SMART PLANTS

Operational excellence and productivity

- IoT devices
- Data analytics
- Automation through robotics

Pilot-testing various smart technologies in our installations, including AI systems for data-driven operations, digital twin, predictive maintenance, autonomous systems

Outcome

Operator with
- In-situ equipment data – with sensors for real-time condition sensing

- Smart goggles – to superimpose standard operating procedures in the wearer's view, with his/her hands free

- Smart wearables (e.g. smart watches) – can communicate via wireless network to track the wearer's location, the health condition (heart rate, body temperature...)

Autonomous robots, or drones
- To automate manual labour intensive tasks

- For security surveillance

DATA ANALYTICS

Business intelligence tools for

- Demand projections, leak analysis, studying trends and correlations of pipe failures with pipe material, age, length, and environmental factors

- Analysing capital and operating expenditure

- Detecting anomalies in financial workflows and for procurement analysis

Data Analytics Platform to incorporate data from multiple source systems for automated processing, to

- Reduce the need for manual acquisition and processing to support multi-dimensional analysis for various corporate and operational functions

- Address the current situation of data in silos by integrating more data streams and enhancing data visibility for decision making

SMART NETWORKS

To monitor the health and performance of our water, drainage and used water networks with extensive sensors

SMART DRAINAGE GRID

a comprehensive suite of flow and water level sensors and CCTVs have been installed islandwide

Data mining and analysis of meteorological and hydrological data to correlate rainfall and hydraulic performance of our drainage systems

To deploy more sensors and CCTVs

SMART WATER GRID

more than 300 sensor stations installed islandwide

Monitor water quality, flow and pressure of the potable water network

Additional sensor stations to

- Improve the coverage of real-time monitoring
- Improve accuracy of hydraulic models for pressure management and valve simulations
- Enable operators to pre-empt potential problems in the network

SMART SEWER GRID

a holistic network of level, flow, Micro-Electrochemical Sensors (MES) and Volatile Organic Compound (VOC) sensors islandwide

- To monitor real-time sewer data such as water quality, flow and level
- To predict service disruptions such as sewer chokes, and
- To provide decision support on pre-emptive actions

Developing a sewer analytics management system to provide predictive intelligence and decision support.

To increase the sensor coverage

- For optimising the network maintenance and rehabilitation,
- To pre-empt and detect anomalies within the sewer network

Outcome

Enhanced system oversight and situational awareness to support waterway operations, fast response and mitigation to manage floods
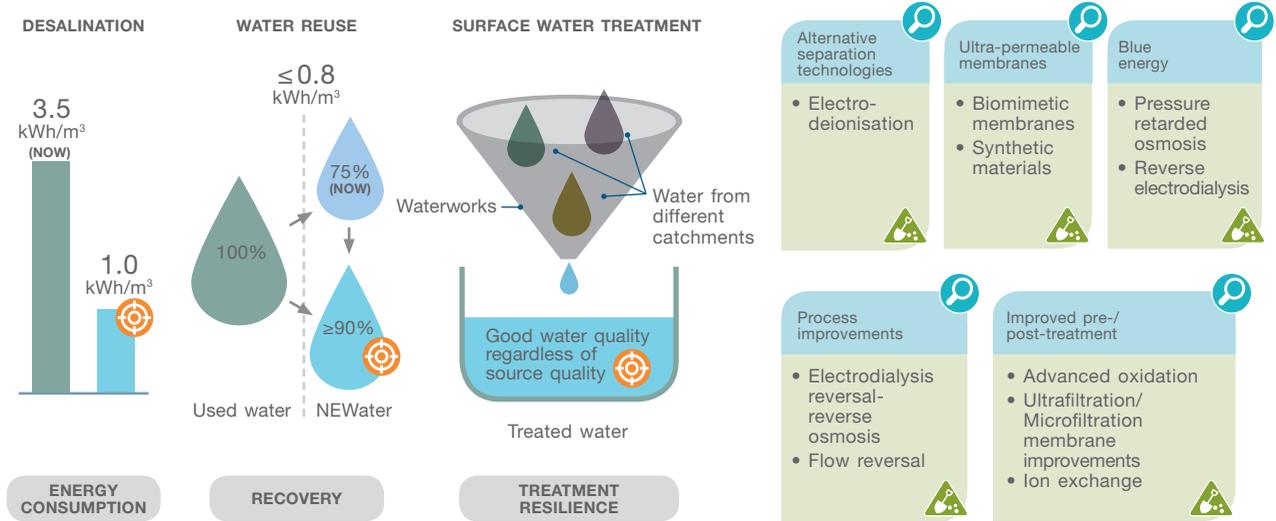
Early detection of pipe bursts

Reduction in service disruption events and shorten response time for crew dispatch through automated works prioritisation

Water Treatment, Desalination & Reuse

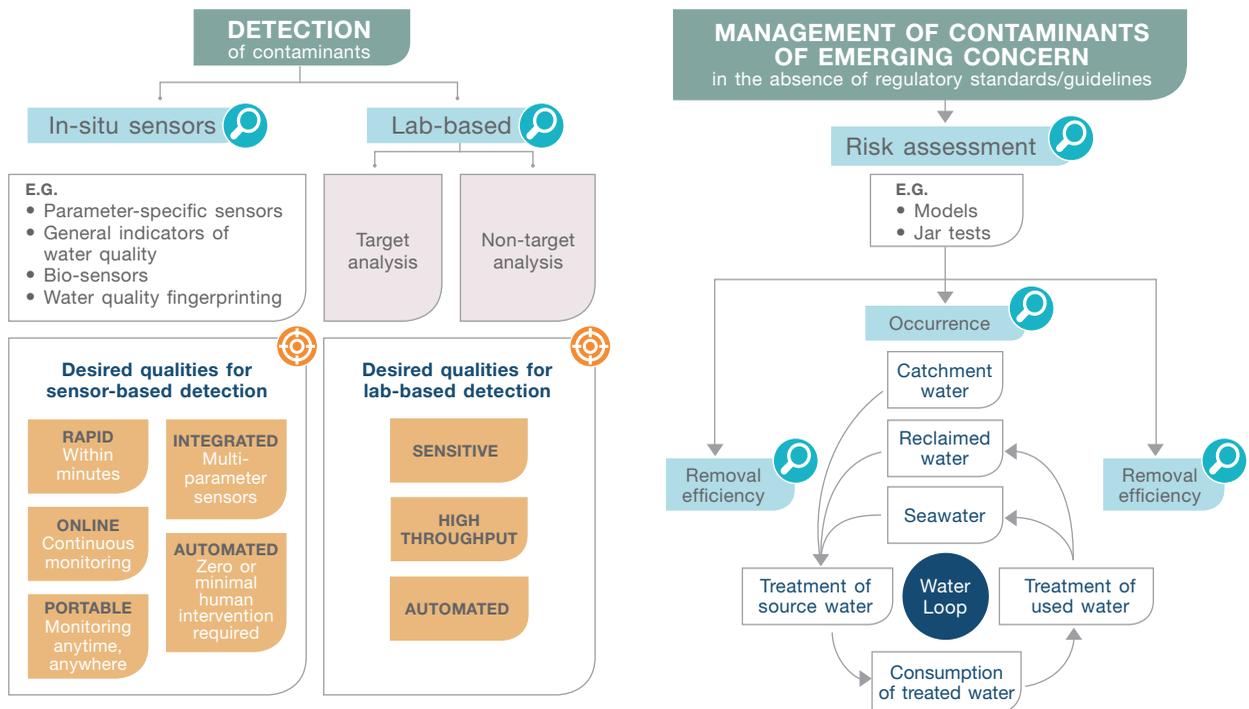⊙ Target   🔍 R&D area of interest   ⚗ Work in progress

The challenges faced in producing potable water varies with the type of source water. Seawater and used water streams offer a potentially inexhaustible supply of water, but the current desalination energy requirements and NEWater recovery efficiencies pose barriers to their sustainable use. For surface water treatment, a key challenge is the unpredictability of water quality in urban catchments. To ensure that product water consistently meets drinking water standards, processes must be able to treat all types of feed water.

DESALINATION

3.5 kWh/m³ **(NOW)**

1.0 kWh/m³ ⊙

ENERGY CONSUMPTION

WATER REUSE

≤ 0.8 kWh/m³

100%

75% **(NOW)**

≥90% ⊙

Used water   NEWater

RECOVERY

SURFACE WATER TREATMENT

Waterworks

Water from different catchments

Good water quality regardless of source quality ⊙

Treated water

TREATMENT RESILIENCE

Alternative separation technologies 🔍
- Electro-deionisation ⚗

Ultra-permeable membranes 🔍
- Biomimetic membranes
- Synthetic materials ⚗

Blue energy 🔍
- Pressure retarded osmosis
- Reverse electrodialysis ⚗

Process improvements 🔍
- Electrodialysis reversal-reverse osmosis
- Flow reversal ⚗

Improved pre-/post-treatment 🔍
- Advanced oxidation
- Ultrafiltration/ Microfiltration membrane improvements
- Ion exchange ⚗

Water Quality & Security

⊙ Target   🔍 R&D area of interest   ⚗ Work in progress

PUB aims to achieve real-time water quality monitoring through the development and implementation of in-situ sensors capable of rapid, online detection of microbial, chemical and surrogate parameters. Given the expanding range of contaminants of emerging concern, there is also a need to conduct robust risk assessment to ensure that operational decision-making is supported by a strong scientific basis in the absence of regulatory standards.

DETECTION of contaminants

In-situ sensors 🔍

E.G.
- Parameter-specific sensors
- General indicators of water quality
- Bio-sensors
- Water quality fingerprinting

Lab-based 🔍

Target analysis

Non-target analysis

Desired qualities for sensor-based detection ⊙

RAPID Within minutes

INTEGRATED Multi-parameter sensors

ONLINE Continuous monitoring

AUTOMATED Zero or minimal human intervention required

PORTABLE Monitoring anytime, anywhere

Desired qualities for lab-based detection ⊙

SENSITIVE

HIGH THROUGHPUT

AUTOMATED

MANAGEMENT OF CONTAMINANTS OF EMERGING CONCERN in the absence of regulatory standards/guidelines

Risk assessment 🔍

E.G.
- Models
- Jar tests

Occurrence 🔍

Catchment water

Reclaimed water

Seawater

Removal efficiency 🔍

Removal efficiency 🔍

Treatment of source water

Water Loop

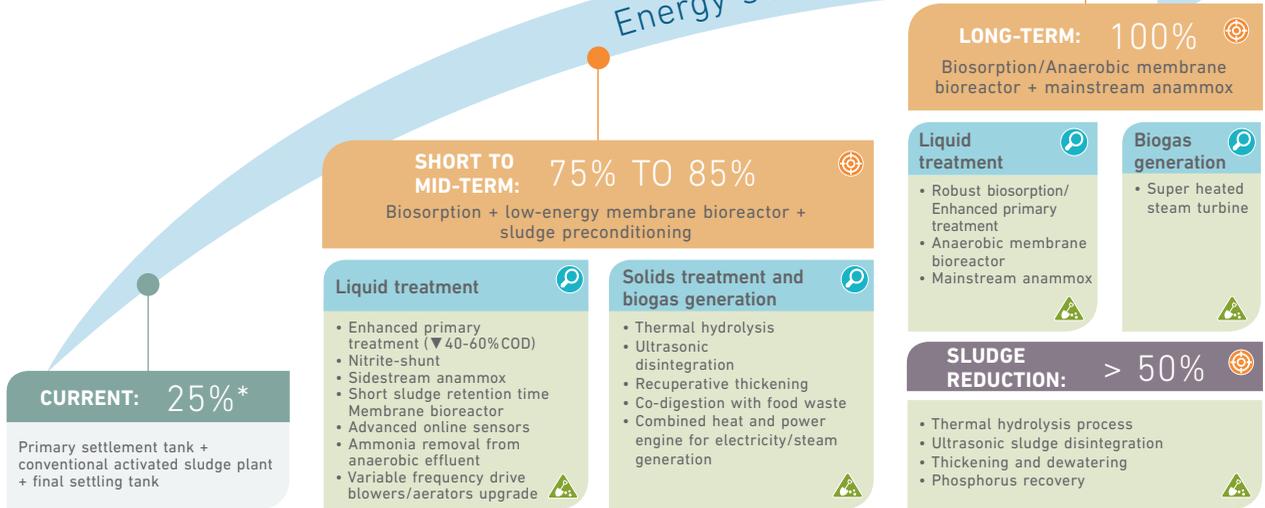Treatment of used water

Consumption of treated water

Used Water Treatment

Increasing water demand, energy costs and land scarcity underscore the need for technological breakthroughs in used water treatment. To this end, PUB is actively looking at technologies that have the potential to significantly reduce energy consumption and chemical usage in liquid stream treatment, and processes that produce more biogas and generate less sludge in solids treatment. To further reduce the sludge footprint, pre-treatment methods to improve the rate of sludge destruction in digesters are also being explored. Ultimately, PUB aims to achieve energy self-sufficient water reclamation plants to ensure long term sustainability.

Energy self-sufficient water reclamation plants ◎

Energy self-sufficiency

LONG-TERM: 100% ◎
Biosorption/Anaerobic membrane bioreactor + mainstream anammox

Liquid treatment 🔍
- Robust biosorption/ Enhanced primary treatment
- Anaerobic membrane bioreactor
- Mainstream anammox ⚠

Biogas generation 🔍
- Super heated steam turbine ⚠

SHORT TO MID-TERM: 75% TO 85% ◎
Biosorption + low-energy membrane bioreactor + sludge preconditioning

Liquid treatment 🔍
- Enhanced primary treatment (▼40-60% COD)
- Nitrite-shunt
- Sidestream anammox
- Short sludge retention time Membrane bioreactor
- Advanced online sensors
- Ammonia removal from anaerobic effluent
- Variable frequency drive blowers/aerators upgrade ⚠

Solids treatment and biogas generation 🔍
- Thermal hydrolysis
- Ultrasonic disintegration
- Recuperative thickening
- Co-digestion with food waste
- Combined heat and power engine for electricity/steam generation ⚠

SLUDGE REDUCTION: > 50% ◎
- Thermal hydrolysis process
- Ultrasonic sludge disintegration
- Thickening and dewatering
- Phosphorus recovery ⚠

CURRENT: 25%*
Primary settlement tank + conventional activated sludge plant + final settling tank

based on full-scale operational data from Ulu Pandan Water Reclamation Plant

Watershed Management

Increasing urbanisation and changing climatic conditions result in higher runoff during rain events. However, expansion of drainage infrastructure is constrained in land-scarce Singapore. There is therefore a need to explore intelligent watershed management technologies coupled with forecasting and warning systems to enhance flood resilience. Concurrently, rainwater is harvested on a large scale for water supply through collection and storage in ponds and reservoirs. To ensure that water quality remains good for potable water production, PUB invests in technologies to monitor, predict and manage levels of nutrients, algae and other contaminants in its catchments and reservoirs.

QUALITY ◎
Ensure that reservoir water quality is good for potable water production.

QUANTITY ◎
Enhance flood resilience of development and safeguard the integrity of drainage system.

Intelligent watershed management (data mining & analytics) 🔍

Watershed water quality and aquatic ecology management & modelling 🔍

Climate change and flood control modelling 🔍

⚠
- Predictive drainage and flood management
- Hydrometeorological monitoring
- Data analytics for strategic planning and maintenance of drainage infrastructure
- Enhanced water quality modelling tools and autonomous real-time prediction platform

⚠
- Algae monitoring and early warning systems
- Nutrient removal system in catchment
- Macrophyte restoration and biomanipulation
- Water quality monitoring systems
- Prediction of algae and metabolite levels
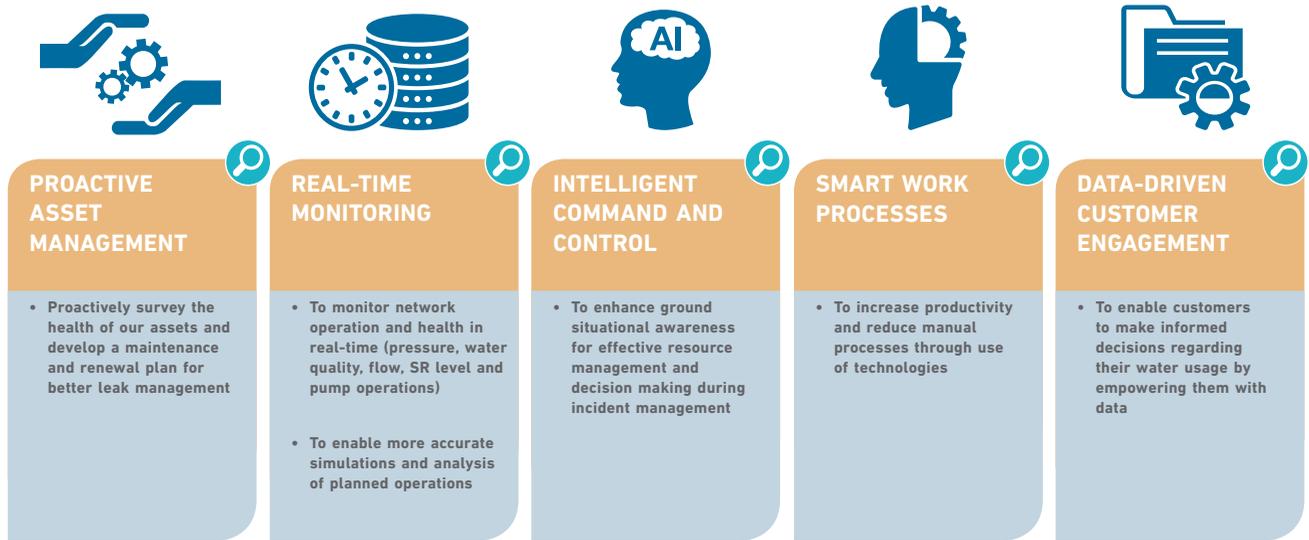- Efficient algae control system

⚠
- Predictions under uncertainties and extreme weather patterns
- Flood risk assessment and cost benefit analyses for policy and decision making
- Water-sensitive urban design and adaptive infrastructure

Target   **R&D area of interest**   **Work in progress**

As Singapore expands its water infrastructure to meet increasing water demand, PUB faces the challenge of extending the water supply and used water networks within an already congested underground environment, while maintaining the conditions of the current networks. To maintain service standards efficiently, PUB will leverage technology to provide remote monitoring of water quality and network pressure, advanced leak detection and diagnostic forecasting of asset failure. PUB also aims to encourage water conservation by providing more accessible and granular consumption data to customers through smart metering and water-saving devices.

Water Supply Network

PROACTIVE ASSET MANAGEMENT

- Proactively survey the health of our assets and develop a maintenance and renewal plan for better leak management

REAL-TIME MONITORING

- To monitor network operation and health in real-time (pressure, water quality, flow, SR level and pump operations)
- To enable more accurate simulations and analysis of planned operations

INTELLIGENT COMMAND AND CONTROL

- To enhance ground situational awareness for effective resource management and decision making during incident management

SMART WORK PROCESSES

- To increase productivity and reduce manual processes through use of technologies

DATA-DRIVEN CUSTOMER ENGAGEMENT

- To enable customers to make informed decisions regarding their water usage by empowering them with data

**NOWCAST & FORECAST SEWER WATER LEVELS**

Sewer analytics & modelling system

- Provide first response advice and location-specific information
- Monitor flow conditions and analyse high-flow points
- Optimise sewer cleaning and maintenance regime
- Optimise network performance through inflow and infiltration source reduction
- Recommend capacity enhancements where needed

TIMELY, APPROPRIATE AND COST-EFFECTIVE MAINTENANCE

Asset condition management

- Understand the structural condition, performance and deterioration pattern of assets
- Facilitate planning for asset renewal and repair
- Better anticipation of asset failure

Used Water Network
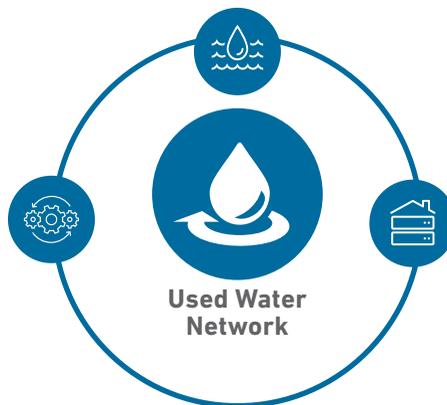
ASCERTAIN RISK & IMPACT OF NEW TRADE PREMISES

Trade effluent module

- Categorise risk and impact of trade premises
- Monitor and alert operators to issues
- Predict limit breaches and provide alerts
- Identify areas for illegal discharge investigations

Workflow envisioned for used water management systems

Sensors → Data → Analytics → Recommendations → Actions

FEEDBACK & LEARNING

Target   R&D area of interest   Work in progress

By 2060, up to 70% of Singapore's water demand will come from the non-domestic sector. PUB aims to reduce industrial water consumption by incentivising the development of solutions that target water-intensive industrial processes, and encouraging the adoption of these solutions. Key focus areas include the development of water-*less* processes, increasing recycling of treated effluent, and the use of alternative sources of water (e.g. seawater) for cooling. In addition, synergies gained from the process, such as the recovery of valuable resources from the reuse of industrial waste water, increase the value proposition of industrial water solutions and therefore warrant R&D.

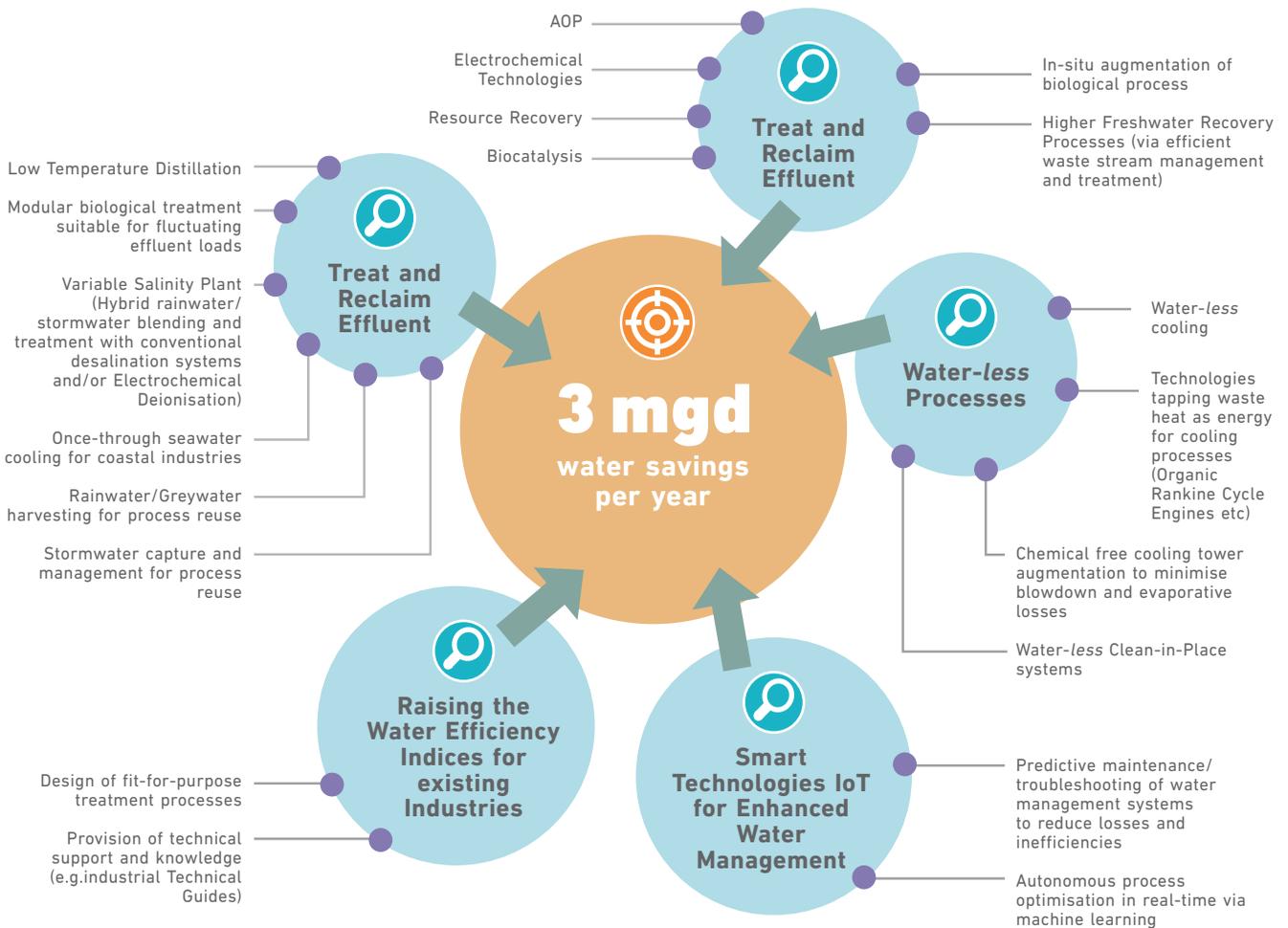## Target Industries

Power Generation   Semiconductors   Petrochemicals   Pharmaceuticals   Food & Beverage

AOP

Electrochemical Technologies

Resource Recovery

Biocatalysis

Treat and Reclaim Effluent

In-situ augmentation of biological process

Higher Freshwater Recovery Processes (via efficient waste stream management and treatment)

Low Temperature Distillation

Modular biological treatment suitable for fluctuating effluent loads

Variable Salinity Plant (Hybrid rainwater/ stormwater blending and treatment with conventional desalination systems and/or Electrochemical Deionisation)

Once-through seawater cooling for coastal industries

Rainwater/Greywater harvesting for process reuse

Stormwater capture and management for process reuse

Treat and Reclaim Effluent

3 mgd
water savings per year

Water-*less* Processes

Water-*less* cooling

Technologies tapping waste heat as energy for cooling processes (Organic Rankine Cycle Engines etc)

Chemical free cooling tower augmentation to minimise blowdown and evaporative losses

Water-*less* Clean-in-Place systems

Raising the Water Efficiency Indices for existing Industries

Design of fit-for-purpose treatment processes

Provision of technical support and knowledge (e.g.industrial Technical Guides)

Smart Technologies IoT for Enhanced Water Management

Predictive maintenance/ troubleshooting of water management systems to reduce losses and inefficiencies

Autonomous process optimisation in real-time via machine learning

● *Commercially available technologies*

Collaborate with Us!

PUB welcomes research collaborations that are aligned with the organisation's mission: to ensure an adequate, efficient and sustainable supply of water. We offer a range of support comprising research funding, testbed opportunities and commercialisation support to bring your ideas to fruition.

FUNDING SUPPORT (PUB)

A

☑ Key criteria 🔍 Target reseach area(s) 📢 Openings ✉ Application platforms 🤝 Featured project

Research & Development (R&D) Fund

Facilitates R&D to increase water resources, keep operational costs competitive, and manage water quality and security

☑ Applied R&D with potential for implementation

🔍 PUB's R&D **Targets & Focus Areas**

📢 Ongoing application

✉ Indicate interest to table a proposal at *pub_research@pub.gov.sg*

🤝 **Rainfall Monitoring and Urban Flood Management System for Singapore**

In collaboration with DHI and H2i

Proof of concept for Short Range Radar [2011]

Validation of Short Range Radar Performance [2013]

Development of the Operation System for Marina Catchment [2016]

★ *Scaling-up of the operation system to whole of Singapore is on-going, with the deployment of 3 additional radars*

Industrial Water Solutions Demonstration Fund (IWSDF)

Facilitates the implementation of high-impact and innovative projects to treat and reclaim industrial used water for process reuse

☑ Water consumption should exceed 10,000 m³/mth

Accomplish at least 5% reduction in water consumption through reuse

Technologies that
• are validated and ready for demonstration-scale implementation

• showcase innovation in the technology itself, and/or its application

🔍 PUB's R&D **Targets & Focus Areas** for Industrial Water Solutions

📢 Ongoing application

✉ Download Project Assessment Form from *www.pub.gov.sg/research/industrialwatersolutions/funding.* Submit completed form through *pub_one@pub.gov.sg*

🤝 **Dicing and Backgrinding Effluent Treatment Plant**

In collaboration with RF360

Operationalisation of plant in February 2018

Water recycling rate increased from 17% to 34% after implementation

More than 100,000 m³ of water saved since commissioning of water recycling plant
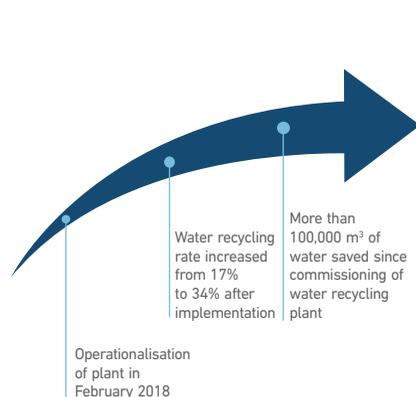
FUNDING SUPPORT (NRF)

Competitive Research Programme (Water)

Support (a) basic and applied R&D in strategic areas, and (b) translation of validated concepts

☑ Project to be carried out in Singapore

🔍 Varies across Request-For-Proposals (RFPs); broad aim of helping PUB meet its operational targets
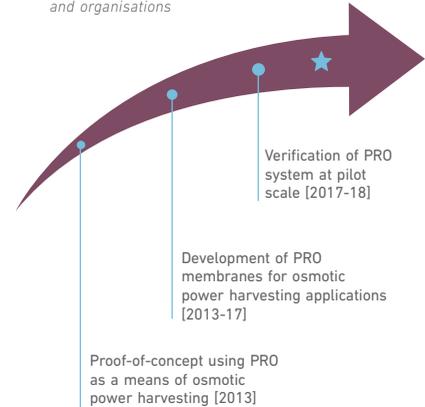
TYPES OF RFPs	
CHALLENGE Address critical barriers and enable progress in the field. May involve achieving stretch targets	**DIRECTED** Build capability under an identified research theme (e.g. energy efficiency in used water treatment)
RESEARCH PROGRAMME Solicit proposals exploring complementary technical areas	**OPEN** Bottom-up channel to solicit a diverse range of water-related solutions without specific research themes

📣 Periodic RFPs, announced through
- Integrated Grant Management System *researchgrant.gov.sg*
- PUB website *pub.gov.sg/research/collaboration*
- Email notification

✉ Request to be included in mailing list at *pub_crp_water@pub.gov.sg*

Pressure retarded osmosis (PRO)

In collaboration with various institutions and organisations

Verification of PRO system at pilot scale [2017-18]

Development of PRO membranes for osmotic power harvesting applications [2013-17]

Proof-of-concept using PRO as a means of osmotic power harvesting [2013]

★ *Verification of PRO system at demonstration scale ongoing under NRF's Urban Solutions and Sustainability Integration Fund.*
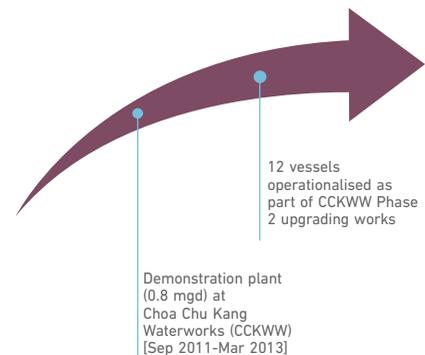
Living Lab (Water)

Incentivise the adoption of new technologies, facilitating commercialisation

☑

Involve a solution provider and an adopter

Carried out in Singapore

Only Singapore-registered businesses and organisations are eligible

Grant quantum will consider strength of business plan (in terms of potential revenue generated and jobs created)

🔍 Project shall involve the demonstration of a water technology that is close to operational stage by an adopter.

📣 Ongoing application

✉ Joint application* by technology provider and adopter. Indicate interest at *pub_crp_water@pub.gov.sg*

Ceramic membranes for surface water treatment

In collaboration with PWN Technologies

12 vessels operationalised as part of CCKWW Phase 2 upgrading works

Demonstration plant (0.8 mgd) at Choa Chu Kang Waterworks (CCKWW) [Sep 2011-Mar 2013]

* Technology provider can be conditionally awarded prior to the appointment of an adopter

TESTBEDDING OPPORTUNITIES

PUB's **operational and R&D-dedicated infrastructure** is available to host and facilitate your research. Technology developers looking to increase their product's operational readiness and relevance can apply to carry out testbeds at our live installations and field sites. Facilities dedicated to desalination and freshwater research are also available.
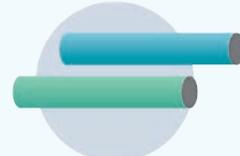
Operational Installations & Sites

Waterworks

Water Reclamation Plants

Potable & Used Water Networks

NEWater Factories

Reservoirs

Variable Salinity Plant

Desalination Plant

✓ Actual operating environments

✓ Technical support from ground staff

R&D-dedicated Facilities

Tuas R&D Facility
Desalination technologies

Van Kleef Centre
Freshwater research

✓ Laboratory amenities* and research/testbed spaces

* Applies to Van Kleef Centre only

TRANSLATION & COMMERCIALISATION

In order to capture the value, ensure continuity and further developments of the R&D projects, PUB, together with industry partners, aims to support the translation and commerclisation of these technologies.

TECHNOLOGY TRANSLATION (INDUSTRY PARTNERS)

Through our partnerships with translational facilities, technology developers can engage experts in engineering design, and access fabrication and pilot testing systems to overcome translational gaps.

Some of our partners include:

Separation Technologies Applied Research & Translation (START) Centre

The START Centre is set up as a national-level facility to bridge this gap, and to provide significant risk mitigation for the commercialisation of materials, equipment and processes related to separation technologies. The benefits are manifold. START serves as a vital platform for academic and research institutions to transform their innovative technologies into commercial products for key industry players.

Environmental & Water Technology Centre of Innovation (EWTCOI)

The EWTCOI was set up in October 2006 as a strategic collaboration between Enterprise Singapore and Ngee Ann Polytechnic. Its mission is to partner strategic industry sectors in applied R&D and consultancy projects to translate ideas into practical solutions or innovations for a sustainable environment.

COMMERCIALISATION (PUB - SINGAPORE WATER EXCHANGE)

Singapore Water Exchange (SgWX) aims to create a favourable environment to accelerate commercialisation by housing a vibrant ecosystem of water companies across the value chain to leverage mutual strengths to push the frontiers of water innovation and business growth. It is a global hydrohub dedicated to the water industry for like-minded professionals to converge and network to tackle global water challenges. Companies housed in Singapore Water Exchange will also have access to networking activities and a suite of services that support technology development, corporate functions, financing, and entry into key regional markets.

COMMERCIALISATION ECOSYSTEM

- Leverage the ecosystem to gain market access in the region
- Opportunities to showcase your innovation through actitivites that convene water professionals at SgWX
- Network with industry partners and form alliances to strengthen your value propositions
- Access a pool of novel technologies to complement and complete your range of solutions
- Investor network to access funds for your scale-up/ financing
- Mentorship and programmes to accelerate commercialisation
- Provide insights to market challenges and opportunities

GENERAL ENQUIRIES

A B *pub_research@pub.gov.sg* C *pub_waterhub@pub.gov.sg*

Scan for more information

www.pub.gov.sg