Dream Factories

+ Destination: A Future Perfect

+ Your Estate. Your Tribe

+ Making the Mark

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The Dream Team

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The Future is Ours

Since Singapore gained independence, its growth has been driven by the manufacturing industry. In the early days, manufacturing activities included the likes of processing raw materials from primary industries into consumer goods, as well as producing high-value chemicals. Today, manufacturing accounts for 20% of Singapore's GDP, and it continues to strengthen Singapore's global standing as an economic powerhouse.

Singapore's rise to manufacturing glory did not happen overnight. Central to this is JTC, which has been master planning and developing land and infrastructure to serve the needs of industrialists since its founding in 1968. Jurong Industrial Estate, Singapore's pioneering industrial estate, is an example of how JTC has been instrumental in creating spaces for businesses to thrive, writing the growth chapters of Singapore's manufacturing success story.

Jurong Industrial Estate's evolution from a mangrove swamp to the highly industrialised area it is today is nothing short of remarkable. Some 650 factories sprung up across the 69km² site in the two decades since its conceptualisation, housing industries ranging from steelmaking and fabrication to shipbuilding and repair. JTC also undertook the building of homes and recreational infrastructure in these industrial estates to form townships, and to improve the attractiveness of the distant site to the workers. The intent then was to diversify Singapore's economy and create jobs—the rationale of which remains very valid even in today's context.

Fast forward to the present day, and we expect that future industrial estates will be vastly different from what we have built over the years. As manufacturing becomes smarter and more advanced, and Singapore continues to develop knowledge-based industries, the next generation of industrial estates needs to be future-ready and equipped to meet the demands of the Industry 4.0 revolution. In the following pages, you will get to discover how JTC is leading the way of this movement by designing these new estates, such as Jurong Innovation District (JID) and Punggol Digital District (PDD).

What makes these estates future-ready? In his 2016 Budget speech, then-Finance Minister Heng Swee Keat provided some clues when he talked about the vision for JID: "Fifty years ago, we transformed Jurong from swampland into a thriving hub for the manufacturing industry that powered Singapore's economic growth. Now, we will take another leap to create the industrial park of the future. This has the potential to transform how we live, work, play, learn and create."

Thus, the industrial estate of the future is a bustling hub of innovation where breakthroughs happen and work meets play in a conducive setting. With amenities like park connectors, fitness trails and even playgrounds, it's a place where you can work hard and play harder. Best of all? You get to do it with your community. And with sustainability woven into its very fabric, the industrial estate of the future is also a greener and more eco-friendly space, with lush greenery and smart design at every turn.

JTC's mission has remained unchanged since Day One: to continuously build Singapore's industrial future, even within the constraints of our land-scarce city-state. By uplifting our industrial estates, we are helping to turn our visions of the future into reality. And with tomorrow's industrial space being an exciting place where transformation is an everyday affair, we are proud to be leading the way towards a brighter, more innovative future.

As I end this note, I look back on JTC's journey from industrial estate planner to agile ecosystem architect and I marvel at how incredible it has been. This publication celebrates that journey and is an ode to the many stakeholders, leaders, partners and staff who have contributed along the way. As someone who has been privileged to be a part of this journey, I look forward to the future of JTC with the confidence that the best is yet to come!

Tan Chong Meng
Chairman, JTC

Woodlands North Coast

Versatile Spaces for Evolving Needs

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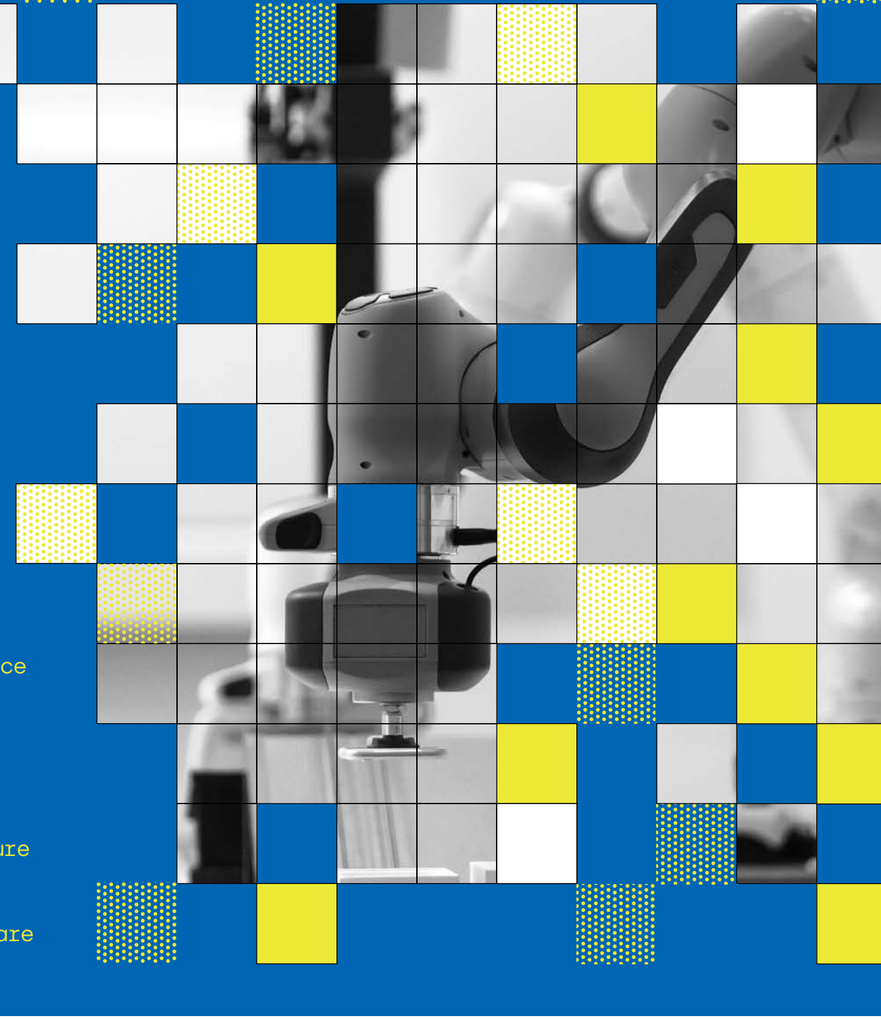
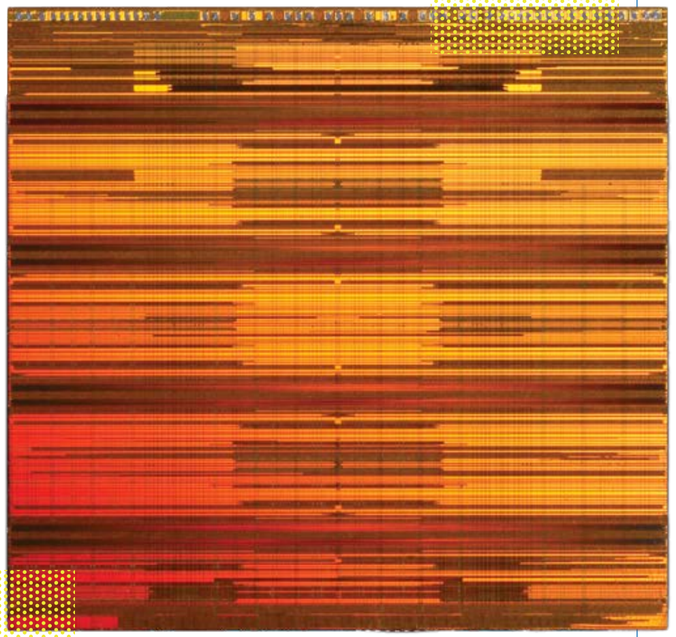
Building Blocks

From game-changing innovation to sustainability drives, we highlight the latest from members of the JTC community—from our estates to the world.



Lighting the Way

Micron



Years' worth of work documents, holiday videos and family photos, all stored on your phone. Space data recorder that's used in satellites to track methane in the atmosphere around the Earth and help fight climate change. You probably do not realise it, but packing such a huge volume of data within a small device that can also withstand the harsh conditions of the rocket launch and space takes big tech. What you might not realise too is that this technology is engineered right here in Singapore.

Micron Technology is a US-based manufacturer and world leader in computer memory and computer data storage solutions. Micron Singapore is the NAND Center of Excellence and home to the industry's most advanced 232-layer 3D NAND technology.

3D NAND is a type of non-volatile flash memory in which the memory cells are stacked vertically in multiple layers. This technology provides scale to future NAND technology transitions that will power new device experiences and infrastructure innovation across the data centre and the intelligent edge.

This is a demonstration of the company's culture of innovation. In 2020, Micron Singapore was designated an Advanced Fourth Industrial Revolution (4IR) Lighthouse by the World Economic Forum Global Lighthouse Network. Then, in 2022, Micron Singapore was designated as a Sustainability Lighthouse by the World Economic Forum. This makes Micron—with NAND wafer fabrication facilities located in Woodlands Wafer Fab Park and Woodlands North Coast—the first semiconductor wafer fab in the world to receive such an accolade. Being recognised as an Advanced 4IR and Sustainability Lighthouse reflects Micron's success in adopting and integrating cutting-edge 4IR technologies, and it continues to lead the way through incorporating smart manufacturing technologies that benefit business, its people and the planet.

A Better World

Reckitt

When the United States faced an acute infant formula shortage in 2022, the largest delivery of the product came from Reckitt Benckiser Group's facility at Tuas, Singapore. Facilitated by the White House's Operation Fly Formula initiative, a delivery consisting of 66 million eight-oz servings of base infant formula powder from Reckitt Benckiser Group's Tuas facility was shipped in July 2022. The Singapore plant situated in Tuas Biomedical Park, a specialised industrial park developed by JTC, is continuing to supply this key ingredient, which is then blended and packaged in the United States.

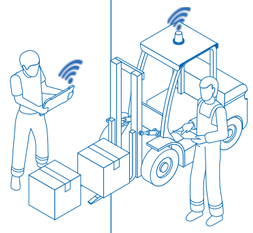
The British multinational producer of health, hygiene and nutrition products, better known simply as Reckitt, is the company behind household names such as Airwi, Dettol, Durex, Enfamil, Finish, Lysol, Mucinex, Nurofen, Strepsils and Vanish.

Reckitt is dedicated to sustainability, with its purpose being "to protect, heal and nurture in the relentless pursuit of a cleaner, healthier world". The company has achieved key sustainability milestones, such as Zero Waste to Landfill in all of its plants across ASEAN and globally, which is nine years ahead of its 2030 Global Sustainability Ambitions. Worldwide, the company has achieved a 94% usage of renewable energy, 96% of factories with zero waste to landfill and a 66% reduction in greenhouse gas emissions worldwide.

Zooming in on Singapore, at the end of 2022, the Tuas facility has achieved a 50% waste reduction as a result of continuous process optimisation and improvement.

An Autonomous Future

Katoen Natie



Warehouse operations dependent on forklifts operated by specialised drivers could be a thing of the past. Belgian chemical logistics and engineering giant Katoen Natie is experimenting with an autonomous warehouse solution engineered by XSQUARE, a subsidiary of homegrown company Goldbell Group. Katoen Natie operates out of Jurong Island with its Jurong Logistics Terminal, and has invested hundreds of millions of dollars into just this facility.

A pilot forklift Autonomous Guided Vehicle (AGV), tailored by XSQUARE for Kateon Natie's requirements, was deployed in 2020. This fleet of one, which utilises LIDAR remote sensing laser technology, barcode and height sensors, quickly expanded to five AGVs by 2021.

Once the five AGVs have been deployed, Kateon Natie is able to redeploy skilled manpower to handle more complex tasks, leaving the AGVs to handle repetitive, but essential operations. This programme with autonomous forklifts is an extension of other similar initiatives, including a driverless truck programme initiated in 2017. The entire Jurong Logistics Terminal is powered by a large solar installation, reinforcing Kateon Natie's goals of reducing carbon emissions.

XSQUARE is a provider of intelligent warehousing solutions in the Asia Pacific region, and its XSQUARE AGV features functions such as interoperability (orchestration of third-party warehouse equipment for seamless operations), hybrid use (autonomous and manual) and maximum safety through 360-degree sensors. The pilot project which started on Jurong Island serves as a test run for Katoen Natie to deploy AGVs in other regional markets, as part of its commitment to automation and digitalisation. "Projects like this bring improvements in safety, quality and productivity," shares Mr Koen Cardon, CEO of Katoen Natie Singapore. "All of which helps us to make a difference for our customers."

Have Your Steak and Eat It

GOOD Meat

Enjoy a hearty meal of big meats without any guilt over the environmental impact of livestock rearing? The possibility is here in Singapore, with GOOD Meat poised as the world's first company to sell cultivated meat, starting with a chicken product in 2020.

Raising animals for their meat is notoriously bad for the environment, with acres of forest cut down for ranches. The production of meat from animal cells instead of slaughtered animals eliminates the need to raise and farm animals for food. Environmental consultant CE Delft performed a life-cycle analysis on the cultivated meat industry and determined that against conventional beef production, cultivated meat had significant environmental benefits: up to 92% less global warming, 93% less air pollution, 95% less land use and 78% less water use. Touting the environmental benefits, GOOD Meat served their meat at the 2022 United Nations Climate Change Conference, where agriculture and food systems took centre stage amidst climate change discussions.

In 2023, Singapore Food Agency (SFA) became the first food safety body in the world to grant regulatory approval to GOOD Meat for the use of serum-free media in the production of cultivated meat. This follows SFA's approval for GOOD Meat's chicken product in 2020, and a 2021 approval for new formats of its pioneering poultry. A subsidiary of San Francisco-based food science company Eat Just, Inc., which focuses on creating safe, healthy and more sustainable foods, GOOD Meat has expanded their operations from JTC Bedok Food City to open its dedicated research and development and production centre in Singapore, the largest cultivated meat facility of its time in Asia.

GOOD Meat has already made inroads into the restaurant industry, partnering with local establishments including Huber's Butchery, making them the world's first butcher to sell cultivated meat; Keng Eng Kee Seafood for their chicken satay; and Loo's Hainanese Chicken Rice, making them the first hawker to sell cultivated meat.

Bits and Bites

SATS Food Hub

Food services might not be a sector one immediately associates with innovation. However, SATS, Asia's preeminent provider of food solutions and a global leader in gateway services, is ready to change that perception with the setup of its high-tech food hub in Jurong Innovation District (JID) by 2025.

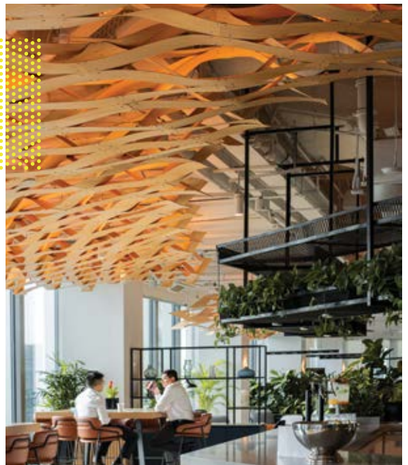
The project brings together all of SATS' expertise in food production with the deployment of automation and robotics to achieve operational efficiency. An Internet of Things (IoT) network will control processes within the hub to aid planning and reduce food waste. Large-batch production of meals will be automated for process efficiency and operational resilience. This move comes as a part of SATS' strategy to strengthen its Singapore core, while growing international and non-travel businesses.

Building on its SATS Global Innovation Hub, SATS will engage communities and stakeholders on innovation and sustainability, while tapping into the talent and collaborative ecosystem afforded by JID for innovation partnerships. Among the technologies to be implemented in this facility are a load and track transport system that uses RFID technology to track raw materials for real-time stocktaking and traceability; an automated system for picking and stacking retort pouches (food packaging made from a laminate of flexible plastic and metal foils); multi-format cartooning; a dashboard for the IoT platform; and a Bento line.

Beneath the Surface

Panelogue

Construction requires sustainable solutions, and that is exactly what Panelogue offers. Specialising in unique, handcrafted surfaces and high-performance wood-based panels gathered from sustainable sources and manufactured through innovative methods, Panelogue aims to shift production and consumption patterns so that builders, designers and architects can create spaces where ecology and urbanisation can progress in parallel. The firm developed its sustainable solution at its facilities in the Sungei Kadut Eco-District (SKED).



Panelogue deals exclusively with engineered materials that are safer and more sustainable. The company's founder and director, Ms Emily Sim, is an advocate of sustainability. She wanted to introduce and push engineered wood, instead of solid wood, to the industry. She started out with offering birch plywood at the first stage of her business. This was followed up with cork, which is harvested without damaging the tree, making it an environmentally friendly material for walls and flooring.

The ultimate goal was promoting conscious consumption through building awareness of alternative materials and purposeful integration of natural materials into a space, while ensuring safety for users. The company introduces these natural materials back into interior spaces, helping create biophilic spaces that are more comfortable for users and better for the environment.

Notable projects completed include examples at Meta, DBS, Dyson and Google.

The name "Panelogue" is derived from the words "Panel" and "Dialogue". Panelogue believes in a customer-centric and consultative approach to identify customisable panels that will be the best fit for any design. Thus, the company takes a consultative approach to recommend the right product that is fit for its purpose, an accurate mix function and cost. Panelogue works with progressive companies and discerning individuals who invest in innovative and sustainable materials.

Lift Off

Skyports

Hailing a cab may be an antiquated concept in the era of mobile apps, but what if the cab in question was an air taxi? It might seem far-fetched but that is exactly what Skyports plans to achieve in the next two to three years. Skyports is an Advanced Air Mobility (AAM) company developing and operating landing infrastructure for the electric air taxi revolution, as well as using drones for a variety of business requirements. Founded in 2018, it comprises two business units—Skyports Infrastructure, a leading enabler of AAM, and Skyports Drone Services, a provider and operator of eVTOL drones for cargo drone deliveries, survey and surveillance.

It plays a leading role in the global development of AAM infrastructure as well as the drone services sector, with the goal of elevating mobility and safety standards while supporting sustainability efforts.

Singapore is one of Skyports' key markets. Its first regional headquarters was set up in Singapore in 2020. Working closely with local authorities and stakeholders, Skyports is developing a calibrated roadmap for AAM and drone services to benefit local businesses and the community. It is also focused on developing interest and talent for the industry and collaborating with local institutes such as Republic Polytechnic, the Singapore Institute of Technology and other IHLs through its internship programme.

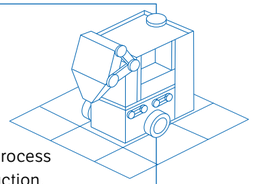
In March 2022, JTC welcomed Skyports as the first AAM company housed in its aerospace cluster at Seletar Aerospace Park. Following the steady growth of its operations, Skyports expanded to occupy a second unit in 2023.

Skyports' aspiration is to create a network of vertiports across its operating markets, which include the Asia Pacific, Middle East, the US and Europe. In Singapore, Skyports is also involved in the development of Seletar Aerospace Park as an AAM centre of excellence in partnership with JTC and EDB.

As for their drone business, Skyports Drone Services has been conducting commercial ship-to-shore trials in Singapore and performing daily inspections at Singapore's reservoirs for Singapore's National Water Agency PUB since 2021. The company has also expanded its services across APAC with the establishment of local branch offices in Japan and Korea.

Robotic Reboot

Fabrica.ai



Tile grouting is backbreaking and labour-intensive work, yet it is a necessary part of virtually every construction project. Fortunately, Fabrica.ai has invented and built automatic tile grouting robots to manage this laborious task, thereby boosting construction productivity. The company is currently piloting these robots on construction sites in Singapore managed by prominent construction firms and has early leads in the US and Europe as well.

For its purpose-built, task-oriented robot, Fabrica had to design multiple proprietary hardware parts that had to go through many iterations. It utilised more than 30 large-format 3D printers to expedite the process and reduce costs for the pilot production.

In the near future, Fabrica is looking to serve as an R&D-cum-manufacturing hub. Its future robotics solutions and testing, beyond tile grouting, prototyping or modular/product upgrades, will be enabled and done here in Singapore at LaunchPad at one-north, a vibrant and collaborative start-up ecosystem developed by JTC. Here, the firm taps into the JTC ecosystem to forge partnerships and conduct in-person meetings and events, important for hardware development. Fabrica is also leveraging on JTC's Built Environment Accelerate to Market Programme, jointly led by JTC, the Building Construction Authority and Enterprise Singapore. This programme gives JTC tenants the platform to better understand the industry's needs through consultation sessions, thus allowing Fabrica to showcase its robots through events such as the Built Environment Demo Day.

Powering the Future

Spectronik

With the G7's 2021 commitment to reach net zero by 2050, the global push for clean energy has been intensified. Stepping forth with a promising solution is Spectronik, a Singaporean start-up specialising in fuel cell solutions. Since its humble beginnings in 2011, the company—which joined the LaunchPad community at Jurong Innovation District in 2017, and moved to CleanTech Three for its expansion—has stood out with its excellence in innovation. Its forte is in the development of high density hydrogen fuel cells that can be equipped in relatively small applications such as industrial vehicles (such as AGVs and golf carts), robots, drones and small agricultural equipment.

Exclusively owned, patented, and 100% developed in-house by the company's Singapore-based team, Spectronik's fuel cell products boast higher efficiency in terms of converting hydrogen to electricity, and better energy output per unit weight compared to similar products on the market. While it boasts clients in 33 countries worldwide, spanning research institutions and universities, to automotive suppliers and even military and industrial drone manufacturers, the award-winning company does not rest on its laurels.

One of Spectronik's latest products is a zero emission, electric van powered by its own hydrogen fuel cell technology. Capable of carrying up to 1.5t of cargo, the van has a range of 500km and can be refuelled rapidly within five minutes, presenting an environmentally friendly transport and logistics solution. The company is currently working towards a pilot trial of the hydrogen fuel cell van within JTC CleanTech Park and surrounding Nanyang Technological University's (NTU) compound. Within the Centre of Excellence for Testing & Research of Autonomous Vehicles NTU (CETRAN) circuit at JTC CleanTech Park, Specktronik is also working with a group of NTU School's Mechanical and Aerospace Engineering students to power a single-seater eco-car with its hydrogen fuel cell.

In the near future, the ambitious company hopes to roll out a fleet of hydrogen fuel cell vehicles—such as vans and minibuses—on the public roads of Singapore. Spectronik also plans to expand its fuel cell R&D, advanced manufacturing and testing facilities in JTC CleanTech Park to support the company's increased commercialisation efforts, at the same time creating high-quality green jobs within the economy.

Illuminating the Future of Healthcare

Illumina

The rise of personalised medicine (PM) has the potential to change healthcare for everyone. However, it requires the generation of tens of thousands of human genomes a year, and at a reasonable price per genome. In Singapore, global genomics and human health company Illumina is helping to power the future of PM.

Illumina's first Singapore facility opened in 2008 and is the engine of genomics innovation. The facility has since grown to three buildings and more than 1,300 employees. Situated in JTC's industrial development at 7 North Coast, it is Illumina's largest manufacturing hub in the world. Geared for high-volume production of genomic technologies, it is the only Illumina facility worldwide that manufactures the full suite of Illumina products ranging from instruments and consumables to reagents.

Headquartered in San Diego in the United States, Illumina develops, manufactures and markets integrated systems for the analysis of genetic variation and biological function. Its industry-leading research and innovation enables clinicians to detect and diagnose diseases earlier, opening new and more effective treatment options. Among the groundbreaking products from Illumina is its most powerful gene sequencer ever, NovaSeqX. This instrument reinvents and revolutionises what is possible on a sequencer, with life-saving implications for patients, with revolutionary speed, scale and accuracy.

The global company's innovations could well be coming from Singapore too, with Illumina's first R&D centre in Asia housed at the same Woodlands site. The centre houses a multinational team of hardware and software engineers who design and develop some of the company's newest products. The North Coast office was awarded the Leadership in Energy and Environmental Design (LEED) Gold Building Certification, certifying it as a "green building".

Connecting Industries, Nurturing Start-Ups

LaunchPad @ one-north and JID

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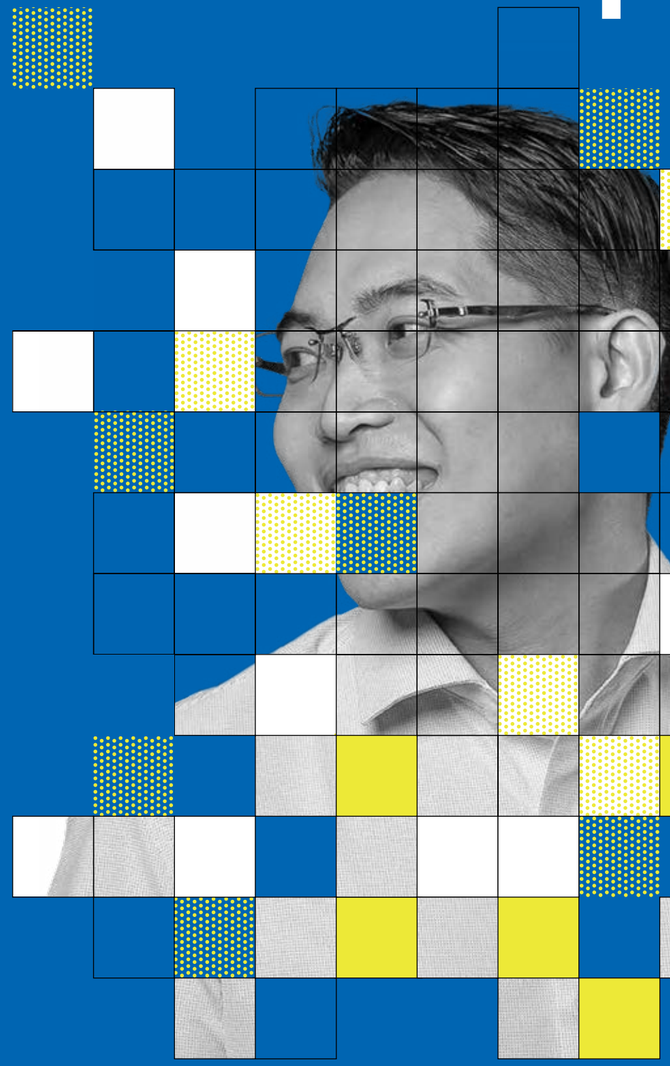
People

The hearts and minds behind our innovations and initiatives.



A Better Environment for All

Ms Irene Pautrisia Tandiono
Senior Project Manager,
New Estates Division

Concrete Plans

Mr Kevin Emanuel Suhartono
Senior Engineer, Future of
Building & Infrastructure Division

A Calculated Move

Mr Ng Kian Wee
Senior Principal Engineer,
Future of Building & Infrastructure Division

Going beyond the call of duty to take care of construction workers.

A Better Environment for All

There was a lot of excitement when plans to further develop Jurong Innovation District (JID) were announced in 2016. The Bulim area alone would boast a suite of cutting-edge facilities and futuristic transport networks—it was going to be an estate of the future. To realise this vision, JTC enlisted the services of contractors from China Construction (South Pacific) Development Co (CCDC), and building work was due to begin. Then the pandemic hit.

With original plans put on hold, it seemed like everything had come to a standstill. In reality, this was not the case. The whole division was put in motion to manage the unprecedented situation. "At the onset of the pandemic, there was a massive outbreak of infection among migrant workers due to the communal living arrangement in dormitories. Construction contractors were challenged to find accommodation options to house the workers and keep them safe," recalls Ms Irene Pautrisia Tandiono, a senior project manager for the Bulim development at JTC. "To assist our contractors and to manage the well-being of the workers, our first instinct was to extend our help to collectively explore alternatives to address the housing issues for the construction workers. As a public agency, we could also assist to expedite the processes or resolve the challenges faced by our contractors."

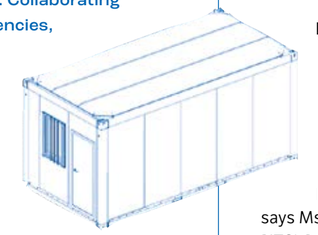
Given that most (existing) dormitories were not able to comply with social distancing regulations at the time, a new solution was needed and speed of implementation was crucial. Although Ms Tandiono and her team were able to find vacant plots of land within Bulim for the construction of the dormitory, there was a shortage of construction materials, bed frames and mattresses in Singapore, all needed to get the dormitory up and running on time.

Inspired by an online video of emergency hospitals erected within weeks in Wuhan, China, Ms Tandiono and her team knew this could be a breakthrough if it could be replicated in Singapore. CCDC was no stranger to the concept of Prefabricated Modular Construction as they were involved in the exercise in Wuhan. Most importantly, CCDC agreed to explore this solution with JTC.

Ms Irene Pautrisia Tandiono
Senior Project Manager,
New Estates Division, JTC

A Will to Serve

Outside of the JID site, JTC also set up temporary dormitories that would pilot improved living standards for workers. The Quick Build Dormitories are single-storey facilities with just 10 beds spaced at least 1m apart, offering each worker more living space compared to typical dormitories that sleep 16 on double-decker beds. Designed to help reduce the likelihood of disease spreading within tightly packed close quarters, this would be part of Singapore's whole-of-nation COVID-19 response. Collaborating with other government agencies, JTC also helped in the conversion of an old factory in Tuas into a Community Care Facility for migrant workers infected with COVID-19.



JTC's efforts extended beyond caring for workers. During the economic slowdown of the pandemic, JTC offered rental support to SMEs. Furthermore, programmes such as SMEs Go Digital and SMEs Digital Readiness webinars were introduced to help them bring their operations online.

"Construction contractors were challenged to find accommodation options to house the workers and keep them safe."

That was how Ms Tandiono, an architect by training, found herself hunched over a pile of concept plans for a new type of dormitory during the Easter weekend of 2020. She then spent the subsequent months tirelessly liaising with numerous government agencies and suppliers to move the project forward. That was, to have the prefabricated modular containers—complete with beds, internal fixtures and fittings—to be made off-site in China, shipped and installed on-site at Bulim. This would speed up the construction process considerably. With the support from the various government agencies, JTC worked with CCDC to bring the concept to Singapore.

"[The prefabricated modules] had never been used for dormitories in Singapore before, so there were a lot of challenges," she recalls. "Like how could we pass the Singapore Civil Defence Force's fire safety test when we couldn't test the materials locally, as the modules were pre-made in China? And how could we optimise the modules to comply with Ministry of Manpower's regulations? What permits would the Maritime Port Authority's need from us for these containers to be brought into Singapore?"

It was not just about building physically safe spaces either—the dormitories should feel like a home for the workers who would be living there. As such, recreational facilities such as basketball courts and community gardens were designed and integrated at the site.

Despite the hurdles, the double-storey dormitory was ready by October 2020, a mere six months after its conception. JTC then lent a hand to facilitate the move for around 900 workers involved in the Bulim project.

"I'm lucky to be working with a team who also believes in the vision and mission of this initiative," says Ms Tandiono. "We all had the desire to see through [JTC's] projects, of course, but our focus was really to provide a better environment for the workers."

With the workers' living situation settled, construction for the Bulim project could proceed through the pandemic. Phase 1 is now slated for completion in 2024, and manufacturing companies can look forward to finding their homes within JTC's Factories of the Future.

Discarded plastics as a construction material? A team goes down to granular details to dream big.

Concrete Plans

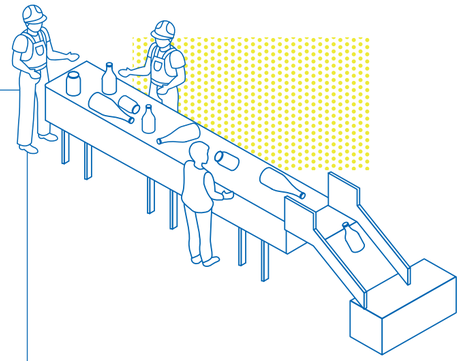
Singapore, like the rest of the world, has had a longstanding love-hate relationship with plastic. The material's adaptability, durability and affordability make it an ideal candidate for everyday use. However, as per the National Environmental Agency's (NEA) report, 982,000t of the plastic waste were generated in 2021 alone. Of that, only 6% was recycled, while the rest was incinerated. Clearly, more needs to be done about this burning issue.

Mr Kevin Emanuel Suhartono, senior civil engineer at JTC, is paving the way towards one possible solution. What if, he wondered, we could leverage plastic's inherent properties in building materials? Leading a team from JTC, and working in collaboration with Temasek Polytechnic and NEA, Mr Suhartono set out to find new answers.

Having been fascinated with mathematics and physics since childhood, Mr Suhartono pursued civil engineering and specialised in building underground transport infrastructure before joining JTC in 2019. He wanted to gain more experience in the construction of buildings, and ended up developing a deep passion for sustainability along the way.

From his research, he had learnt that people around the world have been experimenting with alternative

Mr Kevin Emanuel Suhartono, senior civil engineer at JTC, is paving the way towards one possible solution. What if, he wondered, we could leverage plastic's inherent properties in building materials?



building materials, such as transforming mycelium into organic bricks. And after attending a sustainability conference a few years ago, he became curious about whether plastic can be used in the production of another in-demand construction material: concrete.

"Concrete is a mixture of water, cement, gravel and sand," explains Mr Suhartono. "Water cannot be replaced, while cement is needed to bind the other components together. Plastic won't have the same strength as gravel to replace it, so the only part left in the equation is sand. The big question when we started was how we could convert plastic waste from its original form—including bubble tea cups, water bottles, or grocery bags—into the right size."

Each plastic grain would need to be reduced to less than 4mm for it to be a suitable replacement for sand, which is used as a fine aggregate to fill the gaps between larger gravel particles. The issue is that there are not many facilities capable of downsizing recycled plastic.

Fortunately, Mr Suhartono and JTC found adept partners in Temasek Polytechnic, which has deep expertise in the area and the right lab equipment to support the project. NEA also stepped in to provide technical advice on the environmental aspect of the project. The innovation project was realised through the Engineering Innovation Challenge, organised by the Public Sector Science and Technology Policy and Plans Office (S&TPPO), under the Prime Minister's Office in 2020.

Following rounds of lab experiments, their solution has been tested on non-structural applications, such as kerbs and drain channels at one of JTC's infrastructure project near Tuas Link MRT station. The project was indeed successful and was conferred the Merit Award at the Public Service Science, Technology and Engineering (STE) Conference 2022. Moving forward, the team will further develop the study to potentially expand the usage of plastic aggregate in other types of building and infrastructure elements.

There are still many challenges to overcome, including ways to bring down the production cost so the material can be adopted more widely across the industry. But finding a solution will ultimately be worth it.

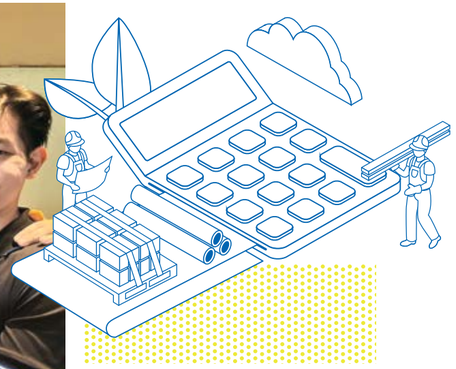
"Sustainability is a big thing, for we don't want to deplete our natural resources. But this project is also about enhancing our construction industry," says Mr Suhartono. "For many of our resources, including sand and gravel, we have been heavily relying on importation from other countries. If we can utilise materials that are available within our country, it will make us more resilient."

Mr Kevin Emanuel Suhartono
Senior Civil Engineer,
Future of Building &
Infrastructure Division, JTC

Building a carbon calculator to pave the way towards greener buildings.

A Calculated Move

Mr Ng Kian Wee (far left)
Senior Principal Engineer,
Future of Building & Infrastructure Division, JTC



It is fair to say that Singapore's vision of becoming a "garden city" has blossomed into a success story. But as the fight against climate change becomes more urgent, the need to green our city has to expand beyond natural spaces—reducing the carbon footprint of our built environment is just as important.

To achieve this, the Singapore Green Building Master Plan was launched as part of the Singapore Green Plan in 2021. One of its ambitious targets is to green 80% of Singapore's buildings (by Gross Floor Area) by 2030. This is especially crucial given that buildings account for over 20% of the country's carbon emissions, mainly due to power consumption.

A building's carbon emission comprises three parts: embodied carbon refers to what is produced in the construction phase, operational carbon is the amount emitted during the lifespan of the building and end-of-life carbon refers to the carbon produced during the deconstruction and waste treatment phase. On average, embodied carbon represents 30% of the buildings' emission, but in Singapore, that number can be as high as 40% due to constant urban renewal.

"There will come a point in time when embodied carbon will contribute a much higher percentage than operational carbon if business-as-usual practices prevail for the Built Environment sector."

Mr Ng Kian Wee, a senior principal engineer at JTC's Built Environment Automation Department, knew that for change to happen, there must first be better accountability.

"There has been extensive research and methods developed to account for operational carbon, and a progressive reduction of it thanks to improving Green Mark energy efficiency benchmarks for Mechanical, Electrical and Plumbing (MEP) equipment and Singapore's grid emission factor. However, carbon accounting for embodied carbon in Singapore remains a challenge due to the lack of robust localised material carbon database," says Mr Ng. "There was also a lack of suitable embodied carbon calculators for local industry use, as their emission factors were more suited to other regions in the world and would result in inaccurate embodied carbon accounting."

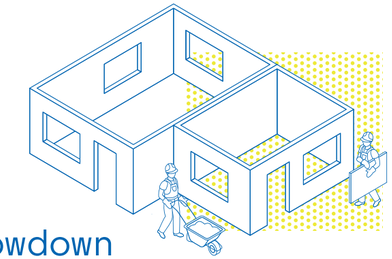
Mr Ng stresses that while embodied carbon might not have received as much attention before, this is not a trend that should be allowed to persist. "There will come a point in time when embodied carbon will contribute a much higher percentage than operational carbon if business-as-usual practices prevail for the Built Environment sector. According to a report by World Green Building Council, embodied carbon will be responsible for half of the building carbon from now till 2050," he shares.

To tackle this, JTC commissioned the National University of Singapore's Energy Study Institute to develop a Building Embodied Carbon Calculator (BECC), in collaboration with the Singapore Green Building Council and the Building and Construction Authority (BCA).

Embodied carbon accounting had been included in the BCA's Green Mark 2021 Whole-Life-Carbon assessment. The embodied carbon calculator will be used by JTC to tabulate embodied carbon of our developments and compute the amount abated against BCA's reference values in the Green Mark 2021 Whole-Life-Carbon section—a step towards meeting JTC's Green Plan target to reduce embodied carbon of our buildings by 30% by 2030.

"The BECC accounts for the upfront carbon of the materials, from cradle (raw material extraction and supply) to its practical completion (construction and installation)," explains Mr Ng. "For example, it took into consideration established building databases for 35 major building materials. These were then localised to the Singapore context via a developed classifier structure. Other aspects like the transportation distances for materials were also included."

The tool was officially launched in May 2022 as a comprehensive spreadsheet. Its latest iteration comes in the form of the Singapore Building Carbon Calculator, a web-based application available on the Singapore Green Building Council's (SGBC) website for the industry's use.



The Lowdown

Embracing embodied carbon accounting brought down the carbon footprint for Punggol Digital District (PDD).

30% lower:
By utilising green construction materials, the embodied carbon for the superstructure of PDD's towers is at least 30% lower than BCA's Green Mark 2021 benchmark value of 1,000 kg CO_2e/m^2 for non-residential buildings.

Carbon negative:
The timber structure, which is used at PDD Tower 4, is carbon negative.

180,000 tonnes:
The preliminary estimation of embodied carbon abatement for PDD superstructures, based on BCA benchmark.

The tool has also been applied in the developmental cycle of JTC's own projects, including the Punggol Digital District and the Jurong Innovation District, and public sector projects as well. "It will allow JTC to make decisions on the use of more sustainable materials, construction methodologies and even material sources that are closer to Singapore. Likewise, the Whole-of-Government and the Built Environment sector can utilise the BECC to achieve similar outcomes."

JTC is in the process of benchmarking the embodied carbon of JTC's standard industrial typologies with the Energy Research Institute @ Nanyang Technological University (ERI@N). "Once the quantified embodied carbon benchmark is completed, JTC will be able to measure and track the amount of embodied carbon abated for its developments every step of the way," says Mr Ng.

The BECC is part of SGBC's repertoire of tools, programmes and initiatives designed to advance built environment sustainability, help to create greener, healthier and low-carbon buildings for everyone, everywhere. Using the BECC will ensure that our buildings can be as green as they are beautiful, which is an achievement that Mr Ng and his team can be very proud of.

Kampung Spirit 2.0

Going beyond building spaces to building and uplifting communities.

At the forefront of developing industrial infrastructure in Singapore, JTC goes beyond laying the groundwork for brick and mortar premises. JTC has also championed the building of something else: communities.

After all, the sense of togetherness, or "kampung spirit" as we call it locally, referencing the Malay word for "village", is part and parcel of Singaporean culture. In the kampung days of yore, villagers had little, but they had each other. Those within the community supported one another: food was shared and help was given where needed. While the kampungs of Singapore have made way for gleaming skyscrapers, the spirit lives on even within industrial communities.

Over the decades, JTC has stuck by the principle that industry transformation can only happen if everyone works together on both an individual and organisational level. To facilitate these connections, JTC has actively created an environment of collaboration across its estates. One example is Seletar Aerospace Park, which houses SMEs like Coway Engineering—an engineering and aircraft servicing company—alongside industry giants such as Bombardier, Airbus and Rolls-Royce. On top of providing physical common ground, JTC also organises networking events, talks and community events for tenants to socialise and spark potential collaborations. Furthermore, regular engagement with the community through focus groups also ensures that their needs and concerns can be heard and addressed.

Launching Into Success

It is not just established companies who benefit from JTC's approach to growing communities within estates. As part of its efforts to support Singapore's quest to become a global start-up hub, JTC established LaunchPad to provide a conducive environment for founders, researchers, venture capitalists and other industry players to mingle under one roof. LaunchPad @ one-north was established in 2015, followed by LaunchPad @ Jurong Innovation District (JID) in 2017. To date, LaunchPad has grown to be one of the region's most densely packed and dynamic entrepreneurial ecosystem that has played host to over 1,300 start-ups, including Carousell, ShopBack and 99.co.

Always seeking new ways to support LaunchPad start-ups in their growth, JTC launched LaunchPad Investor Network (LINK) in May 2022. The new initiative curates and connects LaunchPad start-ups with global companies to catalyse business and financing opportunities. It also allows start-ups to work with them on joint innovation and R&D activities, to test-bed and scale their solutions and to tap on their regional and global networks for market expansion. In addition, JTC proactively encourages start-ups to use LaunchPad as an "innovators' playground" to test new technologies or validate their business concepts by providing suitable space to support test-beds.

Connecting the Dots

JTC has also been bringing together its vast network of partners in new ways. The Industry Connect Office, for instance, was opened in 2021, at CleanTech Three @ JID as a one-stop centre to support local manufacturers in their Industry 4.0 transformation.

Given the rapid changes catalysed by breakthroughs in technology, keeping up with industry transformation is critical for companies to stay competitive. While the digital acceleration brought on by the pandemic has given many SMEs the awareness to change with the times, not all know the technological tools available in the market or can identify the correct solution to their problems. Many also have skill gaps in their workforce and training is needed to help their workers transit into new digital roles.

The JTC Industry Connect Office in JID thus steps in as a growth partner. It assists in matching companies to various channels that can link them to solution providers, technology enablers, Institutes of Higher Learning, trade associations and government agencies. Through this process, companies can also better identify problems and solutions, be it to partner the right companies or to train and upskill their workers. As part of the JTC Industry Connect Office's initiatives, companies can also participate in sharing sessions on ways to improve productivity from global and local partners including Bosch Rexroth, McKinsey and the Advanced Manufacturing Training Academy (AMTA).

A community that stays together, farms together

Ang Mo Kio Industrial Park 2 Association

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Nestled within the motoring companies and manufacturing firms at AMK Industrial Park 2 is a little slice of paradise. Here, locally grown vegetables flourish while fish swim in a specially built tank nearby. A clever irrigation system transports nutrient-rich water from the tank to the vegetable plots, which is absorbed by the plants before flowing back into the tank.

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The Community Aquaponics Farm is a volunteer-run initiative that grows and distributes food for over 200 needy families weekly. Conceived by Daniel Ling, the founder of IT management firm MegaNet, the project is a collaboration between JTC and 23 other tenants from the AMK Industrial Park 2 Association.

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In just three years, the farm has grown into a place where members of the public can also visit and help, bringing together the working community within the industrial park and the residents around it. "The people in the industrial park don't really benefit from this financially," says Mr Ling. "But we bond through this space—we are like brothers and sisters."

Many Hands Make Sustainable Work

Of course, transformation is not just about automation. With a looming climate crisis, the growth of businesses must also be environmentally sustainable. To that end, JTC has joined forces with A*STAR's Singapore Institute of Manufacturing Technology, TÜV SÜD Asia Pacific and four other companies to build a new tool called Green Compass in 2022. Through a four-step model, local enterprises can learn how to reduce their carbon emissions, energy, water, waste products and business costs.

By nurturing the many communities under its care and building new pathways for the sharing of knowledge and resources, JTC continues to help industries in Singapore thrive. After all, it truly takes a kampung, a village, to raise the companies of tomorrow.

Of New Processes and New Blood

Company Journey 1

Aik Chin Hin

Founded in 1974, Aik Chin Hin is one of the leading hardware and light machinery distributors in Singapore for the construction and manufacturing industry. Its impressive product portfolio of clients includes construction equipment brands such as Makita, Balma and Hikoki. The company is currently managed by the second and third generations of the Seow family and occupies 16 units in JTC Ang Mo Kio Industrial Park 2 (AMKIP2).

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Internal Community 1
(Aik Chin Hin Benefits)

Working With Other Businesses in AMKIP2

Located within a mature residential estate, AMKIP2 has a fantastic tenant mix of small and medium-sized enterprises, allowing for collaborative opportunities within the community. Aik Chin Hin has established business dealings with neighbours like Lee Sing Engineering for metal work and Goh Lee Hwa Automobile for jobs that require spray paint.

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Industry Connect 2c

Temasek Polytechnic—Upskilling of Workers

Aik Chin Hin was also connected with Temasek Polytechnic's National Centre of Excellence for Workplace Learning. This allowed their workers to continually upskill via on-the-job training programmes.

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Industry Connect 2b

Institute of Technical Education (ITE) and Republic Polytechnic—Internship Programmes

Through JTC's Industry Connect, Aik Chin Hin provided internship opportunities for students from ITE and Republic Polytechnic. The interns were placed in various roles across its business operations, from administration to servicing and repair works, as well as warehousing operations. Through this initiative, Aik Chin Hin had the invaluable opportunity to both learn from and nurture the future generations of talent.

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Internal Community 2
(Aik Chin Hin Giving Back)

Community Farm

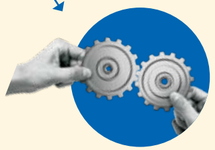
The AMKIP2 Association gives tenants a friendly, informal way to come together. Aik Chin Hin is an active member and even supplied the water pumps and generators for the community garden [see box on page 27].

\+

Industry Connect 1

Grants

Aik Chin Hin was selected to be part of JTC's Industry Connect initiative for its potential for upscaling and willingness to embrace digitalisation. One of the benefits the company received is access to the Enterprise Singapore's Productivity Solution Grants, which enabled Aik Chin Hin to list their products in e-commerce platforms, even establishing its own web portal.



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Industry Connect 2a

Singapore Polytechnic—Digital Workflow and Processes

The Industry Connect supported Aik Chin Hin through linking the company up with Institutes of Higher Learning. Beyond talent acquisitions, this allowed the company to tap into fresh new ideas. For instance, students from Singapore Polytechnic's "Introduction to Enterprise Innovation" elective would propose solutions and frameworks to address some of Aik Chin Hin's challenges. This includes helping the company digitalise its backend repair operations for greater efficiency and productivity.

Taking a Heritage Business Into the 21st Century and Beyond

Company Journey 2

Tiong Lian Food

Founded in 1947, Tiong Lian Food is a third-generation family business that imports and distributes pork and meat products. The company planted its humble roots in the very same kampung where Mr Benson Teo's father worked as a butcher; today, it is a thriving operation with a customer base comprising restaurants, hotels, e-commerce platforms and more. Tiong Lian Food has an almost 200-strong team today and a manufacturing plant at JTC's Pandan Loop Industrial Estate that recently underwent a $7 million upgrade.

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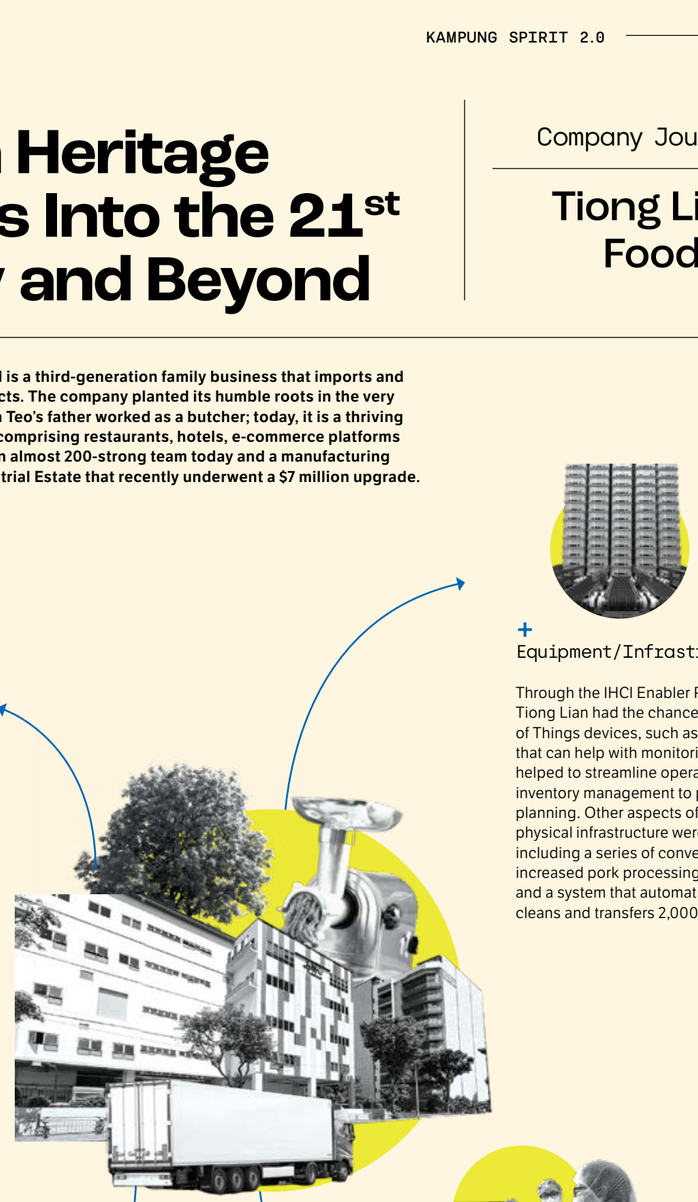
Traditional Business

For decades, much of the work at Tiong Lian was labour-intensive. Every step of the business, from butchering to storage was done by hand. But as the business grew, the limitations and inefficiencies of this set-up became increasingly apparent. It was clear to Mr Teo and his sons who work alongside him in the family business that they needed to embrace digitalisation and automation.



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Equipment/Infrastructure

Through the IHCI Enabler Programme, Tiong Lian had the chance to install Internet of Things devices, such as data sensors that can help with monitoring output. This helped to streamline operations from inventory management to production planning. Other aspects of the plant's physical infrastructure were also automated, including a series of conveyor belts that increased pork processing by up to 50% and a system that automatically organises, cleans and transfers 2,000 crates a day.

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Transforming With the Times

When Singapore Business Federation and Workforce Singapore launched the Industry 4.0 Human Capital Initiative (IHCI) Enabler Programme with support from JTC in 2020, Tiong Lian was one of the first companies to jump at the opportunity. The eight-week programme helped the company identify and trial key areas to digitise, while also mapping out ways to upskill their team.

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Manpower

As a result of automating numerous processes, Tiong Lian's employees can now focus on more engaging and fulfilling work while also upskilling themselves. This is especially the case for more mature members of the team, 15% of whom are aged between 60 and 70. To ensure that everyone feels confident working with new machinery, Mr Kelvin Teo, the third-generation leader and currently the company's business operations manager, adopted senior-friendly designs, including larger buttons, and personalised training and demonstrations.

Growing From the Core

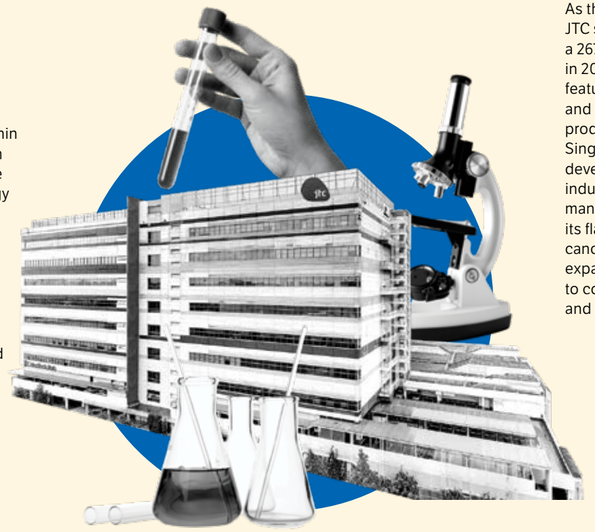
Company Journey 3

MiRXES

MiRXES was founded with an ambitious goal to "discover, develop and deliver accurate preventive healthcare solutions for cancer, cardiovascular, metabolic and infectious diseases and make them accessible to all". In 2022, it opened the first Industry 4.0 manufacturing facility in Southeast Asia to produce diagnostic test kits in vitro—but they could not have done it alone.

+ Planting Roots

MiRXES first became a tenant within the one-north Biopolis ecosystem in 2011 when it was still part of the A*STAR Bioprocessing Technology Institute. When the company spun out on its own three years later, the three founders decided to remain in the biomedical and life sciences R&D hub due to its state-of-the-art infrastructure, vibrant community and proximity to pharmaceutical companies and Institutes of Higher Learning.



+ Room to Bloom

As the company began to expand, JTC supported its growth by allocating a 267-m^2 unit at JTC MedTech Hub in 2016. Equipped with thoughtful features such as separate corridors and loading bays for clean finished products, JTC MedTech Hub is Singapore's first custom-built development for the medical technology industry. It became home to MiRXES' manufacturing site for GASTROClear, its flagship product for early gastric cancer detection. Its premises were expanded with additional unit space to consolidate its warehousing and ancillary office functions.

+ Leading the Charge

The next phase of MiRXES' fight against cancer is centred on bolstering the company's innovation, manufacturing and testing capabilities to extend its end-to-end pipeline. JTC joins the company in this expansion journey. In 2022, MiRXES launched its first and largest Industry 4.0 in vitro diagnostic manufacturing site in Southeast Asia—an $8 million facility at JTC MedTech Hub.

+ The Fight Continues

Now a key player in the biomedical community, MiRXES continues its growth. Apart from spreading its manufacturing facilities at JTC MedTech Hub, it also kick-started its bio-bank operations in 2022, within its first home at Biopolis. The project is set up in collaboration with a healthcare consortium, with a focus on cancer screening and testing in its quest to develop the world's first nine-in-one cancer blood screening test kit for early detection.

Launch and Boost

Company Journey 4

Carousell

Founded by Mr Lucas Ngoo, Mr Marcus Tan and Mr Quek Siu Riu in 2012, Carousell is a classifieds marketplace for preloved items. Just over a decade later, it is now a unicorn with a US$1.1 billion valuation. It is one of several success stories to emerge from JTC's LaunchPad.

+ Carousell's First Home

When Carousell was born, the start-up scene in Singapore was still in its infancy. Fortunately, as the founders are alumni of the National University of Singapore's Overseas Colleges, they were given the opportunity to join an NUS incubation facility located within Block 71 Ayer Rajah Crescent (now part of LaunchPad @ one-north). At the time, it was the first and only co-working space for start-ups in Singapore.

+ Valuable Connections

During their time there, the Carousell team became part of a network comprising fellow technology entrepreneurs, who would support and learn from each other. Another neighbour at Block 71, venture capital firm Quest Ventures, subsequently became an investor in Carousell.

+ Onwards and Upwards

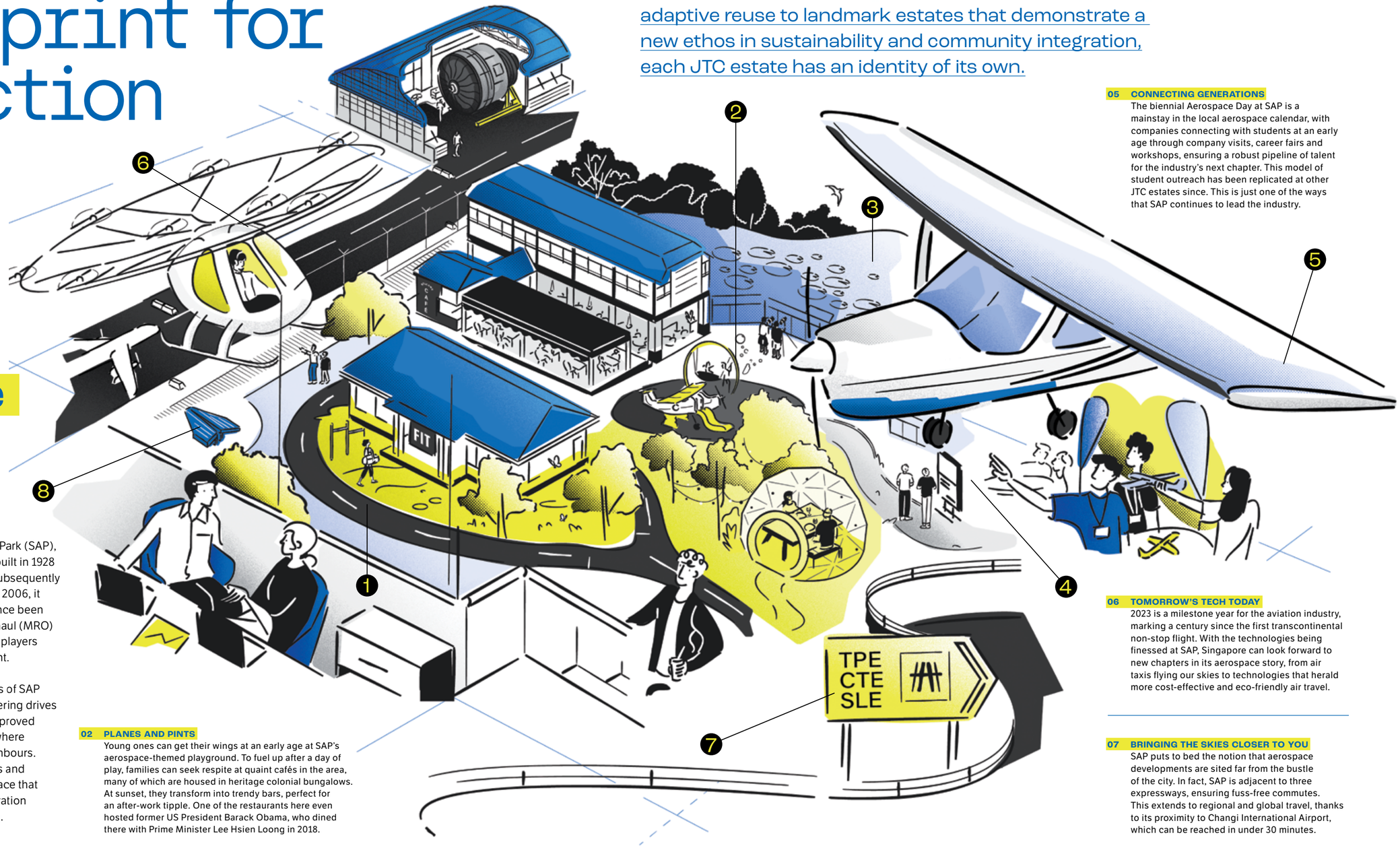
Carousell graduated from LaunchPad @ one-north in early 2017, moving into a bigger office in Tanjong Pagar to accommodate its growing team. But the team had such great memories of Block 71 that they even named a collaboration area after it. As the business grew, it began acquiring companies such as One In Shoes, Ox Luxe and Refash.

+ Home Sweet Homecoming

In 2022, Carousell returned to its first home, LaunchPad, but now with a new role to play. A company that has journeyed from being a hopeful start-up to becoming part of Singapore's growing list of unicorns, Carousell now works with JTC on programming and community building efforts, such as organising tech talks on topics such as best practices for go-to-market strategies. The company is also heavily involved in the Action Community for Entrepreneurship (ACE) through its mentorship programme, while one of the founders also sits on ACE's board of directors.

Blueprint for Distinction

From historical sites brought into the 21st century through adaptive reuse to landmark estates that demonstrate a new ethos in sustainability and community integration, each JTC estate has an identity of its own.



Seletar Aerospace Park

Bridging Worlds: A Space That Connects New and Old, Work and Play

Aviation connects worlds. At Seletar Aerospace Park (SAP), it is also what bridges the past and future. First built in 1928 as a strategic airbase for the Royal Air Force, it subsequently became Singapore's first international airport. In 2006, it was master planned as a 320-ha site, and has since been transformed into a Maintenance, Repair & Overhaul (MRO) hub to more than 60 local and global aerospace players who are driving the industry's future development.

A place with an intriguing history, the true glories of SAP lies in the present and future. The physical clustering drives greater synergies across businesses through improved convenience and cost savings to be enjoyed—where suppliers, customers and partners are also neighbours. More than a congregating ground for the movers and shakers of the aerospace industry, it is also a space that welcomes a larger community through full integration of lifestyle attractions and green estate planning.

01 ROUND THE OVAL
The Oval, SAP's in-house lifestyle hub, is a stone's throw away, allowing you to go from boardroom to boardwalk, and presentation hour to happy hour in a matter of minutes. Like Singapore itself, The Oval's greatest allure is its diversity; there is something for everybody. Those not looking for a meal will still find something here, from a fitness studio to an events space that is a famed site for weddings and birthdays.

02 PLANES AND PINTS
Young ones can get their wings at an early age at SAP's aerospace-themed playground. To fuel up after a day of play, families can seek respite at quaint cafés in the area, many of which are housed in heritage colonial bungalows. At sunset, they transform into trendy bars, perfect for an after-work tipple. One of the restaurants here even hosted former US President Barack Obama, who dined there with Prime Minister Lee Hsien Loong in 2018.

03 NATURE NEXT DOOR
Nature is not a foreign concept to those at SAP. Thanks to deliberate and thoughtful greening efforts, aerospace companies can enjoy nature at their doorstep. At the top of the list is the tranquil and rustic Hampstead Wetlands Park, home to snags and habitat islands that provide wildlife with shelter, nesting spots and resting grounds.

04 A SHARED JOURNEY
While it looks to the future, SAP also embraces its lasting relationship with Singapore's aerospace history. Many milestones were marked here, including the arrival of Singapore's first commercial flight in 1930 and combat during World War II. Future generations can better understand these events through the area's heritage trail and string of carefully preserved buildings.

05 CONNECTING GENERATIONS
The biennial Aerospace Day at SAP is a mainstay in the local aerospace calendar, with companies connecting with students at an early age through company visits, career fairs and workshops, ensuring a robust pipeline of talent for the industry's next chapter. This model of student outreach has been replicated at other JTC estates since. This is just one of the ways that SAP continues to lead the industry.

06 TOMORROW'S TECH TODAY
2023 is a milestone year for the aviation industry, marking a century since the first transcontinental non-stop flight. With the technologies being finessed at SAP, Singapore can look forward to new chapters in its aerospace story, from air taxis flying our skies to technologies that herald more cost-effective and eco-friendly air travel.

07 BRINGING THE SKIES CLOSER TO YOU
SAP puts to bed the notion that aerospace developments are sited far from the bustle of the city. In fact, SAP is adjacent to three expressways, ensuring fuss-free commutes. This extends to regional and global travel, thanks to its proximity to Changi International Airport, which can be reached in under 30 minutes.

08 PLANESPOTTING
Benches shaped like origami paper planes give visitors an idea of what they can see from The Oval's boardwalk: planes of all sizes, including private jets and commercial airliners, roaring down the runway as they depart or glide into Seletar Airport.

Sungei Kadut Eco-District

Ready for Tomorrow

Despite being one of Singapore's oldest industrial estates, the sprawling 500-ha Sungei Kadut Eco-District (SKED) will present a whole new facet of industrial estates upon rejuvenation. Set as a destination for the next wave of manufacturing, the facelift of the estate makes way for new growth industries like agri-food tech. At the same time, it also caters to longstanding industries such as metal and machinery, timber and furniture, alongside waste management and recycling. These industries make up SKED's four distinct zones: the Agri-Food Innovation Park (AFIP), SK North, SK Central and SK South. Rejuvenated with new future-ready technologies and facilities, the SKED experience demonstrates that you truly can have the best of both worlds—the old and the new.

01 AFIP: THE FUTURE OF FARMING

Farming is one of mankind's oldest industries, but it is propelled to the future at SKED. About 18-ha of land at SKED has been set aside for the first phase of development for Agri-Food Innovation Park (AFIP). Here, systems engineers, plant scientists and aquaculture nutritionists will come together to set new standards for indoor farming and aquaculture hatcheries. The co-location of agri-tech activities will also drive innovation and shepherd the discovery of new synergies.

02 GREEN AND BLUE PURSUITS

As Singapore sets its ambitions on becoming a City in Nature, we also have to reimagine how manufacturing activities can be conducted—alongside non-industrial activities within a park-like environment. As such, much effort has been put into creating the Green and Blue Master Plan for SKED, which leverages on its proximity to surrounding nature to enhance the working environment while preserving the biodiversity of the natural ecosystem. The end result: a model of a new industrial estate co-existing harmoniously with nature.

As part of the green and blue vision for the estate, special efforts are also taken to protect the coastal areas of Sungei Kadut, a low-lying area susceptible to flooding from rising sea levels and increased rainfall intensity due to climate change. Rather than relying solely on hard engineering, nature-based solutions were explored, resulting in a coastal protection plan that also creates recreational sites and ways to improve active mobility connectivity.

03 LESSONS FOR THE WORLD

Transformation is not new to Sungei Kadut. In the 1970s, it rose from a mangrove swamp to a thriving hub for the sawmill and woodworking industries. Its ongoing rejuvenation into an eco-friendly estate for new growth industries certainly will not be its last. The lessons gained from these experiences, such as how to infuse data into estate planning and how to design industrial spaces that are adaptable and responsive, will be increasingly exportable to the rest of the world.

04 COOL IS IN THE AIR

Industrial estates are sometimes associated with stifling urban heat. At SKED, however, the rejuvenated estate will enjoy cooler temperatures thanks to the proposed generous green cover that stands at 40% of the district.

Transformation is not new to Sungei Kadut. In the 1970s, it rose from a mangrove swamp to a thriving hub for the sawmill and woodworking industries.

05 SK NORTH: STRETCHING RESOURCES FURTHER

SKED is home to the Kranji Built Environment Hub, which comprises Kranji Green and TimMac. Both these facilities have become familiar names in the industry, and are supporting the built environment ecosystem's transformation for the future.

Kranji Green makes land use more efficient by offering Singapore's first multi-storey facility for various industries, including recycling, which is traditionally a land-intensive process. Functioning as a hub for waste management and recycling, companies based here recycle discarded metals, plastic, paper, as well as construction materials into useful materials like pallets and furniture.

Meanwhile, TimMac brings together small and medium enterprises from the metals, machinery and timber industries to help them transform and improve their productivity and work in an efficient high-rise and multi-tenanted space.

Both Kranji Green and TimMac were designed in consultation with associations, designed and built to meet the industry's needs. Co-locating different parts of the built environment value chain also fosters greater business collaboration and the building up of a strong industry ecosystem.

06 SK CENTRAL: AHEAD OF TRENDS

Completed in 2019, Trendspace is a high-rise development in SKED built as the first in Singapore to cluster furniture and fit-out companies. Built with the aim of promoting industry collaboration, the eight-storey development houses a cross-section of companies within the industry, from furniture manufacturers, distributors and material suppliers to fit-out specialists.

07 SK SOUTH: NEW WAYS OF WORKING

This area features a mix of uses, from light industries to new forms of co-working and co-living spaces. Waterfront views further add to its cool factor—both literally and figuratively.

08 THE PLACE TO BE

Traditional industrial estates go silent at the end of the workday, but the upcoming revamp of Sungei Kadut promises to keep the area active and vibrant with new recreational nodes and dining options. Apart from creating a better work-and-play environment for the working community, this liveliness will likely attract residents in surrounding neighbourhoods to see SKED as more than just an industrial estate, but a vibrant addition to their greater living environment.

09 STELLAR CONNECTIVITY

When completed in the 2030s, the SKED mobility corridor will arguably be one of its most popular features. Envisioned to be a lively thoroughfare, it is set to connect the entire estate, keeping amenity centres, product showrooms, shops, restaurants, parks and recreational facilities within reach of a short walk or bicycle ride, making the estate more accessible and inclusive for the community.

Defu Industrial City

Expansive Versatility for Reimagining Traditional Businesses

An estate developed in the 1970s, Defu Industrial Estate has been going through a metamorphosis. Rising from this is an eight-storey development catering to B2 industrial businesses requiring heavier manufacturing and production: the Defu Industrial City. Designed to support a wide variety of trades—from warehousing to manufacturing—the units at Defu Industrial City each enjoy its dedicated loading and unloading bay, lift landings and parking lots for both cars and heavy vehicles.

The units at Defu Industrial City further stand out with their sheer expansiveness. With ceiling heights ranging from 4.5 to 8m, and unit floor size spanning 405 to 5,745m², these cavernous spaces present unparalleled versatility for customisation.

Defu Industrial City is also developed as an all-in-one concept serving not just businesses, but the workers within the industry. Dormitories on the rooftop conveniently house workers on-site. The site also gives the communities convenient access to recreational facilities such as basketball courts and outdoor fitness corner, all integrated with green pockets for relaxation.

01 HIGH-RISE LIVING

On the rooftop of Defu Industrial City is a 700-bed dormitory, conveniently located on-site for workers to rest and relax at the end of the workday, without the need for additional commuting.

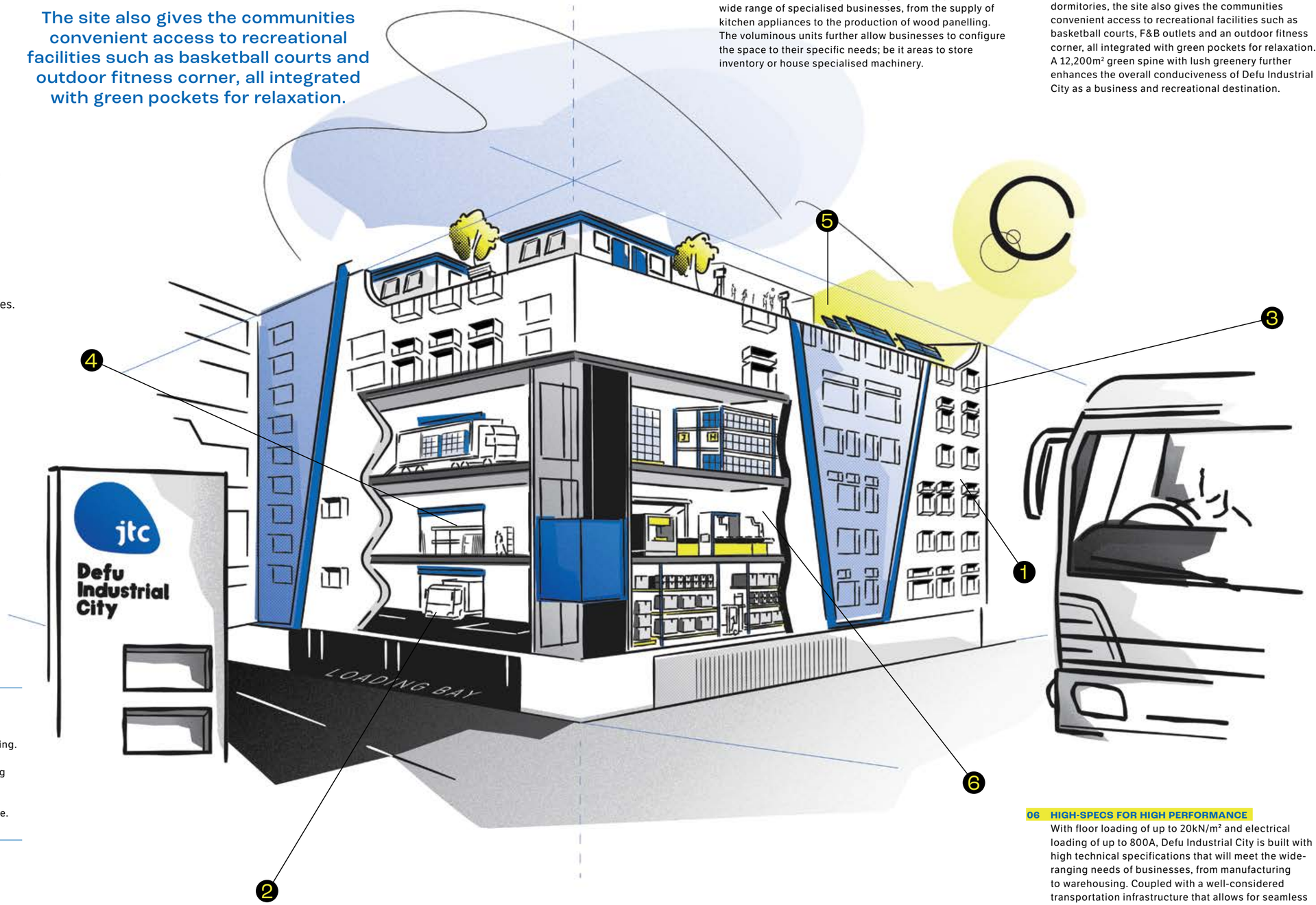
02 RAMPED UP EASE

A wide, two-way central ramp allows even massive 40-foot vehicles to move effortlessly through the building. This means goods can be transported right to or from the doorsteps of each unit. There are dedicated loading and unloading bays for swift drop-offs. On top of that, each unit enjoys designated parking lots and level lift landings for both production floor and mezzanine office.

03 SUN SALUTES

Integrated onto the roof of Defu Industrial City are solar panels spanning 3ha. The clean energy harvested from this solar deployment goes directly into the grid, contributing to Singapore's Green Plan 2030 sustainability targets.

The site also gives the communities convenient access to recreational facilities such as basketball courts and outdoor fitness corner, all integrated with green pockets for relaxation.



04 SPACE TO IMAGINE

With a wide range of units up to 5,000m² in size and ceiling heights ranging from 4.5 to 8m, the expansive spaces within Defu Industrial City are designed to support a wide range of specialised businesses, from the supply of kitchen appliances to the production of wood panelling. The voluminous units further allow businesses to configure the space to their specific needs; be it areas to store inventory or house specialised machinery.

05 A HUMAN SPACE

Defu Industrial City is also developed as an all-in-one concept serving not just businesses, but the workers within the industry. Apart from the rooftop workers dormitories, the site also gives the communities convenient access to recreational facilities such as basketball courts, F&B outlets and an outdoor fitness corner, all integrated with green pockets for relaxation. A 12,200m² green spine with lush greenery further enhances the overall conduciveness of Defu Industrial City as a business and recreational destination.

06 HIGH-SPECS FOR HIGH PERFORMANCE

With floor loading of up to 20kN/m² and electrical loading of up to 800A, Defu Industrial City is built with high technical specifications that will meet the wide-ranging needs of businesses, from manufacturing to warehousing. Coupled with a well-considered transportation infrastructure that allows for seamless accessibility between businesses and suppliers, the design of Defu Industrial City will lend greater ease and efficiency to business operations.

Wafer Fab Parks

Fabricating for the Future

Represented in a nanometre, a unit that equals one-billionth of a metre, semiconductor chips are minute in size but big business. In 2021, 1.15 trillion chips were sold worldwide. That amounts to approximately 130 million sold per hour. Some estimates suggest that if all the semiconductors sold in 2021 were stacked atop each other, they would extend beyond the cruising altitude of commercial jetliners.

Semiconductors are integral building blocks powering the technologies that define modern life—everything from 5G connectivity to the Internet of Things.

At JTC's Wafer Fab Parks, manufacturers do more than power our future: they also power the local economy, contributing to more than 80% of Singapore's electronics manufacturing output and more than 7% of its gross domestic product as of 2023. The key companies of this industry, including Micron, GlobalFoundries, Siltronic and UMC, are all located within JTC's various Wafer Fab Parks.

At JTC's Wafer Fab Parks, manufacturers do more than power our future: they also power the local economy, contributing to more than 80% of Singapore's electronics manufacturing output and 7% of its gross domestic product.

01 GOAL GREEN

All four Wafer Fab Parks would be distinctly greener with trees planted along the roads and pedestrian walkways, thanks to a partnership between JTC and the National Parks Board.

02 RESPECTING NATURE

The development of the Wafer Fab Parks is guided by ecological reports that assess the impact of the project on the area's ecology. Measures to mitigate this impact have been introduced, including the translocation of wildlife to other sites in Singapore and inspecting trees for wildlife and relocating them with the aid of qualified specialists.

03 BIG BUSINESS

JTC's four Wafer Fab Parks—in the North Coast, Pasir Ris, Tampines and Woodlands—stretch more than 374ha and house 15 global semiconductor companies that boast a workforce of more than 19,000. The country accounts for about 11% of the global semiconductor market and 5% of wafer capacity; 20% of global semiconductor equipment is manufactured here. Companies at JTC's Wafer Fab Parks include

- North Coast: Micron, Broadcom
- Pasir Ris: UMC, SSMC, Soitec
- Tampines: Silicon Box
- Woodlands: Global Foundries, Micron

04 NO PART TOO SMALL

While the parks are homes to international movers and shakers, they are also dynamic communities supporting local SMEs. Proximity to MNCs—such as GlobalFoundries, SSMC, and Micron—has put local companies such as EMK Technologies and Mega Valve & Fitting Pte. Ltd. in good stead to lend their services to these global producers. In doing so, SMEs are also given the opportunity to play a vital part in developing our national semiconductor industry.

05 SET FOR SEMICONDUCTORS

Semiconductor operations are complex processes requiring extremely specific demands in the manufacturing environment. This includes exacting factors spanning stable electrical and, ultrapure water supply, to even tempering vibration within the dust-free cleanrooms where these operations are performed.

06 TOMORROW'S TALENT, TODAY

More than just housing the semiconductor industry, JTC's Wafer Fab Parks also offer a platform for connecting with students, fresh graduates and mid-career professionals. Such connections are key to building a pipeline of talent for the future. JTC works closely with academia, industry associations and other government agencies to build and nurture these networks. JTC hosted the inaugural Electronics Industry Day in 2019. The event connects industry players with students from Institute of Higher Learning to foster the nurturing of new talent.

one-north

A North Star in Work-Live-Play-Learn Integration

What's in a name? In the case of one-north, it's a reference to both geography and excellence. The term is a play on Singapore's geographical location one-degree to the north of the equator. It also alludes to the high-level research and development that goes on within: info-comm technology, media, science and engineering, biomedical and life sciences, and pioneer research into emerging industries. From new ways of thinking about pharmaceuticals to a fresh spin on storytelling, one-north is home to companies and start-ups that frequently go above and beyond the competition. With names like A*STAR, P&G, Grab, Razer and Lucasfilm all within the one-north community, every day is an opportunity to interact and innovate, with movers and shakers.

Beyond its status as Singapore's premier R&D cluster, one-north is also one of the very first estates in Singapore to pioneer the live-work-play-learn integration. one-north is not only designed for the community to thrive at work; it is an environment for every individual to flourish in different areas of their lives—from physical and mental well-being to the bonds they build with others.

01 WFH WITH A DIFFERENCE

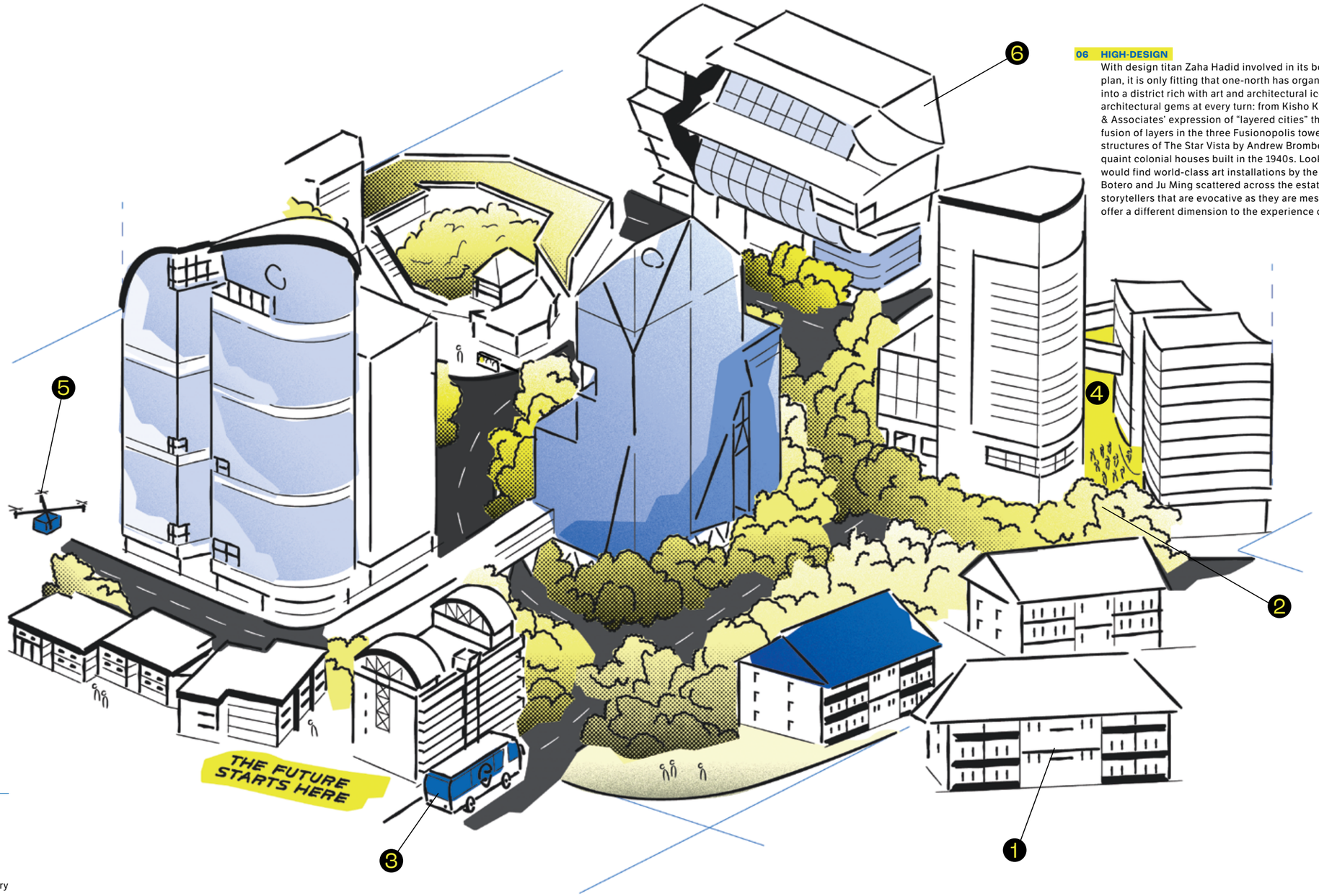
Even before "work from home" (WFH) was in vogue, the community at one-north was already pioneering that concept, albeit with a slightly different interpretation. With a multitude of residential options available here, from heritage colonial-era houses and apartments in Wessex precinct to the vibrant community of professionals and students at modern co-living spaces such as lyf one-north Singapore, one-north is truly a modern-era district that seamlessly integrates living and working spaces into one.

02 GREEN IN ITS GENES

According to studies, being immersed in nature can boost problem-solving skills by up to 50%. At one-north, the community enjoys exactly that. About 16ha of one-north's 200ha is an oasis of greenery, forming the central spine that connects the precincts within the estate. Some of this greenery has taken root through ground-up efforts; one-north's first community tree planting in 2018 saw 16 companies and eight individuals donating 115 trees to spruce up nature in the area.

03 LEAVE THE CAR BEHIND

By working closely with local stakeholders, one-north has earned the distinction of being the first car-lite business park in Singapore. These partnerships led to 20 companies and their staff pledging to go car-free for a whole day in 2019. To make the switch from cars more appealing, the one-north Rider, an on-demand electric shuttle bus service, has ramped up its operations and accessibility. People can book trips simply with their mobiles and travel to 31 stops throughout one-north, including MRT stations and food spots like Ghim Moh Market and Holland Drive Market.



06 HIGH-DESIGN

With design titan Zaha Hadid involved in its bold master plan, it is only fitting that one-north has organically grown into a district rich with art and architectural icons. There are architectural gems at every turn: from Kisho Kurokawa Architect & Associates' expression of "layered cities" through the vertical fusion of layers in the three Fusionopolis towers, to the soaring structures of The Star Vista by Andrew Bromberg, to even quaint colonial houses built in the 1940s. Look closer and you would find world-class art installations by the likes of Fernando Botero and Ju Ming scattered across the estate. Silent storytellers that are evocative as they are mesmerising, they offer a different dimension to the experience of the district.

It also alludes to the high-level research and development that goes on within: info-comm technology, media, science and engineering, biomedical and life sciences, and pioneer research into emerging industries.

04 FIND YOUR TRIBE

Another novel feature of one-north is its consideration for the training and recruitment needs of its people. Various business schools in the area make it easy to gel organisational development with day-to-day tasks. At the same time, being close to top universities and institutes of higher learning present ample opportunities for academia-industry collaboration and talent acquisition. The one-north team also promotes a community spirit through a range of business and social events lined up at its public spaces, and networking events. Since 2015, there have been more than 600 events held in partnership with JTC at one-north with over 120,000 attendees, including family and friends of those who work here.

05 WHAT'S BREWING? THE FUTURE

The estate's reputation as a leader in research and development attracts many to spearhead their future innovations here, including ones that many can only dream of. In 2018, one-north became the first drone estate in Singapore to facilitate the trial of innovative unmanned aircraft systems and commercial use-cases in an urban setting. Apart from test-bedding facilities, one-north is also home to LaunchPad, which caters to young companies in the science, info-comm, media and engineering industries. LaunchPad serves as a cradle of innovation, placing start-ups within the proximity of industry giants and higher learning institutions, which can be tapped for talent. Looking for the next big thing in tech? You might just find it at one-north.

Tuas Biomedical Park

A Powerhouse for Singapore's Manufacturing 2030 Plan

As Singapore moves forward with Manufacturing 2030—a 10-year plan to elevate the country as a "global business, innovation and talent hub for advanced manufacturing"—the biomedical industry has a key role to play, as Minister for Trade and Industry Mr Chan Chun Sing shared in his speech at Biopharma Industry Day 14 May 2021. Tuas Biomedical Park (TBP), a 280-ha specialised industrial park home to 7,000 employees and 14 global bio-pharmaceutical companies as of 2022, is a beating heart within this industry.

01 OF VISION AND GUMPTION

Though established in 1997, the seeds for the development of TBP were sowed in the 1980s by then Deputy Prime Minister of Singapore, Dr Goh Keng Swee. Often called the "economic architect" of Singapore, he saw the potential of the field way ahead of big global trends. It was a demonstration of phenomenal vision and plenty of gumption to push through.

02 AN ECONOMIC WORKHORSE

With more than 30 bio-pharma plants across diverse modalities producing around $20 billion worth of products for global markets, the bio-pharmaceutical sector contributes approximately 8% of Singapore's manufacturing GDP as of 2022.

03 HIGH CONCENTRATION OF TALENT

Seven of the top 10 global pharmaceutical companies have major operations in Singapore. Out of these, six call TBP home in Singapore—AbbVie, GlaxoSmithKline, Novartis, Pfizer, Roche and Sanofi. This is a testament of the world-class infrastructure of the estate.

04 ON THE SHOULDERS OF GIANTS

These global movers and shakers form a dynamic community within TBP. As part of the Bio-pharmaceutical Manufacturer's Advisory Council (BMAC), a council comprising government agencies and bio-pharmaceutical companies promoting manufacturing and operational excellence, they drive advancement by allowing all within TBP to lock-step with the best in the industry.

"Today, our biomedical sector is thriving. It employs 25,000 workers and contributes almost one-fifth of our manufacturing GDP. We have also attracted major projects, including Sanofi and BioNTech—these are leading firms for vaccine manufacturing facilities...

We placed bets early and our bets paid off. We were able to vaccinate Singaporeans months before we would otherwise have been able to, saving time, saving lives, making a huge difference to Singapore. Had we not sought out top talent 30 years ago, then continued to build up our biomedical research teams and activities, and develop home-grown talent, all this would never have happened."

PM Lee Hsien Loong, 2022 National Day Rally speech

Future Perfect

Being a cradle for industries, industrial estates of the future are multidimensional spaces with a larger role to play. We invite thought leaders of different fields to share their perspectives.

With a mandate to drive Singapore's economic growth, JTC has always kept a keen eye on global economic trends. One does not produce master plans for industrial estates without considering what the future holds. The economic livelihood of Singapore is not just coiled around the engines of technological innovations and advanced manufacturing capabilities, but it is also increasingly entwined with the health of the planet.

As a nation, Singapore is committed to achieving net zero carbon emissions by 2050. In a whole-of-country response, sustainable initiatives in the little red dot have been ramped up in every sector. For instance, the manufacturing industry currently accounts for 20% of Singapore's GDP. In order to maintain its GDP share, the sector will have to grow by 50% in the next decade. This would take innovation, not just to create higher value products to raise global competitiveness, but also for more sustainable practices that will support and sustain this growth. This includes innovation in terms of how industrial estates are planned and built, so as to provide companies with an environment that aligns with their green thrust.

Mr Wong Mun Summ, co-founder of architecture firm WOHA that designed Punggol Digital District (PDD), notes that the future will be bright if everyone is on board with planet-saving solutions. Until then, the race to dial carbon emissions down to zero will continue to be a challenge.

Thankfully, the solutions are multidimensional, with different solutions for different sectors. Rolls-Royce regional president Dr Bicky Bhangu pins his hopes on sustainable aviation fuel, which in its purest form can reduce carbon emissions by 80%. At the same time, he also points to the supporting role of the ecosystem at Seletar Aerospace Park (SAP) and how the industry cluster can work together towards a net zero aerospace park.

Indeed, while research and development can bring greener tools and products, the move towards sustainability also takes behavioural change. At the level of the industrial estate, Professor Arnoud De Meyer, a global academic leader in business management and professor emeritus at Singapore Management University, points to creating ecosystems with circular economies, where the waste of one industry can be used as a resource for another. Setting up industrial estates that can foster such collaboration, in turn catalysing innovation for new solutions, is thus critical. In this sense, industrial estates play a bigger role than just a space provider: they are also ecosystems that can power a greener, better future for all through their sheer scale.

JTC is in a key position in moving the needle of green initiatives and practices in the journey to transform Singapore's industrial future, just as it sets the trend for smart industrial parks like PDD and Jurong Innovation District. "We have to take the lead in certain areas, and this is reflected in our developments," JTC Chief Executive Officer Mr Tan Boon Khai says. JTC tenants are looking to the organisation to establish a framework for carbon neutrality within the estate.

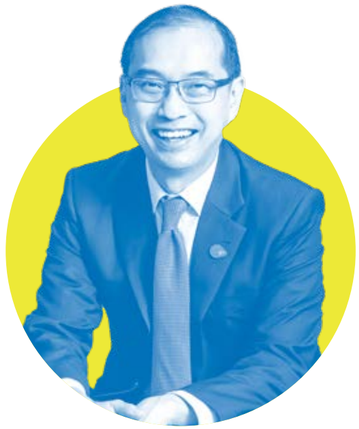
Aside from integrating sustainable systems, what does the industrial park of the future look like? The four aforementioned titans of industry weigh in with their visions—each with a unique perspective spanning estate development, business management, architecture and advanced manufacturing. Their pictures range from the practical to the fantastical, all extrapolated from current socio-economic realities. For industrial estate planners, the next mission is executing Industrial Estate 4.0. However, it also goes beyond that to paving the way towards a better future for all.

Building Singapore's Industrial Future

"Singapore's competitive advantage is to turn dreams into reality. JTC is relooking at the future of industrial estates in Singapore, and laying the groundwork today to build the next generation of industries in Singapore—one that will be smart, sustainable and seamlessly blend in with its surroundings."

Appointed CEO of JTC on 1 September 2020, Mr Tan Boon Khai brings with him diverse experience from the public and private sectors. He was the former Chief Executive of the Singapore Land Authority (SLA) and Regional General Manager of Singapore and Malaysia for The Ascott Limited.

A law graduate from the University of Nottingham in the United Kingdom, he has also served as Justice's Law Clerk and Assistant Registrar of the Supreme Court, as well as District Judge in the then Subordinate Courts of Singapore. His last appointment in public service was as Deputy Senior State Counsel and Deputy Public Prosecutor in the Attorney-General's Chambers of Singapore.



Mr Tan Boon Khai
Chief Executive Officer
JTC

Not long after he joined JTC as Chief Executive Officer, Mr Tan Boon Khai went cycling with a group of cycling enthusiasts from Joo Koon, through the mature industrial estates of Tuas, to the end of Tuas South Boulevard. There, he saw a lamp post like no other. Plastered with colourful stickers, Tuas Lamp Post 1 is the only one of its kind, a pole that warrants a photo pitstop from cyclists circumnavigating the island. Mr Tan, with a keen eye developed from more than a decade of real estate experience, immediately saw the structure as a symbol of progress in Singapore's industrial estates. "Who says industrial is boring?" he quipped to his cycling mates. "No one should think of industrial estates as dirty or sterile—it's sexy, it's exciting, it's a destination however you regard it."

While staying true to its purpose of strengthening Singapore's industrial capability to drive the nation's economic development, JTC has also created industrial estates as destinations: for factory workers at the start of its journey in 1958, then for researchers and scientists during Singapore's thrust to rise within the global knowledge economy and, increasingly, for residents and the community to enjoy leisurely pursuits.

Beyond a provider of strong infrastructure to build strong industries, JTC is also an agency of transformation. Its impact does not lie in its past glories, though milestones and breakthroughs over the last 55 years have been plenty. Its impact lies in the future. Opportunities and challenges abound—in new business models, increasing digitisation, accelerating technological developments, sustainability pressures and, as the past two years have presented us, unexpected geopolitical events. As JTC has demonstrated since its establishment to transform a swamp in Jurong to Singapore's first industrial estate, success rests on a clear-sighted vision of long-term economic goals vis-a-vis business trends. "We look at market cycles and work with industrialists to understand business trends and plan ahead. When industries need space or have access to facilities, we are there to provide a whole suite of services," Mr Tan says.

In the face of rapid changes, JTC has emerged from its function as infrastructure developers to become industry builders, creating hubs with its strategic allocation of businesses. To name a few, these hubs span from petrochemical, biotechnology to aerospace. Its role will evolve further as Singapore's commitment to net zero carbon emissions by 2050 requires a whole-of-country response. If industry contributes the lion's share of total carbon output, how can industrial parks respond to business cycles and industrialists' needs while doing its part to save the planet? It is an exciting time to be a master planner.

Manufacturing the future

Evolution of JTC's industrial estates over the years

1961

Jurong Industrial Estate

To diversify Singapore's economy and to drive job creation, the Economic Development Board (EDB) under the direction of then Finance Minister Dr Goh Keng Swee reclaimed an undeveloped site in western Singapore to build Jurong Industrial Estate. Plants involved in steelmaking and fabrication, shipbreaking, shipbuilding and repair, oil rig construction, timber and sawmilling, set up shop. By 1968, almost 150 factories were built, providing jobs for 14,000 people. Recreational infrastructure and housing were also added to enhance Jurong's attraction as a workplace.

1968

Kranji Industrial Estate

JTC was formed from EDB to specifically drive the planning and development of Singapore's industrial infrastructure. Among its first programmes was land reclamation and expansion of Kranji Industrial Estate, housing Singapore's sawmills. Kranji, together with adjoining estate Sungei Kadut, became the manufacturing centre for the country's raw timber, as well as wood products and furniture.

Mid-1970s

Island developments

Capitalising on the growth potential of the petroleum industry, JTC developed facilities for oil refineries on three islands in southern Singapore to overcome Singapore's land constraints. These were Pulau Ayer Chawan, Pulau Merlimau and Pulau Pesek. A decade later, it would construct Singapore's first petrochemical plant on Pulau Ayer Merbau. This cluster of islands formed the beginning of Jurong Island.

1984

Singapore Science Park

JTC supported the country's shift to a modern, science-and-technology focused economy with the development of Singapore Science Park. Generous business incentives and the estate's proximity to the National University of Singapore and the National University Hospital helped to attract global technology and R&D companies looking for synergistic communities.

Ecosystems Powering the Future

To be sure, JTC has adapted its ecosystem model—first implemented in the 1960s to supply Jurong Industrial Estate with a ready worker pool—to spark innovation and develop talent for Industry 4.0, where smart technology prevails. In the upcoming Punggol Digital District (PDD), the nation's first Smart District, industry and academia are situated in the same premise. "We specifically site business park buildings next to the Singapore Institute of Technology's (SIT) new campus," says Mr Tan. "Students who are fluent in technology or digital services can graduate and work in the companies there. In turn, firms can provide internship or collaboration opportunities to the university. There's an interdependency."

The strategy closes the distance between industry and academia even more than that which exists between Jurong Innovation District and the Nanyang Technological University, and one-north and the National University of Singapore. In both instances, industrialists and researchers are minutes-drive from each other. In PDD, SIT is mere minutes by foot. If business growth is ever more dependent on technology, tightening the physical divide between schooling youth and companies helps to develop relationships that lead to a pipeline of tech talent.

Expounding on JTC's hand in moulding ecosystems, defined as a collective whose value as a whole is greater than all of the companies individually, Mr Tan says: "Where we can, we bring companies together to work things through. Instead of travelling 30 to 45 minutes to get a service, if someone next to you can provide the same thing, you just go in, lock the door, discuss and you're done. Over time, you will know people better because they are near you. You can sit down and collaborate. Communication technology can lower the barrier to these collaborations but sometimes, nothing beats being next to each other."

A Green Slate

Proximity is key not only in fostering collaborative ecosystems—it is also key to green solutions in the next phase of JTC's projects.

Pledging to do its part in reducing global carbon emissions, the company published its first sustainability report in 2022. In 2021, it published the results of a two-year circular economy study of Jurong Island, where energy, water and chemical waste from over 50 energy and chemical companies on Jurong Island were analysed to determined how they could be re-used in a closed loop, the technical standard for measuring sustainability. With the opportunities identified, JTC sought solutions that would be trialled on Jurong Island, then introduced into future JTC estates.

Additionally, rejuvenation plans for the Sungei Kadut Eco-District, JTC's upcoming centre for new growth industries such as agri-tech and environmental technology, are designed to facilitate a circularity model.

"We want to reduce as much wastage as possible. What do we keep, what not? How do we re-adapt buildings for use? A classic example is Jurong Town Hall, our former headquarters which has been gazetted as a national monument. Instead of building from scratch, we have renovated and reconfigured it."

"It's an ongoing process," says Mr Tan of the quest to become net zero. But even before the push through government policy, JTC has integrated environmental elements into its estates through strategically placed pockets of nature. "If you look at the way one-north is master planned, there is a green trail running through the middle of it," says Mr Tan. "You can't see it from the outside, but it connects to the Rail Corridor, and you can walk or jog through the estate." Today, JTC has parlayed its position as developer-manager of more than 80% of Singapore's industrial estates to launch green initiatives across the island, installing solar panels on unutilised rooftops and state land, setting up machines to recycle food waste and introducing tree planting programmes in its estates to mitigate urban heat.

It does not stop there. The company is also working with firms to help them to reduce their carbon output. "Ultimately, a structure is still a structure," Mr Tan says, "the operations inside matter." Thus, in conjunction with global digital solutions provider TÜV SÜD and the Agency for Science, Technology and Research, JTC produced Green Compass, an assessment and roadmapping tool that helps local businesses to track their operational effluent and reduce it. "Net zero by 2050 is a whole-of-nation effort. Naturally, we need to look at what we can do on our end. We might be an estate developer and builder, but we are also looking at how we can work with our companies, to help them either decarbonise or reduce their carbon emissions."

1995

Wafer Fabrication Park Woodlands
JTC set up its first wafer fabrication estate in Woodlands to bolster the fast-growing semiconductor industry, the products of which are integral to the electronic devices we use today.

1997

Changi Business Park
As Singapore transitioned into high-value, knowledge-based economy, JTC created an ecosystem to facilitate commercial activities. Changi Business Park not only houses high-tech businesses, software companies and R&D labs, it is close to Changi Airport, simplifying transportation logistics.

2001

one-north
Marking its commitment to advance the New Economy, JTC diversified its portfolio with a focus on knowledge-based and technology-intensive industries. one-north in Buona Vista was developed to be a biomedical, info-comm technology and media hub, but one that also integrated social and recreational activities. The blend of live-work-play-learn elements set a precedent for JTC's innovative approach to designing industrial estates.

2009

Jurong Island
JTC completed a historic 15-year land reclamation project that amalgamated several islands into one land mass three times the size of the original 10km². Today, Jurong Island is an ecosystem of more than 100 companies in the petroleum and petrochemical sectors as well as related service industries.

2010

Seletar Aerospace Park
The estate dedicated to the fast-growing aerospace industry welcomed its first tenants with an ecosystem model. Seletar Aerospace Park housed businesses spanning the sector's supply chain, maintenance, repair and overhaul, as well as training facilities. From 140ha, it would more than double its size to 320ha in two decades.

2013

CleanTech One
Completion of the first phase of CleanTech Park, Singapore's first eco-estate. The park was conceived to develop and trial green solutions, and positioned next to Nanyang Technological University to facilitate the exchange of ideas between academia and industry.

“Singapore, going into its sixth decade as a nation, is gearing up for a renewal of its industrial infrastructure that also integrates circular economy solutions. Sungei Kadut Eco-District is in the works; Kallang-Kolam Ayer is being master planned.”

Innovations, Invisibly Integrated

According to a 2019 global status report, the building and construction sector spews 39% of man-made CO_2. Of this, 70% comes from the operation of buildings. The other 30% is embodied carbon emission, the carbon produced from the full supply chain of building materials and processes. As estate developers, JTC has to rethink its approach to construction.“Because of sustainability pressures, when we build now, we want to make sure that we do it better,” Mr Tan says. “We want to reduce as much wastage as possible. What do we keep, what not? How do we re-adapt buildings for use? A classic example is Jurong Town Hall, our former headquarters which has been gazetted as a national monument. Instead of building from scratch, we have renovated and reconfigured it as an office building specially for trade associations and grassroot organisations.” LaunchPad at one-north also demonstrates how JTC transformed high-rise industrial units into productive spaces for start-ups and incubators.

He points to the work of the Urban Redevelopment Authority, whose conservation efforts allow Singaporeans to keep a part of their history. “The same can apply to industrial buildings,” says Mr Tan. “You can’t just demolish everything and rebuild. There’s increasingly a sense not only of nostalgia, but of a pride that we can keep some of these old structures.”

“Even if a building has to be torn down, the materials are re-used or re-adapted as far as possible, or parts of the structure can be kept or integrated into a new design,” says Tan. To see how it can rejuvenate mature industrial estates at Yishun and Kallang-Kolam Ayer industrial areas, JTC launched a competition that asked the architecture community to re-imagine the estates with the goal of preserving parts of it. “When you see the entire thing, it may look very new, but somewhere along the way, if you look closer, you see parts of the old. We wanted to seed these ideas and see where this would get us. We want to push boundaries to see what’s possible and what’s not.”

The question for the future is: how can JTC design buildings to last longer, while also responding to business cycles. “How do we imbue an industrial building with sustainable elements while knowing that it might be irrelevant 20 years later? How do we reconfigure it? We are at the start of the journey,” says Mr Tan. He adds that resolving the dilemma between building to suit and building to last, through astute planning and prediction of future trends, may also yield answers to Singapore’s land scarcity issue.

Around the world, cities are transforming old industrial areas into vibrant mixed-use areas combining businesses and manufacturing facilities with learning centres, green spaces and residential clusters. Singapore, going into its sixth decade as a nation, is gearing up for a renewal of its industrial infrastructure that also integrates circular economy solutions. Sungei Kadut Eco-District is in the works; while the mature estates of Yishun and Kallang-Kolam Ayer are also slated for rejuvenation.

The Government has provided the national will to achieve net zero. Beyond that, technology is a game-changer, in supplying sustainable building materials and processes, in making structures nimble, through their sensors, data and connectivity, in responding to the needs of their environment. “The future of industrial estates is that they should be quite intuitive—things work without you quite knowing it,” says Mr Tan. “It’s also about how industrial estates, different as they might be, can fuse into its surroundings. You don’t realise that you live next to one, or even in one. Today, we are quite deliberate about it in our planning. We say this is residential, across the road, it is commercial and across the road, it is industrial. In the past, the differences would have been very stark—this is where you stay, this is where you work. But with technology, with better planning and better design, all these things can be developed together. The ecosystem is quite contained.” Livelihoods, lifestyle, life—all in one dynamic, even sexy, circle.

2014

Jurong Rock Caverns
JTC rolled out Southeast Asia’s first underground oil storage facility to support the oil companies on Jurong Island. Hollowed out from rock 130m beneath the seabed under Jurong Island, the nine-storey tall caverns can store about 1.5 million m^3 of liquid hydrocarbons, or the equivalent 580 Olympic-sized swimming pools.

2025

Punggol Digital District
In Singapore’s first Enterprise District, zoning regulations were relaxed to stimulate innovation and growth in digital industries through tighter integration of academia, research institutions, industries and start-ups. Here, Singapore Institute of Technology shares facilities with the business park in a lush 50ha smart estate featuring lifestyle amenities for the community, blurring the live-work-play-learn boundaries even more.

2026

Jurong Innovation District
Dubbed “the industrial estate of the future”, the 600-ha park was designed to drive growth in new industries such as advanced manufacturing, clean technologies, robotics, smart logistics and urban solutions. It is a one-stop destination for technology development as companies can learn, research, innovate, test, and manufacture their products within the estate.

2030

Sungei Kadut Eco-District
Aligning with Singapore’s push to be carbon neutral by 2050, the country’s timber and wood-products manufacturing centre will be rejuvenated with the addition of agri-food technology, waste management, and recycling industries in a bid to create a circular economy where waste is reused.

Thrust of Net Zero

In the decade that it set up its manufacturing, testing, training and research facilities at Seletar Aerospace Park, Rolls-Royce has fine-tuned its operations thanks to multi-agency partnerships. Now, the power player in aerospace engines and propulsion is belting up for its quest to reach net zero carbon emissions. Its president of Southeast Asia, Pacific and South Korea, Dr Bicky Bhangu, explains where JTC comes in.

Singapore is a hotbed for many industries, drawing multinational companies from sectors spanning biotechnology to pharmaceuticals, petroleum and petrochemicals to engineering and semiconductors. As they look to adopt sustainable initiatives, one stands out for the enormity of the task ahead. Accounting for 2% of greenhouse gas emissions, aviation is one of the hardest industries to decarbonise. Yet, it cannot renege on its responsibility, according to Dr Bicky Bhangu.

“We have a collective duty across the supply chain all the way through to airlines and customers to ensure that there is a pathway to net zero,” he says. Rolls-Royce has a three-tier approach to address the energy transition.

The first is engine efficiency. “We have invested and will continue to invest in research and development to advance materials capabilities in engine formulation,” shares Dr Bhangu. Already, the company has seen disruptive shifts in engine efficiency and performance. “The next generation of our Trent engine, the UltraFan, will deliver a 10% efficiency improvement in fuel consumption than the Trent XWB, which powers the Airbus A350. The XWB meanwhile is already 15% more efficient than the first generation of Trent engines that came to service in the 1990s.”

The second part is electrification. There is a huge advanced air mobility (AAM) market that can be positioned in the US, Europe, Japan, Korea and Singapore. In the near-term,

On the wings of an ecosystem

Rolls-Royce thrives on partnering with the best minds in science and business.

When Rolls-Royce set up its regional headquarter in Seletar Aerospace Park in 2011, it plugged into an ecosystem that propelled its growth into aero-engine manufacturing technology. At the site level, JTC has been a key enabler in facilitating Rolls-Royce’s industrialisation pathway, evolving equipment and infrastructure over time to enhance productivity. It is a partnership that also links Rolls-Royce to academia, research institutions and private companies, all of which give the company a keen competitive advantage.

Dr Bhangu notes that Rolls-Royce will double its fan blade output in a few years’ time, whilst headcount will only increase marginally. “This is where the ecosystem comes in handy. It is not just within the aerospace sector, but partnering with NTU, NUS and A*STAR to develop the technologies that we can deploy into our manufacturing and MRO facilities.”

Such teamwork has already produced game-changing innovations. For example, Rolls-Royce’s Smart Manufacturing Joint Lab—which taps into the best minds at A*STAR has developed robots that automate spraying protective coatings on fan blades for the company’s Fan Blade Singapore (FBSG) manufacturing facility. These automation solutions replace humans in spraying chemicals onto fan blades, ensuring consistency in production while eliminating health risks to employees.

Another innovation is the high-integrity inspection camera system that cuts manpower requirements by 50%. This system involves an array of cameras and specialised lighting to capture detailed images of jet engine fan blades to improve product inspection processes. It was designed with the help of A*STAR with additional input from other Singaporean technology companies.

The ecosystem is integral to Rolls-Royce’s growth. “We have to be quick in developing, industrialising and deploying technologies, and taking that IP and monetising it into our facilities. That is our focus in the future,” says Dr Bhangu.

Dr Bicky Bhangu
President
Rolls-Royce Southeast Asia,
Pacific and South Korea

Rolls-Royce is also focusing on the power and propulsion aspect of electrical vertical take-off and landing (eVTOL) vehicles—an air taxi, for example. But the game changer will be regional jets that run on a hybrid system that pairs the best in gas turbine technology with the efficiency you get from electrification. "You significantly reduce CO_2 emissions while getting the payload and nautical miles for longer distance flights. The technology is complex because you're combining several types of science—aerodynamics, mechanical engineering and fluid dynamics—together with the electrical systems. We are developing that technology now," reveals Dr Bhangu.

The third is focused more on short-term, where Rolls-Royce is modifying its products to be compatible with sustainable aviation fuel (SAF). SAF is derived from renewable waste and residue raw materials. Used in its purest form, it can reduce CO_2 emissions by 80%, making it the biggest contributor to net zero. Currently, it is blended with Grade A kerosene fuel but producing it is expensive and there is not enough of it. "The aerospace industry needs to invest more in SAF if it's serious about achieving net zero," opines Dr Bhangu. "In the meantime, we are future-proofing our products."

At the industrial estate level, the company's emphasis is on transitioning towards green energy adoption. This is especially critical since the manufacturing of aviation parts is an energy intensive business. "Our fan blade manufacturing facility is energy intensive. We melt titanium in blast furnaces that reach up to 1,100°C. That's a huge amount of energy usage. Then, the product goes through 78 different processes before completion," shares Dr Bhangu.

Rolls-Royce has installed solar panels at its Seletar Campus, which give the site operations 8% of its electricity. But solar panels alone won't be enough to get the energy intensive facility to net zero. Dr Bhangu reveals that it takes a collaborative professional company to make things work. "It's great to see the Civil Aviation Authority of Singapore, Singapore Airlines and Temasek all coming together to encourage ramp up of SAF. Our engine test cell infrastructure is ready, so when we test our engines, we can use pure SAF as well as a blended fuel. Having these initiatives supported by JTC, having an aligned vision in transitioning to net zero is critical."

It is not just the facility that has to be net zero, but the surroundings as well. This is a push factor for the company as it makes a holistic shift within the Seletar Aerospace Park community. "Yes, we can do our own activities, as can an aerospace company or a clean fuel producer. But to do it collectively, to co-share, that's where JTC can be more of a custodian in managing the whole energy in, energy out system and forge a path to the park's green energy future," enthuses Dr Bhangu. "What will the energy mix of the park look like? Where are we sourcing our energy from, and is it green in the first place? How can we monitor carbon dioxide emissions? These things matter because as an organisation, we need to show our green credentials to our customers and suppliers as well. Across the industry, the technologies that we invest and deploy will generally make it quicker to implementation when there is a positive return on investment. And on occasions where ROI is challenging, co-investment and co-creation among partners can help to reduce the pressures."

Having an integrated approach to sustainability within Seletar Aerospace Park signals that it is moving in the net zero direction. Dr Bhangu is excited to see SAP's development into an Advanced Air Mobility (AAM) hub in the future, with companies such as Skyports (which builds eVTOL terminals) setting up within the park. "Progress in connectivity is not limited to communications, Wi-Fi and the Internet, but in closing physical distances as well, as we move from electric land-based transportation to electric air mobility. It's the future of urban commuting," opines Dr Bhangu. "When people jokingly ask if I get to work in a Rolls-Royce car, I say 'No...we are not in the automotive but aerospace engines business. But one day, I want to say, No...but I fly to work in a Rolls-Royce powered eVTOL.'"

Rolls-Royce's comprehensive strategies towards the energy transition offers interesting insights for all. It is not just about how an organisation runs its operations—but where. Being in an environment that shares a similar commitment toward sustainability, and one that sparks innovation through collaboration, is just as critical for companies navigating their way towards a greener future.

The Sky Is the Limit

The Co-founding Director of WOHA, Mr Wong Mun Summ is a Professor in Practice at the National University of Singapore's Department of Architecture and co-directs the Integrated Sustainable Design Masters Studio. He is also appointed to the Seidler Chair in the Practice of Architecture at the University of New South Wales in Sydney, Australia.

He sits on the Nominating Committee of the Lee Kuan Yew World City Prize, the Design Advisory Board of DesignSingapore Council. He is also a member of the CBTUH Masters of Tall Building and Vertical Urbanism Advisory Panel. WOHA brought its visionary, multi-faceted sustainable design to the development of the Punggol Digital District. Here, he paints a picture of cities 50 years from now—one where lines between industrial, residential, educational, and even urban and natural are blurred.

Mr Wong Mun Summ
Co-founding director
WOHA Architects

The architecture of WOHA integrates different systems—natural systems, social systems and economic systems—into a cohesive design. In land-limited Singapore, real estate comes at a premium, and over the years, we have developed a high-density high-amenity approach that maximises and intensifies land use. By layering different programs and creating multiple ground levels, where people can find amenities that are typically located on the ground floor further up in the integrated developments, more real estate value is created. Many of our strategies are applied in our design for the Punggol Digital District (PDD). For example, publicly accessible sky terraces, sky parks and a collaboration loop that connects the business park and campus of the Singapore Institute of Technology (SIT).

We strongly believe that as architects we need to be very future-positive and have an optimistic outlook. We look at least 50 years into the future and try to imagine a liveable, sociable city that exists in balance with nature. In our vision of the future, we believe that we would no longer be in crisis mode. By then, technology and policy-making would have caught up and provided solutions for the critical issues we are struggling with at present. Namely, climate change, loss of biodiversity and the energy crisis. There would be diverse clean energy sources, industry and production will be integrated into the urban fabric as much as residential, educational and work spaces, as well as nature. The city would be shrinking its footprint and getting closer to taking up as many resources as it can replace. It would be self-sufficient in renewable energy, water and food, and carbon neutral in its operations and embodied energy.

The key is how we can transition from now to then. At the moment, urban planning is very two-dimensional. We segregate industrial zones from business, civic and residential districts. These silos are not integrated, and people spend a lot of time commuting from one to the other. When we plan cities three-dimensionally, and integrate the different urban and natural systems, we open up a lot of new opportunities to implement diverse mobility solutions. We can get away from only utilising the ground plane with massive roads and freeways, and shift to solutions that are underground, on the water and in the air. On-demand, autonomous vehicles will allow logistics to be operated during off-peak times, making better and more productive use of infrastructure. This enables us to transform the way we use land, design buildings and make space for people and nature.

A 15-Minute Vertical City

When we move from segregated 2D urban planning to innovative integrated 3D planning, we will save time, space, energy and emissions. This will, in turn, improve quality of life for all. Imagine life taking place within a three-dimensional 15-minute sphere that integrates industry, production (including food production), work, living, learning and playing.

All aspects of life will take place within this sphere on multiple ground levels and multiple urban connections from below the ground to the sky. This three-dimensional high-density, high-rise, high-amenity approach layers and integrates systems vertically. We would have a subterranean services and logistics layer, commercial, community and nature layers on or near ground level, residential, educational, leisure, industrial, manufacturing, food production, work and office layers in the middle, and aerial drone and energy layers at the top.

This may sound like a vision for the distant future, but the genesis of this vision is already built into PDD, and many of these approaches are being implemented as we speak. We have an underground service and logistics layer, a car-free ground level with a conserved forest, parks and recreational public spaces, a middle layer that houses both work and educational spaces (connecting and integrating the business park with the Singapore Institute of Technology Campus) as well as ample greenery, and a top layer for energy production.

This can be the future—where humans and nature co-exist in regenerative, circular systems in liveable and resilient cities of the 22nd century. Singapore is a good crucible for experimentation because its natural constraints have been a catalyst for the development of innovative solutions. We have the institutions, government, and human resources. We are an international port that attracts talent. If we can demonstrate how it can be done, it will not only solve Singapore's problems, but also set an example for the world, where other cities can adapt our island's solutions to enable change that benefits humans, the built environment and nature.

Manufacturing Imperative

Professor Arnoud De Meyer—global academic leader, business academic at the Lee Kong Chian School of Business of Singapore Management University and founding Dean of INSEAD's Asia Campus in Singapore—is one with deep insights from decades of experience in top international institutions in Europe and Asia. He drills down on how industrial estates need to evolve for Singapore to succeed in the future.

To realise the industrial estate of the future, we need to have a clear commitment to manufacturing as the driver to the economy. We also need to have a deep understanding as a population, what the government already understands, that manufacturing is essential to the survival of Singapore. We cannot become a pure service economy. Cities like London, New York and Tokyo have hinterlands to draw from—we do not. If we want to keep professional services such as accounting and law in the country, we need to keep manufacturing. Our target for the sector should be 20% of our GDP, which is comparable to countries like Japan and Germany, and higher than that of UK and France, which is around 10%.

We also need to constantly improve our productivity, but not necessarily focus only on labour productivity. Instead I refer to total factor productivity, where the combination of capital, technology, materials, processes and people are utilised in the most efficient way possible. Then, we can be competitive with India in producing the latest iPhone even though we have a high labour cost. We have to create industrial estates where highly advanced manufacturing can happen. These estates need to combine pure manufacturing with 3D printing, additive manufacturing, engineering facilities and probably research facilities.

The industrial estate should be in an urban area where possible. People prefer to live close to their place of work. They save time on the commute, but more than that, the proximity of a workplace allows people flexibility in organising their day. Perhaps work in the morning, then take care of their parents, then work again in the afternoon; or work from home and drop by the workplace for a few hours, perhaps for a meeting. These different labour patterns will require better integration of working, living and lifestyle environments.

The Kallang-Kolam Ayer district, for example, has a lot of old industrial estates and old public housing. In the old-fashioned approach, you would say that these industrial estates need to make way for residential development. But then you would force people to commute. If you upgrade the district to a nice environment that attracts high-end manufacturing and engineering, you could have people moving back and forth between home and work. It is a much more flexible work organisation, which is what all of us want to have.

I also see a move all over the world towards more integrated industrial estates, where independent companies work together and have good relationships with each other. Jurong Island is an example of that, where there is a concentration of oil and gas businesses, as well as engineering and logistics companies. Another example is Sungei Kadut Eco-District, where you have agro- and agri-companies coming together in an ecosystem based on agriculture. That is very different from what I saw 25 years ago, where an MNC would set up a subsidiary or factory here that would have very little to do with its neighbours.

Arnoud De Meyer
Professor Emeritus of
Operations Management
Singapore Management University

Looking ahead, what can be considered is linking industrial estates here to those elsewhere in the region to form a regional network for partnerships between our industrial estates and those in other cities for division of tasks.

Integrated ecosystems (such as the Circular Economy implemented within the Jurong Island community) can explore how the by-products of some companies can serve as resources for others. Denmark's Kalundborg Eco-Industrial Park and some of South Korea's industrial complexes are some examples. To illustrate: pulp from Wilmar Sugar in Australia, which produces sugar from sugar cane, used to be dumped. But someone came up with the idea of burning it for electricity. Today, Wilmar's sugar mills in Queensland, which sit in the midst of sugar cane plantations, are powered by steam produced by burning the leftover fibre, with the excess energy going to the Queensland power grid.

For most industries, the technical solutions for low carbon footprint are there, but they might not be economically feasible to implement. We need to get the price down, and that is where joint management of non-competitive resources in an industrial estate can help. Of course, Singapore will still need to do some carbon offsetting. We are already at the limit of land reclamation, so I do not see how we can create mangroves and places that will help in carbon offsetting. That is why we need to have good relationships with Indonesia and Malaysia, because they have plenty of space. For them, it is a good business if they can sell carbon offset.

For Singapore to thrive, we need to stimulate a spirit of innovation and entrepreneurship. The idea that you must constantly upgrade yourself needs to be part of the culture. The concept of Punggol Digital District (PDD), where there is collaboration between the Singapore Institute of Technology (SIT) and companies on the premises, is very promising. It is great to integrate a university into an industrial estate.

A long time ago, when Silicon Valley was about Hewlett-Packard, Intel and other hardware-based companies, a study was done, showing that carpooling was a major driver of innovation. Engineers who worked for these companies and lived in the same neighbourhood would share rides into the office. In the car, they would talk about what they were doing—"How would you solve this?"—so there was this interaction between engineers that improved the ecosystem knowledge. I call it ecosystem goods, the knowledge that you share with each other that does not destroy your intellectual property. Maybe that interaction can happen in the shared spaces of industrial estates here. When I visit these places, I see that companies have their own cafeteria. That is fine, but you can think about adjoined facilities designed to encourage sharing. That is what I hope for the industrial estate of the future—one where you have enough common spaces for people to exchange ideas and build up knowledge, that is highly integrated with a circular economy and into its urban environment, so people have flexibility in organising their work.

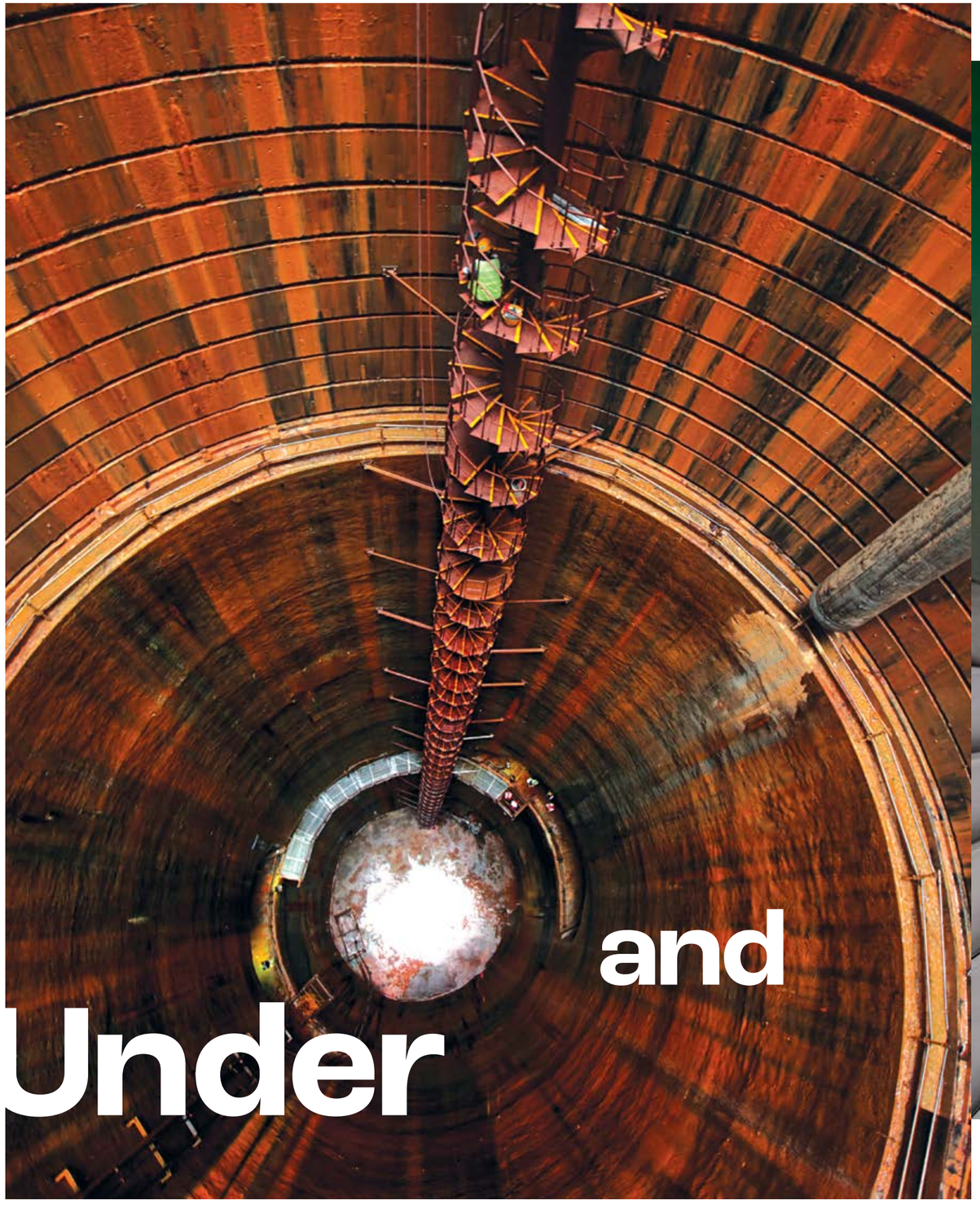
Singapore's competitive advantage has always been its location. Sir Stamford Raffles was no dummy when he chose Singapore as a trading hub. We are between the Middle East, India, Southeast Asia and East Asia. Before, the weight of manufacturing was in Europe and the US, and a lot of the traffic was trans-Atlantic. Now, with the rise of China, the remaining importance of Japan, Australia as a source for raw materials and a quickly evolving Middle East and India, we are even better located.

Beyond that, the environment here is conducive to business: we have stable and predictable industrial policies, a good intellectual property regime, a well-educated workforce, constant efforts to upgrade skills and efficiency in setting up businesses. You can ramp up a factory quite quickly.

The government has also invested enormously in Industry Transformation Maps (ITMs)—roadmaps for productivity improvement, internationalisation and innovation and skills development. But making companies aware of them, and letting them understand what's in it for them, is still a challenge.

We should also know more about the region we live in. Most people know Tokyo, Shanghai, New York and London, but how many of us have been to Medan or Surabaya? There is so much going on in Ho Chi Minh City and Jakarta in terms of entrepreneurship and new ideas. Looking ahead, what can be considered is linking industrial estates here to those elsewhere in the region to form a regional network for partnerships between our industrial estates and those in other cities for division of tasks. For example, a company could have its manufacturing processes in one city and its innovation centre in another, but all within JTC estates. Just as varsities learn from their satellite campuses in other cities, we can also enrich our perspective through a regional industrial estate network—especially for Singapore to better play its role as a regional and global hub.

Under and Over



Innovative use of overhead and underground spaces within JTC estates, guided by a focus on sustainable development planning and future-forward thinking.

A STUDY IN CONTRASTS:
The cylindrical industrial access shaft that tunnels down into the Jurong Rock Caverns (L) and the sleek staircase that spirals through the Razer SEA Headquarters at one-north (R) form a visually interesting juxtaposition to demonstrate the many ways to imagine the use of industrial spaces.

Sky Corridor

JURONG INNOVATION DISTRICT

Walk Into the Future of Commuting

Zipping around in an autonomous vehicle (AV), on a sky corridor high above the busy traffic on the ground. This is not a scene from a sci-fi movie, for the future is now.

For the workers, students and commuters of Jurong Innovation District (JID), the district's 11-km Sky Corridor redefines commuting by stretching across the five precincts in JID (NTU, CleanTech Park, Bulim, Bahar and Tengah), 8m above ground. Integrated with MRT stations, it efficiently connects workplaces, transport hubs and community spaces within the 620-ha business park.

A verdant path for walking, cycling and green commuting, it is set to be an icon for JID. And with JID being a living lab for new solutions, travelling down the Sky Corridor in an AV could very possibly be the norm in the in the years ahead.

Jurong Island Pond

Still Waters Run Deep

The Jurong Island pond is a demonstration of how human design and design by nature can combine to create exceptional solutions.

With Singapore's annual rainfall steadily increasing through the decades, and rainstorms of greater frequency and intensity as a result of climate change, stormwater management and flood protection measures have become critical areas in estate planning. The Jurong Island Pond spans 8.9ha and holds a lot beneath: up to 125,000m³ of rainwater, the equivalent for filling 50 Olympic-sized swimming pools. This flood-resilience feature is the product of JTC's expertise in urban design, engineering and deep knowledge of the island's geology. By building a pond over Jurong Island's unique geological feature of an underground body of water-bearing permeable sand, it leverages on nature to reduce the need for costly and resource intensive upheavals to the drainage infrastructure.

Underground District Logistics Network

JURONG INNOVATION DISTRICT

A Logistics Hub, Concealed

There is more than meets the eye at Jurong Innovation District (JID)—literally. Hidden under Bulim precinct, within the 620-ha estate is an underground network, designed for the efficient packing and movement of goods. A first of its kind in Singapore, the District Logistics Network (DLN) spans across 70ha and boasts 3km of paths dedicated to freight logistics. Designed for advance logistics transport, the DLN will even employ Automatic Guided Vehicles (AGVs) for the delivery of goods straight to the doorsteps of businesses within the estate, all through the underground network of paths.

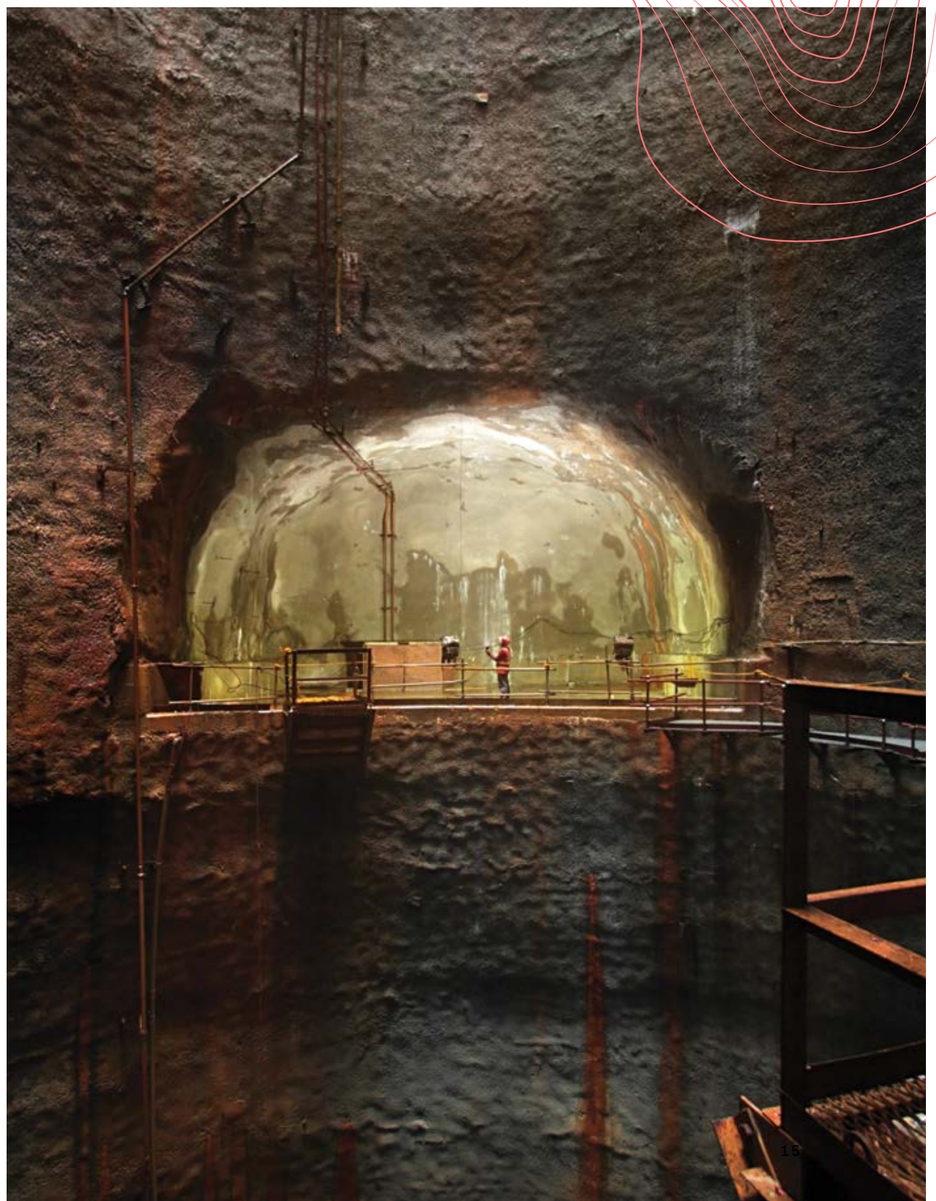
The vast subterranean network not only offers efficiency in terms of logistical support for the businesses at JID. By directing heavy vehicles underground, it takes traffic load off the roads, and frees up land, which is a scarce resource in Singapore, for other usage, from higher-value business facilities, to green pockets and lifestyle venues for the community above-ground.

“The JRC demonstrates that we must constantly think out of the box, be bold in tackling our challenges, be tenacious in execution in order to create new space for ourselves whether it is physical space, whether it is space which is metaphorical, thinking space, international space and development space.”

Prime Minister Lee Hsien Loong at the Official Opening of the Jurong Rock Caverns on 2 September 2014.

Jurong Rock Caverns

JURONG ISLAND



Breaking New Ground, Underground

There are many firsts behind the five caverns, 130m under the seabed of Banyan Basin off Jurong Island. Its construction called for the adoption of cutting-edge construction technology of the times, such as sealing the caverns with hydrostatic pressure by surrounding them with water-filled tunnels and boreholes, and lining the interiors of each space with cement, applied through high-pressure spray.

Launched in 2014, it was the first commercial underground rock caverns facility for the storage of liquid hydrocarbons in Southeast Asia. Its capacity: a whopping 1.47 million m^3 of liquid hydrocarbons.

More than a construction feat, Jurong Rock Caverns is a demonstration of foresight, determination and innovation. The underground construction cost 30% more than if it would have been above ground. Yet this project also effected the saving of some 60ha of land—enough to house six petrochemical plants. The expertise gained through the construction of this groundbreaking initiative further expands the capabilities of our teams, opening up new possibilities for the future.

Sky Terrace Gardens

FUSIONOPOLIS ONE AT ONE-NORTH

Wild Green Yonder

When Fusionopolis One started construction in 2003, the iconic development comprising, Symbiosis and Connexis, became the first building in Singapore to adopt the super-column construction method that ensures that the building is not swayed by strong winds. Yet the design of Fusionopolis One is a pioneer in more ways. Integrated within the 1.3-million ft^2 space of Symbiosis and Connexis are 13 sky gardens. These green spaces not only draw nature inwards, they also serve to diffuse urban heating. The green design by Japanese architect Kisho Kurokawa comes more than a decade before government regulations required developers to replace greenery displaced and lost from the site, and for communal green spaces to be integrated into new developments.

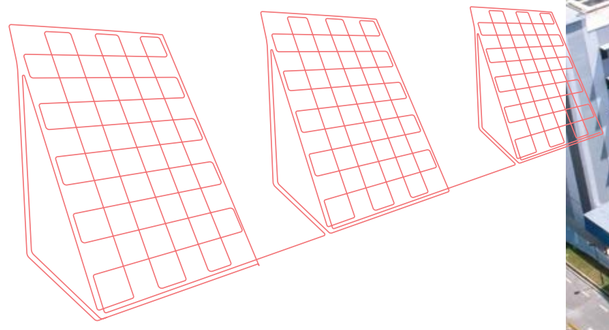
The lush landscaping of the 13 sky gardens have been thoughtfully executed to promote biodiversity, going beyond decorative flower beds to feature ponds and even water wells. More than a design feature integrated for environmental well-being, they have also become spaces for mental well-being. They form a green oasis for the diverse community at Symbiosis and Connexis—places to unwind, perhaps screen out telecommunications signals in future and simply to reconnect with nature, even while in a highly developed business park.

Sun Salutes

Transforming the function of roofs beyond that of lending shelter and protection from the elements is JTC's SolarRoof programme. Launched in June 2017, SolarRoof is Singapore's first solar energy business model that exports solar electricity, generated from the rooftops of JTC's buildings, to the national power grid.

The result of a test-bed project from JTC's first Open Innovation Call in 2015, the first SolarRoof buildings—including JTC Space @ Tuas Biomedical Park and Offshore Marine Centre, among the 24 JTC buildings across the island—have been contributing clean energy to the national power grid. By making solar adoption easy and more accessible for the 14,000 businesses in JTC's estates, with zero upfront capital outlay, the SolarRoof programme has been deployed to more than 60 JTC buildings as of April 2023.

JTC's dedication towards green, transformative use of space has taken the solar initiatives beyond rooftops. In July 2022, it was announced that a new type of floating solar panel system—the first of its kind in Singapore—will be piloted close to shore on Jurong Island. Adapting from patented technology developed by Norwegian company Ocean Sun, it comprises solar panels attached directly onto large circular reinforced membranes. The membranes are, in turn, protected by a high-density polyethylene pipe structure that surrounds them, creating a stable and safe platform that can withstand stronger waves and rough sea conditions so that solar energy can be harnessed reliably.



Solar Panel on Rooftops

ACROSS JTC SITES

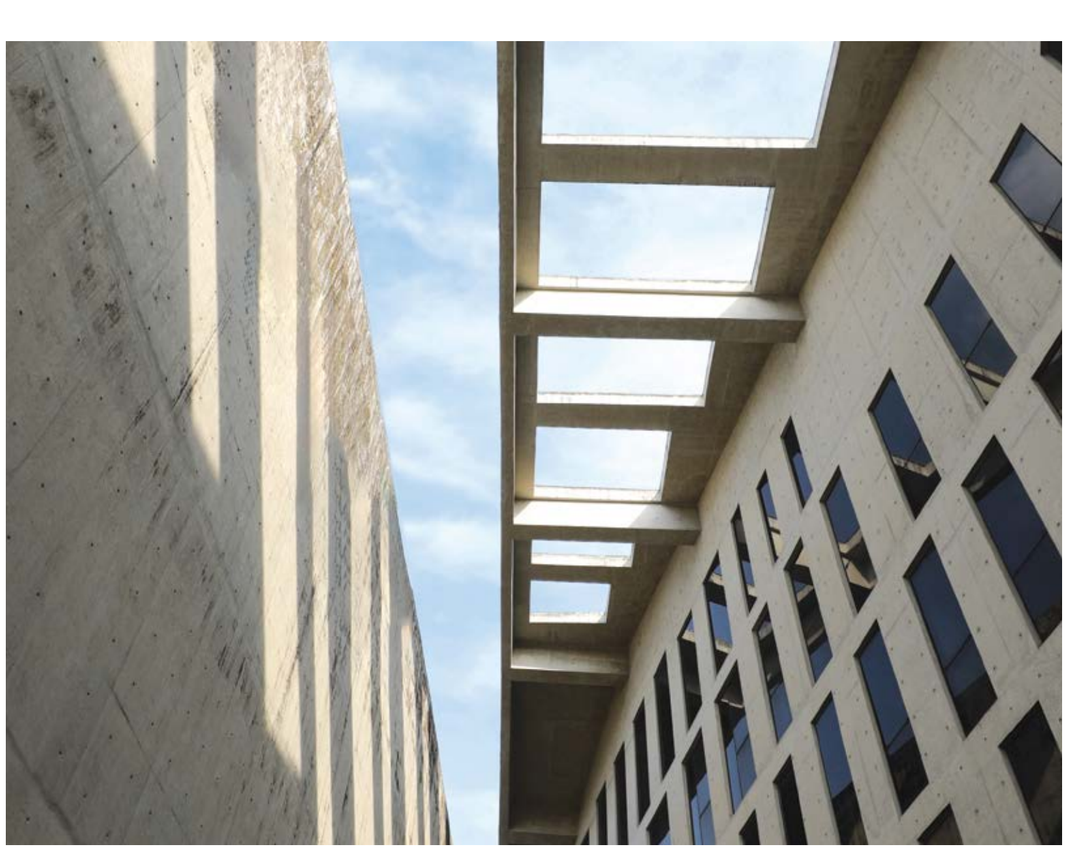
Life. Lines.

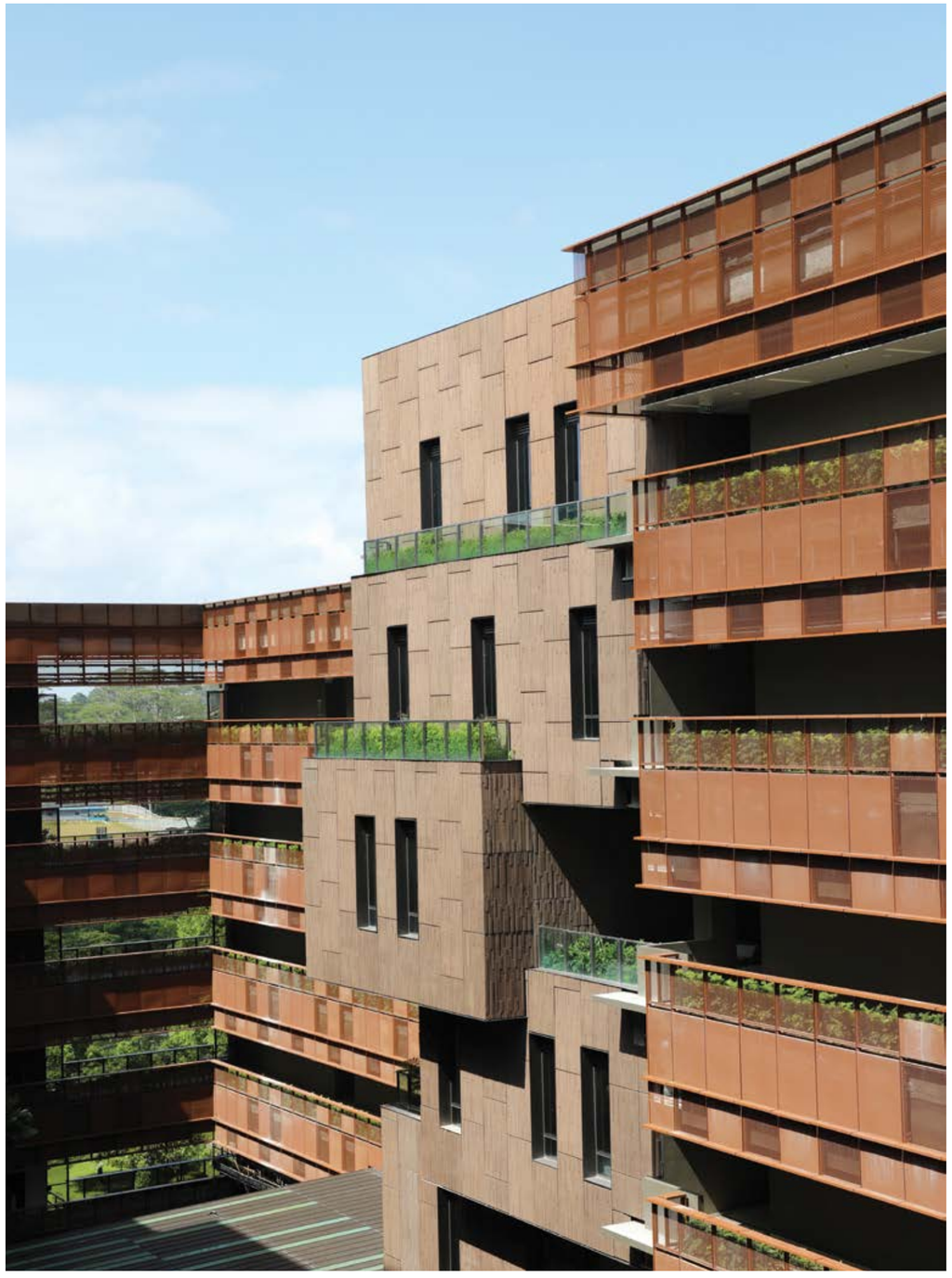
From brutalist internal structures to organic, curvaceous silhouettes, there is artistry in the iconic buildings within JTC's estates, and a living story behind them.

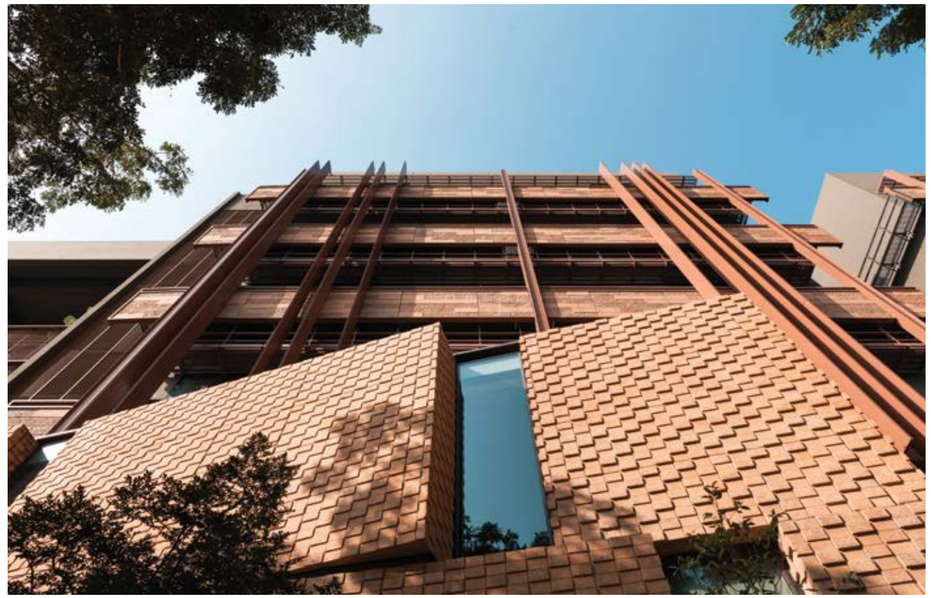
Wah Son Engineering

Within this sleek monolithic form is an industrial space made conducive for the people within. Singapore firm ipli Architects broke the massive space into smaller forms to create intimacy, with an internal courtyard where all can enjoy a moment of respite. A vegetable garden within the courtyard even provides food for the kitchen. Its concrete exterior might appear stoic, but the multitude of openings on the top and sides allow a playful cast of light and shadow, while providing natural ventilation.

SELETAR AEROSPACE PARK



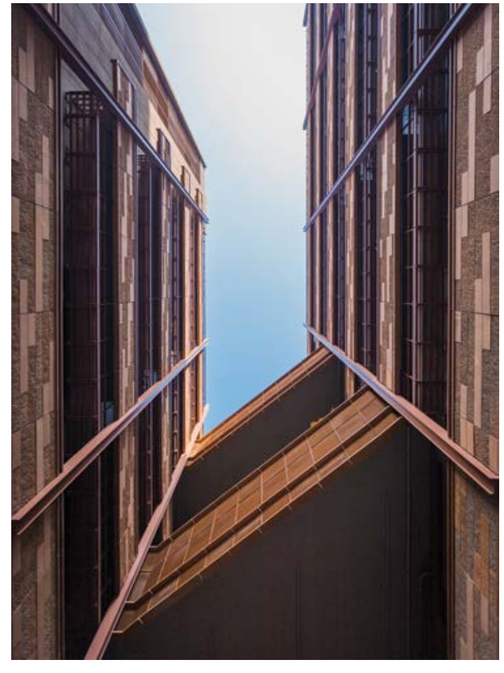




JTC CleanTech
THREE

Behind the visually arresting fragmented arrangement of the blocks at CleanTech Three is a fine balancing of considerations for the natural and built environment. Apart from allowing maximum daylight and natural breeze, the design also provides corridors that catalyse movement across the site. On the lab level, the main corridor loop connects all blocks and overlooks the atrium, the verdant heart of the site. Communal bridges, meeting rooms and outdoor seating areas situated along the main loop, alongside numerous flexible spaces across the site further form spaces for interaction. Beyond the walls, the sloped terrain is preserved while terraced gardens are seamlessly woven into the natural landscape. Mirroring the corridor between the blocks, an existing wildlife corridor is also preserved.

CLEANTECH PARK, JURONG INNOVATION DISTRICT

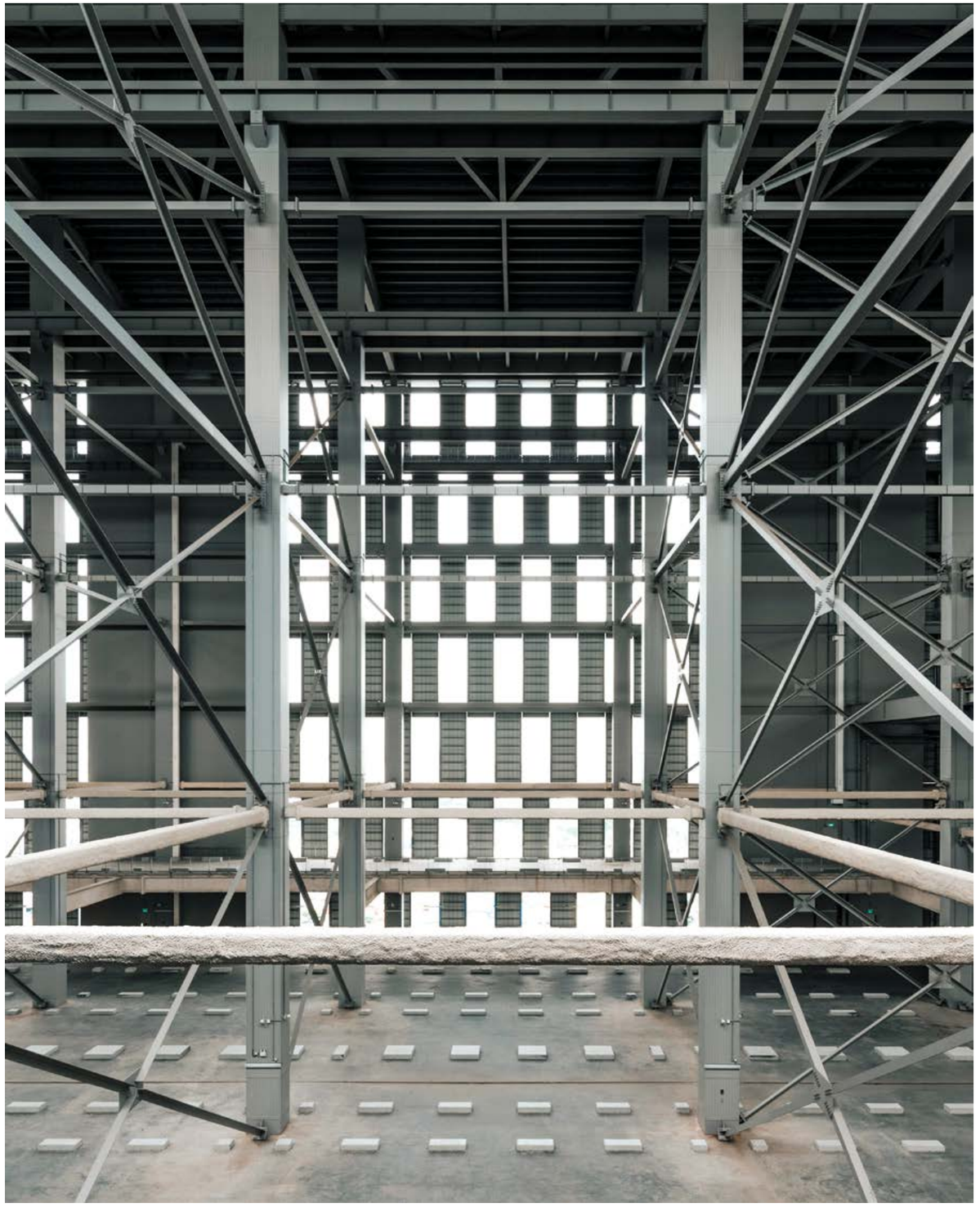


JTC Logistics

HUB @ GUL

Behind the stoic structure of JTC Logistics Hub @ Gul (JLH) lies a future-forward blueprint. A next-generation logistics facility that places container depots, warehouses and a heavy vehicle park all under one roof, JLH is the first of its kind. Designed to deliver elevated operational efficiency and productivity though the integrated development, it is set to catalyse the growth and transformation of the industry.

GUL CIRCLE



JTC Chemicals

HUB

With the interlacing of hexagonal elements on the facade bringing to mind chemical bonds, this Green Mark Gold Plus project is built to house the production, storage and packing of various chemical goods. From non-flammable to blast-prone goods and even hazardous materials, there is certainly more than meets the eye. Apart from meeting stringent health and safety criteria, the design of JTC Chemicals Hub also integrates innovative solar shading and well-ventilated facades for maximum energy efficiency.

TUAS SOUTH

1&7

NORTH COAST

A mixed-use business and lifestyle precinct in the northern part of Singapore, Woodlands North Coast offers first-of-its-kind flexible industrial space usage. This allows businesses to house non-industrial functions and manufacturing operations under one roof. The design of the space is also significant in the parts unseen: within the estate is a car-lite working environment where heavy vehicular access is segregated to underground. In doing so, spaces are opened up for the creation of pedestrian footpaths and green pockets, allowing the industrial estate to develop the vibrancy of work-live-play-learn lifestyle hot spot and the serenity of a recreational venue.

WOODLANDS NORTH COAST

Wilmar
INTERNATIONAL HEADQUARTERS

Its organic form and tiered landscape terraces almost mimics the hilly topography of the environment. The links to nature does not end there for this iconic structure by Eric Parry Architects. Tree-like steel structural columns flank the sides of the central public passage linking to the public park, while natural anodised curved aluminium panels on its façades mimics the gentle form of a pebble-like sculpture. The Green Mark Gold Plus building features design solutions that lend cooling effects, while a sensitively curated landscape palette further promotes biological diversity of ecosystems, habitats and biomes.

ONE-NORTH

Eclipse

Designed by Andrew Bromberg, the reflective chrome-fritted glass facade of Eclipse is a sight of futuristic minimalism; and in its centre, a vision of a modernist landscape, where man-made structures coexist with nature. An unexpected green oasis occupies the heart of the nine-storey structure: a lush courtyard with meandering footpaths, arched bridges and raised platforms over running water and ponds.

ONE-NORTH

Jurong
TOWN HALL

Gazetted as a national monument in 2015, Jurong Town Hall was designed by Singapore firm Architects Team 3 and completed in 1974. The brutalist icon remains evergreen in the new millennium. A glass roof over the concourse lends natural illumination to the civic space, while an inward-sloping structure provides shade. It was formerly the headquarters of JTC, which played a key role in developing the first industrial estates in Singapore to support the nation's industrialisation drive. This icon that stands as a historical symbol of Singapore's economic progress continues to play a key role in Singapore's economic development as home to the Trade Association Hub.

JURONG TOWN HALL ROAD

Punggol Digital District

Big data and industrial infrastructure come together in a visionary development.

The year is 2025 and JTC's Punggol Digital District (PDD) has unveiled its first phase of developments. In the bustling 50-ha mixed-use district servicing key growth sectors in the wider digital economy, workers and students are going about their own business as part of an ecosystem of innovation.

Amidst them are residents of a different nature: the mobile robot workers of PDD.

Take the example of just one robot. It moves among the human residents with an awareness suggesting sentience. In a built-in basket, it holds a delivery package and a food order. Recognised and expected by the wider system, it zips through security clearances, going from building to building. The human security officer need only check its screen or the contents of its delivery. Once inside the building, more digital communication takes place between the robot and the lift system; a car is assigned, picks up the robot, and delivers it to the designated floors where it rolls or walks to its final destinations. The relevant employees open their doors and receive their deliveries, allowing our metal friend to be on its way, with no other interventions on the part of the delivery recipients.

Robots, smart buildings and machine learning systems—these are just a few examples of how PDD is turning the realm of science fiction into science reality.

With the adoption of cutting edge technology a common thread in JTC's work over the decades, PDD—an estate integrated through a smart technology infrastructure—represents a logical next-step. The entire physical industrial estate is managed by a highly autonomous digital information system: the Open Digital Platform (ODP). Applied in full effect, it even has the potential to connect all JTC estates, island-wide. This would be unprecedented, as far as industrial estates go, anywhere in the world.

As of the time of writing, the ODP is still being developed. Co-designed and co-developed by JTC and GovTech; this is the digital backbone of PDD. There is no other estate in Singapore with similar technology.

With the adoption of cutting edge technology a common thread in JTC's work over the decades, PDD—an estate integrated through a smart technology infrastructure—represents a logical next-step.

An Autonomous Future

Beyond robots for autonomous delivery, cleaning, security and other tasks, is a smart system for the overall management of PDD. The buildings are automated to an extent, with functions such as climate control, security, lighting, escalators and the aforementioned elevator systems, all wired for greater energy efficiency and better user experience.

The "magic", so to speak, lies in the smart technology that enables PDD's various systems (including robots) to communicate with each other. In many applications, getting different systems to talk to and understand one another is challenging. Integrating across proprietary systems is costly and complex. Thus, many building systems work independently of one another and still require human oversight.

The ODP brings together the various systems in PDD, enabling optimisation of building management and resources, while depicting real-time conditions in PDD. This is achieved through an open standard multiprotocol middleware. This interoperability layer enables the various systems in PDD—the robots, security, building management—to "talk" to one another. Linked to the ODP are PDD's security, autonomous delivery and environmental data. Gathering this data are numerous Internet of Things (IoT) sensors located throughout the buildings, around the district and even aggregated from other government agencies. Examples of the data gathered are room occupancy from people counting sensors, elevator status, lighting, mechanical and electrical systems usage, and even information about the environment, such as temperature and rainfall. The ODP will also collect data from beyond PDD, including on the weather and traffic conditions across the island. This data is overlaid for better sense making.

An Invisible Hand That Moulds Your Experience

The science fiction aspect extends into the more functional area of building management. The ODP's primary function is aimed at providing an enhanced tenancy experience, from the waiting time for an elevator, to the control of indoor temperature. Yet the ODP is also a pillar supporting the estate's sustainable building management.

Briefly, the platform's AI uses the collected data to automate and optimise the building's facilities and functions for greater efficiency.

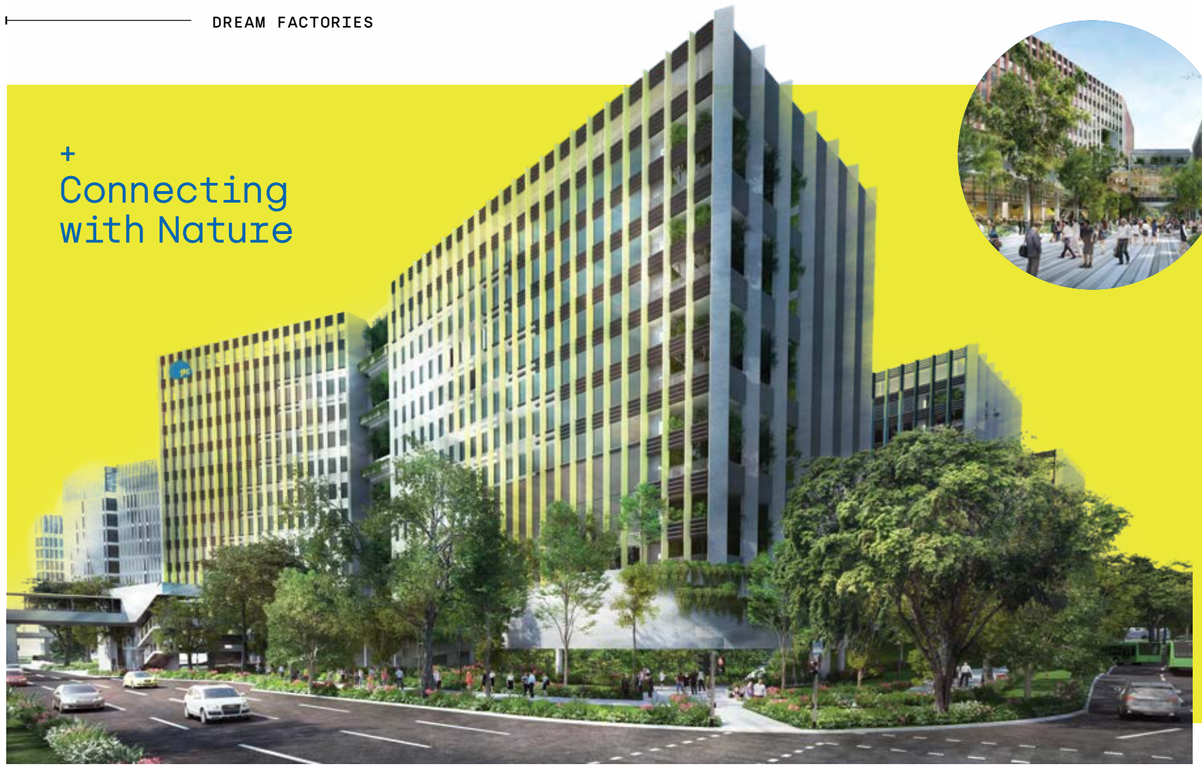
+ Beyond the Software: Fostering Collaboration

+ Singapore aspires to be the smartest city in the world. Many factors influence whether this will be successful. One of these is the relationship between businesses and academia.

+ When SIT moves its campus to PDD in 2024, its proximity within the business park will promote close collaboration between the two and provide businesses with access to talent from the university.

+ Students will find themselves with plentiful opportunities. PDD will be home to a vibrant ecosystem of organisations, including digital leaders in key growing technology sectors such as Cybersecurity, Blockchain & Fintech, Robotics & Artficial Intelligence, Cloud Computing and Smart Living.

+ To support this close relationship, the fifth floor of the high-rise developments will be linked by a Collaboration Loop, featuring shared facilities such as meeting pods and sky terraces.



+ Connecting with Nature

+ The interplay between technology and nature is an important aspect of a smart city. Throughout the world, smart developments are emphasising the natural element as much as the innovative, and PDD is no exception.

+ Green facilities were incorporated into PDD's Master Plan from the onset. PDD will have 30% less energy and water consumption and 50% less waste generated as compared with similar developments. Throughout the site, 10,000m² of solar panels will be installed. These will earn PDD the Building and Construction Authority's (BCA) Green Mark Platinum, awarded only to those developments that meet stringent criteria in terms of environmental impact.

+ As for green spaces, the standout is the Heritage Trail, whereby the existing Punggol Road will be transformed into a 1,300-m pedestrianised link, preserving the existing trees along the road. The Heritage Trail will link Punggol Waterway to PDD and the upcoming residential district at Punggol Point.

+ Green systems such as urban farms and rooftop solar panels are also in the works. They will help increase energy efficiency and reduce the district's carbon footprint.

+ Other facilities include a campus boulevard, which is an 800m-long pedestrianised street, situated between SIT and JTC's business park; a nexus for retail and dining; various common spaces and a market village. All of these will be within easy access of the Punggol Coast MRT station.

For example, analysing the data collected from various building systems, such as CCTVs, turnstiles and elevator movement data, will enable the platform to efficiently manage the elevator systems by applying AI/ML. Understanding the movement patterns of building visitors allows the ODP to predict peak and lull periods in advance—the ODP could then dispatch additional lift cars during peak periods or enable them where they are needed most. During lull periods, these lift cars can then be powered down for optimised energy savings.

Another example is the application of AI/ML to manage the thermal comfort within the meeting rooms. Tapping on building system and external weather data, and by controlling air flow into the room, the platform can manage the room temperature according to usage. With this intelligent control, the meeting rooms not only offer better thermal comfort for the users, but potentially higher energy savings.

Modelling and simulation are also features of the ODP. Drawing on the overlaying of public datasets, staff in the command centre are able to simulate responses to events such as inclement weather, public transport delays and train breakdowns. Staff can then use this data to pre-empt and develop contingency plans for the community.

With regard to facilities management, the ODP alerts when a building asset shows signs of impending fault. Repair works can be carried out with proactive management, improving response time as compared with acting only when a complaint comes in.

Many time-consuming and manual tasks such as cleaning, security, and last-mile delivery can be performed by autonomous robots. The Singapore Institute of Technology (SIT), scheduled to move to its new campus in PDD come 2024, is working with local robotics firm d'Construct Robotics to study the deployment of these robots.

As a result, the building staff are free to focus on other duties rather than spending time on fault detection, security patrols, and other labour-intensive processes—thus delivering higher value service to the community within PDD.

Tapping Into the Potential of a Digital Twin

The ODP also presents a wealth of practical benefits through a critical component of the system: the "digital twin".

This is a graphical representation of PDD enhanced with real-time data, showing what is going on where and when. The digital twin collects real-time data from sensors and maps it onto a 3D-modelled virtual copy of PDD. Representations of the data collected are then translated onto the digital twin, utilising Building Information Modelling systems to enhance accuracy.

This represents a vast amount of real-time data to tap into—and to create new business opportunities with.

Let us consider once more the opening to this story. Specifically, to turn the science fiction of an industrial zone where robots go about their business alongside people, requires planning and testing. With a feature such as the digital twin, researchers and engineers can set up exacting simulations to test all manner of parameters. Since the digital twin uses all the data of the actual

+ Power to the People

Beyond operational and estate management efficiencies, the Open Digital Platform (ODP) at Punggol Digital District also translates to newfound conveniences and improved experiences for the community within.

+ **Beat the crowd**
With its ability to track footfall and live crowd analysis, the system allows you to know exactly how busy your favourite stall or eatery is, so that you can make smarter decisions when it comes to maximising your lunch hour. Robot delivery services could also bring your favourite hawker fare straight to your office on days when you just want a quick but satisfying fix.

+ **Smart transactions**
The ODP is able to support unmanned retail through a facial recognition payment system. This could translate to the possibility of smart retail concepts being rolled out within the district.

+ **Carbon-light commuting**
As a Carlite District, PDD is well connected to the public transport system, and has cycling pathways integrated. To encourage carbon-light modes of commuting, the district also offers a suite of end-of-trip facilities such as smart lockers for bicycles, find-your-locker applications and shower booking facilities.

environment, historical and present, it will be possible to create working models that are as close to reality as possible. Crucially, a simulation is risk-free.

Indeed, given the appropriate data, the system should be able to demonstrate the effect of having robots interacting regularly with humans and the environment for years in a matter of days, or even hours.

To illustrate how the PDD community can tap into the potential of this system: SIT and d'Construct Robotics will be using the ODP and the digital twin in executing their study on deploying robots at PDD. Similarly, other innovators within PDD ecosystem could save time and money spent on developing physical prototypes and solutions, thanks to precise modelling systems and tools.

Having completed the bulk of their testing via simulation, they might also be able to bring their products to market sooner.

Perhaps the most obvious benefit to tenant companies at PDD is the ability to stress test their own systems, and run their own simulations in a close-to-live environment. What would once take years of trial and error can now be learned in a matter of days.

Academia, particularly SIT, will also be permitted access to the digital twin as a living laboratory, providing authentic and experiential learning opportunities. For those concerned about data and personal security, sensitive data will be anonymised and curated, before being provisioned via secure micro-services for test-bedding.

As a Strategic National Project, PDD is a showcase of how technology and innovation can be integrated to create a district that merges work, play and living in the 21st century.

A Legacy of Excellence

A smart district of the future requires smart construction techniques. JTC was appointed as a Centre of Excellence in 2016 for infrastructure projects and facilities management services, and R&D in innovation, safety and construction productivity. This experience is exemplified in the construction of PDD.

Several innovative techniques are used in the site's development. At the planning stage, the overall plan was crafted using 3D mapping software and Building Information Modelling, for virtual Temporary Occupation Permit inspection.

Drones have also been deployed to monitor the site's progress. The drones are sent out weekly, taking around 900 pictures, which are then fed into the mapping software. Supplemented with data from on-site omni-directional cameras, workers are provided an up-to-date model of the site. They can then check their progress more accurately than if they had to perform a personal inspection—a task that would have taken hours to complete. By automating such processes and sharing the data on a common cloud platform, companies working on PDD have managed to cut down on manpower and build time by 20%.

As a Strategic National Project, PDD is a showcase of how technology and innovation can be integrated to create a district that merges work, play and living in the 21st century.

Jurong Island

Closing the Circle

The circular economy of energy and chemicals hub, Jurong Island leads the way in sustainable development.

Singapore's global rise as a powerhouse in the energy and chemicals sector would be incomplete without the story of Jurong Island.

It's a story not just of economic growth, but innovative thinking from JTC that rallied skeptics and stakeholders alike into building a new and common vision for Singapore's development. Amidst rising unemployment, declining entrepot trade and remnants of colonialism in the 1960s as well as the recession of the 1980s, Singapore forged ahead and developed seven idyllic islands into an energy and chemicals hub. Since then, Jurong Island has become home to a vibrant Energy & Chemicals (E&C) industry—one that contributes a total of 3% to Singapore's GDP and employs over 27,000 people.

While manufacturing has always been at the heart of what fuels progress along with the development of modern cities and businesses, its tenets look vastly different in today's social economic landscape. Today, all industries—including E&C—must balance economic growth and the global call for more sustainable business practices. Antonio Guterres, the UN's secretary-general, described the climate emergency as a "code red for humanity," a stark warning to businesses, citizens and governments. Collective action and systematic change are needed to address deep institutional problems and make an impact across the value chain. But how can businesses toe the line between profit and planet? Where do they even begin to decarbonise and transition into a "net zero green business?"

It's exactly within this conundrum that JTC is well placed to provide expertise on the most pressing and existential issue facing businesses today. Drawing on decades of expertise in planning industrial estates, JTC can once again rally various stakeholders to bring to life a vision for the "circular economy", a paradigm shift being championed by global sustainability experts. It's a new model of production and consumption that involves sharing, reusing, recycling existing materials and products as long as possible, to extend the life cycle of a product and reduce waste.

Linking Hands For Solutions—and Success

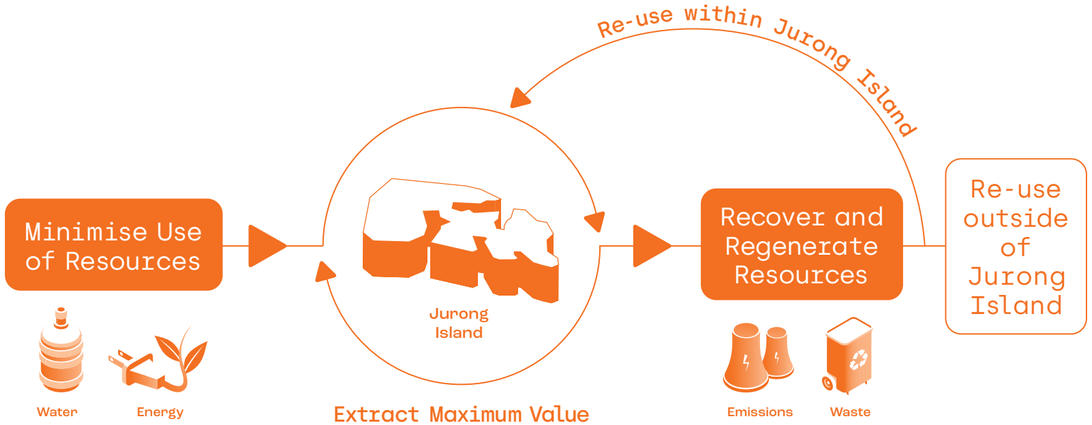
Pursuing this vision requires a radically collaborative approach involving cooperation and transparency from players who are also competitors. This is why the pioneering Jurong Island Circular Economy (JICE) study led by JTC was such a feat. It brought together 51 global companies including Chevron, ExxonMobil and Shell to share data for a common goal—identifying synergies to reduce resources used at a systems level. For example, a company can sell a byproduct of their manufacturing process to a neighbouring company that's part of the ecosystem.

"THE [CIRCULAR ECONOMY] STUDY WILL ENABLE US TO LOOK BEYOND INDIVIDUAL COMPANIES' EFFORTS, AND FROM A SYSTEM LEVEL TO DISCOVER OPPORTUNITIES FOR FURTHER RESOURCE OPTIMISATION AS A BUSINESS COMMUNITY."

Mr Goh Koon Eng, Vice President, Commercial of Chevron Oronite

There is also the opportunity for companies to sell what is normally seen as waste to another company that has value for it, putting truth to the old adage "one man's waste is another's treasure". This not only reduces the amount of waste that goes into a landfill, but also translates to new business opportunities for companies on both ends. Regardless of the type of circular process, companies can leverage existing infrastructure of piperacks and pipelines on the island and build from there.

Not only does this approach help address systemic issues, it also fosters a new way of working among the business community towards a mutually beneficial goal. Mr Goh Koon Eng, Vice President, Commercial of Chevron Oronite said that "the [circular economy] study will enable us to look beyond individual companies' efforts, and from a system level to discover opportunities for further resource optimisation as a business community."



AS THE “LANDLORD” OR INDUSTRIAL DEVELOPER FOR JURONG ISLAND, JTC CAN FACILITATE CONNECTIONS WITH COMPANIES TO UNCOVER MUTUALLY BENEFICIAL OPPORTUNITIES FOR SIMILAR PROBLEMS AND SOLUTIONS.

The JICE study is a positive step towards more impact and transparency on a systems level—and towards demonstrating the power of “we”. With 51 companies collaborating, the overall competitiveness of the chemical park is enhanced, especially as it transitions into its vision to become more sustainable. Commenting on this collaborative competitiveness, Ms Geraldine Chin, chairman and managing director, ExxonMobil Asia Pacific Pte. Ltd. said that “the Jurong Island ecosystem allows companies to work synergistically to progress technologies to reduce emissions and waste, while ensuring competitiveness.”

Some of the clear opportunities for greater collaboration that the study found is to develop an island-wide Virtual Power Plant (VPP) network to optimise the power output of the Distributed Energy Resources (DERs) such as solar and energy storage systems on the island.

At the heart of Jurong Island’s success is collaboration and transparency—two critical criteria for fostering the systems-level innovation required to address today’s pressing climate change issues. While good for the planet, it also shows how working together can deliver the economies of scale and resource efficiency that businesses need.

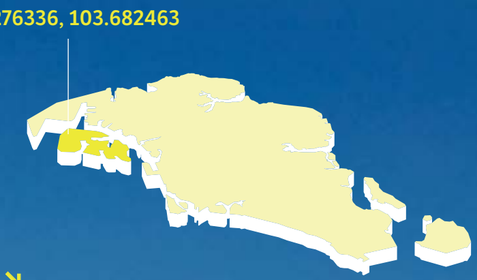
JTC is well placed to help companies on Jurong Island decarbonise their operations as a neutral partner in the ecosystem and facilitate collaboration among companies. As the “landlord” or industrial developer for Jurong Island, JTC can facilitate connections with companies to uncover mutually beneficial opportunities for similar problems and solutions.

To realise the vision of a sustainable Jurong Island will also require technological innovation. Two innovation calls, namely the Jurong Island Innovation Challenge (JIIC) and Jurong Island Renewable Energy Request-For-Proposal (JIRFP), were launched in August and October 2021 respectively.

Taking its role as an enabler for systems-level collaboration, JTC partnered with Enterprise Singapore (ESG) to launch JIIC, calling for start-ups and SMEs to tackle challenges faced by the companies in Jurong Island—to co-develop solutions to address problem statements on water, energy and chemical waste. Among the 45 proposals received were some successful matches between the solution providers and Jurong Island companies.

Jurong Island’s Circular Impact

Under the Green Economy pillar of the Singapore Green Plan 2030, Jurong island will transform into a sustainable energy and chemicals park that operates sustainably and exports sustainable products globally.



2 million tonnes

The goal by 2030 is to realise at least 2,000,000t of carbon capture potential, and achieve more than 6,000,000t of carbon abatement per annum from low-carbon solutions by 2050.

1.5x

Output of sustainable products is targetted to increase by 1.5 times from 2019 levels by 2030, and by 4 times come 2050.

World class energy efficiency

By 2030, all refineries and crackers located in Singapore will be in the top quartile of the world in terms of energy efficiency. To this end, ExxonMobil has increased energy efficiency of its operations by over 25% between 2002 to 2019 through process improvements and plant upgrading. The CO_2 emissions avoided is equivalent to removing 600,000 cars off Singapore’s roads over the same time period.

In the Energy Efficiency National Partnership Awards held in October 2021, CCD (Singapore) was given the “Best Practices” award for its efforts in reducing emissions through steam optimisation, with ExxonMobil, Afton Chemical and Petrochemical Corporation of Singapore (PCS) receiving an honourable mention for their respective energy efficiency improvement efforts.

New carbon capture technologies

Jurong Island will also be grounds for the R&D and piloting of new carbon capture technologies, exploring novel ways for utilisation of the carbon captured.

1st Hydrogen-ready power plant

Part of the innovative firsts at Jurong Island includes the construction of Singapore’s premier hydrogen-ready power plant, expected to be ready by 2026. Designed to operate on fuels with 30% hydrogen content, the combined cycle gas turbine power plant will have the potential to generate up to 600MW of electricity.

The energy-efficient technology, as compared to other power plants in Singapore, will also result in reduction of 220,000t of carbon emissions annually. This is equivalent to having 47,000 cars off the road each year.

THE GLOBAL PUSH INTO THE CIRCULAR ECONOMY MIGHT BE A RECENT TREND, BUT THIS IS NOTHING NEW TO JTC...

JIRFP, co-organised by JTC and EMA and supported by ESG, sought to encourage technical providers to work with Jurong Island companies, with a focus to test-bed innovative renewable energy proposals. Three projects were awarded in mid-July 2022: the Innovative floating solar deployment in dead sea spaces by Keppel Energy Nexus; the development of virtual ledger for green hydrogen production by Tuas Power and EDF HQ Singapore; and the use of existing storage tanks for energy storage by VFlowTech.

JTC CEO, Mr Tan Boon Khai, said, "JTC is working with companies and stakeholders to pilot new sustainability innovations and capture opportunities in a circular economy. As Jurong Island transforms into a more sustainable energy and chemicals park, it can, and will, play a leading role in spurring game-changing technologies, making it more competitive and sustainable in the long term."

Wisdom From the Past: A Proven Way to Collaborate

The global push into the circular economy might be a recent trend, but this is nothing new to JTC, which has been championing a similar integrated approach ever since the 1960s.

The development of Jurong Island was guided under a similar integrated ecosystem philosophy, in order to optimise resources between companies.

The concept of Jurong Island was born amidst a climate of uncertainty and two constraints: planning and managing land in a resource-strapped country, and alleviating pollution. The 1970s were marked by the development of three new oil refineries which in turn created bigger production capacity and the need for intensive land reclamation projects. But as we now know, the cost of rapid growth is the impact on the planet and communities—a delicate tradeoff that JTC was acutely aware of even back then. This was always at the forefront of difficult decision making but Singapore prevailed at upholding environmental standards, making sure the right checks and balances were always in place. Former Cabinet minister Mr S. Dhanabalan recounted an incident where Singapore showed unflinching commitment to protecting the environment. When Sumitomo built its petrochemical plant in the mid-1970s, it had to make the necessary investments to meet the environmental requirements set by The Ministry of Environment.

While the first 20 years were marked by oil production, the late 1980s, after the country slipped into its first post-independence recession in 1985, saw the birth of the petrochemical cluster of Jurong Island. Mr Philip Yeo, then-Executive Chairman of the Economic Development Board (EDB), spearheaded an innovative "cluster approach" to create a critical mass of related industrial activities in a smaller area. There are two key principles underpinning this approach. Firstly, it's to create a supportive ecosystem of companies across the value chain—from upstream refineries to downstream chemical companies, utilities and logistics companies. Secondly, this allows for a plug-and-play model of solutions where companies can connect to shared utilities and services, thus benefitting from economies of scale. All of this is connected via common pipeline service corridor.

This cluster approach is our first glimpse of the circular economy in action. Yeo said that "If you create the cluster, you must make sure that they [the companies] service as well as support one another." It emphasised a symbiotic relationship between companies, where the output of one plant would become the input for another plant, while concurrently sharing core capabilities and infrastructural facilities, thus resulting in economies of scale.

The significance of the planning in the early decades of independence is many-fold. It set the foundation for an approach that balanced the needs of economy and environmental sustainability. It was also the genesis for what we know as the circular economy today. Perhaps also important are the answers they present. These ecosystems might have been created in a different time, but the challenges businesses today face—a similar outlook of economic uncertainty and climate change concerns—echo that of the past. It is indeed possible to look into history to find answers for the future.

An Invitation to Be Part Of The Solution Forward

This integrated ecosystem of seamlessly integrated infrastructure solutions—with its foundation laid down decades ago—is what has made Jurong Island the world class chemicals hub it is today. As the world we live in becomes increasingly complex and uncertain, remaining competitive will be difficult without a clear vision and integrity to do what is right for the double bottom lines of profit and the planet. But as the history of Jurong Island's development proves, there is a possible way forward.

Jurong Island not only provides a working model, with proven expertise and experience from the past, but also a vision of what the future could be.

On the Green Side

Growing industries within gardens.

Jurong Eco-Garden

At the heart of the Jurong Innovation District, nestled in between the fringes of Nanyang Technological University and CleanTech Park, is a 5-ha park. Launched in 2014, Jurong Eco-Garden is a lot more than a tranquil green space. Leveraging on water sensitive urban design, such as rain gardens and bioswales to retain and filter rainwater, the park also serves as a green and blue system for the industrial development surrounding it. With a new pedestrian overhead bridge across the Pan-Island Expressway being constructed to link the garden to residents in Jurong West, it also a platform for connecting different communities—a place where work and play intermingle in green harmony.

JURONG INNOVATION DISTRICT

Hampstead
WETLANDS PARK

Rustically beautiful, the 3.23-ha Hampstead Wetlands Park might appear to be a nature reserve. After all, it is home to a variety of flora and fauna such as the Blue Percher dragonfly, White-throated Kingfisher and Blue-tailed Bee-eater birds that inhabit freshwater ecosystems, and a hotspot for nature photographers. Yet the tiered landscape of the park—from plains with sparse clusters of trees, to medium-height shrubs, to the tall, dense forest core—bely a rewilding effort. The raw wetlands habitat was enhanced by naturalising a waterlogged area that was formerly part of the Seletar Base Golf Course. Today, boardwalks and nature trails are strategically placed to minimise human impact on the delicate habitats, while giving visitors a front-row seat to observe nature in its full glory.

SELETAR AEROSPACE PARK

TimMac

@KRANJI

Taking greening to new heights are the vertical greenery and sky gardens of TimMac@Kranji. Developed to meet the high specifications and exacting demands of companies in the metals, construction machinery and timber sector, it is also thoughtfully designed to reduce its ecological impact on the wildlife of nearby Sungei Buloh Wetlands Reserve. Proudly standing along the northern coastline of Singapore, its eco-sensitive design gives a peek into the clean, green and technologically advanced industrial estates of the future.

SUNGEI KADUT ECO-DISTRICT

one-north Park

A green spine running through the estate, one-north Park comprises a series of green spaces. Forming a 16-ha park corridor linking Rochester East and West, Biopolis, Fusionopolis North and South, and Mediapolis, these parks transform commuting within the 200-ha estate into an immersive nature experience. A lush space for workers and residents alike to take a moment of respite, it is also where built-environments and nature convenes, and where work meets play at all hours of the day.

ONE-NORTH

Jurong Island

GREEN DRIVEWAY

Changing perceptions of industrial estates, one tree at a time—that is the Greening Jurong Island project. A collaborative effort between JTC, National Parks Board (NParks), the companies on Jurong Island, the Association of Process Industry (ASPRI) and its members, it is the biggest greening initiative on the energy and chemicals hub. Some 34,000 new trees have been planted on the island as of 2022, adding shade, colour and vibrancy. However, these trees perform more than a decorative function. Tapping into NParks' expertise, trees with hardiness, drought resistance and the ability to thrive in the industrial backdrop of Jurong Island were carefully chosen. Ground conditions were also analysed before strategic planting was done in a multi-tiered manner to mimic a forest structure. This was adopted to ensure longevity and diversity in Jurong Island's streetscape. Beyond creating pockets of greenery and biodiversity on Jurong Island, the tree planting exercise has also transformed Jurong Island into an eco-friendly workplace environment.

JURONG ISLAND

Industries 2050

Combining the creative flair of students from Nanyang Academy of Fine Arts (NAFA) and the design thinking of architecture students from National University of Singapore (NUS), we present youthful visions of industrial estates of the future.

The Arcade Hereafter

Surmounting resource challenges with technology and an unbridled optimism.

Chiam Yong Qin

Undergraduate, Department of Architecture, NUS

Jessin Goh

BA(Hons) Design Practice, NAFA

In imagining industrial estates in 2050 and beyond, we injected a strong sense of fun and excitement into our work, *The Arcade Hereafter.* This is an expression of the positive outlook we have of our future, and the optimistic attitude we take in tackling the issues and challenges that might arise with rapid advancements in technology and the industry, as well as an increasingly fast-paced life.

Some key issues include resource depletion across different industries, affecting various stakeholders. In particular, the problem of scarce land resources is going to become an increasingly prominent issue in Singapore. With a rapidly increasing population, ever-expanding industries but a finite and limited space, Singapore is going to have to build even higher into the skies—or deeper underground.

The issue of depleting fossil fuels is also a rising concern. Countries are already switching to more renewable sources of energy. We foresee a continuation of this trend and imagine new sources of renewable energy that could be used to power the different aspects of the Arcade.

Last but not least, *The Arcade Hereafter* also hopes to be self-sufficient in terms of food and water supply. In this reimagined estate, the community within is self-reliant on their crops and fresh, clean water supply is free to all.

Our model of an industrial estate in 2050 takes Jurong Island as a starting point, and we demonstrate our vision through intertwining elements of an amusement park—a vibrant environment brimming with positivity and surprises. Within such a model, we outline our vision for sustainable solutions. For instance, the ferris wheel is re-imagined to be a water filtration system, capable of providing clean water continuously to the population residing and working around it. It is powered by renewable kinetic energy, harnessed through bumper car lifts that also illustrate our vision for new ways of connectivity in the near future.

This filtration system also provides water for crops and plants which can be harvested by each individual household and office. Users can also choose to purchase or sell these crops within the population and transactions will be transported, and delivered on a cart along created tracks. This is represented by roller-coaster carriages, which will once again be powered by renewable sources of energy harvested on site.

Our artistic presentation of the future industrial estate as a theme park is not just an expression of a youthful spirit. It also expresses our vision for more dynamic estates where everyday moments are little less mundane and a little more experiential, where the everyday comes alive.

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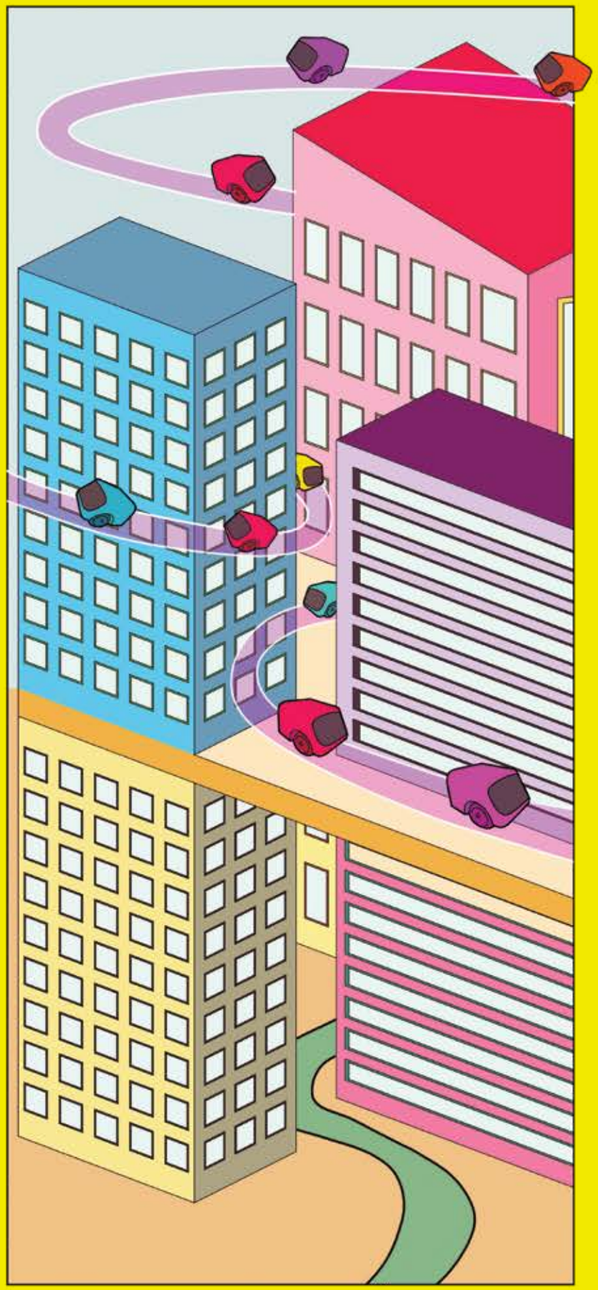
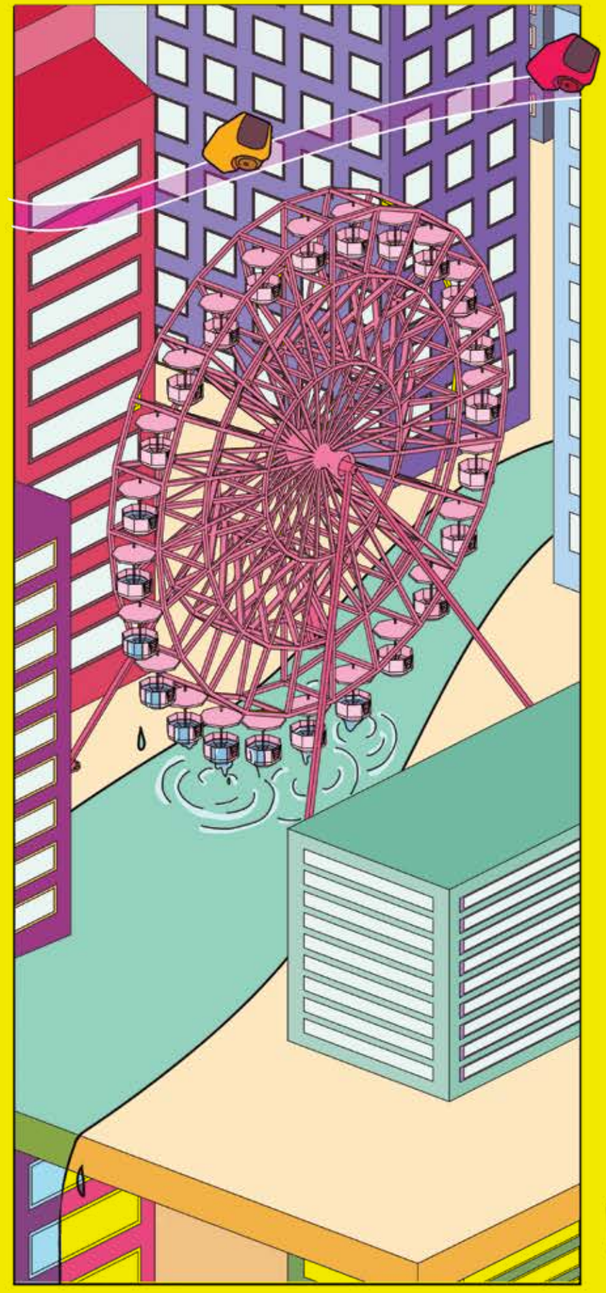
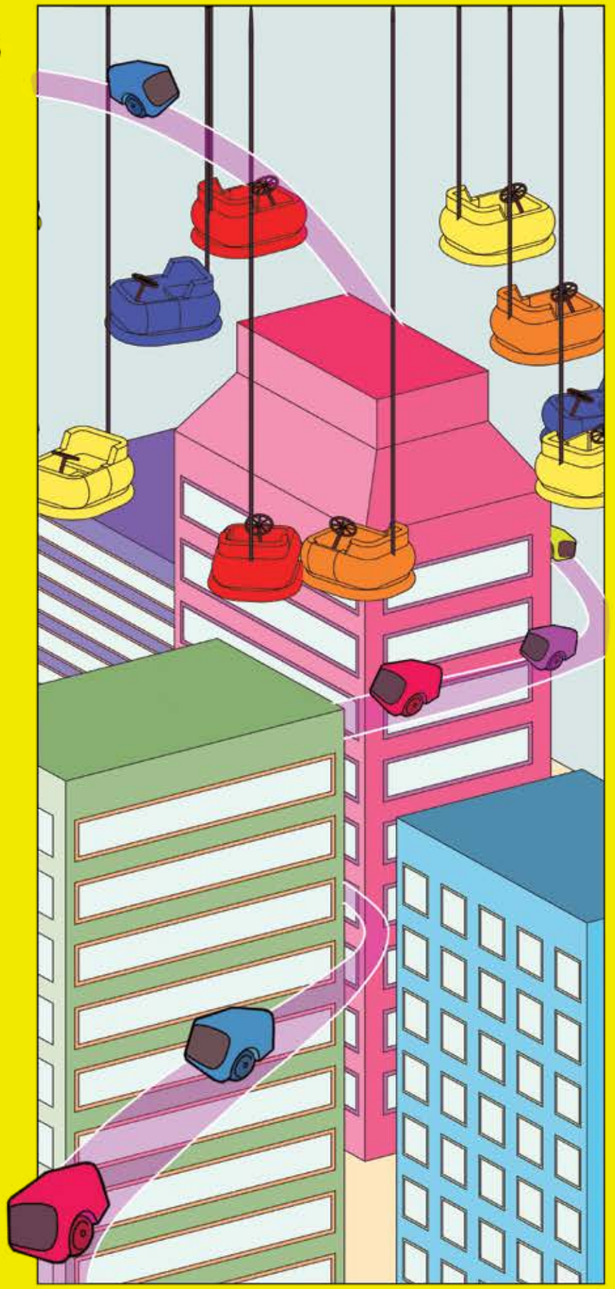
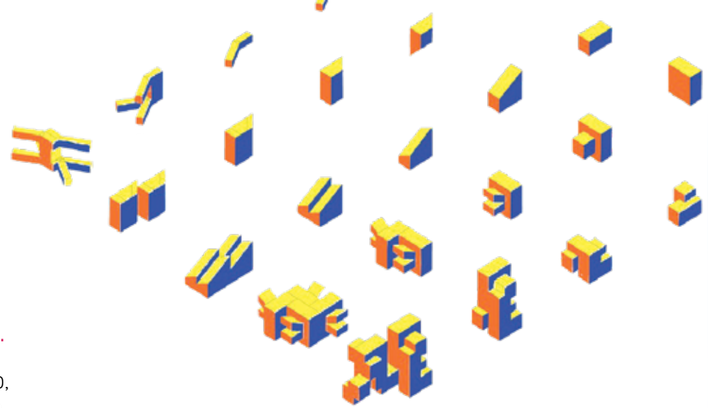
Jessin Goh

BA(Hons) Design Practice, NAFA









Equal Dreams

Industrial estates as an instrument to bridge social gaps.

Ang Zhi Yan

Diploma in Fine Art, NAFA

William Tay

Undergraduate, Department of Architecture, NUS

The Fourth Industrial Revolution would, by 2050, have fully addressed the climate issues we face today and net zero buildings would be the norm. However, we foresee the growing trend of increased automation to create potential social tensions.

From automated logistics to advanced manufacturing equipment, novel technologies would no doubt play an important role in Industry 4.0 and even beyond. This leaves us to speculate if factories can function without human workers in the future. While governments cannot simply allow full automation to displace the workforce of entire industries, structural unemployment would likely rise, especially among a demographic of workers who are unable to fully keep up with new technologies.

The increasing world population—already surpassing eight billion people today—could exacerbate the situation, with larger polarised groups and a widening gap between those able to keep up with industrialisation and advanced technology, and those left behind.

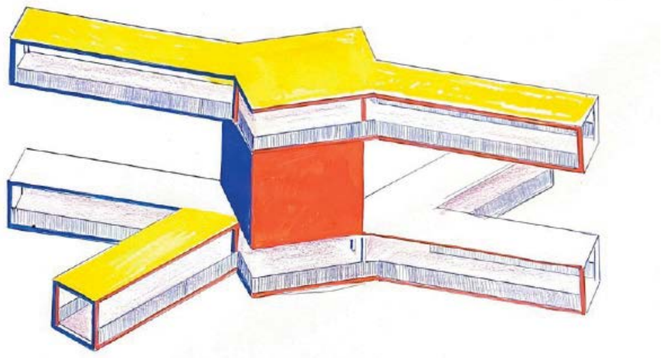
In our design of the industrial estate of 2050, we thus propose creating an ecosystem where all, regardless of economic status or technological savvy, can come together to contribute to the betterment of our environment.

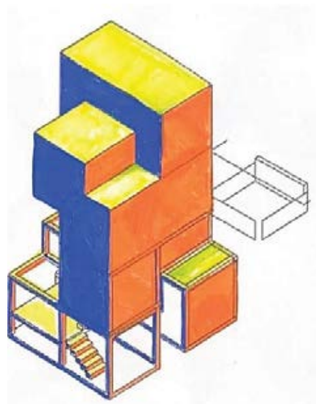
Three key tenets anchor our vision. The first is to bridge income inequality brought about in the industrial revolution, and the second is to subtly question our push for automation and possible consequences of such pragmatism—when does it go too far? The third is to address the grievances of those negatively impacted by automation.

To this end, we employ design thinking to establish walkable estates. Walking is more than a green and healthy means of commuting. It is also a powerful equaliser that brings together people from different walks of life. In designing these walkable estates, we propose creating clean, green, built-environments that promote maximum productivity of workers. Cities must be fueled by sustainable energy. Singapore's location on the equator is positioned well to harness solar energy through building-integrated photovoltaics panels equipped with sensors, monitors and connection to a well-established smart grid system. The sustainability efforts behind the industrial estates would thus benefit extended communities.

As a team of architecture and fine arts students, we seek to solve these issues through the exploration of built forms and operative design. Drawing upon two disparate sources of inspiration—Anthony Di Mari and Nora Yoo's *Operative Design: A Catalogue of Spatial Verbs* and *Avatar: The Last Airbender* by Michael Dante DiMartino and Bryan Konietzko—we explore a modular design that employs volumetric operations on a hypothetical cube. Apart from facilitating connectivity through a walkable estate design, we also seek to create interesting forms that present homogeneity, yet offer unique solutions through the built environment. We hope to pique the curiosity and perhaps nudge the general public and readers of this publication to question how pushing the boundaries of architecture and art can contribute to the discussion of social equality.

As youths of Singapore and of an increasingly interconnected world, we hope to inspire others to solve these issues for the good of our future.





Looking Beyond Boundaries

A future where all is harmoniously integrated—be it work and play, or nature and modernity.

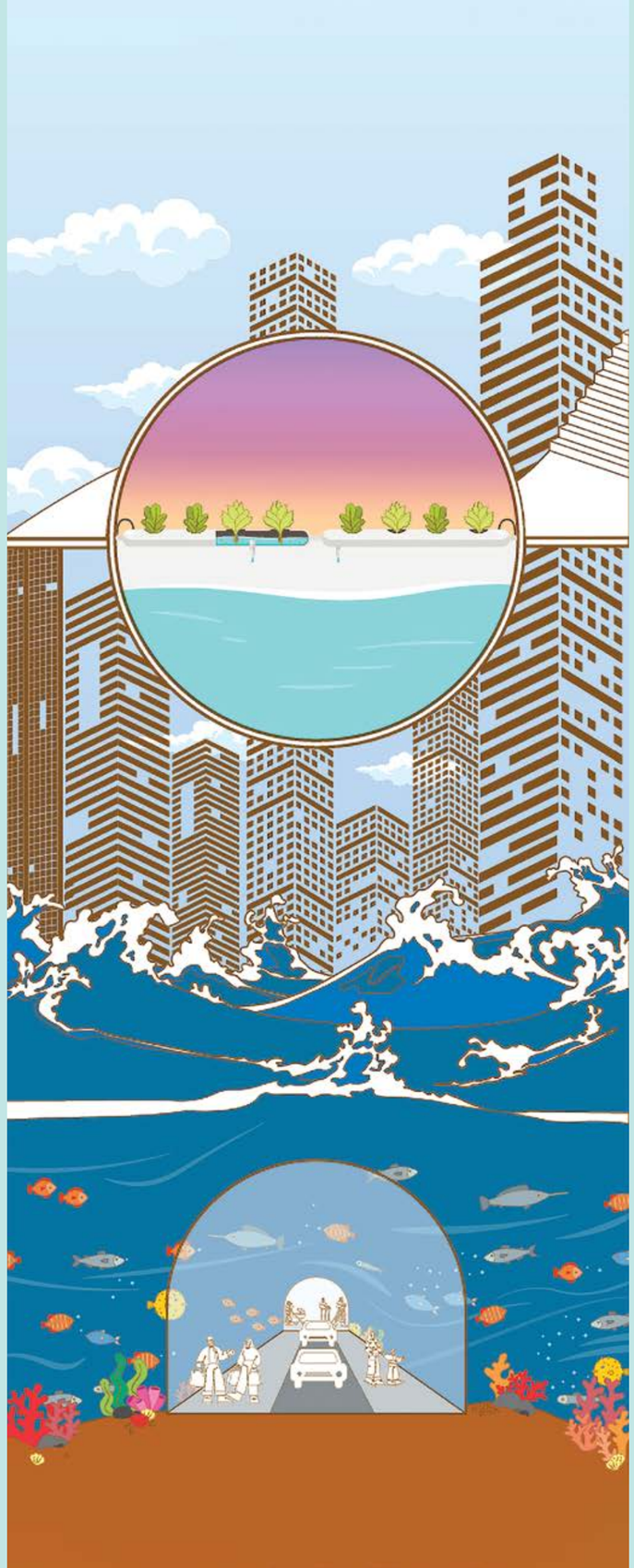
Imagining life beyond 2050 requires immense trust in generations that lead up to it and an ambition far greater than we might currently have.

As the world pushes for net zero emissions, we see the talent, capital and passion being poured into this endeavour. Yet more often than not, industries are progressing with their individualistic mission to reduce and offset emissions within their own sector. Can technology keep up with the pace at which our climate is changing? Can we solve the world's problems by working in silos?

We propose that industries must unite to meet climate goals before it is too late. As a result, industrial estates will also take on a new outlook: estates will see an integration of different industries and technologies so as to deliver maximum impact. As the industrial estate of the future homes, multiple sectors, cross-industry meeting spaces and event halls would be included into the hub to promote business partnerships and technological advancements.

The industrial estate of 2050 would also be entirely powered by a combination of renewable energy sources. The free energy of the sun and wind could be harnessed through a decentralised power system, where each industrial building or zone can sustainably power itself. With hope, nuclear fusion should be economically viable by 2050, and the estate's energy capacity can be easily upscaled by having a modular toroidal fusion reactor—just like stacking rings on a stick. Carbon capture, utilisation and storage systems should also be incorporated into the estate in order to continually offset emissions. Put together, these solutions could create industrial estates that are sustainable, resilient and reliable—qualities that will appeal to a wide range of industries, from chemical and biosynthetic processing, modern precision manufacturing and even to agriculture.

We also foresee fully automated processes: food could be produced in hygienic, hands-free and cost-effective vertical farms. Synthesis of chemicals and organic substances could be autonomously controlled to reduce human exposure. Precision materials and instruments could be efficiently manufactured by means of an optimised production line. All of these could be controlled through a system wirelessly connected to an integrated command



centre and office, managed by skilled workers who are equipped to operate, maintain and diagnose arising issues.

The estate offices are located centrally and adjacent to an integrated work-and-leisure hub. Work-life balance would be a given by 2050; food, leisure and exercise options would be plentiful for the average estate worker during or even after working hours. Extended amenities such as childcare services, business suites and tech-services would also be incorporated into the hub to bring a full city-living experience into the estate.

We also foresee that climate change impacts would reshape the way we live in 2050. With land scarcity and rising sea levels, we foresee the establishment of marine-based estate zones. This expansion into the sea via an integrated network of floating and submerged marine estates could be sites for nurturing marine cultivation, such as seaweed farming and sustainable seafood, to help in the sustainable substitution of other food sources that are depleting. The proven success of the marine estates can also reaffirm the feasibility of water-bound living in the unfavourable outcome of sea encroachment.

By looking beyond boundaries, be in spatial use or differences that separate industries, we can build a future-proof industrial estate for 2050 and even beyond.

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Smart Estates—With Roots in Nature

A heightened appreciation for nature in a high-tech future.

The possibility for built industrial environments to evolve and be adapted for the future is vast with the rise of smart technologies, sensors and Artificial Intelligence (AI).

For instance, smart technologies could be used to facilitate the monitoring of production processes, allowing for increased accuracy and quality assurance. New technologies could also help to create a more vibrant and sustainable ecosystem, such as the implementation of green energy initiatives.

These positive steps not only address the evolving needs of industrialists, but also the people working within the estates. AI can help optimise production processes and automate certain activities, resulting in a decrease in man-hours and waste. Advancements in info-comm could also be applied in establishing a community-building programme that would allow local businesses to interact and collaborate with each other.

Indeed, keeping industrialists competitive in the global marketplace while creating a better future for our community is the backbone of the future industrial estate's design.

In the future envisioned, city planning will incorporate smart city technology whereby architects will be able to reduce wasteful practices, increase productivity and drive cost efficiencies. This can be done by understanding urban mobility, energy consumption and the interplay of different types of infrastructure. Currently, climate change and dwindling natural resources threaten humanity. Architects are called upon to tackle these complex problems and develop innovative approaches to resolve them. Adopting environmentally friendly building practices is but one option. Future environmental and climate security can only be ensured by incorporating economic considerations into all aspects of the architecture industry.

In the same vein, there is a need to reduce the amount of trash in landfills to better optimise limited land resource. In the future, land space will be scarce and it is important to make good use of space and energy. Architects could take into consideration three main factors: the materials, how energy-efficient they are and the site. If these key areas are taken into account and a more holistic approach is taken, sustainable design can become the norm in the industry.

Yet the future is not all steel and cement. We foresee a heightened appreciation for nature with the thrust towards sustainability. In our imagined estate of 2050, we have also dreamed up a futuristic and green cityscape—smart, wired, yet decidedly rooted in nature. The industrial estate of 2050 is thus more than a cog in the economic machinery. It is a space for play—a space to connect to a community and a physical manifestation of the dreams youths today have of the future.

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The Red Dot's Race to a Green Future

What does it take for local industrial estates to stay at the fore of the global drive toward sustainability? Mr Poon Ek Whye, Project Manager at JTC and former JTC Undergraduate Scholar, shares a young person's vision.

Singapore stepped on the accelerator of climate change goals when we declared net zero emissions by 2050. It is a bold commitment that will take the effort of many stakeholders. With industry and buildings collectively contributing 45% to primary carbon emissions and 30% to secondary emissions, industrial estates play a huge role.

Since the 2005 launch of the Green Building Master Plan, industrial estates have made significant progress on environmental sustainability. In fact, Green Mark certifications are the norm among industrial buildings today, even though industrial buildings present unique energy efficiency challenges rarely seen in residential or commercial typologies. Think cold rooms or server rooms that run 24/7, or cleanrooms with very high air change rates and air filtration, all of which are energy-intensive to operate. Achieving the highest certifications in industrial buildings therefore requires a strategic combination of technology and design solutions, such as highly efficient district cooling plants complemented by buildings designed to minimise heat transfer and optimise natural ventilation.

Substantial as existing efforts are, more is needed to drive Singapore's pathway to net zero. For industrial estates to be future-ready and to punch above their own weight, three interrelated paradigm shifts are crucial.

The first shift is to adopt a whole-life carbon accounting mindset. This means looking beyond just operational carbon emissions, but also the upstream embodied carbon emissions rising from the manufacture, transportation and installation of building materials, and the downstream emissions such as those from commute, waste treatment and disposal.

The adoption of mass engineered timber for Tower 4 in Punggol Digital District brought about drastic savings in embodied carbon. For buildings with higher floor loading requirements, such as factories, scrap-produced steel could help avoid an estimated 63% of embodied carbon emissions from concrete reinforcements. We are also constructing building facades with reused materials from carefully and gently deconstructed older buildings. I believe this practice could be made more commonplace in the future.

Waste accountability ties in closely with the second paradigm shift: the move towards residue-to-resource circular economies. In the city of Kalundborg in Denmark, the local power station forms the "heart" of an organically developed circular economy. Process steam generated by the station contributes to 15% of the city's oil refinery's needs and 100% of a pharmaceutical company's needs. Gypsum residue is also delivered to a plasterboard company.

In other places, a matchmaker that maps out resource flows and identifies potential synergies may be a necessary catalyst. The matchmaker could also invest in resource conveyance, such as in the case of the Ulsan-Mipo Industrial Complex in South Korea, where process steam is distributed via a $90 million steam "highway" to an ecosystem of manufacturing businesses.

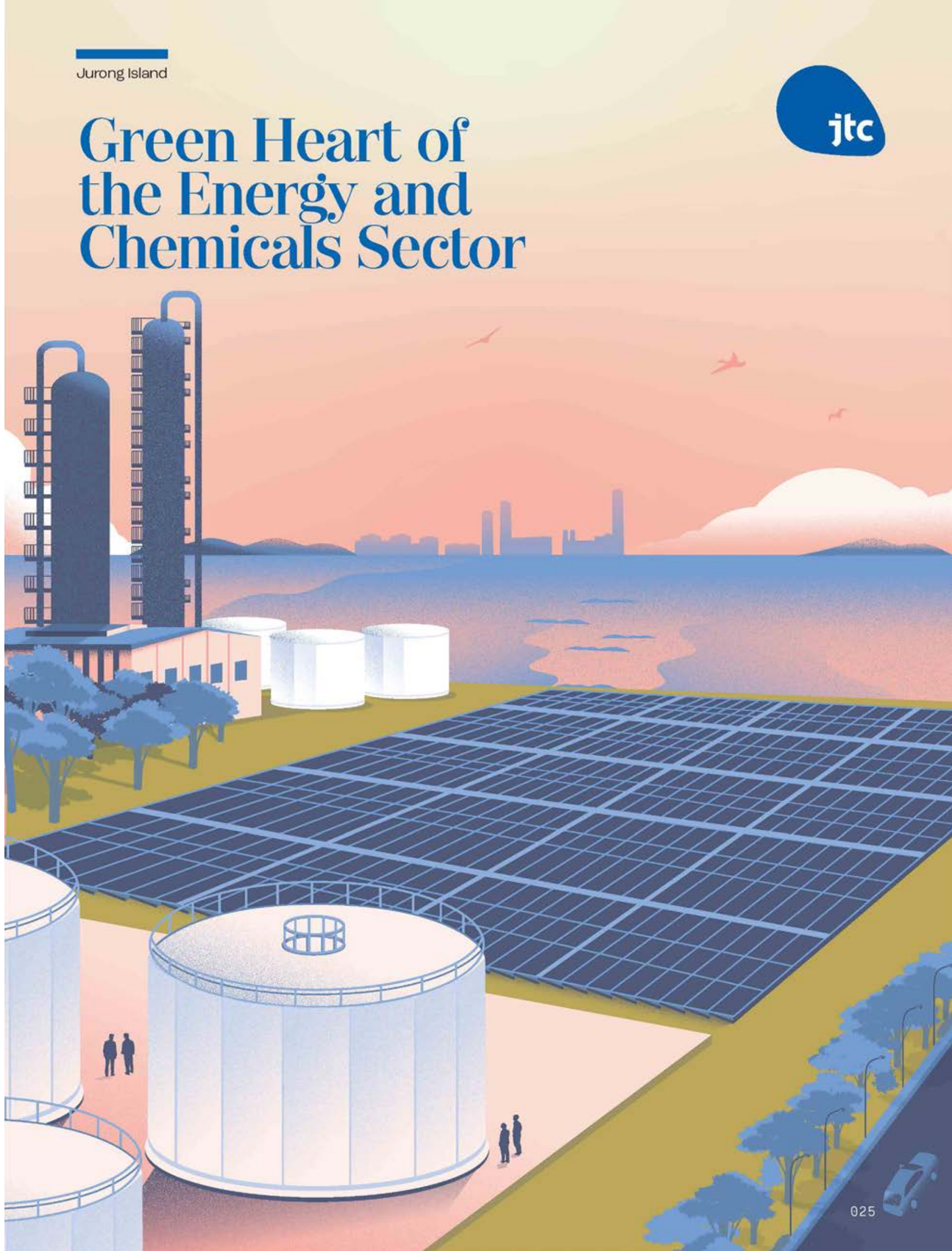
In both organic and curated scenarios, quick wins in profitability will help circular economies gain traction. Perhaps Singapore's industrial estates could develop an online estate-wide platform with a Materials Marketplace that serves as a "clearing house" for trading residue products—from scrap metal to construction and demolition waste, to even used office stationery—between companies.

Finally, there is a need to harness the Internet of Things (IoT) to optimise sustainability performance. Sensors could be integrated with a building management system, to enable the adjustment of air conditioning, fresh air and lighting in a responsive manner based on occupant demands and weather conditions.

Yet even with the trifecta in place, there is still a need to close the gap to net zero further. While the baseload power requirements of the industrial estate continues to draw from the national grid, peak demands could be bridged by a combination of solar energy, stored in battery-like storage systems to eliminate intermittency even on a cloudy day, as well as on-site ammonia or hydrogen fuel cells.

Climate change continues to pose an "asymmetrical" challenge for land-constrained Singapore. We can realise more carbon abatement potential if breakthroughs can be achieved not just technologically, but also in the way we master plan our industrial estates and its ecosystem, with life-cycle thinking in mind. As corporate sustainability rapidly shifts from choice to critical necessity, the hope is that green premiums will become more widely accepted with the aid of sustainability grants, and the eventual affordability of green technologies. To realise this vision takes a will to overcome mounting challenges and a fluidity to devise new solutions.

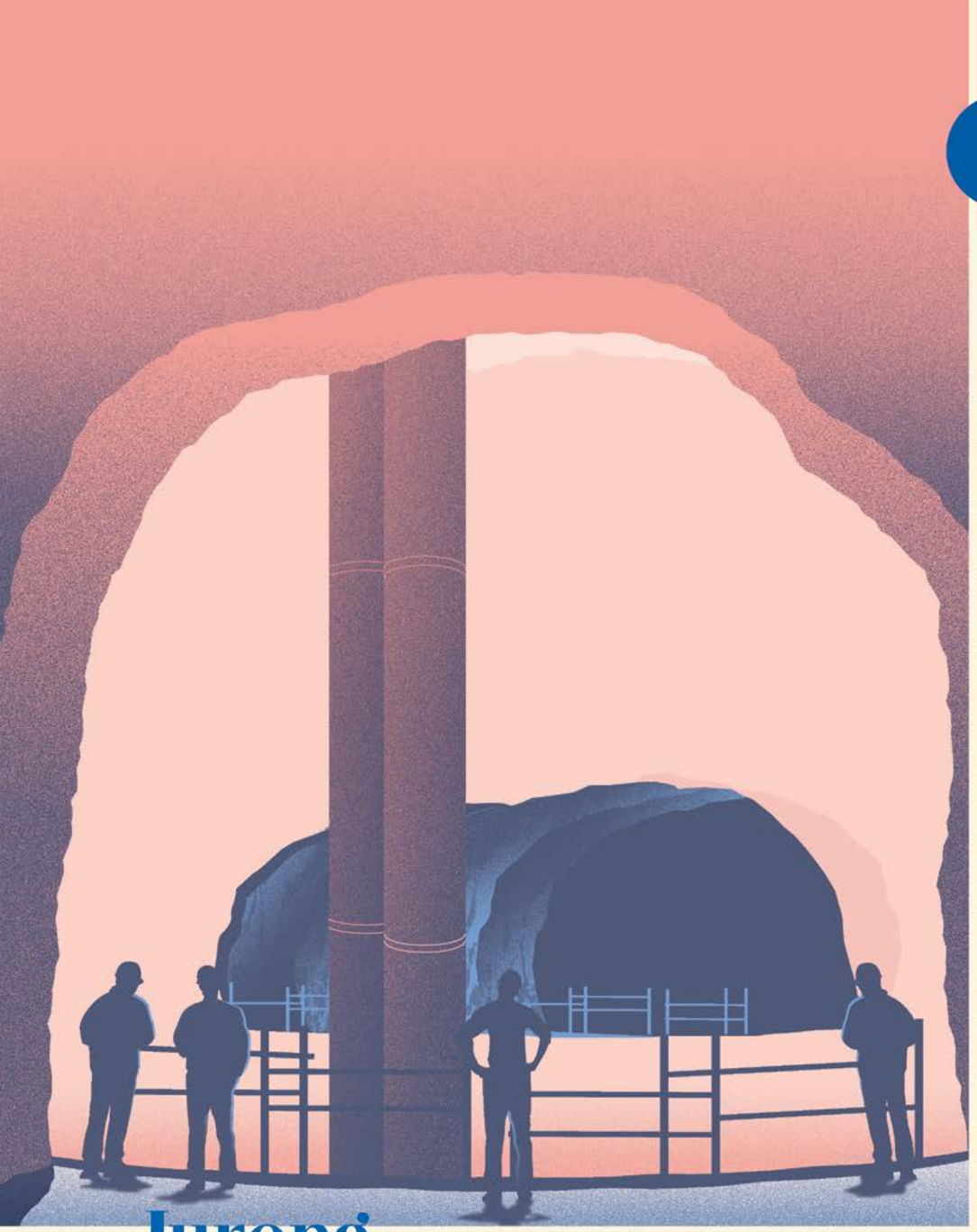
Mr Poon Ek Whye is a Project Manager at JTC and part of the team behind the development of Jurong Innovation District. Previously a JTC Undergraduate Scholar, he holds a Bachelor of Engineering in Civil Engineering from University College London and a Master of Science in Construction Engineering and Management from Columbia University.



Your Future: Here and Now

+

A diverse collection of JTC estates designed to propel industries to the future



Jurong Rock Caverns

A Groundbreaking Solution

www.jtc.gov.sg

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The Dream Team

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Sungei Kadut Eco-District

Transforming the Old, Welcoming the New

Sungei Kadut Eco-District

“**It also welcomes new growth industries, with the district’s first phase of development for Agri-Food Innovation Park (AFIP), bringing together high-tech urban indoor farming, food production and manufacturing including alternative proteins, and associated R&D activities.**”

One of the first industrial estates that helped to lay the foundation for Singapore’s manufacturing industry in the early days of independence, Sungei Kadut is being rejuvenated to support the transformation of existing industries, capture new industries and lead new work, live and play concepts.

The new Sungei Kadut Eco-District (SKED) is carved into four new precincts for food-tech and agri-tech, waste management and recycling, metals, timber, and furniture industries. This includes TimMac for the timber, metal and machinery industries, Kranji Green for the waste management and recycling industries, where the proximity of the developments provides for existing timber, furniture, construction and waste recycling industries better efficiency and productivity through optimally laid out multi-user developments with shared facilities and services. It also welcomes new growth industries, with the district’s first phase of development for Agri-Food Innovation Park (AFIP), bringing together high-tech urban indoor farming, food production and manufacturing including alternative proteins, and associated R&D activities.

As an eco-district, SKED also integrates “nature ways”—pathways with multi-tiered plantings that mirror the natural structure of a forest. These nature ways link parcels of green spaces and wildlife habitat, while allowing the SKED community to fully appreciate the nature around the estate.

500ha
for new growth industries

18ha
of land set aside for the first phase of development for Agri-Food Innovation Park (AFIP) to develop Singapore’s food-tech and agri-tech sectors

40%
green cover
With more parks, green roofs and trees, Sungei Kadut’s green cover will quadruple from 10% today, providing a more comfortable environment for the community

40%
Percentage of land in SKED set aside for future growth industries. This translates to approximately 200ha

Jurong Innovation District

Asia’s Leading Advanced Manufacturing Hub

Jurong Innovation District

“As the region’s first sustainable estate for advanced manufacturing, Jurong Innovation District sets the benchmark high. The estate’s collaborative ecosystem further establishes it as grounds for driving industry solutions of the future.”

For those at the forefront of the fourth industrial revolution, Jurong Innovation District (JID) presents a space powered by state-of-the-art district infrastructure. Designed as Asia’s advanced manufacturing hub, JID’s curated ecosystem, encompassing the entire manufacturing value chain, combines its sophisticated infrastructure to catapult businesses into the future.

Integrated within the estate is an extensive underground district logistics network (DLN) that will enhance the efficiency of freight movement and support autonomous goods delivery in JID. The first of its kind in Singapore, the DLN serves to direct heavy vehicles underground, effectively reducing congestion on the roads and freeing up space above-ground for more amenities that benefit the community. As Singapore’s largest living lab, this is where the innovation from some of the world’s leading names in advanced manufacturing—the likes of Bosch Rexroth, Hyundai, Makino, Shimano and Sodick—take shape. A one-stop hub that integrates talent and training, research, technology providers and factories of the future, JID is also home to a growing ecosystem of student talent, researchers, technology and training providers, all coming together to create a collaborative landscape.

Our community is brought together not just in labs and offices, but also picturesque pockets of green spaces. The verdant grounds of Jurong Eco-Garden and Bulim Park exist in perfect harmony.

An Enabling Ecosystem

Designed for driving innovation within the community, JID is where talent are groomed at facilities such as Nanyang Technological University, A*STAR Advanced Manufacturing Training Academy and Bosch Rexroth Regional Training Centre. The estate is also a hub for R&D, with influential movers and shakers such as Surbana Jurong Campus, Digital Capability Center Singapore and A*STAR facilities such as its Singapore Institute of Manufacturing Technology and A*STAR National Metrology Centre.

11-km
Sky Corridor
A transportation artery for the district, it takes pedestrians, cyclists and autonomous shuttles to all corners of the estate

620-ha
one-stop advanced manufacturing hub

95,000
jobs

32,000
talents

Seletar Aerospace Park

Where Leading Aerospace Companies Soar

Seletar Aerospace Park

> **An idyllic enclave for its residents, a lifestyle hub where a cluster of 32 colonial bungalows have been refurbished to house cafes and restaurants, spas and shops.**

Where over 60 multinational giants and local companies come together to create a world-class ecosystem supporting aerospace activities from Maintenance, Repair and Overhaul (MRO) to research and training. This is Seletar Aerospace Park (SAP), Asia's leading aerospace hub and choice investment destination for high value-added aerospace services.

JTC aeroSpace Phase 3 (AS3), situated in proximity to the facilities of big-name industry players such as Airbus, GE Aviation and Rolls Royce, further provides state-of-the-art facilities and plug-and-play modular spaces designed with Industry 4.0 processes in mind.

SAP is also a heritage enclave: an idyllic space for its residents, a lifestyle hub where a cluster of 32 colonial bungalows have been refurbished to house cafes and restaurants, and other lifestyle amenities.

The Hampstead Wetlands Park, with its scenic boardwalk and viewing decks, lends the community front row seats for observing diverse plants, birds and other wildlife that inhabit freshwater ecosystems. This place for rest and recreation is also a green sanctuary, providing birds and other wildlife with shelter, nesting spots and resting grounds.

60
MNCs and local companies

6,000
aerospace professionals

20 mins
to/from the city

30 mins
to/from Changi International Airport

3
expressways. Enjoy excellent connectivity via Tampines Expressway (TPE), Seletar Expressway (SLE) and Central Expressway (CTE)

3.23-ha
green sanctuary that is the Hampstead Wetlands Park

Woodlands North Coast

Versatile Spaces for Evolving Needs

Woodlands North Coast

“A new generation estate that integrates retail, dining, residential areas and institutions of higher learning, it will be a dynamic economic centre.”

A new-generation estate that integrates high value-added industrial activities and waterfront residences with retail and amenities within walking distance, Woodlands North Coast (WNC) caters to the evolving needs of the industries, keeping in-step with industrial landscape advances. Ringfenced as the Woodlands Experimental Zone (WEZ), it is the first development that offers businesses the flexibility to use up to 70% of space for service-driven activities alongside manufacturing operations.

For companies in the clean and light manufacturing space, this translates to the ability to house production, R&D, product design, prototyping and even after sales services all under the same roof.

A new-generation estate that integrates retail, dining, residential areas and institutions of higher learning, WNC will be a dynamic economic centre.

A 1km car-lite boulevard connects residents to the scenic Woodlands Waterfront park, providing the community a place to enjoy a leisurely bicycle ride or stroll to discover the offerings of the retail spaces flanking the boulevard.

WNC is within walking distance to the upcoming Multi-Modal Transport Hub (MMTH), which includes the newly opened Woodlands North MRT station and the upcoming Singapore-Johor Rapid Transit System (RTS) and Bus interchange. At the confluence of local and regional transportation networks, the estate would be a catalyst to local and international economic integration, creating new employment and investment opportunities. This is in proximity to three cross-island expressways and integrated transport hub that connects the community to the future bus interchange, the Causeway and Rapid Transport Systems (RTS, to be completed in 2026) which links to Johor Bahru, Malaysia. This is an estate that offers unparalleled connectivity both within and beyond Singapore.

150ha
A new-generation mixed-use estate with campus-like developments and car-lite features.

750m
North Coast Vista—a car-lite boulevard that runs across the estate.

25,500
new jobs in Woodlands North Coast

7
soccer fields of interconnected commercial vehicular network at basement level, increasing logistics efficiencies and creating a car-lite estate for the community

1.4-km coastline
Embrace nature at the Woodlands Waterfront Park

Industry-academia collaboration
Get to work with with almost 14,000 students from Republic Polytechnic

CleanTech Park

Singapore’s First Eco-Business Park

CleanTech Park

> **The proximity to Nanyang Technological University further lends ease for talent outreach and co-innovation.**

An eco-business hub within the Jurong Innovation District (JID), JTC's CleanTech Park is where movers and shakers in clean technologies, advanced manufacturing and urban solutions industries congregate.

Currently home to over 50 companies from research institutes, corporate labs and R&D companies, CleanTech Park gives companies access to collaboration within a vibrant community of like-minded peers. The proximity to Nanyang Technological University further lends ease for talent outreach and co-innovation. Located within the park is also JTC's Industry Connect Office, a one-stop centre to help businesses accelerate their Industry 4.0 transformation.

CleanTech Park is full of spaces designed to take ideas through to fruition. Customisable offices and high-specification laboratories aside, it is where companies can test-bed myriad innovations. Being situated in the heart of the JID, companies will also find themselves supported by a full value chain of activities, from production to distribution.

With an emphasis on preserving the natural environment and biodiversity of the area, CleanTech Park holds the honour of being the first development bestowed the Platinum Green Mark for Districts Award by the Building and Construction Authority (BCA). This is the choice location for corporations that walk the talk in all aspects when it comes to sustainability.

3 parks
located within Jurong Innovation District

60 companies
2,500 working professionals

130 species of flora and fauna
Discover a serene biophilic working environment close to nature, with invigoratingly lush greenery and intriguingly rich biodiversity

Wafer Fab Parks

Powering the Future

Wafer Fab Parks

“Immaculately planned to deliver connectivity and world-class amenities, the Wafer Fab Parks are designed for companies to power advances in the electronics industry.”

One-fifth of global semiconductor equipment is manufactured here, contributing to 11% of the global semiconductor market share and more than 7% of Singapore’s GDP as of 2023. JTC’s four wafer fab parks—located in the North Coast, Pasir Ris, Tampines and Woodlands—form a critical node in the global semiconductor value chain, driving everything from 5G connectivity, Artificial Intelligence to the Internet of Things.

Immaculately planned to deliver connectivity and world-class amenities, the Wafer Fab Parks are designed for companies to power advances in the electronics industry. Already within the community are movers and shakers such as Micron, a world leader in innovative memory solutions; Siltronic, one of the world’s leading producers of hyperpure silicon wafers; and leading global semiconductor foundry company UMC.

These industrial parks are also rejuvenated for a more designed for vibrant and conducive work ecosystem, through greening efforts in collaboration with National Parks Board.

430ha
spanning four Wafer Fab Parks

15
global semiconductor companies

9 out of 15
top semiconductor companies located in the Wafer Fab Parks

>19,000
professionals

20%
of global semiconductor equipment is manufactured in Singapore

one-north

An Icon of Singapore’s Knowledge Economy

one-north

“Beyond offering a serene slice of nature, the series of parks lend connectivity; a space where the entire community can convene in their commute and recreation.”

one-north is the epicentre of Singapore’s innovation ecosystem, the physical manifestation of the city-state’s drive towards playing a leading role in the global knowledege economy. Global names such as Autodesk, GlaxoSmithKline, Procter & Gamble and Seagate have anchored at one-north; companies such as Grab, Razer and Wilmar have also made it their regional and international headquarters. It is a creative environment that has attracted world-class research talent and investments; institutions of higher learning, such as INSEAD and ESSEC Business School, also call it home.

This is a one-of-a-kind business park that brings to life a whole new work-live-play-learn ethos. Zaha Hadid Architects’ masterplan for the 200-ha site was a vision that wove nature with architecture. Breaking ground in 2001, with Biopolis as its first cluster, the business park has been in continuous evolution through phased development.

A central linear park running from north to south of the estate remains its green spine. Beyond offering a serene slice of nature, the series of parks lend connectivity; a space where the entire community can convene in their commute and recreation.

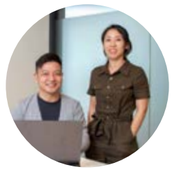
This is also where heritage and modernity meet. While the colonial Wessex estate preserves the quiet idyll of a bygone era for its residents and working community, a dazzling array of on-trend dining, shopping and lifestyle offerings bring city-centre living to the one-north community.

8
distinct precincts

400
leading companies

5 institutes
of higher learning and corporate universities

15 public
research institutes



50,000
knowledge workers

LaunchPad @ one-north and JID

Connecting Industries, Nurturing Start-Ups

LaunchPad @ one-north and JID

“Custom-designed to meet the unique needs of early stage tech start-ups, LaunchPad offers affordable and vibrant plug-and-play spaces to launch and grow businesses.”

If you are ready to be the next unicorn, let us take you there. We understand the challenges of starting something from scratch—this is why we created LaunchPad at one-north and Jurong Innovation District (JID). Custom-designed to meet the unique needs of early stage tech start-ups, LaunchPad offers affordable and vibrant plug-and-play spaces to launch and grow businesses.

More than work facilities, LaunchPad offers access to a community of like-minded peers to experiment and grow with. Dedicated communal spaces and a series of curated work and play events allow for increased opportunities for interaction and collaboration. The networking extends beyond that between start-ups, but also between community partners such as, Action Community for Entrepreneurship (ACE)—the lead trade association supporting Singapore’s start-ups and 35 established companies that play the role of enablers.

LaunchPad @ one-north caters to young companies in the biomedical, urban solutions, transport and mobility, advanced manufacturing and ICT spaces. It places start-ups within proximity of giants within the high-tech business cluster, alongside higher learning institutions which can be tapped for talent. At LaunchPad @ JID, start-ups across various industries, from advanced manufacturing, urban solutions to precision engineering cross-polinate by sharing resources and knowledge.

In 2022, JTC’s LaunchPad Investor Network (LINK) was also launched. This initiative connects eight highly successful international corporations— from sectors spanning agrifood, fintech, logistics, urban mobility to sustainability— to over 700 start-ups within the LaunchPad community. Corporations are provided with a greater access to co-innovation, funding and wider networks to take them into the next stage of growth.

1,300
tech start-ups supported since the official opening of LaunchPad in 2015

700
Currently home to start-ups from varying sectors ranging from Food & Agriculture to Healthcare, Financial Services to Consumer Goods

40%
Number of enablers supporting the start-ups in their growth journey

60,000m²
of start-up spaces offered by LaunchPad

Punggol Digital District

The Future, Now: Singapore’s First Smart District

Punggol Digital District

> **A hub for key growth industries of the digital economy, supporting operations in areas such as cybersecurity and digital technology, it will foster a thriving business and lifestyle ecosystem that attracts talent and enables innovation.**

Punggol Digital District (PDD) is where integrated master planning and technology come together to create improved liveability and sustainability at a local district level. At the heart of the district lies the Open Digital Platform, which results in a digital twin for facility management, and for businesses to tap on for testing of innovative solutions, robots and drones. A hub for key growth industries of the digital economy and supporting operations in areas such as cybersecurity and digital technology, PDD will foster a thriving business and lifestyle ecosystem that attracts talent and enables innovation.

The waterfront mixed-use district will also be home to the new Singapore Institute of Technology (SIT) campus, piloting the Enterprise District concept that will foster a collaborative ecosystem featuring digital businesses, academia and high-tech lifestyles. The growing community spans from leaders in robotics to blockchain specialists, from international to homegrown names, from government agencies to cybersecurity associations.

Envisioned to be a car-lite precinct, PDD is set to become a community playground and green heart for all residents of Punggol, integrating nature, such as water features and green spaces, all within the high-tech 50-ha estate.

800-m
pedestrianised street
A pedestrianised street between the future SIT campus and JTC's business park buildings is linked directly to the waterfront, other developments within the district and the Punggol Coast MRT station.

1.3-km
green link
Converted from the Old Punggol Road, a Heritage Trail extending from Punggol Waterway Park to Punggol Point Park connects the community to three parks, while conserving the existing trees along Punggol Road.

Opens
from 2024

50-ha
smart estate pushing the boundaries of digital technologies

28,000
jobs

12,000
students

30–40%
The Open Digital Platform tracks and manages energy usage in real time—the buildings in the district are projected to be 30–40% more energy efficient than conventional buildings

Defu Industrial City

Rejuvenated for Vibrant Versatility

Defu Industrial City

12,200m²
green spine and lush greenery lend a different dimension to the industrial estate

327,080m²
gross floor area

4 blocks
133 industrial units

3-ha
solar roof panel. Sustainable energy solutions integrated within the building design

> **Being situated along the eastern manufacturing belt of Singapore further puts it in proximity to a thriving industrial community, facilitating collaboration and networking.**

In the mature estate of Defu, a versatile new industrial space designed for a wide variety of businesses brings a fresh breath of life: Defu Industrial City. This vibrant venue is anchored by a gleaming flagship complex built for modernity and reimagining traditional industrial operations. The seven-storey complex, Singapore's largest ramp-up multi-user industrial development, supports a wide variety of trades. With expansive units that are highly customisable, the businesses it serves span from warehousing to logistics, and precision manufacturing. The 133 units, each with two 40-foot container loading bays at the door step and an ancillary mezzanine office, can be modified to meet the needs of different operations.

Being situated along the eastern manufacturing belt of Singapore further puts it in proximity to a thriving industrial community, facilitating collaboration and networking. Defu Industrial City also brings businesses closer to customers and suppliers. Directly connected to a major expressway, and a mere 20-minute drive from the Singapore Changi Airport, one of the largest transportation hubs in Asia, it offers the convenience of connectivity.

Surrounded by lush greenery and featuring sustainable design such as solar panels on the roof, Defu Industrial City is the product of a new estate planning ethos. Thoughtful features such as a purpose-built dormitory and recreational amenities further lend a holistic appeal.

Tuas Biomedical Park

A Hub for Global Giants

jtc

Tuas Biomedical Park

“A world-class manufacturing hub that allows for process development and large-scale manufacturing operations of biomedical companies, it is home to some of the biggest global medical companies today.”

Where best-in-class facilities meet best-in-industry names—this is Tuas Biomedical Park. A world-class manufacturing hub that allows for process development and large-scale manufacturing operations of biomedical companies, it is home to some of the biggest global medical companies today.

A centrally-located integrated infrastructure development—JTC Space @ Tuas Biomedical Park, launched in 2015—further adds on to the hub, and the wider Tuas South industrial estate, with shared facilities, amenities and industrial space.

This is where innovations come to life. Beyond just a physical venue, it is also a community. The Biopharmaceutical Manufacturer's Advisory Council (BMAC), a council comprising government agencies and biopharmaceutical companies promoting manufacturing and operational excellence, drives advancement by allowing all within TBP to lock-step with the best in the industry.

Close to Tuas Checkpoint and future Tuas Port

Easily accessible via Ayer Rajah Expressway (AYE) and Pan Island Expressway (PIE)

280ha

14 global
medical companies

7,000
employees

6 out of 10
biggest global pharmaceutical companies call Tuas Biomedical Park home, including AbbVie, GlaxoSmithKline, Novartis, Pfizer, Roche and Sanofi

$467 million
Tuas Biomedical Park New Vaccine Production Facility located in Central Singapore commenced in Q2 2022

Jurong Island

Green Heart of the Energy and Chemicals Sector

Jurong Island

“Home to over 100 leading global petroleum, petrochemical and specialty chemical companies, the island is also where sustainability initiatives and green solutions are pioneered.”

At the centre of Singapore's energy and chemicals industry beats a green heart: Jurong Island. Home to over 100 leading global petroleum, petrochemical and specialty chemical companies, the island is also where sustainability initiatives and green solutions are pioneered. Under the Green Economy pillar of the Singapore Green Plan 2030, Jurong Island is envisioned to transform into a sustainable energy and chemicals park.

Sustainability initiatives on Jurong Island include solarising rooftop and vacant land. Already generating 12.3MWp at Jurong Island, JTC is putting in greater effort to increase the solar capacity of Jurong Island eight-fold by 2030, making it the estate with one of the largest solar deployments in Singapore. This is also the site where some of Singapore's most exciting clean energy facilities are situated. To be launched in 2026 are the Keppel Sakra Cogen Plant hydrogen-ready power plant, and Sembcorp Industries' $900 million multi-utilities centre, which incorporates a new 600MW hydrogen-ready power plant. Keppel is also conducting a feasibility study of developing a power plant that could use ammonia directly as a fuel on Jurong Island.

Green solutions aside, Jurong Island is also home to a dynamic Circular Economy. Already with an organically integrated ecosystem, it is the perfect backdrop for the Jurong Island Circular Economy (JICE) Study led by JTC. This study sees 51 companies including Chevron, ExxonMobil and Shell coming together to share data on energy, water and chemical waste, and identify potential synergies, with the aim of optimising resources and reducing waste at the system-level.

The collaborative landscape brings further advantage for members of the Jurong Island community: the integrated ecosystem of the estate connects suppliers to customers all within one place, allowing companies to benefit from greater economies of scale and resource efficiencies.

World's top 5
refinery export hub

World's top 10
hub by chemical exports volume

>100
leading global companies

>18,000
energy and chemicals professionals

>$50 billion
worth of investments

Jurong Rock Caverns

A Groundbreaking Solution

Jurong Rock Caverns

“This commercial subterranean storage facility further complements and enhances the existing network of integrated infrastructure on Jurong Island, strengthening Singapore’s position as a leading global energy and chemicals hub.”

An engineering feat that literally broke new ground, Jurong Rock Caverns (JRC) is Southeast Asia’s first commercial underground rock caverns facility for the storage of liquid hydrocarbons.

Located 150m beneath the Banyan Basin on Jurong Island are five caverns with a total of nine storage galleries. Combined, the five storage galleries have the capacity to store up to 1.47 million m^3 of liquid hydrocarbons such as crude oil and condensates.

This commercial subterranean storage facility further complements and enhances the existing network of integrated infrastructure on Jurong Island, strengthening Singapore’s position as a leading global energy and chemicals hub. The facility is currently being utilised by ExxonMobil to support the operations of both its refinery and aromatics plant on Jurong Island.

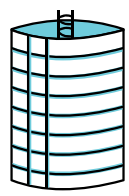
JRC was conferred the Institution of Engineers Singapore’s Prestigious Engineering Achievement Award in 2015. Beyond being an engineering and construction feat, the caverns are also a demonstration of ingenuity in estate planning. By utilising subterranean spaces for storage, approximately 60ha of land above ground is saved for higher value-added activities.

Phase 1
2007–2017
Duration of the construction work

60ha
Area of usable land saved, which is equivalent to 84 football fields

$1 billion
The cost of constructing the caverns

165,000m^3
Capacity of each storage gallery. Each cavern consists of two storage galleries



27m(h) x 20m(w) x 340m(l)
The dimensions of each of the storage galleries within the Jurong Rock Caverns