DR PANG CHEE MENG

CHIEF ENGINEERING AND TECHNOLOGY OFFICER, PUB

"Managing water demand is as important as securing an adequate supply of water"

Singapore is recognised worldwide as a forward-thinking city and a model for integrated water management. Faced with the constraints of limited land and natural water resources, it recognised as early as the 1960s that a sustainable water supply was key to becoming one of the world's most advanced metropolises.

CRISTINA NOVO PÉREZ

Singapore's National Water Agency, PUB, has successfully closed the "water loop" and manages the whole water cycle, from rainwater collection, purification and supply of drinking water to wastewater treatment and reclamation to produce NEWater, the country's brand of recycled water. PUB has led a successful journey to meet the nation's water needs with investments in research and technology to treat, recycle and supply water in an integrated, effective and cost-efficient manner. In this interview, we hear from Dr Pang Chee Meng, Chief Engineering and Technology Officer of PUB, about the water reuse developments and policies that have made this success story possible.

Can you briefly tell us about your career path and your current role at PUB?

As Chief Engineering and Technology Officer at Singapore's National Water Agency PUB, I lead PUB's Technology Department to drive our research and programmes for the development and application of new water technologies in the entire water cycle.

Prior to my current role, I have experience in wastewater treatment and water-policy development, having served as the General Manager of the Jurong Water Reclamation Plant and a stint at the then-Ministry of the Environment and Water Resources. Between 2011 and 2012, I was also actively involved in the development of water-related standards in Singapore and various international subcommittees that developed new ISO standards for water reuse.

Later, I led the Industry Development team at PUB to formulate and implement strategies to grow the Singapore water industry and facilitate the commercialisation of new water technologies.

How has water reuse technology and policy evolved in recent years? Is there still room for improvement?

Singapore is a highly urbanised and dense city, with limited land to store and collect all the water we need. The government started exploring water reuse as early as the 1970s and commissioned a study to determine the feasibility of producing reclaimed water. While it was technically possible, there were concerns surrounding the reliability and high cost of the technology then.

By the 1990s, membrane technology's cost and performance had improved considerably. Other countries such as the United States were also increasingly using it for water treatment and reclamation.

There was a stigma against water reuse due to misperceptions surrounding its water quality. At PUB, we learnt from leading examples of water reuse and in 1998, set up a team to test the latest proven membrane technology for water reclamation. Two years later, we commissioned a full-scale demonstration plant that could produce 10,000 cubic metres daily. The ultra-clean, high-grade reclaimed water was named NEWater and its quality is well within the WHO and USEPA's requirements for drinking water.

Water reuse has been implemented in Singapore since 2003 for indirect potable and non-potable uses. Today, water reuse is generally well accepted and widely practiced, not only in Singapore but in many parts of the world with many reuse projects. For us in Singapore, we believe that we are the first in the world for wafer fabs operators to use NEWater to produce ultra-pure water for their wafer fab production. This industry requires water quality that is more stringent than for drinking.

Technology-wise, we are incorporating membrane bioreactors in our wastewater treatment plants which will deliver better quality NEWater at lower cost, smaller footprint and lower energy. Source con-

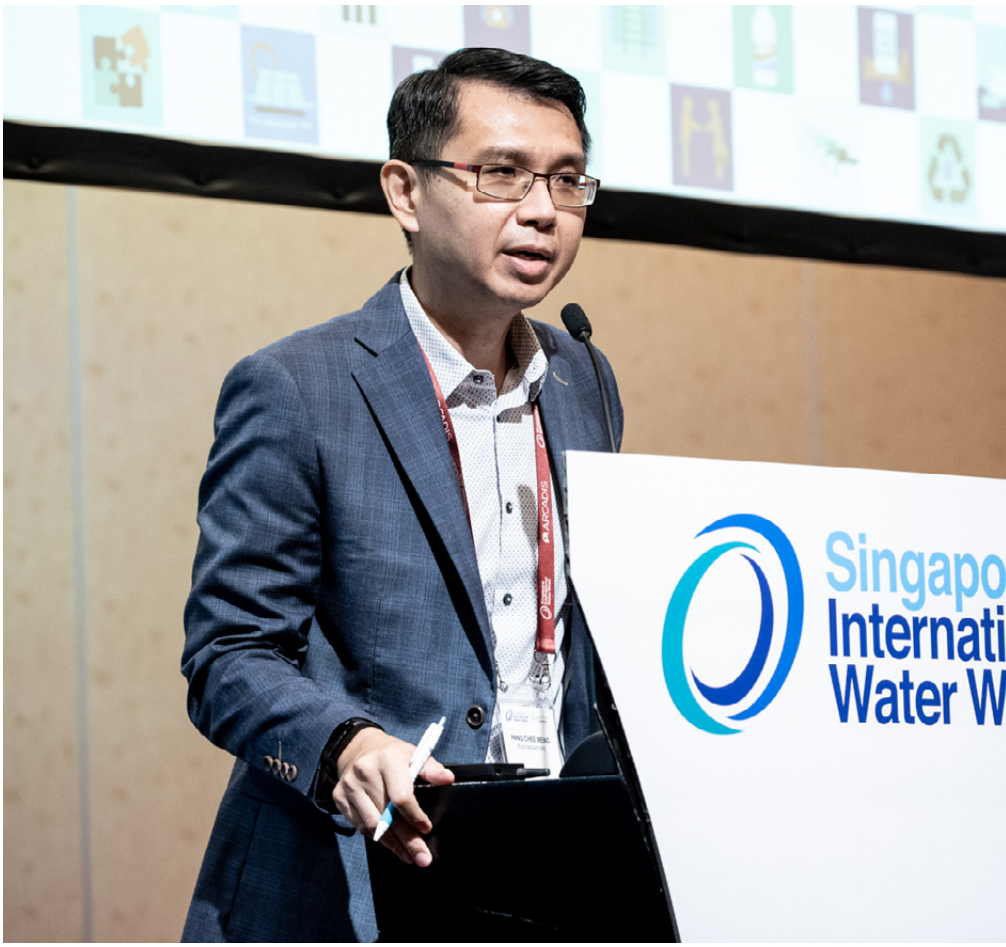
trol is key, and we have tightened our monitoring and enforcement of industries through regulations to ensure our treated effluent is good for NEWater production. Monitoring systems and sensors are installed in factories of concern to ensure compliance with discharge standards and proper disposal of their waste.

Singapore is successfully closing the water loop by recycling used water. Does PUB plan to develop the recovery of resources from used water?

We are actively pursuing resource circularity to reduce our waste footprint as part of the circular economy. This involves reducing the volume of sludge produced from our water reclamation plants and waterworks, as well as using environmentally friendly products and harnessing co-location synergies.

One example of this is Tuas Nexus – the integration of the Tuas Water Reclamation Plant (Tuas WRP) and the National Environment Agency (NEA)'s Integrated Waste Management Facility (IWMF). This is a sustainable and energy self-sufficient solution meeting Singapore's long-term solid waste management and used water treatment needs.

By employing the latest technologies, Tuas Nexus will harness the synergies of the water-energy-waste nexus from used water and solid waste. The by-product of one facility becomes a resource for the other facility. For example, IWMF's Food Waste Treatment Facility will convert source-segregated food waste into food waste slurry that is suitable for co-digestion with used water sludge at the Tuas WRP. The co-digestion of food waste and used water sludge will increase biogas production by 40 per cent at the Tuas WRP, compared to biogas yield from the treatment of used water sludge alone. The biogas produced will then be combusted at the IWMF and the combustion heat energy recovered to improve the overall plant thermal efficiency and boost electricity generation. The electricity generated by IWMF will be used to fully power the operations of Tuas Nexus with excess to be exported to the grid.



"We are the first in the world for wafer fabs operators to use NEWater to produce ultra-pure water for their wafer fab production"

As the world's first integrated waste and water treatment plant, its completion will prove momentous for Singapore's overall sustainability journey.

In 2021, we also launched a request for proposal to seek innovative solutions and technologies that can recover useful resources such as chemicals in water and used water treatment processes and minerals (i.e. rare metals) from seawater desalination brine.

Digital is an integral part of Singapore's integrated management approach. What are PUB's plans for further leveraging digital solutions in its operations in the coming years?

PUB has continuously invested in technology to achieve smarter water quality management, network improvements, integrated customer engagements, and smarter work processes. We are always on the lookout for innovative solutions that can make our water operations more effective and energy efficient, and renewable energy is one avenue that we are investing in. Through rigorous research and development (R&D) over the years, we have integrated technology throughout the water loop to optimise our opera-

> **Employing the latest technologies, Tuas Nexus will harness the synergies of the water-energy-waste nexus from used water and solid waste**

tions – from stormwater management to potable water production; and used water collection and reclamation. We are leveraging more smart technologies and digital solutions in our operations. With sensors, predictive models, automation, and other digital technologies, we can detect and pre-empt problems before they occur.

PUB is also keen to empower customers with near real-time information on their water consumption to encourage behavioural change and good water saving habits. In January 2022, we started installing smart water meters in residential and non-residential premises, which can record customers' water readings automatically several times a day and sends the data via a digital communication network back to PUB wirelessly. The smart water meters are also pivotal in enabling PUB to achieve greater operational efficiencies. With the daily water usage data, PUB will be able to optimise water production and network management by understanding water demand patterns at different times of the day across various zones. The data collected can also be used to quickly detect and locate potential leaks within the water supply network.

To help users unlock the full benefits of their smart water meters, we have also launched the *MySmartWaterMeter* portal. This is an online portal where users can log in anytime, anywhere to view their daily water usage and even hourly breakdown. There are other useful features on the portal – users can set monthly water goals, receive possible leak alerts in the house, do a comparison with similar household types and get water saving tips.

The Smart Water Meter Programme is an important pillar in PUB's Smart Roadmap, which outlines our vision to digitalise Singapore's entire water system. These and other digitalisation projects will help PUB to become more efficient and productive, in our transition to becoming a smart utility of the future.

Despite its dividends, digitalisation is not always easy or straightforward to implement. In Singapore, PUB works with both the private sector and academia to commercialise innovations. It co-invests with organisations and opens up some of its facilities for real-world tests, which are isolated from the rest of its network for safety. We believe that water utilities can harness digitalisation in a variety of ways to enhance employees' ability and empower them to perform their duties at work more effectively.

Could you tell us about the use of digital technologies in the area of smarter water quality management with artificial intelligence and automation?
Artificial intelligence has greatly improved the effectiveness and efficiency of our work processes. For example, the Smart Water Grid collects real-time hydraulics and water quality data across Singapore to monitor water quality and pressure. This automated data collection and analysis has streamlined our planning processes to fulfil Singapore's daily water demand.

> **"We are always on the lookout for innovative solutions that can make our water operations more effective and energy efficient"**

Digital technology has also empowered our officers with the means to enhance water quality monitoring while improving productivity. For instance, we have automated the monitoring and detection of micro-invertebrates in treated water, using a smart scalable micro-invertebrate detector system with image analytics capabilities. The previously manual and labor-intensive process is now an automated system which has helped achieve long-term benefits, including annual savings of 550 manhours per plant as compared to manual inspection, and increased monitoring frequency and round-the-clock surveillance.

Singapore's total water demand, which includes non-domestic water sector consumption, is expected to almost double by 2060. What type of policies is being used to encourage circularity by industrial water users?

We encourage water circularity from industrial users through policies and incentives to minimise wastage and maximise the efficiency of water through recycling and reuse.

Under the Mandatory Water Efficiency Management Plan (WEMP), large non-domestic water users are required to submit their water efficiency management plans to PUB annually and propose water conservation measures for implementation. This helps companies to better understand their water usage patterns and manage their water usage. With the data collected from the plans, PUB develops water efficiency benchmarks and best practice guidelines for the different industries and sectors to share with companies and further help them improve water efficiency.

PUB actively engages the large non-domestic industrial water users (such as those in the Wafer Fabrication and Semiconductor sector, the Refineries, Petrochemicals and Chemicals sector and the Biomedical sector) with the intent of expediting the implementation of innovative water recycling/conservation solutions within their premises.

To help companies mitigate risk and defray the financing gap between R&D and full implementation of innovative technologies, PUB offers both funding and technical support to companies through PUB's Water Efficiency Fund and Industrial Water Solutions Demonstration Fund. In doing so, PUB hopes to build confidence amongst the industry in novel technologies and expedite the adoption of innovative water solutions in industrial premises which would increase water recycling and conservation.

PUB also organises forums and seminars where companies can share their experiences in implementing water recycling/conservation projects and learn more about emerging technologies for water recycling.

Managing water demand is as important as securing an adequate supply of water. Achieving a sustainable level of water consumption and managing the impact of water on the environment takes the commitment and participation of the community. When firms reduce their water footprint, use alternative water sources such as seawater and maximise their water recovery by reclaiming waste streams, they make every drop of water count and reduce their water costs too.

NEWater is a pillar of Singapore's water sustainability. This success story is not only about technology, but also about public acceptance. What lessons learned along the way would you share with other countries that are getting started on water reuse?

Marina Reservoir.
© PUB, Singapore's National Water Agency

An important part of the NEWater success story is its high public acceptance. But this did not happen overnight. We recognised that the key to a successful water reuse programme is the ability to gain public confidence and acceptance.

Right from the start, we had focused our public communications efforts on the rigorous and robust treatment processes using advanced membrane technologies to produce NEWater, and the benefits of NEWater as a viable source of water. By benchmarking against drinking water guidelines set by the United States Environmental Protection Agency (USEPA) and the World Health Organisation (WHO), it provides reassurance of NEWater's quality.

PUB co-invests with organisations and opens up some facilities for real-world tests, isolated from the rest of its network for safety

Before NEWater's launch, we held extensive briefings for all stakeholders such as community leaders, business communities and government agencies to help them understand that NEWater is a safe and sustainable source of water for Singapore. We organised educational tours for the media, bringing them to Europe and the United to learn about their water reuse programs. We also produced a documentary on the technology of NEWater and the water reuse experience of other countries.

A key pillar of our outreach programme is the NEWater Visitor Centre. This was set up in early 2003 to educate visitors about water sustainability in Singapore and how NEWater is produced, through interactive tours and educational workshops.

Water treatment processes are energy intensive. Can you comment on the carbon footprint of the "Four National Taps" (local catchment, imported water, NEWater, desalination) contributing to Singapore's diversified water supply, and the steps PUB is taking to decarbonise its operations?

The production of NEWater and desalinated water are more energy intensive compared to the other two water sources, and these are the areas where we hope to source innovative solutions that can fit our operational needs while also contributing to a reduction in our carbon emissions.

PUB aims to achieve net zero carbon emissions by mid-century, and we plan to do so by reducing the energy consumption of PUB's water treatment processes, as well as using more clean, renewable energy in said processes.

To do so, we adopt a three-pronged approach of 'Reduce, Replace, Remove'.

PUB has been working with industries and research institutes to develop and test next-generation membranes that can substantially reduce the energy required for desalination and used water treatment by 50% or more.

Specifically, we aim to halve energy consumption to desalinate seawater. Today, about 3.5 kWh/m^3 of energy is expended to convert seawater to drinking water and we aim to reduce the energy required to 2 kWh/m^3. Likewise, for NEWater, we aim to reduce the energy consumption by about half through improvements in membranes and improving recovery without additional energy input.

To replace fossil fuels with clean, renewable sources of energy such as solar power, PUB currently harvests some 70 MWp of solar power from both its land-based (roof top) installations and floating solar photovoltaic (PV) systems. PUB is considering two other large-scale floating solar PV systems at Lower Seletar (100MWp) and Pandan Reservoirs (44MWp) and to do so in an environmentally sensitive manner. With our ongoing R&D efforts, we expect to abate approximately 600 kt CO_2e/year or 60% of total emissions from our water treatment processes by mid-century.

Capturing and removing carbon that we release into the atmosphere is the next big task on hand and is an emerging technology focus area. PUB is already studying new technologies such as carbon capture, utilisation, and storage (CCUS) and carbon removal solutions that can be integrated with our water treatment facilities, to effectively remove the remaining 40% or 400 kt CO_2e/year of emissions.

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