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From food to fuel

At O·PARK1, food waste is converted to energy and compost without creating a stink

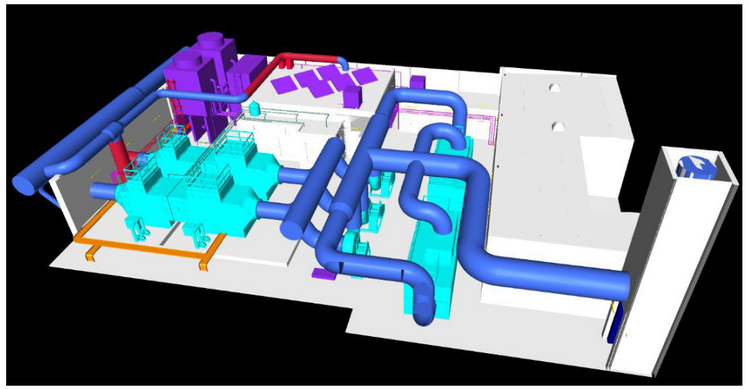
Authors David Pegg and Michelle Shun

Hong Kong is a food lover's paradise. Its strong tradition of food culture embraces both regional delicacies and fusion foods that reflect its long history of international trade. But the moniker 'culinary capital of Asia' comes at a price, with over 3,000 tonnes of food waste produced every day in the territory.

With food waste the largest municipal solid waste category being sent to landfill, Hong Kong's Environmental Protection Department put in place a strategy to develop a number of organic resources recovery centres that would make effective use of this waste and help reduce carbon emissions. Phase one of the project, O·PARK1, which opened in July 2018, converts food waste into energy and compost.

The first organic resources recovery centre in Hong Kong, and one of the largest of its kind in Asia, O·PARK1 is located on a 2.2ha site on Lantau Island and has the capacity to treat 200 wet tonnes of source-separated organic waste each day. The food waste, generated by commercial, industrial and institutional establishments, is digested by micro-organisms, which then produce

1: O·PARK1, which opened in 2018, turns organic food waste into biogas, which is used to generate energy



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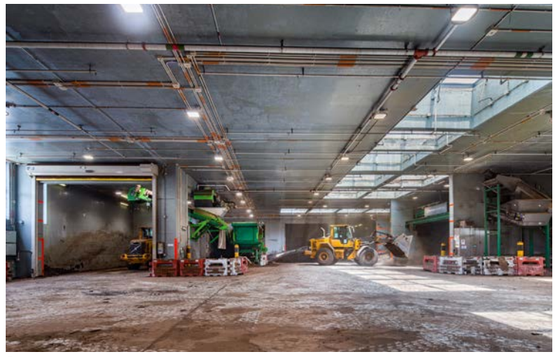

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2: It was essential that Arup addressed the issue of bad odours created by the facility. A CAPCS treats the air before it is discharged

3: The composting hall has a flat soffit, which maximises headroom and minimises ventilation volume

4: The spaces created by the inverted beams on the roof have been filled with planters, helping to green the site

biogas. This biogas powers the facility and is used to provide around 14 million kWh surplus electricity to the grid annually. Every element of the process has been carefully considered for its environmental impact, with the digestate converted to about 6,500 tonnes of compost per year and wastewater either reused or treated before being discharged to the public sewer.

O·PARK1 was procured by the local government under a design-build-operate contract with an 820-day design and construction phase and an operating period of 15 years. The contract was awarded to consortium OSCAR Bioenergy Joint Venture, comprising Suez, Atal and RosRoca, with Arup acting as the designer. Arup provided detailed design services, including architecture, structural engineering, geotechnical engineering, civil engineering, process (centralised air pollution control and wastewater treatment), electrical, building services, fire strategies, landscape architecture and BIM.

Air discharge

As the first in a series of O·PARKs, a central plan of the O·PARK1 brief was proving to the citizens of Hong Kong that this type of facility would not tarnish their communities with bad odours and pollution. Arup responded with a strategy that ranged from rigorous facilities cleaning to a negative pressure site design that would draw air inwards in order to prevent odours escaping, and a centralised air pollution control system (CAPCS) to treat the air before discharge.

However, the government also set the air discharge limit for the site at a stringent 130,000m^3 per hour. When Arup assessed the facilities' enclosed volumes to be treated and allowed for the required 12 air changes per hour (ACH) in the main process area and wastewater treatment plant, plus 10 ACH in the pump room, it found that the air discharge volume would exceed the limit set forth under the environmental impact assessment.

Arup overcame this challenge by first, minimising the volume of every space, particularly the composting hall (one of the most odorous environments on site), where it used an inverted beam design to reduce the internal size. Second, the firm implemented a cascade air flow strategy to make efficient use of the air that was drawn into the facility buildings.

Inverted beam design

With the aim of maximising the operational headroom while minimising the ventilation volume in the composting hall, Arup proposed inverting the structure to use upstand beams, leaving the soffit of the hall flat, effectively moving the unusable void between beams onto the roof. In addition to decreasing the internal volume without impacting the operational headroom, the design created a clean ceiling surface. Arup assigned only the bare minimum of utilities here – lighting and sprinklers for fire services.

With the inverted beams creating compartments on the roof, Arup turned this arrangement into an advantage. The rectangular voids between beams have been filled with compost produced on site and used as planters to grow vegetation. This helps to green the industrial plant, which overall has 30% green coverage.

Cascade air flow strategy

The cascade air flow strategy proposed by Arup also helped reduce the total volume of air that needed to be treated and discharged by making efficient use of the air drawn into the facility. In total, the strategy cut down consumption, and therefore discharge of air, by two-thirds, simultaneously lowering energy consumption by reducing the amount of air being treated.

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Arup analysed the operator's normal operations to find out which areas would be unstaffed and which would need operator access. The firm then configured the plant into zones such that fresh air would enter buildings in staffed areas, before being drawn into areas with restricted staff access and a medium pollutant load, and finally into unstaffed areas with high dust content before being treated by the CAPCS.

The CAPCS comprises two wet scrubbers that remove dust from air coming from the composting building, a chemical scrubber with a two-stage acid and alkaline cleaning process to remove ammonia and hydrogen sulphide, and an activated carbon filter, which discharges to the stack.

Green and clean

Odour control was considered in such great detail that every truck exiting the site is required to be washed. However, space constraints were such that there was no room for the trucks to manoeuvre from the weighbridge to the tipping bunker and washing facilities in a linear fashion.

To overcome the issue, Arup combined the tipping bay and the wash bay into one unit with two rapid-roll doors – one at the front, one at the back. In order to retain the odour seal, the back door is shut when vehicles enter, with the front door closing behind them before they are given access to the bunker via the back door. When the tipping process is complete, the truck is once again sealed between the two doors, where it is washed.

Any water that runs off from the wash is collected, reprocessed and reused on site to minimise water consumption. Wastewater that comes from the dewatering process of the food waste residue after anaerobic digestion (AD) is also treated and reused in the pre-treatment process (crushers and sieves).

O·PARK1 generates around 14 million kWh of electricity per year through the AD process, which produces a biogas rich in methane that can be used for both heat and electricity generation. The biogas is purified and dehumidified before feeding into the highly efficient combined heat and power (CHP) units for power generation. As well as being self-sufficient in terms of its own energy consumption, the plant powers up to 3,000 households annually as a result of the surplus electricity it feeds into the grid. The renewable energy that powers the site and local homes, combined with the carbon emission savings that would otherwise arise from landfill, reduce greenhouse gas emissions by 25,000 tonnes each year.

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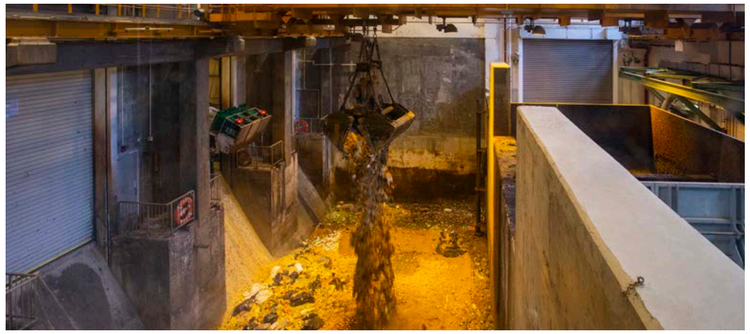
5: Fresh air first enters the facility in the staff areas

6: In order to best use the limited space, the tipping bay and vehicle wash bay have been combined

7: O·PARK1 is able to treat 200 tonnes of biodegradable waste every day



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8: The plant produces enough energy to power up to 3,000 houses per year

9: The open-air elevated walkway allows visitors to gain a good view of the site

10: 3D BIM was used to conduct swept path analysis on vehicle movements around the site

Look and feel
Ensuring the waste trucks look and smell clean is part of the wider initiative to ensure the facilities are amenable to the community while having a minimal negative effect on their neighbourhoods. O·PARK1 is situated adjacent to a major highway near the airport and is visible to the public. It was therefore important to adopt an aesthetic design that harmonises with its surroundings.

The brown-grey building cladding was selected to match the mountains behind, while the large airducts running from the compost building to the chemical scrubbers were placed along the link bridge so that the deodorising process is visible.
On the roof, cladding was used to hide the pipework and the chemical scrubber, making the site seem less industrial. The architects allowed a slot on the front face that gives visitors a hint of the pipework and is used by the contractor to load and unload equipment.

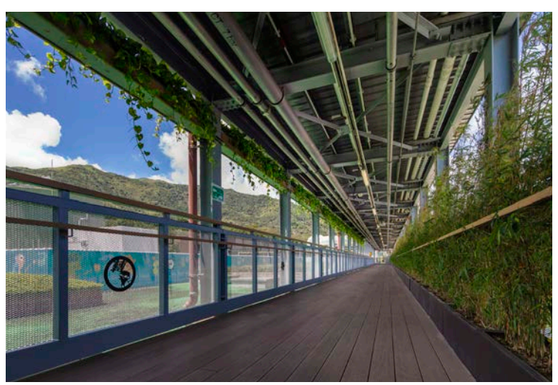
The stack was designed to minimise its visual impact, with Arup proposing a rectangular rather than circular construction. By changing the height and width ratio in this way, the stack is less obvious. The rectangular shape also allows for easy maintenance access.

Staff amenities were also considered in the design, with a courtyard garden set into the top floor of the office building. This provides staff with an open space, and glass walls along the garden's perimeters give the office and conference rooms extra sunlight.

Visitor experience
An important strength of Arup's design was its thinking behind the visitor experience, which was vitally important for educating the general public. The firm's Architectural team helped configure the plant in such a way that visitors could experience it without coming close to the operational areas. Visitors are able to walk through the site and view the core processes from a protected environment, with the inverted beam design acting as a talking point that highlights how much thought has gone into odour control. An open-air elevated walkway is central to the design, giving views across the plant but also allowing visitors to hear and observe the industrial environment. From the bridge they can see how the site blends into the natural setting, with mountains behind and the sea on the other side. They can also see the AD tanks where the crushed food waste is converted to biogas, and the wastewater treatment plant in the middle of the site.

After the link bridge, visitors come to a visitor gallery where they can look down through skylight windows into the composting area, providing views of the normal working processes, such as trucks taking the compost from one tunnel to another. The bunker area where organic waste is tipped and crushed is also visible. Visitors thus can see the site operations from a safe distance, allowing them to be educated about the way the plant works.

BIM
There was no formal requirement to use BIM but because Arup had designed similar facilities using the technology, it went ahead with this strategy. As the project developed, both Suez and Atal also adopted 3D BIM, meaning that the whole project has been completed in BIM. The model was also used to carry out a swept path analysis to simulate vehicle movements around the site to ensure these could be undertaken safely.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Arup also developed a virtual reality application that integrates with the 3D BIM model, allowing the client to assess operational and maintenance tasks before entering the real environment. The client is able to use 3D goggles to 'walk' through the plant and visualise a particular job, such as removing equipment from a difficult space, which is helpful for safety and operational training as well as planning.

O·PARK2
Work began on the next stage of the government's plan, O·PARK2, in October 2019 and it is scheduled for commissioning in 2022. The plant, located in Sha Ling in the region's northern New Territories, will adopt advanced technologies to recycle 300 tonnes of food waste per day into biogas and other useful materials. Arup's role on the project is to provide independent certification of the design deliverables and, through a team of site-based engineers, provide independent certification of construction and commissioning activities.

Arup is also helping the Hong Kong government to identify additional waste facilities up to 2041. This work includes a pilot trial of a food waste pre-treatment facility for co-digestion, combining sewage sludge and food waste in the same anaerobic digester tank to create biogas.

As the client explores the future of organic waste management, O·PARK1 stands as a testament to what can be achieved, reducing landfill volume by around 73,000 tonnes each year while producing renewable energy and compost.

11: Work on O·PARK2 is already under way. It is expected to be commissioned in 2022

12: The plant has over 30% green coverage and has reduced landfill volume by 73,000 tonnes per year

Authors
David Pegg was the Project Director. He is a Director in the Hong Kong office.

Michelle Shun was the Project Manager. She is an Associate in the Hong Kong office.

Project credits
Client Environmental Protection Department, Hong Kong Special Administrative Region
Contractor OSCAR Bioenergy JV
Architecture, building services, civil, fire, geotechnical, process and structural engineering and sustainable infrastructure design Arup:
Ryan Adi-Putra, Karma Barfungpa, Mathew Brown, Christy Chan, Patrick Chan, Thomas Chan, Vince Chen, Joseph Cheng, Hilary Cheung, Ray Cheung, Hilda Chiu, Harry Choi, Yiu-Bond Choi, Elaine Chow, Carrie Chu, Mohammed Danish, Nilda Galvez, Aatisha Gupta, Don Ho, Rex Ibanez, Berlin Ip, Aniruddh Jain, Thomas Jiang, Yiu-Fai Kan, Jason Khoo, Cammy Kong, Dominic Kwok, Kathy Lai, King-Chak Lai, Romario Lai, Kwan-Yau Lam, Maggie Lam, Sharjeel Larik, Morize Lau, Yee-Ting Lau, Joey Law, Vincent Law, Bill Lee, Jason Lee, Kam-Tim Lee, Kitty Lee, Siu-Yuen Lee, Brian Lei, Andy Leung, Gavin Leung, Louis Liu, Franky Lo, Edie Luo, Carlson Ma, Martino Mak, Wilson Mak, Arnd Manzewski, Dhaval Mehta, Candy Mok, Giuseppe Mollica, Andrew Ng, Angel Ng, Calvin Ng, Kenneth Ng, Roy Ng, Raymond Pak, Simon Pearce, David Pegg, Edgar Po, Dora Shum, Kin-Pui Shum, Michelle Shun, Iota Sin, Taurino Singson, Andy So, Edith So, Edward Stonehill, Susanne Sugiarto, Raymond Sy Guan, Stanley Sze, Albany Tam, Grace Tam, Megan Tang, Paul Taylor, Morriz Tsang, Simon Tsang, Sum Tsang, Alex Tsoi, Ricky Tsui, Muhammad Umer, Raymund Vega, June Wang, Billy Wong, Calvin Wong, Ensen Wong, Eugene Wong, Louis Wu, May Yam, Daphne Yan, Alan Yang, Sam Yau, Sunny Yip, David Yu, Doris Zhang.

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