them to set sustainability disclosure requirements. Therefore, we will closely monitor any developments related to the ISSB Climate Standard implementation and ensure that we are well-equipped to assist our clients in meeting their reporting obligations effectively.

Charting organisational decarbonisation pathways

Client: MTRC

As the project consultant, we worked with MTR Corporation to establish a carbon reduction roadmap for the company's railway and property businesses towards 2030, 2040 and 2050, using the Science-Based Target initiatives (SBTi), with the goal of attaining carbon neutrality by 2050 and creating an actionable zero-carbon plan. Both top-down and bottom-up approaches were adopted to develop technically feasible and budgeted actions, covering existing and new properties, railroads, stations, depots, and rolling stock.

To secure companywide support, workshops and site visits were conducted with various departments and divisions to thoroughly understand their difficulties and needs. This was to ensure that all parties agreed on the action plans, which include energy saving and carbon reduction initiatives, sourcing of renewable energy and new investment strategies.

To develop a comprehensive carbon reduction targets and roadmap, we drew on global

benchmarking insight into the most cutting-edge and upcoming technologies. Additionally, we conducted extensive carbon emission modelling and financial analysis for key initiatives.

Considering future economic growth and business development, a life-cycle approach analysis for MTRC's wide range of portfolio was conducted. This also predicted future carbon emission and evaluated how to reduce it through different interventions. With Arup's strategic planning, MTRC has continued to partner with Arup for the Stage 2 Carbon Study to support the next step in science-based target verification and future carbon management to achieve its carbon neutrality target.

Actionable SBTi plans

Client: Nan Fung Development

We are collaborating with Nan Fung to develop a plan of action in accordance with the SBTi guidelines aimed at reducing carbon emissions. This roadmap encompasses all of their properties, including hotels, residential, office and retail spaces.

Drawing on our in-depth knowledge of the Hong Kong property market, insight into Nan Fung's ESG focus and big data analysis, we are formulating cost efficient, sustainable plans with achievable objectives that match Nan Fung's vision while aiming to reach net-zero goals in the future.

Fostering landlord-tenant ESG partnership

Client: Henderson Land

To align its commitments with that of the Hong Kong government's 2050 carbon neutrality pledge, Henderson Land has promised to make all new office development projects meet BEAM Plus Gold standards or higher. Not only that, but the developer is aiming to reduce their emissions across the board – Scope 1, 2 & 3. These include all kinds of emissions associated with the company's business operations, directly and indirectly related to the organisation's value chain.

To help Henderson Land account for Scope 3 emissions related to its tenants, Arup has designed an industry-first Landlord-Individual-Tenant ESG Partnership Programme, taking sustainability to the next level for all of Henderson Land's building occupants. The ESG partnership programme is underpinned by four pillars: Carbon Neutrality, Health & Well-being, Integrated Culture, and Partnership for Good.

This programme is designed to motivate and incentivise tenants and their employees to pursue sustainable goals based on data, as well as to take part in ESG-positive initiatives and be rewarded for it. The goal is to enable a collective shift towards ESG advancements.

Our big data management platform based on Neuron™, a proptech platform developed by a joint venture between Arup and Venturous Group, enables tenants to easily monitor and evaluate their efforts. This allows them to create effective ESG reports and have transparency in their ESG performance. Neuron™ has harnessed modern digital twin technology to create a digital version of the physical building. This digital twin then processes data, empowering users to make better decisions and optimise their operations.

Combining BIM and facility management modules, a comprehensive set of data covering 12 ESG areas such as energy, carbon emissions and waste operations are visualised in real-time. This gives tenants an understanding of how they can develop their own effective ESG strategy. Such a comprehensive building data platform is an essential tool for organisations seeking to comply with local and international ESG sustainability assessment standards, such as the Hang Seng Corporate Sustainability Index, the Dow Jones Sustainability Indices and the Morgan Stanley Capital International (MSCI) ESG Indexes.

Furthermore, the platform is capable of providing assistance with ESG reporting disclosures such as those required by Hong Kong Exchanges and Clearing Limited ESG Reporting, Global Reporting Initiative (GRI), and the TCFD recommendations.

Separately, to facilitate setting up of a carbon reduction target for Henderson Land, Arup has conducted energy and carbon audits for six existing commercial and retail buildings to get an initial feel of potential carbon reductions for the entire existing building portfolio. Arup has also conducted energy and carbon audits for six commercial and retail projects of Henderson Land to help the group set portfolio-wide decarbonisation goals.

Assessing physical and transition risks

Client: Swire Properties

This ongoing project aims to investigate and analyse the physical and transition risks linked to climate change for Swire Properties. It will assess possible risks along with potential opportunities related to a lower-carbon economy taking into account the TCFD framework.

We have conducted a climate change risk assessment on 60+ buildings across seven cities including Hong Kong and those in mainland China and North America. This was an analysis of potential climate hazards and vulnerabilities of their respective properties. The climate change risk assessment aims to evaluate the importance of each business and operation area to potential climate change impacts. Based on the results, a resilience plan has been prepared along with recommendations to mitigate key climate risks.

Climate change risk assessment

Client: New World Development

For New World Development, we have conducted a climate change risk assessment on over 25 properties in Hong Kong and mainland China, analysing potential hazards and vulnerabilities that these properties may face.

An assessment was conducted to analyse the sensitivity of operational elements to the impacts of climate change. Based on the findings, a resilience plan and a set of proposed measures were developed to mitigate any critical risks associated with climate change.

Once this climate change risk assessment project on the company's portfolio is completed, details regarding the physical and transition climate-related risks and opportunities will be disclosed in accordance with the TCFD recommendations.

Arup has designed an industry-first Landlord-Individual-Tenant ESG Partnership Programme, which aims to take sustainability to the next level for all occupants of Henderson Land's buildings. The Shanghai 155 - Henderson Metropolitan complex in Shanghai, China is pictured above.

To ensure climate resilience of the client's new buildings, it is essential to create a list of recommended key initiatives which should be factored into their design and operation. Therefore, we have also developed a Climate Resilience Strategic Guidance for New Buildings. This guidance outlines the high-level principles and strategies for overcoming various climatic hazards such as flooding, extreme heat and cold, strong winds, water shortages, and more.

Advisory on climate adaptation strategy

Client: Hang Lung Properties

The study examined ways for Hang Lung Properties to adapt to climate change and improve its climate-related governance, development plans, and disclosures in line with the TCFD recommendations.

In the study, we assessed the physical climate hazards, including flooding, tropical cyclones, and heatwaves, for four properties in mainland China and 11 properties in Hong Kong. We conducted scenario analyses, referencing both local and international scientific data and findings. We also utilised downscaling techniques to compile and derive climate projections for specific climate risks.

A risk resilience assessment was conducted to identify and evaluate the potential impacts of climate risks on the client's business and operations. This assessment helped determine the level of vulnerability and criticality for different areas, allowing the client to prioritise adaptation needs among their existing properties.

Comprehensive Climate Resilience Consultancy for West Bund Financial Hub

Client: Hongkong Land

Hongkong Land is leaving its mark on Shanghai's skyline with the acquisition of the West Bund site. Covering an area of over 23.1 hectares and located on the riverfront of Xuhui District, this mixed-use development is poised to become a prestigious new landmark in Shanghai's vibrant cityscape.

Thanks to the municipal and district governments' visionary plans to establish a new global financial hub, the project is on track and scheduled for completion in five phases by 2027. With a vast developable gross floor area of over 1.1 million square metres, this ambitious undertaking is set to transform the city's landscape and cement its position as a leading international financial centre.

Hongkong Land has enlisted the climate and sustainability services of Arup to conduct a thorough climate resilience study for the West Bund Financial Hub project in Shanghai.

Once completed, this iconic project will encompass a wide range of top-notch amenities, such as Grade-A offices, a world-class retail mall, luxurious hotels, upscale residences, a cutting-edge convention centre, and a plethora of cultural, sports, and recreational facilities.

To ensure that the development meets the highest environmental standards, Hongkong Land has engaged the climate and sustainability services of Arup to carry out a comprehensive climate resilience study. The study comprises several key components, including:

– Climate projections until the end of the century, as referred to in the IPCC Assessment Report 6, are modelled using suites.

– Updating design parameters based on projected future climates.

– Climate resilience engineering design.

– Estimating the financial implications of climate change.

This process empowers Hongkong Land to identify areas in need of improvement. Our team of expert engineers specializes in drainage, electrical, HVAC, structure, and façade. They join forces to offer a comprehensive approach in addressing any issues.

By leveraging climate projections, our team, which includes climate scientists, collaborated closely with the client to identify potential adjustments for all engineering designs. This comprehensive approach guarantees that our advice is specifically tailored to the project's requirements and can be implemented effectively.

In addition to providing climate resilience engineering design, Arup has also assisted the client in quantitatively estimating financial risk using a bottom-up approach within the TCFD framework. By doing so, we were able to provide a quantitative assessment of climate risk and gain buy-in from relevant stakeholders.

Offshore wind farm: going bigger and deeper

As East Asian countries strive to reduce their carbon footprint, offshore wind farms have emerged as a promising solution for generating electricity. In addition to benefiting from higher and more consistent wind speeds, offshore wind turbines offer multiple advantages over their onshore counterparts.

Some East Asian countries are building more or new offshore wind farms to harvest wind energy more effectively and efficiently for their decarbonisation goals. Compared to their onshore counterparts, offshore wind farms provide a more reliable source of electricity, thanks to higher and steadier winds that are captured by larger blades, allowing for the generation of more power per turbine. Countries and regions bordered by the sea, such as China, Taiwan, Japan, Korea, Hong Kong, the Philippines, and Vietnam are planning to build more offshore wind farms and take advantage of their marine environment.

When planning and designing offshore wind farms, engineers must consider a variety of factors, such as the site characteristics as well as operational and maintenance challenges. It is also essential to take into account the extreme climatic conditions at the planned location, as well as any potential regional seismic hazards.

Thought leadership in clean energy strategy

Over the past few years, policymakers, energy companies, infrastructure developers and investors have enlisted Arup to help them with the planning and design of offshore wind farms in the region.

To better inform policymakers and energy companies in East Asia, Arup has conducted various research studies to demonstrate how offshore wind farms can be utilised as part of their national energy strategies.

Our research findings help them create well-thought-out plans and objectives for the future of renewable energy. One recent study was commissioned by the World Bank in collaboration with BVG Associates, advising emerging markets on how they can prepare for the increased use of renewable energy generated by offshore wind farms.

For a country to be successful in adopting clean energy, the report has identified four pillars:

1. Strategy

– Security of energy supply
– Cost-effective energy for consumers
– Economic benefits
– Climate and environmental obligations
– Attracting foreign investment

2. Policy

– Volume and timescales
– Cost of energy
– Local jobs and economic benefit
– Environmental and social sustainability

3. Frameworks

– Marine spatial planning
– Leasing
– Permitting
– Off-take and revenue
– Export system and grid connection
– Health and Safety, standards, and certification

4. Delivery

– Industry oversight
– Supply chain
– Ports
– Transmission network
– Financing

The report further recommends implementing rules to increase transparency in the energy market and achieve compliance with affordable clean energy goals.

Recommended actions for the Philippines

According to another report compiled by Arup for the World Bank, the Philippines' total technical potential offshore wind resource is estimated at 178 GW. Large areas around the country's coast have technically extractable wind resources. Approximately 90% of these resources are found in waters deeper than 50m, necessitating the use of floating offshore wind turbines. This report's proposed roadmap is the first step in creating a successful offshore wind industry in the Philippines.

To help focus efforts, the roadmap groups actions into priority themes, corresponding to immediate, near-term, and longer-term actions for the Philippine Government to consider.

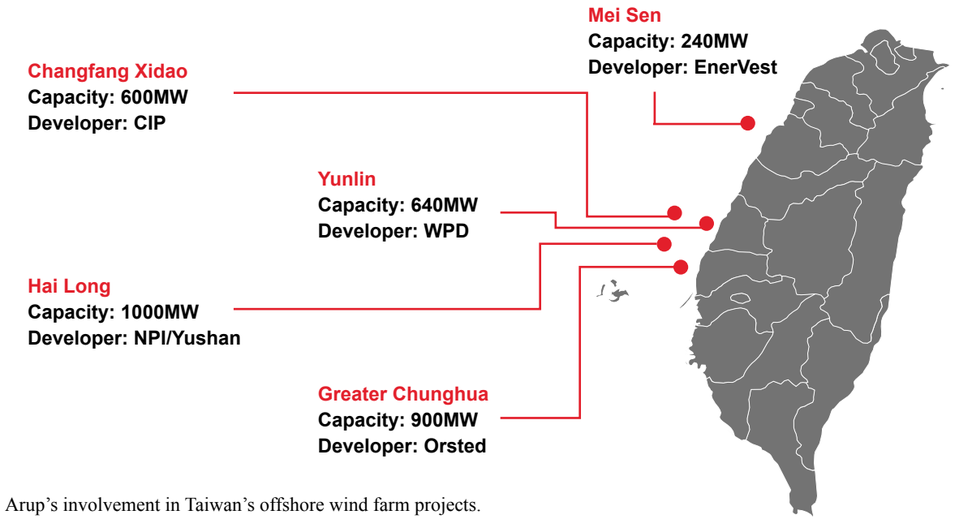
Helping Taiwan achieve its offshore wind farm strategy

Taiwan is a highly developed offshore wind energy market in East Asia. To help reach its net-zero emissions target, the island's government outlined ambitious goals for offshore wind power in their 2022 report.

This report reviews a plan for the island to generate 60% of its total energy from renewable sources by 2050. It additionally specifies that 40GW of wind-power capacity is expected to be installed by then; half of this amount is due to be set up by 2035.

Key Factors for Successful Development of Offshore Wind in Emerging Markets

Offshore Wind Roadmap for the Philippines



Arup's involvement in Taiwan's offshore wind farm projects.

Currently, Taiwan has two operational offshore wind farms, with a combined capacity of 237MW. Formosa 1 was completed in 2019 with a capacity of 128MW, followed by the Taipower offshore wind farm, which was completed in 2022 with 109MW. Both are managed by the Taiwan Power Company (Taipower).

These two facilities will soon be supplemented by four major projects in round 2, which, combined, will contribute an additional 2.5 GW of electricity.

All four upcoming wind farm projects in round 2 — Changhua 1 & 2a (900MW), Formosa 2 (376MW), Changfang Xidao (589MW) and Yunlin (640MW) — are located off Taiwan's western coastline near the Taiwan Straits, where most of the population resides.

In round 3, four offshore wind farms have been awarded by the Taiwan government but have yet to move into the construction phase. These include Hai Long 2 & 3 farm (1,044MW), Changhua 2b and 4 farm (920MW), Zhong Neng farm (300MW) as round 3.1, as well as another 300MW Taipower project as round 3.2.

Over the past few years, Arup has been engaged by various developers to advise on site assessment and planning, foundation design, structural engineering, electrical engineering, and project management of the Changfang Xidao, Yunlin, Hai Long, and Greater Changhua projects.

Technical due diligence leads to successful acquisition

By the end of 2022, Gentari, the clean energy business of the Malaysian oil and gas company Petroliam Nasional Bhd (Petronas), acquired a 29.4% stake in the 1,044MW Hai Long offshore wind project in Taiwan from Northland Power Inc., which had held a majority 60% stake in the project.

Gentari's decision was made partly based on Arup's technical due diligence advisory services. To bring clarity to the prospect and facilitate the client's investment decision, Arup undertook a wide-ranging review, including detailed review of the competition's capacity to be awarded; review of the project company's participants, key contractors and sub-contractors' track records, resources, procurement plans and their local facilities; technical review of engineering and design, including wind turbine generator, foundation, electrical works and other major components; and review of procurement plan and compliance with local supply requirements.

We also evaluated potential risks associated with the local supply chain, upcoming facility plans, and the ability to implement project plans. Furthermore, we conducted a rigorous review of the project itinerary, financial projections, consent forms and permits.

Designing Hong Kong's first offshore wind farm

By early 2023, the Hong Kong-based CLP Power was seeking government approval for an offshore wind farm project off the coast of Sai Kung for construction. The proposed project is located about 9km east of the Clearwater Bay peninsula and 5km east of East Ninepin Island in the south-eastern waters of Hong Kong, off the coast of Sai Kung district in water depth of approximately 30m.

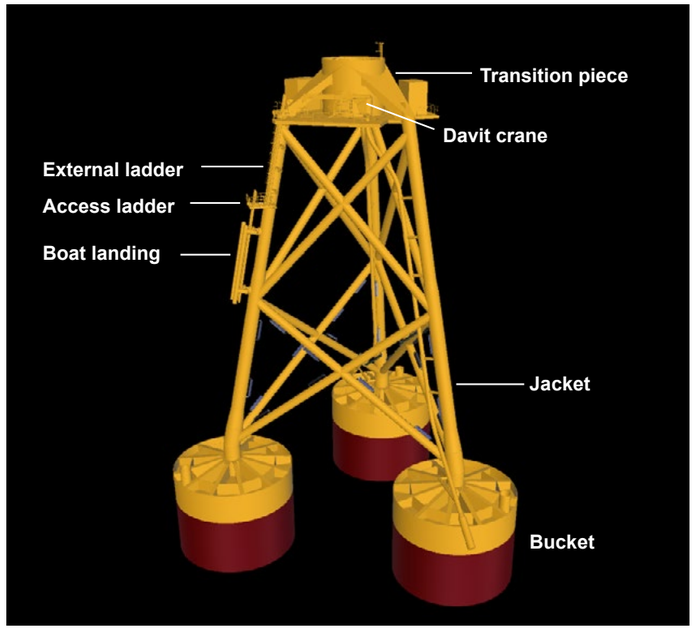
Analyses of seabed conditions show favourable conditions that should allow for the installation of suction bucket jacket foundations, an innovative foundation type that reduces environmental impact. The Environmental Protection Department mandates the use of suction bucket foundations to avoid the need for piling.

Arup pioneered the development for the design for the suction bucket jacket structure, performed site-specific and wind turbine generator-specific Integrated Loads Analysis for at least two wind turbine generator models.

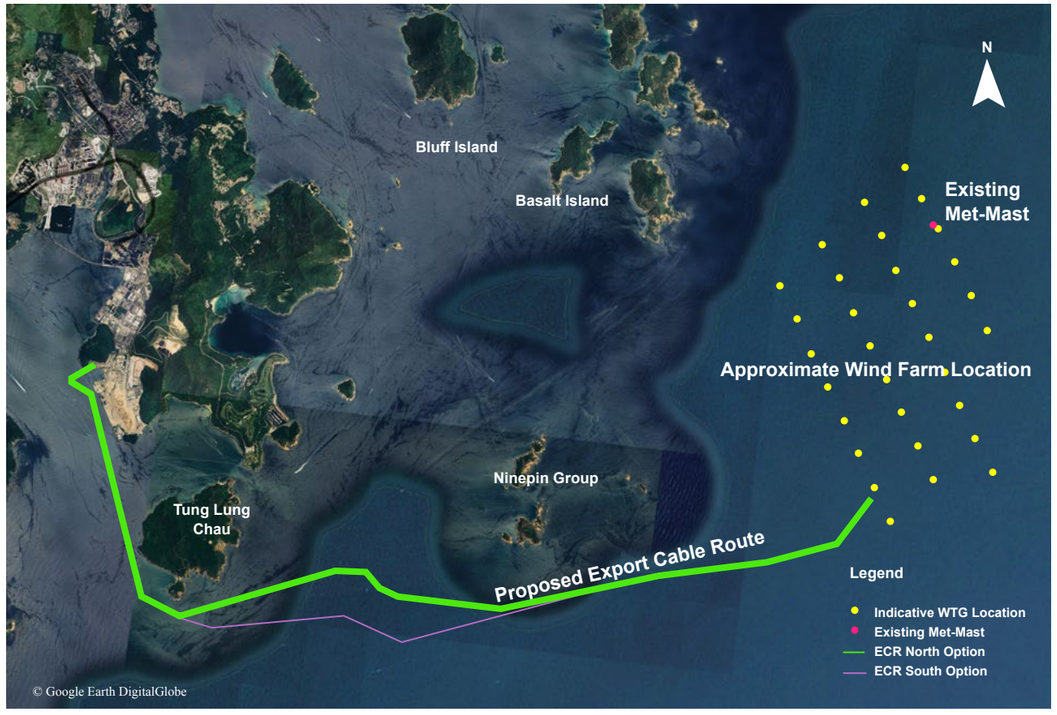
CLP was considering building 17–23 wind turbine generators, each with a capacity of 11–15MW, as well as inter-array cabling at a voltage of 66kV, one 66kV/132kV offshore substation, and 2–3 x 132kV export cables of approximately 20km in length to a landing point in the Fat Tong Chau area.

CLP is aiming to commence construction of this new offshore wind farm project at the start of the 2024 development plan cycle. They commissioned Arup to perform technical feasibility work for this project, which would be the first of its kind in the city. This included design and engineering services from Arup.

We designed an electrical and auxiliary equipment substation to accommodate up to 255MW capacity, and performed structural, mechanical, and



A three-legged jacket structure supported by suction bucket foundations is considered for the concept design supporting a 15MW wind turbine generator. (J-tubes and galvanic anodes are not shown.)



The proposed offshore wind farm project is located approximately 9km east of the Clearwater Bay peninsula and 5km east of East Ninepin Island in the south-eastern waters of Hong Kong, off the coast of Sai Kung district, in water depth of around 30m.

architectural design of the topside to confirm design feasibility and obtain pre-certification assurance to proceed with detailed design.

We also pioneered the development for the design for the suction bucket jacket structure, performed site-specific and wind turbine generator-specific Integrated Load Analysis for at least two wind turbine generator models, and primary and secondary steel designs at the level required to assess design feasibility and obtain pre-certification assurance to proceed with the detailed design. This included the design, layout and specifications for the inter-array and export cables based on the requirements. High-level schematics were provided to provide an overview of the system.

This commission is the continuation of Arup's design and installation of the first offshore meteorological mast supported on suction bucket foundations in 2012, in which case a met mast was employed to collect wind and metocean data for the purpose of building an offshore wind farm.

Suction bucket foundations are a unique and efficient type of foundation that can provide high stability, durability, and ease of decommissioning for offshore wind farm projects. They are also more flexible and suitable for a wider range of soil conditions. Furthermore, they are considered a more environmentally friendly solution since their impact on marine mammals during construction and future decommissioning is minimal.

Designing aseismic offshore wind turbine foundations in Japan

Japan's offshore wind farms face unique challenges particularly in terms of mitigating the risk of earthquakes and typhoons, which distinguishes them from those in other East Asian countries. Therefore, thoughtful responses to these challenges are essential when designing offshore wind farms in Japan.

Arup has assembled a specialised offshore wind farm design team comprising members from the firm's offices in the UK, Hong Kong, Sydney and Tokyo to develop a unique methodology that not only incorporates Japanese approaches but also ensures compliance with both Japanese and international offshore wind farm and seismic design regulations.

Arup's commitment to excellence is supported by its in-house methodology, which leverages the firm's proprietary automated structural design and optimisation tool. This tool assists in streamlining the design process and ensuring optimal structural performance.

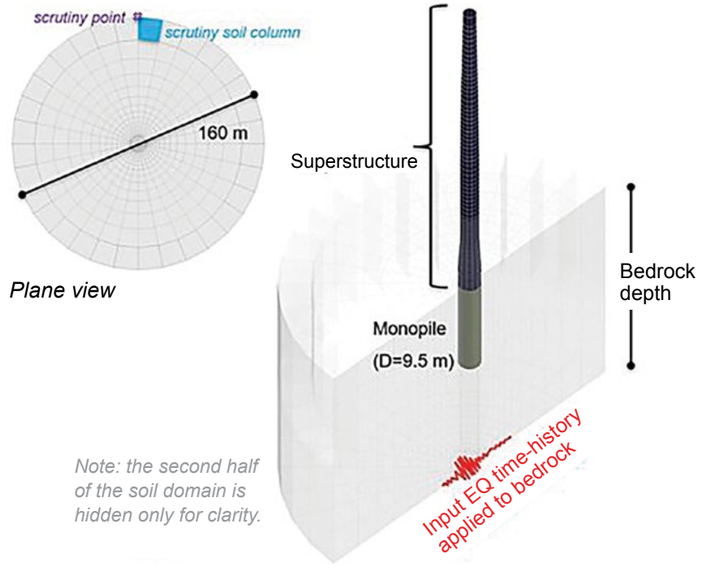
One of the challenges in designing this foundation was incorporating seismic design requirements into a non-seismic design meant for European conditions. To address this challenge, it was necessary to simultaneously evaluate both Japanese and international design requirements during the design process.

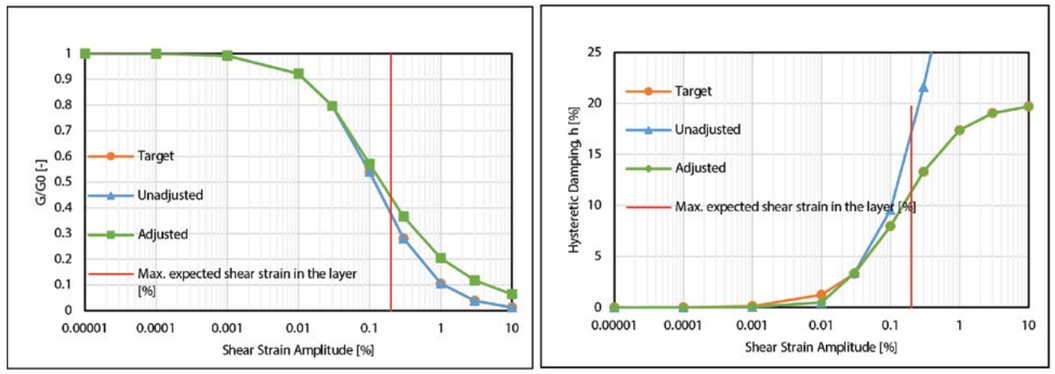
When assessing seismic design for offshore wind foundations, it is important to consider a 500-year return period earthquake and simulate potential soil liquefaction during an earthquake. This ensures the foundations are resilient and can withstand seismic events.

Time history analysis is considered the most appropriate method for evaluating the structural response to earthquake events. This analysis involves using recorded or synthetic ground motion time histories to simulate the dynamic behaviour of a structure during an earthquake.

With this methodology, Arup has supported potential renewable energy developers by delivering an aseismic offshore wind turbine foundation design, enabling them to succeed in their project bidding. This achievement has also positioned Arup as a leading consultant, pioneering offshore wind innovation in the Japanese market.

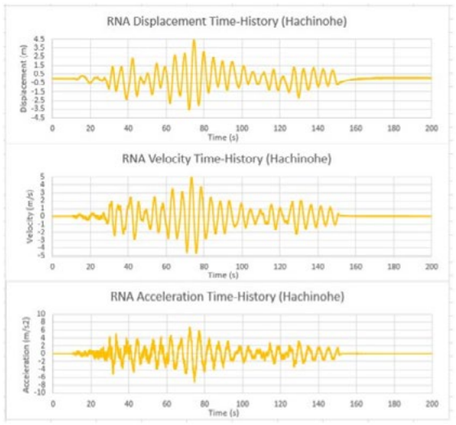
The monopile design has been evaluated for its ability to withstand seismic events. The diameter of the monopile is optimised to ensure its stiffness and resistance to bending. The application of earthquake time-history allows Arup engineers to assess how the monopile and surrounding soil will respond to ground shaking during an earthquake.

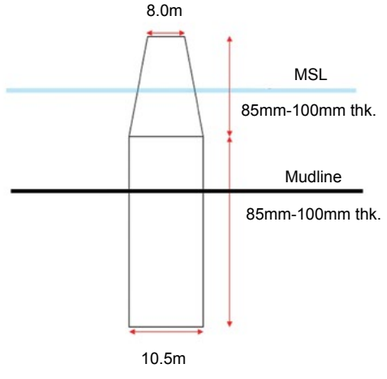




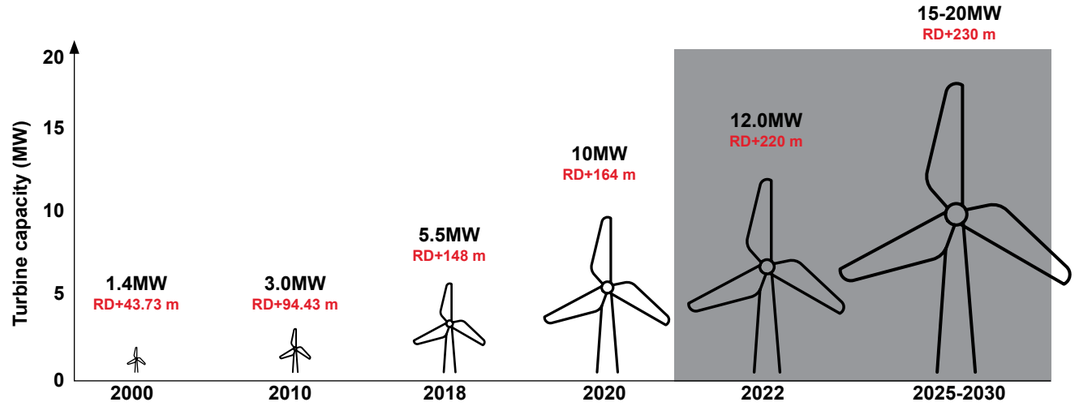
To account for the non-linear soil characteristics of the site at different strain levels, the time history analysis incorporates stiffness degradation curves and damping curves. The analysis also takes into consideration an appropriate soil hysteresis model to define the curves.

These charts illustrate the displacement, velocity and acceleration of the monopile design seismic response in relation to one of the seismic waves fitted to the Japanese Building Standard Law's spectrum (specifically, a Trench type earthquake).





The diagram on the left illustrates the geometry of the monopile foundation designed for offshore wind installations. Determining the mean sea level (MSL) is crucial for designing and installing a wind turbine foundation. Accurate data, including site-specific information, ensures that the foundation is installed with the correct length and diameter to withstand the forces and environmental conditions. Site-specific parameters are hidden in this diagram.



It is estimated that by 2030, a large offshore wind turbine with a rotor diameter (RD) of 230m may produce a capacity of up to 20MW.

Future challenges

As the demand for renewable energy increases, bigger and more efficient wind turbines are being developed to meet this need. While this will bring many benefits, it also poses its own set of engineering challenges that must be addressed.

To take offshore wind farms to the next level, more advanced materials that are more resilient and durable need to be developed. This will enable the wind turbine structure to withstand increased levels of stress from the wind and waves, which is particularly important in Asia Pacific where typhoons occur during summer months. Meanwhile, larger turbines require larger and more stable foundations to support them. This can be challenging in areas with deep water or poor soil conditions.

While the amount of energy that can be generated by a single offshore wind farm depends on a number of factors, including the size and design of the turbine, the wind speed and direction of the installation site, and the efficiency of the turbine's components, it is estimated that by 2030, a large offshore wind turbine with a rotor diameter of 230m may produce a capacity of up to 20MW.

Arup will continue its innovative approach to helping with offshore wind farm deployment in order to mitigate risks associated with climate change and reduce any other negative environmental impacts.

Clearing the runway for sustainable aviation

To achieve net-zero carbon emissions in the aviation sector, a combination of lower and zero carbon fuels will be necessary in addition to relatively mature renewable energy sources.

At the 77th International Air Transport Association (IATA) Annual General Meeting in October 2021, a resolution was passed by IATA member airlines committing them to achieving net-zero carbon emissions from their operations by 2050.

Despite a history of efficiency improvements in areas such as aerodynamics, propulsion and operations, the aviation sector acknowledges that these improvements alone will not be sufficient to meet the CO_2 emission targets in a growing market.

To achieve net-zero carbon emissions within the aviation industry, a combination of renewable energy sources will be necessary. This can include solar panel installations, offsetting, and the utilization of more advanced renewable energy sources.

With well recognised expertise in engineering design, Arup has a team of highly skilled engineers who specialise in the design and implementation of renewable energy infrastructure for the transportation sector.

Drawing on our thought leadership, we conduct research from time to time to assist clients and policymakers in staying up to date on emerging technologies. We also conduct feasibility studies to identify potential solutions. In recent years, we have conducted a few studies around the world to study the potential of hydrogen-powered aviation.

Hydrogen in aviation: end-to-end supply chain study

Client: FlyZero – Aerospace Technology Institute

To explore the potential for transforming fuel use in the UK aviation sector, the Aerospace Technology Institute has commissioned Arup, alongside other consultants, to conduct a study and look at the end-to-end supply chain, including liquefaction, storage, transportation and connectivity, costs, and environmental impact. The report was completed in January 2022.

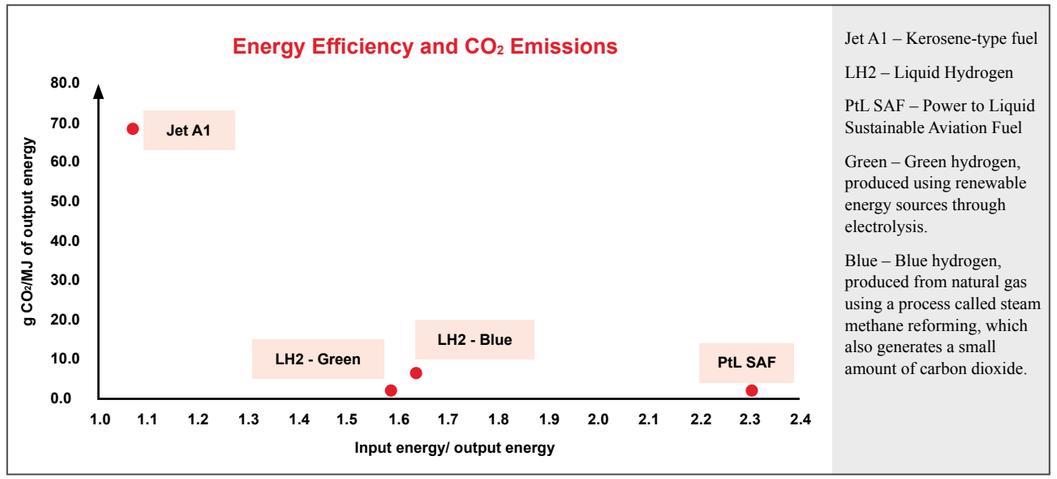
Energy efficiency and carbon emissions

Hydrogen has the potential to become an ideal fuel for the aviation sector. In addition to its near-zero and zero carbon emissions, hydrogen boasts a high energy content per unit mass, approximately 190-196 MJ/kg. This is nearly four times higher than that of jet fuel, which stands at around 46 MJ/kg. This means that hydrogen can store more energy in a smaller mass, making it an attractive fuel option for aircraft, where weight is a critical concern.

The following table extracted from the report compares the embodied energy and emissions across the main pathways for supplying conventional jet fuel, hydrogen, and synthetic fuels.

Fuel	Pathway	Embodied energy (MJ/kg fuel)	Embodied emissions (CO_2/kg fuel)	Output energy (MJ/kg)
Jet A1	Conventional	46	3,160	43
Hydrogen	Green	190	260	120
Hydrogen	Blue	196	1,294	120
Synthetic	Power-to-liquid via green hydrogen	99	128	43

Comparison of pathways in terms of embodied energy and emissions.



Liquefaction

Hydrogen has a low density, which means that it must be either compressed or liquefied to be stored efficiently. This requires significant investments in storage and transportation infrastructure. For aviation, hydrogen must be liquefied (in all but small-scale uses), which requires appreciable electrical power.

To address this limitation, the report examines the potential annual demand in the UK for electrical energy in the liquefaction process. It also considers the additional costs related to liquefaction, transport, and connectivity, as well as environmental concerns.

Storage

There are several methods available for hydrogen storage, which play a crucial role in meeting diurnal and seasonal demand requirements. Whether it is for operational or strategic purposes, hydrogen storage is a significant factor to consider.

Geologic storage options can be used for very large-scale gaseous storage. Salt caverns, depleted oil and gas reservoirs, aquifers, and hard rock caverns are all examples of geologic storage means. For aviation use, liquid hydrogen is the preferred option as it can be stored in very-high pressure tanks. Cryogenic storage will form an important part of the solution for small-scale applications such as on aircraft.

To use cryogenic storage, liquid hydrogen is a volumetrically much more efficient means of storing hydrogen compared with gaseous hydrogen and, in any event, is required for fuelling most hydrogen aircraft concepts. Note: Some short-range aircraft use compressed gaseous hydrogen, but concepts for medium- and long-range aircraft require liquid hydrogen.

For large quantities of liquid hydrogen, static storage is in tanks. The tanks are spherical as this presents the lowest surface area for the contained volume to minimise the boil off losses due to thermal gain. The tanks are pressurised to around 7 bar with perlite thermal insulation within the annulus between inner and outer shells, which is also maintained at a vacuum.

Transport and connectivity

Pipeline transport of hydrogen is the most effective method of moving large volumes of gaseous hydrogen. Pipeline transport of hydrogen can be achieved either as pure hydrogen at different pressures or by blending it into existing natural gas transmission and distribution pipeline systems at various blend percentages and pressures. The report further examines road, rail and ship transport options, including their applicability, challenges and cost implications.

Environmental issues

To gauge the environmental impact of generating hydrogen, the report assesses how different pathways affect the overall well-to-wake emissions and corresponding mitigation measures, including the embodied energy and emissions of blue, green and synthetic hydrogen, the need to offset the embodied emissions associated with each fuel needed to achieve carbon neutrality or net zero, and

Pipeline transport of hydrogen is the most effective method of moving large volumes of gaseous hydrogen.

the impacts of emissions of low CO_2 fuels.

Conclusion

The total UK demand for hydrogen in aviation has been estimated by FlyZero, to be anywhere between 1.6 and 4.0 million tonnes a year by 2050. The UK is estimated to have produced around 0.7 million tonnes of gaseous hydrogen in 2019, largely for industrial and chemical purposes, such as making ammonia and fertilisers. Increasing hydrogen production two-fold to five-fold between now and 2050 is not of itself a huge challenge.

As recommended in the report, the UK as a whole must embark on a transition from a largely natural gas powered present to a sustainably fuelled future. The National Grid's Future Energy Scenarios document offers three possible futures under different assumptions. But all three anticipate the need to increase by six-fold or more the amount of sustainable electricity produced in the UK. And all three scenarios allocate 80 TWh of hydrogen energy to a combination of maritime and aviation usage. This trajectory is broadly consistent with the FlyZero planning scenario and shows that, while aviation faces a transition to new fuels of some magnitude, the same is equally true for the UK as a whole.

The report points out that there are some important policy issues that need to be addressed. In the UK, the cost of producing blue hydrogen is lower than the cost of green hydrogen. While the carbon emissions can be managed to a large extent, it is still a non-renewable, extractive process. Policymakers should therefore consider whether interventions to encourage green hydrogen are in the public interest.

Second, the cost of electricity supplied by solar plants abroad will be cheaper than North Sea wind-generated electricity. Thus, if left to market forces, one might expect to see the UK becoming reliant on imported hydrogen. This entails geopolitical consequences concerning security of supply.

Finally, the scale of liquefaction that will be required is orders of magnitude greater than is currently being delivered. This will be a key technological capability that is essential, specifically for hydrogen's use in aviation at any significant scale. Policymakers should consider whether this is a strategic capability that UK should develop.

Solar PV feasibility study for Hong Kong International Airport

Client: Airport Authority Hong Kong (AAHK)

The AAHK and its key aviation-related business partners have committed themselves to achieving net zero carbon by 2050 at the Hong Kong International Airport, with a midpoint target of 55% absolute emissions reduction by 2035 from a 2018 baseline. Installing solar panels to harvest heat and solar hot water system where possible and purchasing renewable energy certificates are part of the AAHK's carbon neutrality plan.

In September 2023, we completed a feasibility study for the AAHK to deploy solar panel within the Hong Kong International Airport. This is a first such photovoltaic (PV) study in Hong Kong. The study covers all existing buildings and planned developments owned and controlled by the AAHK, its key aviation-related business partners that joined the 2050 Net Zero Carbon Pledge, government departments located on the Airport Island, including those at the Three-Runway Systems site, and other spaces such as car parks, transport shelter canopies, open areas and marine coves on the Airport Island.

This study is a breakthrough in the use of PV cells in an airport environment. They are typically off limits to airports due to their visibility and potential interference, but this solar energy is showing promise and suggests that solar cells installed on airport rooftops could provide a significant power source for an airport.

In addition to researching the latest global solar technologies for air travel, the report also includes comparative case studies from other international airports, including a high-level case study about floating PV under development, and another feasibility study on deploying integrated PV technologies on the southern and eastern façades of Terminal 1.

Owing to safety concerns, solar installations will have to comply with stringent safety regulations including structural safety, and resilience to extreme weather. They must not create any glare that could interfere with pilots' vision. In the report, we have identified the potential disruptions to airport operations caused by installation and construction works.

The report further includes the most important components of deciding whether to go solar: installation cost, long-term energy savings and potential impact on the environment. Meanwhile, remote monitoring and proper maintenance are important to ensure that the solar panels are working optimally over the course of their lifespan.

The study includes developing an overarching PV implementation roadmap for the AAHK in the short term (0-2 years), medium term (2-5 years) and long term (5-10 years), with a target to achieve 55% absolute emissions reduction by 2035 against a 2018 baseline.

Arup has recently completed a feasibility study for the Airport Authority Hong Kong to deploy solar panels at the Hong Kong International Airport.

Building a greener future

These two recently completed projects in Shanghai and Guangzhou respectively demonstrate Arup's innovative approach to sustainable building and infrastructure design. From smart campuses to prime office towers, they set a new standard for sustainability by seamlessly combining green features with architectural beauty and functionality.

Client:
CapitaLand

Scope of services:
Sustainable development strategy, smart building design, HVAC system design, vertical transportation consultancy services, and commercial renovation design review

Raffles City The Bund, Shanghai

Located in the North Bund, Raffles City The Bund occupies a prime location and is the third Raffles City commercial complex in Shanghai, as well as the world's 10th. This development, which opened in July 2021, features a shopping mall and two 50-storey Grade-A office buildings, offering a total gross floor area of 420,000m².

The project sets a new benchmark for green buildings in China, with three green building certificates, including China Green Building Label, US LEED and UK BREEAM.

Arup provided sustainable development strategy, smart building design, HVAC system design, vertical transportation consultancy services, as well as commercial renovation design review throughout the planning, design and construction stages.

Energy efficiency

Raffles City The Bund utilises refrigerants and HVAC systems to minimise CO_2 emissions. After analysing the building's energy consumption, the Arup team designed a wide range of energy-saving features including ice storage cooling system, daylight sensors and high-efficiency lighting system. High-efficiency mechanical equipment were installed, such as energy-efficient air-conditioning system with high performance cooling towers and variable speed drives for pumps.

To achieve an optimal balance between energy cost and occupant comfort, we recommended the implementation of an ice storage cooling system. This system involves making ice during off-peak hours when electricity tariffs are lower, helping to reduce energy costs by up to 25%, when compared with traditional cooling systems.

Apart from optimising the design of the building envelop to encourage natural ventilation and lighting, we further used Computer Fluid Dynamics (CFD) simulations to optimise the curtain ventilator system and analyse the interior airflow distribution with both natural and mixed ventilation strategies. The aim of which was to reduce the energy consumption, improve indoor air quality and thereby occupants' thermal comfort.

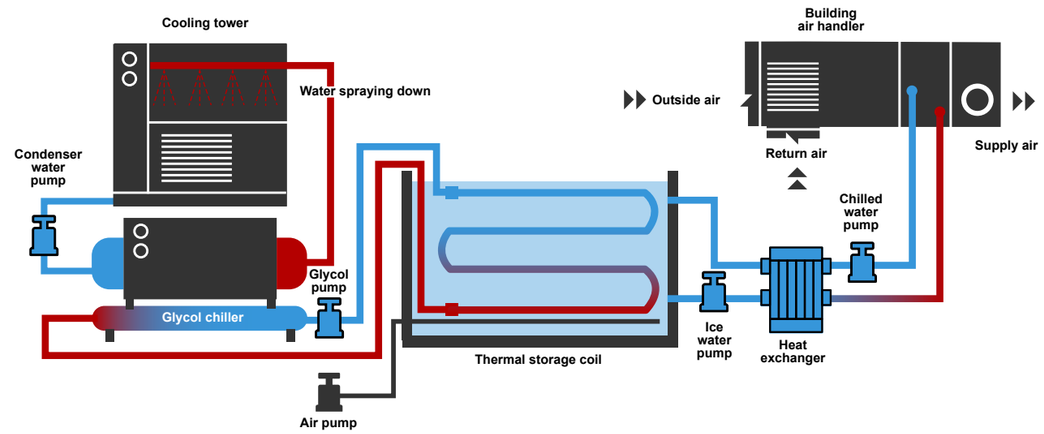
Moreover, the integrated shading system we designed for the office buildings bring together architecture and function, featuring intelligent controls that allow for the adjustment of daylight levels, as well as protection of occupants from glare.

With such energy efficiency features, total operational energy usage reduction was expected to exceed 10%, or 5,300 MWh/year. This will help to mitigate more than 260,000 tonnes of carbon emissions per year. Overall, the estimated annual utility cost avoidance is 13%, or about US$824,000.

Green roof and water efficiency

The office towers boast a massive 2,000m² rooftop garden that can be used for various occasions. Its unique green design minimises the absorption of heat on the roof surface and reduces the city's 'heat island' effect, leading to improved thermal comfort for its occupants.

This green roof is designed to capture stormwater run-off and store it in a 715m³ storage tank. This stored water is then treated, which is then reused for irrigation, basement and street washing, and cooling towers to reduce stormwater run-off and



Arup has designed and deployed an energy-saving ice storage cooling system, which can reduce electricity costs up to 25% compared to traditional systems.

replicate the natural hydrology process. In addition, the installation of high-efficiency flush fixtures in Raffles City The Bund would result in reduction in potable water use by 47%. Total water savings annually are expected to be about 38,000m^3.

Award-winning tall building project

Raffles City The Bund was voted by attendees of the Council on Tall Buildings and Urban Habitat (CTBUH) 2022 International Conference held in November 2022 as the Audience Award winner in the Systems Award category at the CTBUH Annual Awards.

The project is recognised for making extraordinary contributions to the advancement of systems engineering in tall buildings, taking the technical solutions and possibilities for tall buildings to the next level.

The green roof utilises a 715m^3 storage tank to capture and treat stormwater, which is then reused for irrigation, cleaning, and cooling towers. This process replicates the natural hydrology process by reducing run-off.

Nansha Campus of HKUST and Guangzhou University, Guangzhou

Client:
The Hong Kong University of Science and Technology (HKUST) and Guangzhou University

Scope of services:
Civil, geotechnics, structural, building services, façade, smart building technology system and sustainability design

The HKUST and Guangzhou University have joined forces to build a new campus in the Nansha district of Guangzhou. This new campus, which is conveniently located next to the Qingsheng high-speed railway station, provides students with easy access to modern amenities and transportation links. From here, teaching staff and students can travel to and from Hong Kong in just 30 minutes.

Built in two phases, the smart campus includes all necessary state-of-the-art amenities needed for teaching and research, such as sports facilities, dormitories, a 24-hour library, along with an energy and data centre. The total gross floor area of the campus is 1.1km^2. The spaces are designed to encourage interdisciplinary collaboration, enhance innovation, and create a strong community.

Arup worked closely with KPF Architects and provided total engineering design services to deliver this smart, sustainable, and resilient campus on a fast-track programme. The scope of services covers civil, geotechnics, structural, building services, façade, smart building technology system and sustainability design.

Net zero ready

In partnership with KPF, Arup was instrumental in designing a campus that is prepared to achieve carbon neutrality when it is in operations. Our design underscores the importance of synergy and efficiency while also limiting both the upfront capital and long-term costs of operation on a university campus.

The outdoor spaces and buildings have been designed with various passive and active features to optimise comfort, facilitate interaction, and minimise life-cycle cost.

The efficient provision of cooling and heating is centralised in a tunnel that incorporates both the chilled and hot water pipes. The 'energy centre' is equipped with a district cooling system and a

decentralised hot water system that recycles the heat generated by the data centre, which helps to conserve energy in an efficient manner.

Flood resilience

In light of the rising flood risk in the region, resilience has been reinforced within the landscape to accommodate water features and implement the sponge city concept.

A vertical design approach was implemented — with a higher elevation in the middle and surrounding lowlands. This was done in order to accommodate the terrain, bring together outdoor areas, and improve drainage within and outside of the campus, thus reducing floods and enhancing the local environment.

Surrounded by three canals, the campus is dedicated to achieving its 'zero water waste' goal, from incorporating the use of rainwater and greywater for reuse in the greywater recycling research programme to minimising freshwater consumption for potable water.

Varying in harmony

The façade features vary from building to building in line with their functions. With Arup's total design approach, the variety of materials — including freeform glass fibre, reinforced concrete panels, glass, fire-rated façade, aluminium, and steel — allowed for the expression of the architectural intent while maintaining a set of core principles: thermal performance, sustainability of the material choice and use, structural performance, constructability and local practice.

The range of different usages for the internal spaces, associated with the large range of façade types, lead to a varied set of performances to which the design had to respond while being economically viable as well as simple to design and construct.

With the first phase coming into operation, the campus offers three undergraduate programmes on artificial intelligence, big data, and smart manufacturing, as well as 15 master's and doctorate programmes including advanced materials and microelectronics.

Robust on soft conditions

The campus is located in one of the areas in South China with soft ground conditions. Due to functional requirements and architectural and landscape considerations, the buildings vary in height and planar shape – some are high-rise buildings without basements exceeding China's code limits, and some require refraining of low vibration to different extents.

Arup's geotechnical experts provided valuable advice regarding performance requirements of ground treatment since the project inception. We thoroughly studied and addressed a range of scenarios of compression, anti-uplift, horizontal resistance for foundations and a variety of combinations as well as differential settlement issues. As a result, the foundation design has fully satisfied the complex functions of the campus and the critical construction programme.

A smart campus in operations

Apart from energy efficiency, water pollution mitigation and flood resilience solutions, the campus has been designed with a vision of providing an integrated data platform for efficient management, with IoT sensors, classes and building operations powered by a sophisticated information and communication technology infrastructure crafted by Arup.

The platform acts as an integrated service-enabling tool which collects, converges and connects data and information between the stakeholders of the campus. With a focus on synergy, the platform will facilitate operation, enhance user experience on campus, and support its long-term sustainability objectives.

The campus is also envisioned as a 'living lab', which will be able to incorporate future technological advancements as they are being developed for expansion and continuous upgrading. The utilities distribution also provides data connection points and electricity supply for the smart monitoring system to connect with so that the campus can be turned into a true 'living lab' for IoT research and development activities to be conducted in a safe environment.

Through these exemplary smart, green and resilience design strategies and features, the campus provides an inspiring environment for students and faculty to live, work, and study. The campus aims to be an example of what can be achieved when a tertiary institution prioritises sustainability in its infrastructure.

The campus, situated at the centre of three canals, has set a goal of achieving 'zero water waste' by utilising rainwater and greywater, while also minimising freshwater consumption.

Innovating for a sustainable tomorrow

Peter Thompson

Peter Thompson, a Director and Energy Business Leader at Arup Hong Kong, is a prominent figure in clean energy infrastructure. With over 34 years of experience, he has managed the design and implementation of numerous energy and infrastructure projects across the East Asia region.

Signed in 2016, the Paris Agreement has spurred the pursuit of clean energy around the world. As signatory countries from the region have committed to reducing emissions, East Asia has made significant progress in transitioning to clean energy sources in recent years.

To this end, Arup has also confirmed a new approach to its work for the energy sector. Since April 2022 Arup's energy commissions have been focusing entirely on low-carbon solutions. They include wind, solar, hydroelectric and hydrogen projects that they assess as advancing progress towards a fully decarbonised future.

One of Arup's leaders in clean energy infrastructure is Peter Thompson, currently a Director and the region's Energy Business Leader based in Hong Kong. He has more than 34 years of experience in the management of the design and implementation of major energy and infrastructure works projects across a wide variety of overseas countries.

As a professional engineer, he has the knowledge and expertise to design and implement renewable energy systems, such as onshore and offshore wind farms, solar, and hydrogen facilities. He is currently providing advisory services and detailed design work for projects being undertaken in Hong Kong, Japan, Korea, and Taiwan.

Geotechnical engineer by training

Following his graduation from UK with a degree in geotechnical engineering, Peter joined Arup's geotechnical engineering team in London in 1988. Throughout most of the 1990s, he was mainly involved in geotechnical works. From 1992-1994, he supervised the construction of 8,000 bored piles for Bangkok's elevated road and rail systems.

In 1994, he returned to London and worked as a geotechnical engineer on the design of temporary support system for Canada Water Station. After three years in London, he moved back to Thailand in 1997; from that year to 2000, he worked as the geotechnical engineering design manager for the planning and construction of a 11km-long metro line in Bangkok.

"One of the most difficult geotechnical projects I've ever worked on was the Bangkok metro system, which includes both BTS and MRT networks," he recalls. "Building infrastructure in Bangkok is difficult due to the presence of thick river soft clay deposits, which are not able to support much weight and easily deform."

Moving to Hong Kong

In 2001, Peter moved to Hong Kong from Bangkok. Initially he specialised in major infrastructure projects for Hong Kong and Southeast Asian countries.

© Marcel Lam Photography

Peter Thompson (rear) and Mark Wallace (front) visited the Northern Section Sub-Sea Tunnel Section site of the Tuen Mun – Chek Lap Kok Link in 2015.

"Compared to the UK and Thailand, where I have previously worked, I enjoy the fast-paced working style of Hong Kong and the immense size and scale of the projects that we typically work on, offering the opportunity for a higher level of involvement and responsibility."

Between 2002 and 2006, he was actively engaged in major infrastructure works in the region. One of his notable accomplishments is the Stonecutters Bridge, part of the Tuen Mun-Chek Lap Kok Link in Hong Kong. He was put in charge of the detailed design of the foundations for the main towers and back-span piers of the bridge.

Tectonic shift in career focus

"My career focus had been on large infrastructure projects until the late 1990s, but I entered the energy business by accident, really, through my involvement with the first liquefied natural gas (LNG) project for CLP," he says.

Between 2005 and 2008, Peter was in charge as the project manager of the preliminary civil engineering design works to support the Environmental Impact Assessment (EIA) and pre-front-end engineering design process for a CLP LNG receiving terminal facility in Hong Kong. "The project is extremely fast track demanding the co-ordination of a multi-disciplinary team to achieve the challenging programme to obtain the EIA approval by early 2006."

The Stonecutters Bridge is 1.3km long with a central span reaching 1,018m. The foundations were modelled using two and three-dimensional finite element analyses capable of modelling the sophisticated loading conditions associated with tall bridges of this type such as ship impact and seismic ground vibrations.

Since then, he has led further projects for LNG import and export facilities, including land-based terminals and floating storage, in the Philippines, Vietnam, and Indonesia.

Transition to renewables

As far back as 2005, CLP already had plans to build an offshore windfarm off the eastern coast of Hong Kong. To make that happen, the Arup energy team headed by Peter was commissioned to design an offshore meteorological mast near Sai Kung.

This mast was intended to measure wind speed and other wind-related factors so as to provide insights to CLP on how best to pursue a large-scale wind farm project. This project was unique in that it employed previously untried suction caisson foundations to hold up the mast. Its success marked the first time such technology had been approved by Hong Kong's Buildings Department, with full-scale load testing carried out as part of this process, he says.

Given the proven success and efficiency of the foundation deployed by Arup for the CLP mast, suction caisson foundations have been increasingly considered as a foundation solution for offshore wind farms in the region since then.

Due to cost considerations, however, the construction of the offshore wind farm had been put on hold until CLP acted in 2022 and applied for building permission. As their trusted partner, Arup was engaged to conduct a technical design and engineering feasibility study for this pioneering offshore wind farm project.

Arup was commissioned to design a wind mast to measure wind speed and other related data, using suction caisson foundations for the first time. This was to help CLP determine the viability of a larger-scale wind farm project.

Fulfilling Asia's offshore wind potential

Peter points out that Asia's offshore wind farm market is vast and there is still plenty of room for expansion, thanks to the region's geographic advantages and strong political will. "Government commitments are a key part of the transition. Without a clear framework at a government level and clear commitments, the necessary change and associated investments cannot be made," he says.

Countries and regions with a large stretch of coastline, such as Japan, Taiwan and the Philippines have been actively expanding their utilisation of offshore wind farms as a reliable energy source. Building bigger and better offshore wind farms is becoming increasingly complex, so Arup's engineers are providing their expertise and innovative solutions to help clients with the planning and designing process.

His vision for the future is to see more large-scale floating projects in place within the next 10-15 years. This would make them more affordable and enable access to new markets in East Asia. Achieving a significant growth in the market would require substantial investments and political backing, which is an ambitious goal.

"Having said that, the consequences of the Ukraine war have had an immense impact on the Asian energy markets, giving governments in the region more impetus to boost their energy resilience and sovereignty."

As policymakers and the industry pursue bigger and better offshore wind farms, there is a need for more innovation in floating foundation design, while ensuring environmental protection remains a priority. This requires a combination of structural design, the use of new materials and sustainable construction techniques, and meeting the requirements for deep water.

"At Arup, we have an impressive track record in offshore engineering and are well-versed in the regional ground conditions. Our East Asian operations have the economy of scale required to develop large projects. We possess strong skills in the infrastructure support necessary for the development of floating systems, such as port infrastructure, maritime engineering, naval architecture, and geotechnical engineering."

Overcoming clean energy bottlenecks

While clean energy sources as alternatives to traditional fossil fuels are rising in popularity, there are also bottlenecks that must be addressed for wider adoption.

At present, solar and wind energy are more costly to produce than fossil fuels and require substantial infrastructure investments. The local supply chain is also limited, while the talent required is not always available in the region, both of which contribute to the obstacles related to their implementation in Asia, according to Peter.

Moreover, cleaner energy sources such as solar and wind are intermittent and therefore requires energy storage technologies, such as batteries and pumped hydro, to store excess energy for use when needed. Storage technologies will assist in many ways to regulate the integration of renewable energy into the grid; they can be used as reserve power to eliminate wasteful spinning reserves, according to Peter.

"They can be used to manage the peak power demands, and hence facilitate the sharing and transmission of electricity between multiple stakeholders in the value chain. Hydrogen can be used as an efficient form of energy storage, functioning in a similar way to other storage technologies."

"Arup is also a leader in digital solutions and can make sense of big data to optimise costs. Our remote monitoring system can help prevent potential operational and maintenance problems," he adds.

Next wave of development

Hydrogen energy has the potential to become a major player in the global energy transition. Green hydrogen is made from sustainable sources of energy such as solar, wind and waterpower. It can be used to generate electricity, heat and fuels for transportation, providing a clean and reliable alternative to fossil fuels.

Hydrogen is one of the cleanest burning fuels, allowing it to be used in certain gas fired systems with a few modifications. Creating green hydrogen at an industrial scale, however, comes at a cost and can present considerable challenges. "Despite such challenges, we are strong advocates for developing a hydrogen economy which can help reduce carbon emissions and accelerate the transition away from fossil fuels."

Open to research collaboration

Despite his vast experience, Peter is always open to new ideas and approaches. He understands that the industry is constantly evolving, and that new technologies and innovations are essential to driving costs down, improving efficiency, and scaling up renewable energy technologies. He encourages his colleagues to think outside of the box and explore new ideas, even if they seem unconventional.

Peter is always open to working with universities to develop new technologies and solutions for the clean energy industry. He has established partnerships with several universities and research institutions, and actively encourages his team to collaborate with academic researchers.

Advice for young engineers

After more than 30 years in engineering and management, Peter found the most fulfilling aspect of his career to be contributing to large-scale infrastructural projects and having an opportunity to shape them.

He portrays himself as an authoritative leader who coaches and encourages younger engineers with care and an open mind. "My advice for young engineers is to work hard, learn as much as possible along the way, take reasonable risks, and believe in themselves. They should also cultivate relationships within their firm and those in the industry, as you never know when those connections will be useful."

On the frontier of transformation

Bruce Chong

Dr Bruce Chong, an Arup Director with over 20 years of experience in the industry, has a profound understanding of the intricacies and possibilities confronting policymakers, urban planners and developers in East Asia.

With over 20 years of experience in the industry, Dr Bruce Chong, an Arup Director, has a deep understanding of the challenges and opportunities facing policymakers, urban planners, engineers and property developers in East Asia. His passion lies in formulating solutions that enhance the resilience and circularity of resources, while also promoting the well-being of communities and tangible social benefits.

Bruce is now focused on advising policymakers and organisations on their decarbonisation and climate resilience strategies, heading up a multi-disciplinary team consisting of climate scientists, designers, engineers, environmental and digital experts. He is also the Skills Leader of Resilience and Sustainable Infrastructure Design Leader in East Asia region.

Industry recognition

The Hong Kong Institution of Engineers (HKIE) Young Green Leader Award in 2013 was a significant milestone in Bruce's career. It recognised his exceptional achievements as a young leader in spearheading Smart, Green and Resilient (SGR) initiatives in the region.

Bruce holds the prestigious title of Cambridge Overseas Scholar while also serving as a Research Fellow at the University of Sydney. His contributions to the profession are highly regarded, as evidenced by his fellowship in the Chartered Institution of Building Services Engineers (CIBSE), the Institution of Civil Engineers (ICE) and the Institution of Engineering and Technology (IET). He is also the founding member of Engineers without Boarders in Hong Kong, collaborating with various NGOs to pioneer and promote humanitarian engineering. As a multi-disciplinary engineer, Bruce actively participates in these organisations, showcasing his dedication to advancing the field and his commitment to staying at the forefront of industry developments.

Bruce was awarded the HKIE Young Green Leader Award in 2013.

Insights from UN conference for young sustainability leaders

"In 2002, I was nominated to represent Hong Kong at the Youth Encounter on Sustainability (YES) conference. It was truly an eye-opener for me. I had the privilege to enhance my understanding of the principles of sustainability in a dynamic world, across geographic and disciplinary boundaries, as well as to develop my intercultural and leadership competences along with other like-minded, motivated young individuals from all around the world."

Promoting SGR development and material circularity

By working with urban planners and designers, Bruce was a pioneer in the development of the SGR systematic planning approach. This approach was based on over a decade of observations and extensive participation in East Asia's urban and infrastructure development.

The three-in-one thinking approach offers a comprehensive conceptual framework that enhances the urban planning process while addressing the current environmental, economic and social challenges. The framework has been officially adopted for all new town development projects in the city. It has also garnered international awards for its valuable contribution to sustainable urban planning.

Since the early 2010s, he has made sustainable waste management and circular economy important focal points of his career. For instance, Bruce has led a research team in collaboration with the Ellen MacArthur Foundation to explore the circular economy potential in China. He has also undertaken key studies on strategic planning for waste treatment, transfer, and recycling facilities for the Hong Kong government.

Facilitating smart city transformation

In the 2011-12 Hong Kong Policy Address, the city's government announced a pilot scheme to designate Kowloon East, which includes the former Kai Tak airport site, as the first Smart City District in Hong Kong. Bruce supported the government in initiating this study and led

Bruce worked as a site and design engineer on mechanical and building services systems in the early stage of his career.

His participation in a global conference organised by the United Nations for young leaders became the catalyst that shifted his career focus towards sustainable development.

The SGR as a planning methodology received the prestigious Grand Award at the International Society of City and Regional Planners Award for Excellence 2022.

Bruce led the design of the Built Environment Application Platform (BEAP), which consists of 10 different apps that cover various domains, including planning and land-use, infrastructure, environment and conservation.

Bruce has also developed a new standard of 3D map production to facilitate Hong Kong's smart city development.

the entire project as the project manager.

In collaboration with various government departments, tech firms, IT solution providers and NGOs, Bruce's team initiated 10 Proof of Concept (PoC) trials as part of study to demonstrate to the public a new approach to enhancing mobility, walkability, resource management and socio-economic vibrancy using ICT and digital data.

In 2017, the city's government unveiled a Smart City Blueprint. As part of this blueprint, the government made the decision to construct a Common Spatial Data Infrastructure (CSDI), which would allow geospatial data from various government departments to be accessible to the public through an online portal.

Bruce led the design of the Built Environment Application Platform (BEAP), which consists of 10 different applications that cover various domains, including planning and land-use, infrastructure, environment and conservation.

The BEAP project is strategically important as it serves as a platform for collaboration among the government, planners, businesses, academia and research institutes. More importantly, it has had a strong influence on the direction of CSDI and the establishment of the GeoData Store by the Hong Kong government.

In addition to BEAP, Bruce has also developed a new standard of 3D map production to facilitate Hong Kong's smart city development. The latest version of 3D map has been produced for Kowloon East afterwards. In parallel, a pilot study has been initiated to develop a Pervasive Positioning Standard, aimed at supporting seamless indoor and outdoor navigation for the Lands Department of Hong Kong.

Mainstreaming climate risk and resilience

For property developers and owners alike, taking mitigation measures at an early stage is key to reducing their vulnerability to climate risks. "During the early stages of planning and designing, we can suggest ways to protect buildings against extreme weather events such as flooding or typhoons. This ensures that the design team has accounted for any possible risks, helping them be better prepared for worst-case scenarios," he says.

A case in point is a probabilistic-based climate hazard model developed by a team of climate scientists that follow the latest IPCC AR6 data. This model, the first of its kind in Asia, enables them to provide location-specific projection data, identify and quantify potential hazards, and recommend practical actions. This model can be integrated with financial models to estimate losses associated with repair damage, replacement, business interruption and downtime.

This model has now been applied to projects for Arup's key private-sector clients, including Swire Properties, New World Development, Hongkong Land, Hang Lung, Hysan Development, Nan Fung and Sun Hung Kai Properties, among others.

"Our integrated sustainability and climate services position us as a leading ESG advisory service provider in the building and construction sector, allowing our property clients to showcase their commitment to sustainable practices beyond the commonly used TCFD standards," he says.

Raising the bar on ESG

Starting from 2022, the Hong Kong Exchange has made it mandatory for all listed companies in Hong Kong to issue an ESG report alongside their annual reports every year.

"Institutional investors usually evaluate a company's ESG performance and ratings from third-party rating agencies such as MSCI and S&P before making an investment decision. Our team of specialists, made up of an esteemed retired professor and climate scientists, can aid listed companies to stand out from the pack in showcasing their dedication towards ESG performance."

Unlike auditing and management consulting firms that have traditionally dominated the generic ESG reporting space, Arup stands out with its interdisciplinary, science-based expertise to evaluate climate risks related to infrastructure and building projects across geographical locations.

Bruce played a pivotal role in spearheading the establishment of The Asian Corporate Coalition for Climate Change Resilience (A4CR), a groundbreaking initiative that aims to foster collaboration and cocreation among key players in the industry. This pioneering coalition, officially launched in April 2022, is dedicated to influencing policymakers, supporting businesses in tackling climate change while capturing green business opportunities in an emerging net-zero world.

On talent cultivation, Bruce actively supports universities and industry organisations in developing education programmes to build ESG talent capacity and upskill the next generation of ESG and sustainable finance professionals. Examples include the Certificate in Sustainable Finance course developed by Bruce in collaboration with the Hong Kong University of Science & Technology Business School and the Hong Kong Green Finance Association; and Executive Diploma in Sustainability, ESG and Green co-developed with the Hong Kong Management Association.

Bruce has emphasised the importance of reviewing operations and meeting necessary ESG requirements at many public events.

Journey towards innovation and expanding impact

Despite the experiences he has enjoyed in his professional life, he still desires to progress further and make a more significant mark by pioneering innovation and groundbreaking work. Bruce's dedication is commendable as he not only manages a busy schedule but also works towards expanding his impact to a wider range of stakeholders beyond the engineering and built environment sector.

As an example, he has recently guided the hosting of a special session on "Designing Resilient and Net-Zero Cities of Tomorrow" for the ADB Southeast Asia Development Symposium. In addition to planning and co-ordinating this session across Arup's offices in Hong Kong and Singapore, he also took charge as the session chairperson and delivered an opening speech to set the tone for the event.

He is involved in various committees of professional institutions. Some of his notable roles include being the Chair of the Real Estate Working Group at the Hong Kong Green Finance Association, a Committee Member of the ESG Group at the Financial Services Development Council, a Committee Member of the Climate Change Advisory Group at the Business Environment Council, and a Committee Member of the Resilience Working Group of Urban Land Institute.

Bruce actively contributes to international development as an advisor to the Summary for Urban Policymakers of the IPCC AR6 reports, including the latest physical science of climate change, science on impacts, adaptation and vulnerability, and science on climate change mitigation means for cities and urban areas.

"The climate change movement needs to be a system change movement, or it will end at northing at all. Building a sustainable future requires the transformation of capitalism and a shift in mindset from everyone, not just environmentalists or specialists," he concludes.

Arup survey brings clarity to advancement of China's low-carbon economy

The 3Rs technologies (Reduce, Restore, Remove) are essential for transitioning to a low-carbon economy as they play complementary roles in reducing emissions, restoring ecology and removing carbon. According to a survey conducted by Arup and Beijing Jiaotong University that involved over 80 industry experts, the 3Rs technologies currently being adopted in China focusing on Reduction and Restoration have reached a mature stage. However, most technologies related to Removal are still in their early stages and need more testing and development.

The 'Reduce, Restore, Remove: A Call to Action' report proposes three complementary strategies to tackle the pressing issue of carbon emissions. The strategies, known as the 3Rs, include reducing emissions, restoring ecology, and removing carbon. The report's findings provide a clear pathway for individuals, governments and organisations to curb and reverse the alarming trend of carbon emissions.

As the world's largest emitter of greenhouse gases, China has the world's largest construction market. A report published by the China Association of Building Energy Efficiency states that China's buildings were responsible for 5.08 billion tonnes of carbon emissions in 2020, representing 50.9% of the nation's total carbon footprint.

Therefore, the building and construction sector not only plays a pivotal role in energy conservation and carbon reduction in China but is also highly contributory to achieving global and national net zero goals.

In collaboration with the Carbon Neutrality Technology and Strategy Research Centre at Beijing Jiaotong University, Arup has carried out an in-depth study to investigate the potential of key measures and technologies required for China's built environment to become carbon neutral, utilising the 3Rs framework as its foundation.

The study first conducted a thorough investigation and evaluation of the existing carbon reduction technologies in the built environment. This was done by combining the research report of the International Energy Agency and the implementation plans formulated by the National Development and Reform Commission, the Ministry of Science and Technology, the Ministry of Housing and Urban-Rural Development, and other government agencies with a literature review.

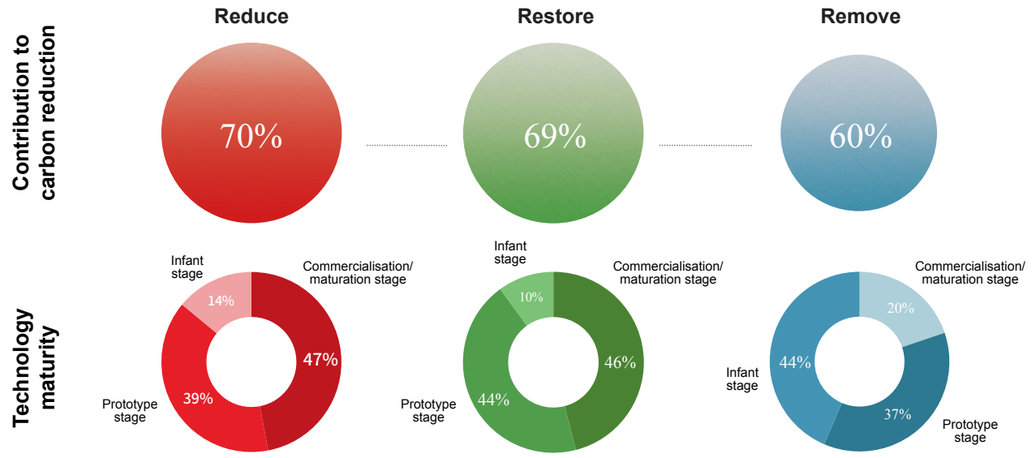
Such efforts have resulted in a list of over 30 '3Rs technologies' focused on the built environment. To better assess their decarbonisation viability and marketability, the study involved over 80 industry experts in a technology maturity evaluation survey.

The data from this survey indicates that the technologies associated with reduction and restoration have made significant progress. Their potential for mainstream adoption is now being actively explored. On the other hand, removal technologies have primarily remained in the research and development and early stages, requiring further evidence of their technical and economic viability.

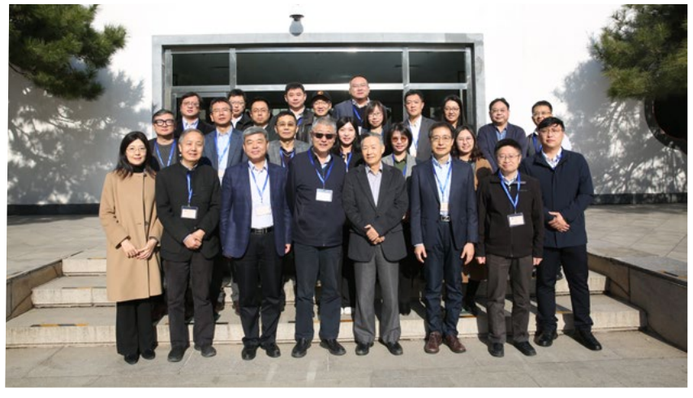
More specifically, 70% of the experts surveyed indicated that 'Reduce' technologies have a very high or high contribution to decarbonisation. For 'Restore', 69% of experts agreed, and for 'Remove', 60% agreed.

Furthermore, the research report delves into the driving factors behind the development of these key technologies. Additionally, the report provides future-oriented scenarios, and offers an overview of emerging technologies across various segments of the building and construction industry.

Carbon reduction contribution and technology maturity analysis of 3Rs technologies



Infant stage - where the technology is proven to work in a controlled environment.
Prototype stage - where the technology has been refined and tested in real-world environments.
Commercialisation/maturation stage – this stage involves continuous refinement and improvement of the technology to ensure its relevance and competitiveness in the market.



Arup co-organised the 'Xiangshan Science Conference' with Beijing Jiaotong University as part of our research and engagement efforts with industry experts in the field of 3Rs.

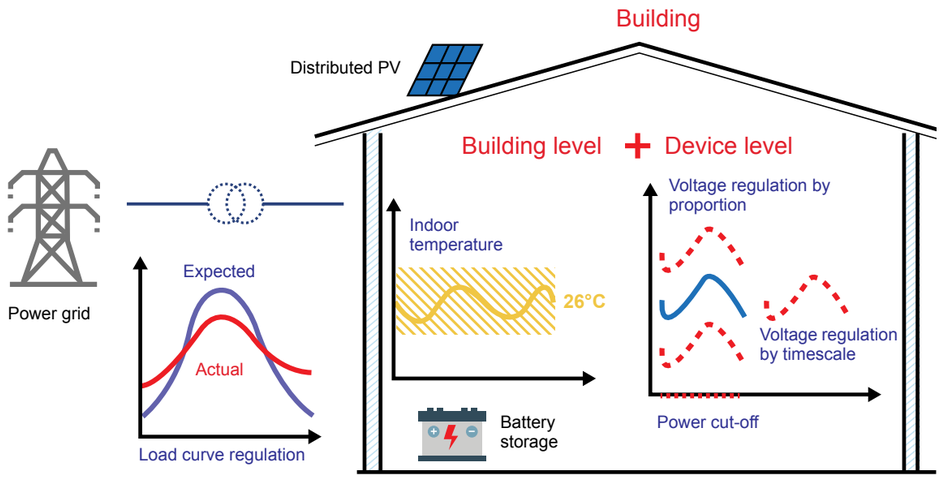
Read the 'Reduce, Restore, Remove: A Call to Action' report:

Read the 3Rs survey report (Chinese version):

It is hoped that the research findings will assist industry participants in developing more effective net zero strategies for the built environment in China. Going forward, Arup is dedicated to advancing the low-carbon transformation of China's building and construction sector by leveraging state-of-the-art technologies and strategic collaborations with industry partners. Our focus on innovation will pave the way to a more sustainable and climate-resilient future for the region.

Putting a smart microgrid to the test

In this study, Arup's MEP engineers collaborated with Tsinghua University to conduct an engineering assessment of a new smart microgrid, which incorporates advanced technologies such as solar PV distributed generation, energy storage, AC-DC conversions, and adaptive load balancing.



A simplified illustration of the Photovoltaics, Energy Storage, Direct Current and Flexible Power (PEDF) (光储直柔) system deployed in a residential property.

The Arup team has developed a comprehensive system framework and evaluation method to analyse the performance of the microgrid and its potential impact on energy efficiency. This innovative approach emphasises the significance of sustainable energy solutions and sets the stage for future advancements in the field.

In China, photovoltaic (PV) systems are currently the most prevalent renewable energy sources for buildings, and they generate direct current (DC). By utilising a flexible DC or AC-DC hybrid distribution system with smart energy management control, we can reduce the amount of energy lost between AC and DC conversions. This is beneficial as many modern devices and appliances, such as those used in homes and offices that require DC to operate.

When such microgrids are combined with DC-battery storage systems, power demand can be more effectively managed, thus allowing for an increased utilisation of solar energy that fluctuates based on seasonal changes or the time of day. In other words, the battery storage system serves to 'cache' excess energy generated in good times for later use when electricity demand is high at peak times.

Called the Photovoltaics, Energy Storage, Direct Current and Flexible Power (PEDF) system, this innovative solution was proposed by academicians from Tsinghua University and the Shenzhen Institute of Building Research. It has been endorsed by the Chinese government, being featured in their 'Action Plan for Carbon Dioxide Peaking before 2030' publication of October 2021 and the 14th Five-Year Plan for the Development of Energy Efficiency and Green Buildings in March 2022.

The PEDF technology as a smart microgrid solution is expected to undergo pilot testing by the end of 2025, with further standardisation and maturation by 2035. The long-term goal is for the building sector to be highly electrified by 2050, with the PEDF technology becoming a universal standard for electrical system in buildings.

About the PEDF system

The PEDF system is much more than just a combination of distributed photovoltaics, energy storage, and DC distribution system. It is essentially a smart microgrid architecture that integrates these technologies into a building's infrastructure to provide flexible control of electricity consumption. The system's distributed DC-based control strategy for each component is key to making it a smart microgrid or nanogrid.

The potential scalability and economic viability of the system could revolutionise power transmission and distribution by shifting from a traditional energy response approach, which is based on non-regulated end-user demand, to a more effective and flexible energy response approach using distributed PV and energy storage to manage building electricity demand based on grid power supply properties.

Key components

Photovoltaics

PV panels generate electricity from sunlight, which can be used to power the building or fed back into the external grid. This helps to reduce the building's reliance on grid electricity and lower energy costs.

Energy storage

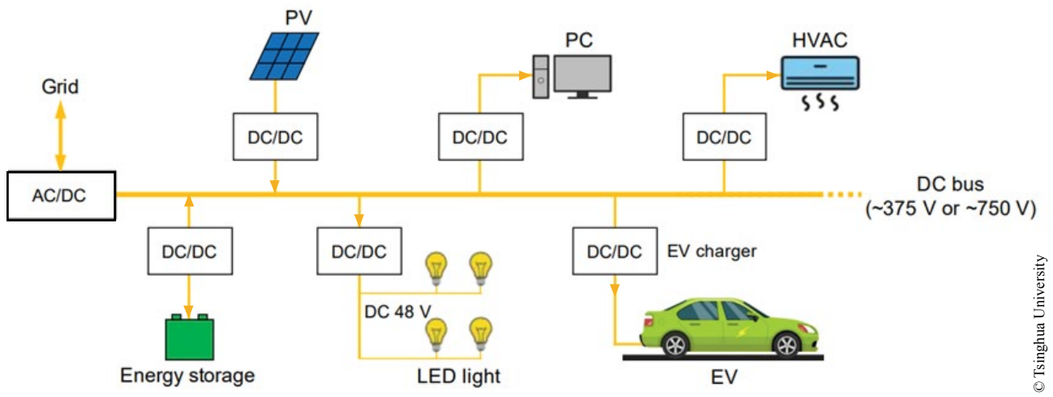
Energy storage, such as DC batteries, allows for the storage of excess energy generated during the day. This stored energy can then be utilised during peak demand periods or at night when solar energy is not available. By doing so, energy loss is minimised as excess energy is not wasted when it is initially generated.

Power distribution or load balancing

This serves to balance the load of energy demand across the microgrid by directing excess energy to buildings, functional spaces, facilities or devices where it is needed most. This can help reduce energy loss by ensuring that excess energy is not wasted due to transmission inefficiencies or overloading of local systems.

The schematic diagram below shows the microgrid of a building, in which the AC-DC converter sets the DC bus voltage based on a reference power, which is the desired power output of the microgrid. The AC-DC converter adjusts the DC bus voltage to ensure that the microgrid is supplying the correct amount of power to meet the demand. The DC bus voltage is the voltage level of the DC power that is being supplied to individual appliances or equipment within the microgrid.

Once the DC bus voltage is set, all the DC-DC converters respond accordingly by adjusting the voltage and current levels of the DC power to match the variable DC bus voltage. In other words, the



The schematic diagram illustrates the microgrid of a building. In this setup, the AC-DC converter adjusts the DC bus voltage based on a reference power to ensure that the microgrid supplies the correct amount of power to meet the demand.

AC-DC converter sets the overall voltage level of the DC power being distributed throughout the microgrid, and the DC-DC converters adjust the voltage and current levels of the DC power to match the needs of individual appliances and equipment.

Engineering evaluation

At the time of writing, over 10 buildings in China have adopted PEDF technology as part of a pilot programme. We studied and evaluated the PEDF system assembly method, design of the PV power generation system, DC microgrid system design, DC system terminal device matching mechanism and control implementation of one of these buildings based on our developed evaluation method.

The experimental building we tested in Shenzhen is a mixed-use building that includes office, residential, exhibition and social/cultural spaces. The building's power supply is sourced from a municipal power grid, which is connected to a 630kVA transformer operating on AC380V. Additionally, the building is equipped with a 200kW AC/DC converter and 150kW of photovoltaic electricity, the latter of which serves as supplementary power sources.

The storage system is outfitted with a 75kWh energy storage battery and a 480AH battery, providing support for up to 345kW. This storage system is versatile and can be used for a variety of applications, including air conditioning, lighting, sockets, security, emergency lighting, charging piles, and data centres.

Configured as an IT grounding system, the system offers DC±375V (true bipolar) and DC48V output voltages. Overall, the evaluation of the PEDF system is based on five aspects, including safety, reliability, energy efficiency, economic viability, and carbon neutrality.

When it comes to safety, one should ensure secure system architecture; select the suitable grounding form; and use very low voltage DC voltage in areas which have a risk of electrocution and other hazards. Reliability in this context refers to the redundancy of the main power supply, by having multiple modules connected in parallel. This enables increased load capacity through a multitude of branch circuits.

Ensuring economic viability involves regulating the charging and discharging of batteries in response to the fluctuations in power load, thus resulting in cost-effective control methods for the exhibition spaces. Carbon neutrality means the system's ability to generate sufficient quantities of clean energy locally to meet local energy needs.

Evaluation results

The evaluation results of the Tsinghua testing DC chamber indicate that the PEDF system offers measurable advantages in terms of safety, reliability, and energy efficiency.

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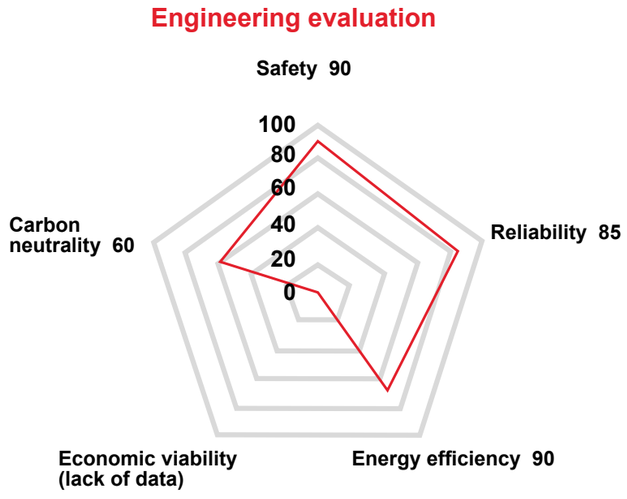


Generally speaking, when compared to AC systems, DC systems have several distinct advantages. Firstly, the voltage in DC systems is higher while the current is lower, resulting in less energy loss during transmission. Secondly, DC power equipment converters in these systems tend to have lower losses, making them more energy efficient.

In smaller buildings, DC systems have smaller energy losses than AC systems due to shorter lines because DC power can be transmitted over shorter distances with less energy loss than AC power. In contrast, in larger buildings, the advantages of DC systems become less clear. As the distance of transmission lines increases, the energy losses associated with DC systems can become greater than those of AC systems.

As an experimental building project, the system carries a lower load, does not generate clean electricity, and has a limited area dedicated to PV generation. Therefore, it is still far from achieving carbon neutrality. Also, due to the project being in the experimental phase, complete operational data is not available. As a result, a cost-benefit analysis could not be conducted. However, implementing strategies such as storing and charging energy at specific times can be highly beneficial in reducing the cost of purchasing electricity from the mains. This approach helps to level out peak and trough usage, resulting in potential cost savings.

Based on our findings, optimising the energy flexibility of buildings through the use of PEDF can enable them to not only consume the renewable energy they generate but also effectively utilise the majority of the energy obtained from solar and wind plants from external grids.

However, a significant challenge in real-world settings is establishing a mechanism that facilitates the interaction between buildings and power systems. Further theoretical studies and engineering practices are still required to effectively address this matter.

In conclusion, the PEDF system is not only a low-voltage power distribution system for buildings, but it also has the potential to revolutionise the power grid. This means that it can shift the current strategy of power transmission and distribution from a top-down approach to a bottom-up approach.

The way forward

To further develop the PEDF system, it is crucial to have a close and interdisciplinary collaboration between various disciplines, such as architecture, building technology, electrical and electronic engineering, computer science, and mechanical engineering.

In the next stage of development, standardising and industrialising key components in the DC microgrid of buildings, especially for DC appliances and devices, should be prioritised to improve the reliability and drive costs down for the wide adoption of PEDF system.

In addition, it is also important to carefully design the smart control mechanism for each type of DC appliance to enable flexible power regulation. Besides DC appliances, DC devices present a challenge for PEDF systems, encompassing DC/DC converters, AC/DC converters, DC plug sockets, and switches. The lifetime and protection mechanisms of these DC devices must be taken into consideration when the voltage of the DC bus fluctuates within a specific range.

Shaping future leaders of sustainable development

Arup University's commitment to cultivating a sustainable development culture has led to partnerships with world-class universities such as the Cambridge Institute for Sustainability Leadership (CISL) to develop master's programmes that focus on executive leadership and strategic planning.

At Arup, sustainable development is at the core of our work. We make sure that the projects we deliver and the work we do contribute to a sustainable future. Arup has developed a comprehensive strategy that encompasses everything from reducing carbon emissions to promoting sustainable design. This strategy goes beyond promoting innovation and best practices. It also aims to instil a sense of collective responsibility, share knowledge across the organisation and drive cultural change.

As part of this endeavour, Arup University has jointly developed and delivers a master's course with the Cambridge Institute for Sustainability Leadership (CISL), a globally influential institute based at the University of Cambridge. A programme, 'Shaping a Sustainable Future', has been specifically designed to equip Arup's current and up-and-coming leaders with the leadership skills, knowledge and practice to find ways to deliver commercial value within this increasingly complex and changing context.

The executive leadership programme is most beneficial for those in the middle to senior management range, offering valuable insights into the necessary changes required to thrive in the future business landscape. Moreover, it equips participants with the skills to effectively lead their organisation, provide expert advice and proactively challenge clients. This programme also supports Arup's commitment to making a meaningful contribution to a sustainable future, as outlined by the United Nations Sustainable Development Goals for 2030.

The programme spans over eight months and comprises of two week-long virtual modules, as well as individual and group project work. This approach ensures that participants gain a holistic understanding of sustainable development and can apply their knowledge in a practical setting. Since its inception in 2020, the course has successfully organised three cohorts, with 132 leaders graduating so far.

Module 1

– Understanding the changing context, engaging with the system

– Commercial implications across value chains, business risks and drivers

– Stakeholders, risks, and drivers in action

– Shared value and individual leadership

Module 2

– Transitions across the system

– Co-creating sustainable futures

– Scaling a sustainable future

– Influencing the system

– Driving change and taking leadership

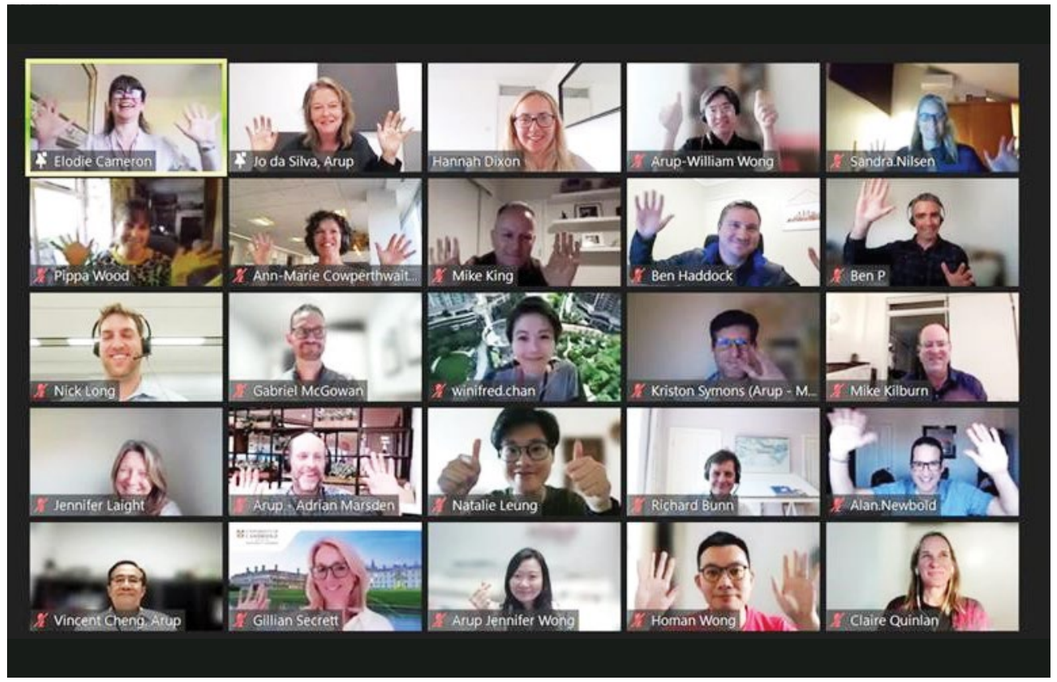
In the most recent cohort, two separate modules were held in November-December 2022 and May 2023, respectively. These modules had overarching learning outcomes that aimed to instil the following outcomes:

– A deeper understanding of how emerging global pressures and trends could impact their regions and operations and those of clients and other key stakeholders, the systemic interactions and complexities.

– Personal and collective confidence to engage actively with clients, challenge the status quo and seek new innovations and opportunities that deliver a sustainable future.

– The ability to engage actively with clients and related stakeholders by understanding the current needs and articulating future risks and opportunities for them within complex systems that lead to positive outcomes.

– An enhanced drive, determination, persistence and commitment to deliver against company's aims, values, commitment and framework for action.



The 'Shaping a Sustainable Future' master's course spans over eight months and comprises two week-long virtual modules, as well as individual and group project work both prior to and following the modules.

The course is directed by Jo da Silva, Arup's Global Leader of Sustainable Development. During a sharing session with the alumni upon completing the course, she commends the course for providing a holistic perspective that enables Arup leaders to see the bigger picture. As a purpose-driven organisation, Arup places great importance on sustainable development and this course equips its leaders with the necessary vision, knowledge and skills to spearhead sustainable initiatives within and outside the organisation, she notes.

Participants express that their participation in the programme has not only enhanced their knowledge of global trends but also instilled them with a newfound confidence to actively engage with clients and fuel innovation. By combining their technical and project management expertise with a broader perspective, they are now better equipped to grasp the bigger picture and make informed decisions.

"Participating in this programme has truly transformed my professional and personal journey. Regardless of your background or role, we all have a responsibility to contribute as much as possible to shape a sustainable future. The fact that Arup has implemented this transformative programme , along with the opportunity to meet many great and ambitious leaders through it, confirms to me that Arup is the right company to work for," says Jasper Hilkhuijsen, one of the programme's alumni.

Apart from this programme co-developed with the CISL, Arup University has previously collaborated with other prestigious universities, such as Imperial College London, the University of Southampton, Kings College London, the Massachusetts Institute of Technology (MIT) and Boston University, to develop three-year master's level learning programmes. Typically, a three-year programme consists of three cohorts, each running for one year.

Reuniting industry practitioners at Asian Knowledge and Innovation Forum 2023

Co-organised by East Asia Arup University and the Hong Kong Polytechnic University (PolyU), the Asian Knowledge and Innovation Forum (AKIF) 2023 was held in Hong Kong on 28 March 2023.

This was the first in-person session since the pandemic, and it brought together more than 80 knowledge management (KM) practitioners. In attendance were representatives from academic, commercial, and government agencies, such as Water Services Department, Fire Services Department, Henderson Land, and CLP.

Themed as 'Amplifying Success with Knowledge and Innovation in the Age of Digitalisation', the event commenced with welcoming remarks from Dr Young Wong, a Board Member of Arup East Asia Region, and Prof Eric Tsui from PolyU.

The event featured three keynote speakers, one of whom was Lewis Fung, Consulting Director at SenseTime. During his talk, he discussed the impact of AI and machine learning on knowledge sharing and innovation. Ben Wong, Head of Open Innovation at New World Development, talked about the creation of shared value through empowering tech start-ups to address actual business challenges.

Bruce Chong, Arup's EA Resilience Skills Leader, is an expert in city 3D mapping and the use of spatial and operational data. In his talk, he provided insights on data generation and practical application. City 3D mapping captures physical and functional aspects of urban environments, aiding urban planning and decision-making.

Dr Eric Cheng, Associate Dean of the Faculty of Education and Human Development at the Education University of Hong Kong, leads the group he facilitates in presenting their discussion results.

One of the event's highlights was 'Knowledge Café', which was led by Yannick Lenormand, Arup's EA Foresight Leader.

During 'Knowledge Cafe', seven discussion tables were set up for the participants and they discussed a wide range of topics they identified as the most relevant ones to their organisations.

The day's another highlight was 'Knowledge Café', which was led by Yannick Lenormand, Arup's EA Foresight Leader. The event was further facilitated by several distinguished KM experts from both local and overseas organisations, providing an opportunity for participants to discuss and reflect on the challenges and opportunities within their specific domains in this digital era.

During the activity, seven discussion tables were set up for the participants and they discussed a wide range of topics they identified as the most relevant ones to their organisations, including urban development, workflow automation, intellectual capital, resilience, communication channels, knowledge succession, healthcare, ageing population, and shared with their insights and foresights.

In the afternoon filled with presentations and sharing sessions, senior and KM executives from esteemed organisations, including CLP Power Hong Kong Limited, PTT Exploration and Production Public Company Limited (PTTEP), Caritas Jockey Club Lok Yan School and Water Supplies Department, took the stage as winners of the MIKE Award 2022.

Representatives from Aurecon, Hong Kong Correctional Services, EY Hong Kong, Henderson Land and PolyU gather for a Knowledge Café session to share ideas and discuss knowledge and information management strategies.

These organisations have proven their mettle and emerged victorious in this prestigious competition, showcasing their exceptional knowledge management initiatives.

The AKIF serves as the premier meeting place for the region's foremost experts and decision-makers in knowledge management. The forum provides a dynamic platform for KM practitioners, executives and academics to convene, stay abreast of the latest industry developments, initiate collaborations, and share best practices.

Read the full story

Co-creating a net-zero future for China

The first Shanghai International Carbon Neutrality Expo in Technologies, Products, and Achievements was held in June 2023, during which Arup hosted a range of panel discussions and sharing sessions on issues such as circular building design, decarbonising existing buildings, climate risk assessment and infrastructure resilience. To coincide with the event, we signed an MoU with the China-UK Low Carbon College, Shanghai Jiaotong University and published two whitepapers, including the China edition of the Reduce, Restore, Remove (3Rs) Foresight Report and the Post-COP27: Building a More Climate-Resilient Asia Position Paper.

Asia Summit on Green Economy

In May 2023, Hong Kong's Business Environment Council and Arup co-organised a summit on green economy transition at Island Shangri-La. The event had an impressive line-up of speakers and panellists and began with a warm welcome from Dr Andy Lee, the East Asia Region Chair of Arup, followed by a luncheon speech by Bernadette Linn, the Secretary for Development. Dr Vincent Cheng, the Director of Climate and Sustainability Services at Arup in East Asia, shared findings of Arup's latest green economy report, decarbonisation, climate resilience and how they can facilitate investment and business opportunities during a panel discussion.

Watch the event's recap here:

From the left: Andy Wong, Head of Innovation and Technology, Invest Hong Kong, Andy Chan, Acting Deputy Director of Environmental Protection, Environmental Protection Department, HKSAR Government, Dr Andy Lee, East Asia Region Chair, Arup, Bernadette Linn, JP, Secretary for Development, HKSAR Government, Simon Ng, Chief Executive Officer, Business Environment Council, Dr Vincent Cheng, Director of Climate and Sustainability Services, East Asia, Arup.

Paving the way for industry development and city resilience

Developed by the Hong Kong Green Building Council, the HKGBC Climate Change Framework for Built Environment has recently been launched. The Framework supports the HKGBC to envision goals on carbon reduction and lower carbon emissions associated with material production by 2030, and net zero emissions associated with materials by 2050, through material selection, design optimisations and resource efficiency. Arup experts contributed their expertise and project experience to the three chapters and underpinned the birth of the framework.

Read the full framework here:

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