氣候變遷下供水安全技術及策略

Technology and Strategies to Mitigate the Impact of Climate Change on Water Scarcity

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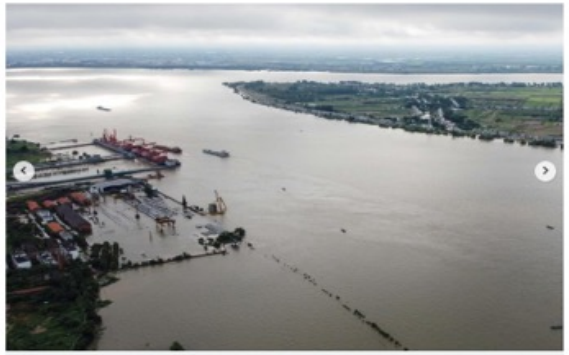
Impact of Climate Change - Recent Flooding Events
氣候變化影響–近期洪水事件

THE STRAITS TIMES

ASIA

China's Wuhan declares red alert as floods disrupt supply chains

Jul 17, 2020



1 of 5 An aerial view of the Yangtze River where the water level has risen in Jiujiang in China's central Jiangxi province, on July 15, 2020. PHOTO: AFP

PUBLISHED JUL 17, 2020, 1:23 PM SGT | UPDATED JUL 17, 2020, 3:33 PM

SHANGHAI (REUTERS) - Large parts of central and eastern China were reeling on Friday (July 17) from the worst floods in decades, as disruption mounted for key supply chains, including crucial personal protective equipment for fighting the coronavirus, and economic damage piled up.

The central Chinese city of Wuhan and the provinces of Anhui, Jiangxi and Zhejiang declared red alerts on Friday as heavy rain swelled rivers and lakes.

Wuhan, on the banks of the Yangtze River where the novel coronavirus emerged late last year, warned residents to take precautions as water levels fast approached their maximum guaranteed safety level.

THE STRAITS TIMES

ASIA

Peninsular Malaysia hit by '1-in-100-year' rainfall, govt says amid severe flooding

Dec 20, 2021

1 of 4 Floods wreaked havoc in the state's Klang Valley, with many areas submerged in water. PHOTO: THE STAR PUBLICATION

Hasbin Hassan
Malaysia Correspondent

KUALA LUMPUR - The widespread flooding seen in many states in Malaysia in the last three days was caused by one-in-a-100-year heavy rainfall, a senior official at the country's Environment and Water Ministry said on Sunday (Dec 19).

"The annual rainfall in Kuala Lumpur is 2,400mm and this means yesterday's (Saturday's) rainfall exceeded the average rainfall for a month. It is something beyond expectations and only occurs once every 100 years," the ministry's secretary-general Zaini Ujang told a news conference. He was referring to rainfall as measured by a rain gauge.

Referring to measuring stations around Selangor-KL, he said as quoted by Bernama, that the Sentul station recorded the highest at 363mm, Gombak (247mm), Jinjang

BBC NEWS

Climate change: Pakistan floods 'likely' made worse by warming

Matt McGrath - Environment correspondent
Fri, September 16, 2022 at 3:09 PM · 3 min read

flooding in pakistan

Global warming is likely to have played a role in the devastating floods that hit Pakistan, say scientists.

Researchers from the World Weather Attribution group say climate change may have increased the intensity of rainfall.

However there were many uncertainties in the results, so the team were unable to quantify the scale of the impact.

The scientists believe there's roughly a 1% chance of such an event happening in any coming year.

- Pakistan dengue cases soaring after record floods
- Going green could save world 'trillions' - study
- Satellites now get full-year view of Arctic sea-ice

In the two months since flooding began in Pakistan, tens of millions of people have been affected, with around 1,500 dying because of the rising waters.

The intensity of the downpours saw the river Indus burst its banks, while landslides

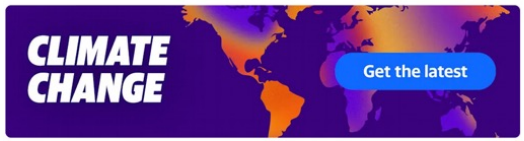
Impact of Climate Change – Severe Water Shortage Events
氣候變化影響–近期嚴重缺水事件

yahoo!news

yahoo!news | Yahoo News

'Moment of reckoning:' Federal official warns of Colorado River water supply cuts

Ben Adler · Senior Editor
16 June 2022 · 4-min read



The Colorado River's reservoirs have diminished to the point that significant cuts to the water supplied to the seven states that rely on it will be necessary next year, a federal official warned Tuesday.

Bureau of Reclamation Commissioner Camille Calimlim Touton told the Senate Energy and Natural Resources Committee maintaining "critical levels" at the largest reservoirs in the United States — Lake Mead and Lake Powell — will require large reductions in water deliveries.

"A warmer, drier West is what we are seeing today," she said at a hearing. "And the challenges we are seeing today are unlike anything we have seen in our history."

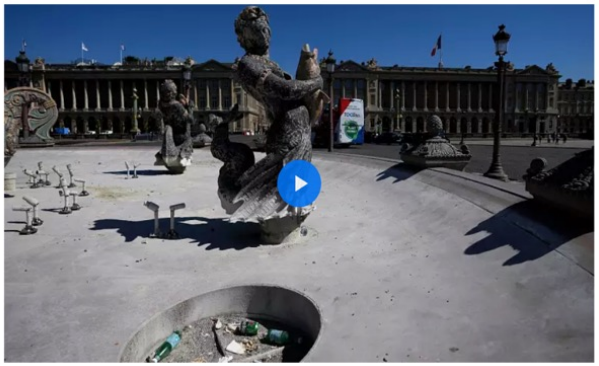
美國科羅拉多河短供水的警告

Home > News > World > Drought and heatwaves: How is Europe tackling unprecedented water shortages?

WORLD NEWS

Drought and heatwaves: How is Europe tackling unprecedented water shortages? COMMENTS

By Richard Good & Alasdair Sandford & Joshua Askew · Updated: 09/08/2022



The fountains of Concorde plaza are empty in Paris, France, as Europe is under an extreme heat wave, Aug. 3, 2022. Copyright AP Photo/Francois Mori, File

SHARE THIS ARTICLE

Soaring temperatures and a conspicuous lack of rainfall have left many European countries grappling with historic droughts this summer.

This is having wide-reaching effects across the region, significantly impacting agriculture, energy production and water supplies.

But how is each European country being affected and what are local authorities doing to combat the problems caused by these extreme temperatures?

France

The French government has set up a crisis team to tackle a historic drought that has left more than 100 municipalities short of drinking water.

Trucks are taking water to those areas as "there is nothing left in the pipes", said Christophe Béchu, the country's minister for ecological transition.

乾旱與熱浪席捲歐洲 ！

我国近70%城市群、65%的粮食主产区缺水问题突出

上游新闻
2022-04-08 15:38 | 重庆晨报上游新闻官方帐号 关注

4月8日，国新办举行2022年水利工程建设情况国务院政策例行吹风会。上游新闻（报料邮箱：cnshangyou@163.com）记者从吹风会上获悉，我国水资源空间分布与人口经济布局、国土空间利用格局不匹配的问题依然没有得到有效解决，还有近70%的城市群、90%以上的能源基地、65%的粮食主产区缺水问题突出。

▲水利部副部长魏山忠。图片来源/国新网

水利部副部长魏山忠表示，我国水资源的时空分布极不均衡，这可能是中国水资源最大的特点。解决时间分布不均的问题，靠修水库调蓄。解决空间分布不均，靠跨流域、跨区域引调水，把水多的地方引到水少的地方。总的来看，我们国家水资源空间分布与人口经济布局、国土空间利用格局不匹配的问题依然没有得到有效解决，我们还有近70%的城市群、90%以上的能源基地、65%的粮食主产区缺水问题突出，已经成为这些区域发展的瓶颈，难以满足经济社会高质量发展的要求。

魏山忠介绍，今年推进南水北调后续工程高质量发展，目前，东中线一期工程已经

Climate Change is Water Change
氣候變化本質是水的變化

- Too Much
  太多
- Too Little
  太少
- Wrong Timing
  時機不對
- Wrong Form
  差的類型
- Wrong Quality
  差的質量

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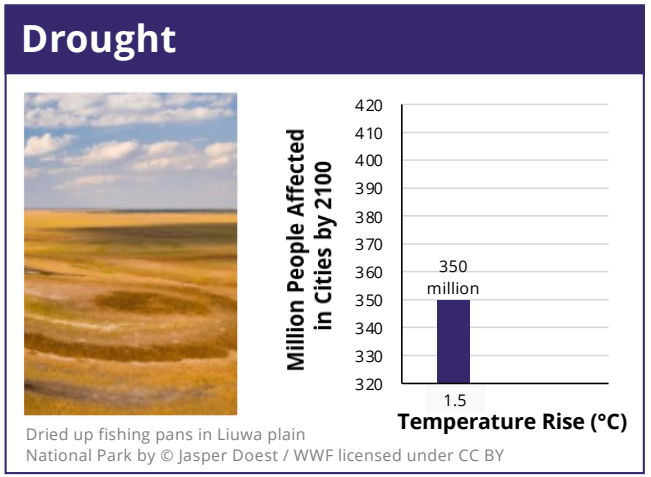
Untitled by © Marcio James / WWF–Brazil licensed under CC BY

Melting ice, Antarctica by © Wim van Passel / WWF licensed under CC BY

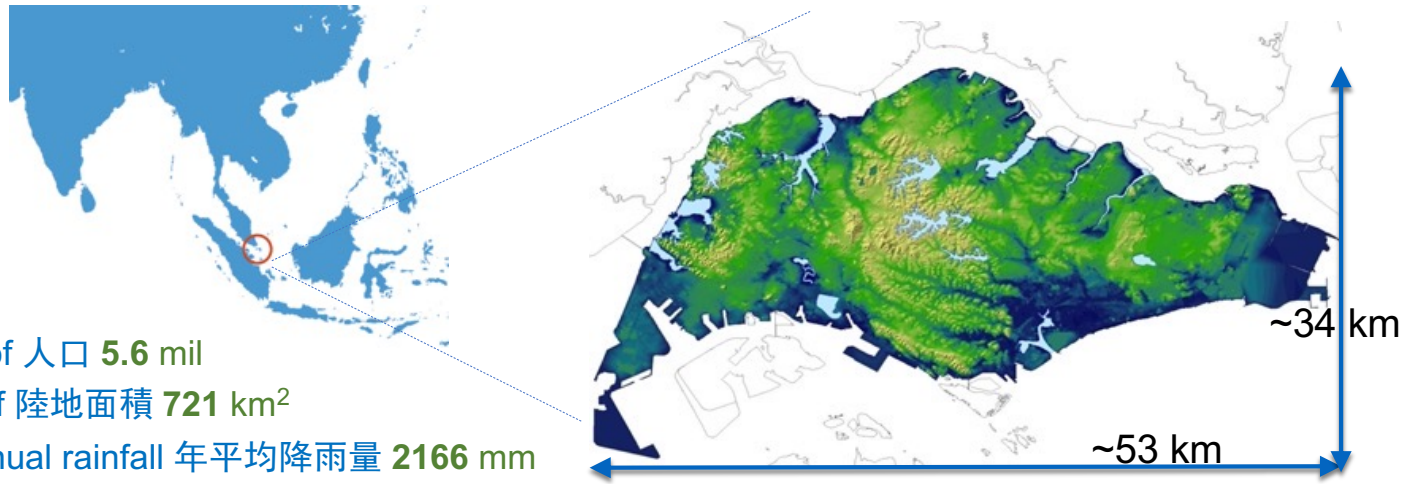


Dried up fishing pans in Liuwa plain National Park by © Jasper Doest / WWF licensed under CC BY

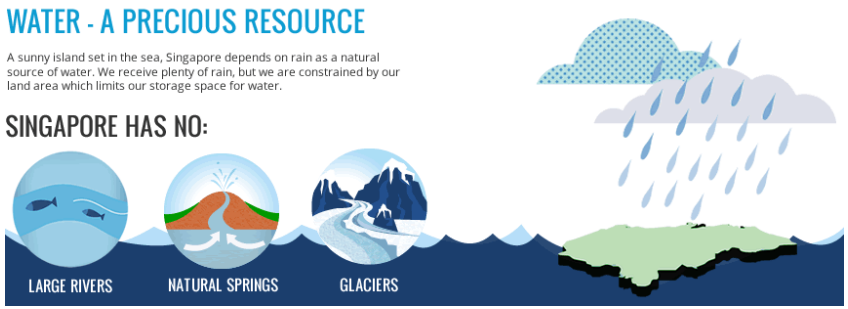
How to resolve challenges to “Too Little” and “Wrong Quality”?
如何解決“太少”和“質量差”的挑戰?

- Practice conservation 實行水節約
- Increase catchment 增加匯水區
- Increase water supply through alternative routes
- Water Reuse and Desalination 通過其他渠道增加。
  供水－水的再利用和海水淡化
- Enhance water quality through treatment processes
  通過處理工藝提升水質

Singapore: A Small Island State 新加坡: 小島嶼國家



- Population of 人口 **5.6** mil
- Land area of 陸地面積 **721** km^2
- Average annual rainfall 年平均降雨量 **2166** mm
- Average Water Demand 平均需水量 **:1.9 mil m^3/day**



http://www.mewr.gov.sg/topic/water-supply

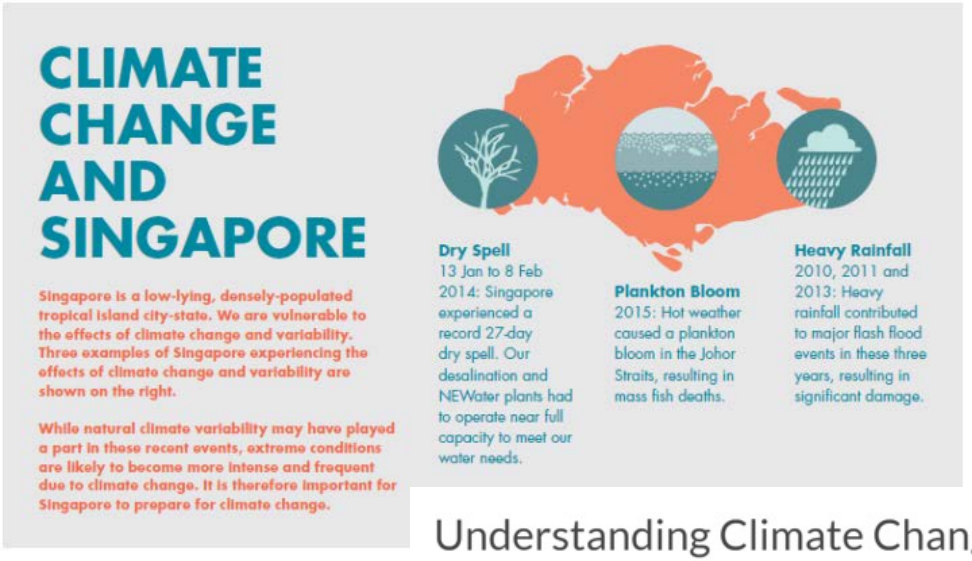
Singapore was ranked first among the countries at the highest risk of high water stress in 2040 (source: World Resources Institute 2015 Report)

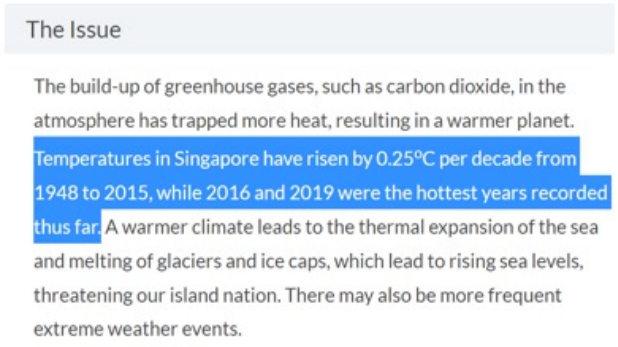
新加坡在2040年面臨高缺水風險的國家中排名第一

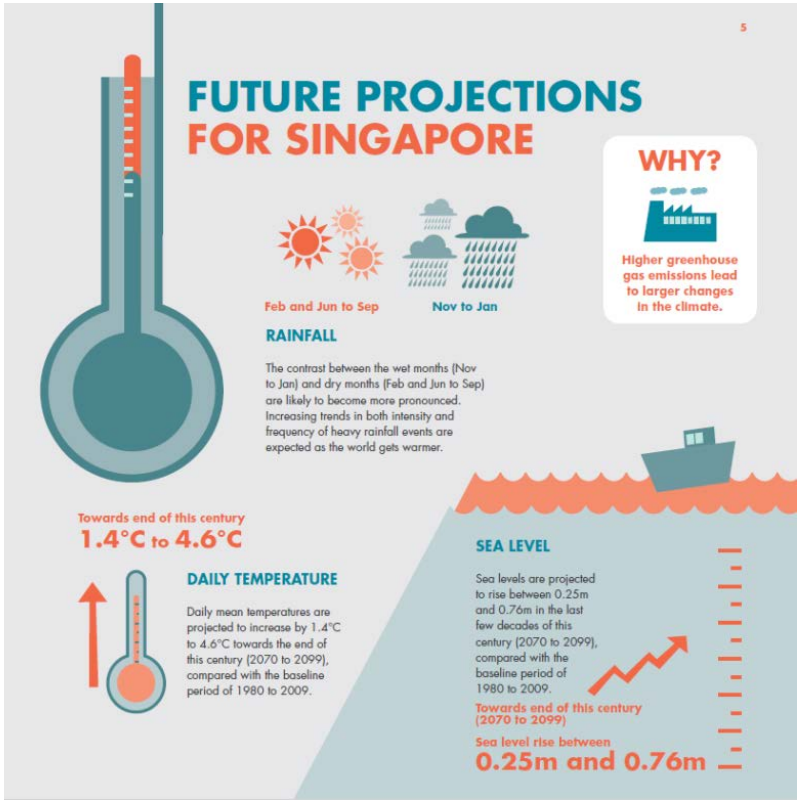
Courtesy from Mr Harry Seah from his presentation on Closing the Water Loop with Reuse (NEWater) at AWWTR2019 Preconference Workshop, Singapore, 29 July 2019.

Water is a national priority 水是國家優先事項

Climate Change on *Singapore*
氣候變化對新加坡的影響



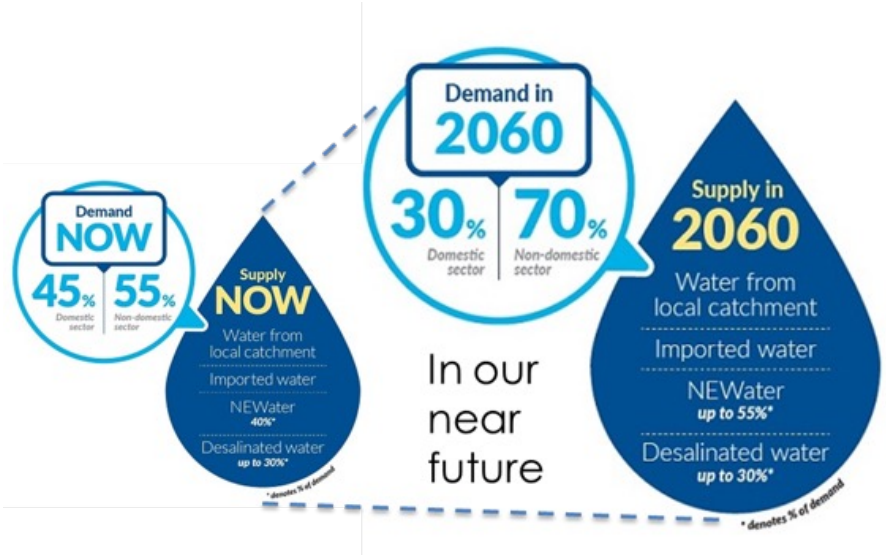


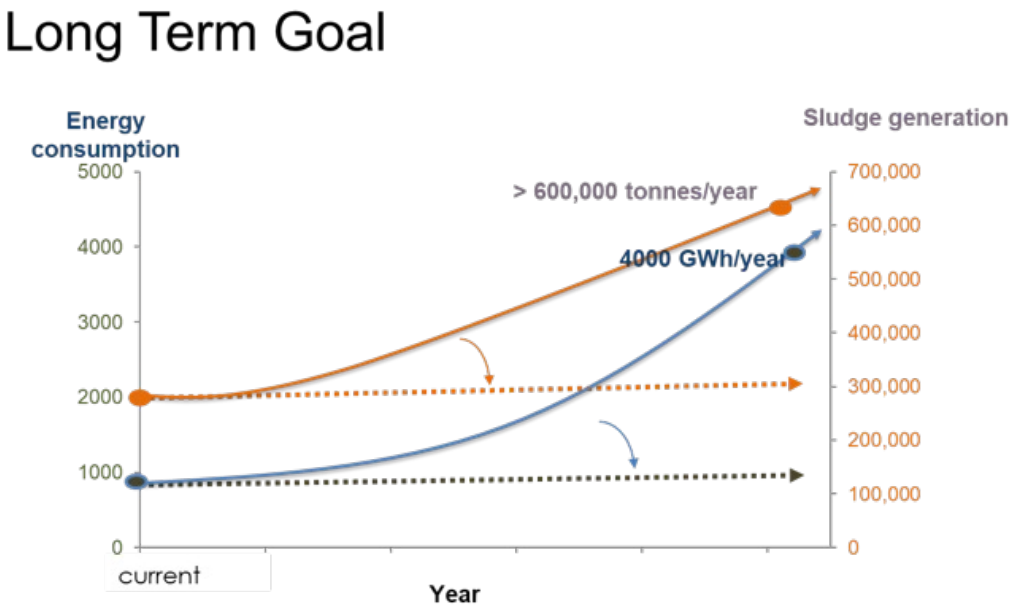


MEWR and MND (2016). Singapore's Climate Action Plan: A Climate-Resilient Singapore, For a Sustainable Future: https://www.mnd.gov.sg/docs/default-source/mnd-documents/publications-documents/climate-action-plan---for-a-sustainable-future.pdf

MEWR (2022). Climate Change: https://www.mse.gov.sg/policies/climate-change

Singapore's Water Demand – *Now and the Future*
新加坡的水需求– *現在和未來*





Long Term Goal

Meet water demand in 2060 at
current energy & sludge footprint
保持當前的能耗和污泥產量,滿足2060年的用水需求

https://www.pub.gov.sg/watersupply/singaporewaterstory

Seah (2019). Closing the Water Loop with Reuse (NEWater), AWWTR2019 Preconference Workshop, Singapore, 29 July 2019.

Sustainable water solutions require coherent management from the different aspects

持續水解決方案需要從不同方面協調一致管理

Water Treatment
水處理

River Management & Rehabilitation
河流管理&修復

Wastewater Treatment
廢水處理

Sanitation
衛生設備

Policy & Regulations
政策 & 法規

Water Reclamation
水再利用

Catchment Management
流域管理

Desalination
海水淡化

Resource Recovery
資源回收

And many more… 還有更多 …

Water is managed by a Single Ministry and a Single Agency
只要和水有相關，都歸屬於一個政府部門

SINGAPORE - WATER POLICY
新加坡 – 水政策

Long Term Planning
長遠規劃

- *Controlled Urbanization*
  受城市化約束
- *Anti-pollution regulation*
  反污染條例
- *Market-based water pricing*
  基於市場的水價

Policy Innovation
政策創新

- *Policy planning.*
  政策規劃
- *Infrastructure building*
  基礎設施建設

Use of Technology
技術嘅使用

- *Investment in Innovative Technologies 創新技術投資*
- *To harvest unconventional water resources 非常規水資源獲取*

Tan (2016). Water. Singapore :Institute of Policy Studies

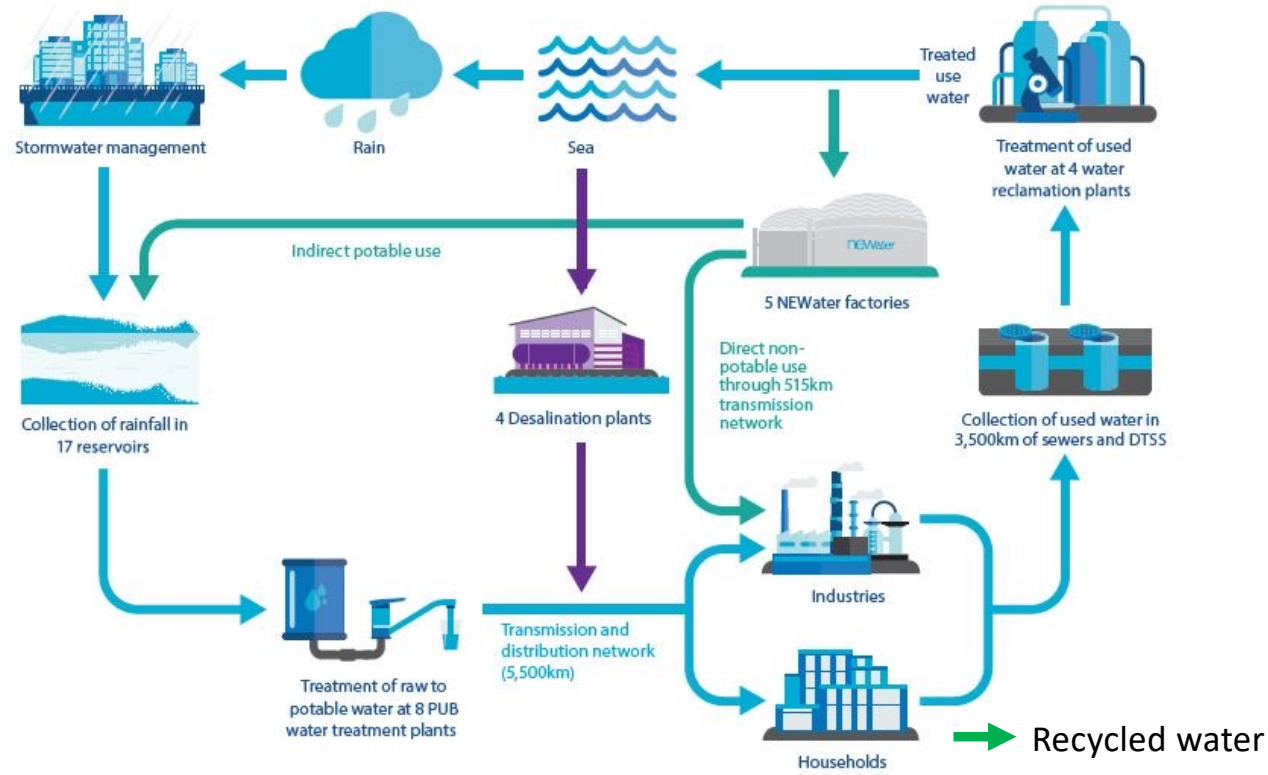
Water & Economic Sustainability 水和經濟可持續性

3 Key Strategies in Providing Good Water 供水的三個策略 ：

Today, Singapore has a diversified supply of 4 different sources; Residents enjoy 100% potable water at tap & 100% sanitation

至天，新加坡擁有4種不同嘅供水源。 居民享受100%嘅自來飲用水同100%嘅污水處理

Closing the Water Loop 中水回用 – 關閉水循環

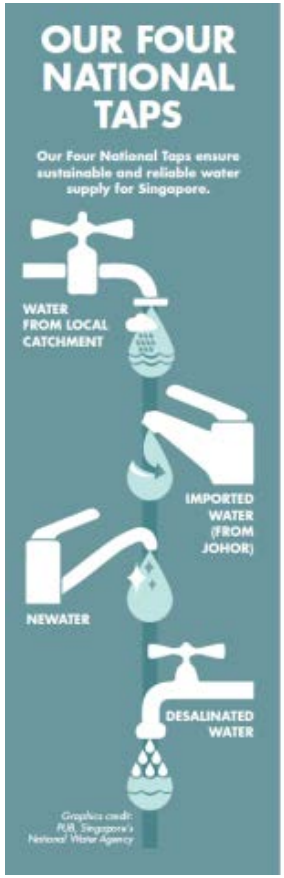


https://www.pub.gov.sg/watersupply/singaporewaterstory

Singapore's Water Supply 新加坡的水供给

Local catchment to Reservoir

NEWater Factory

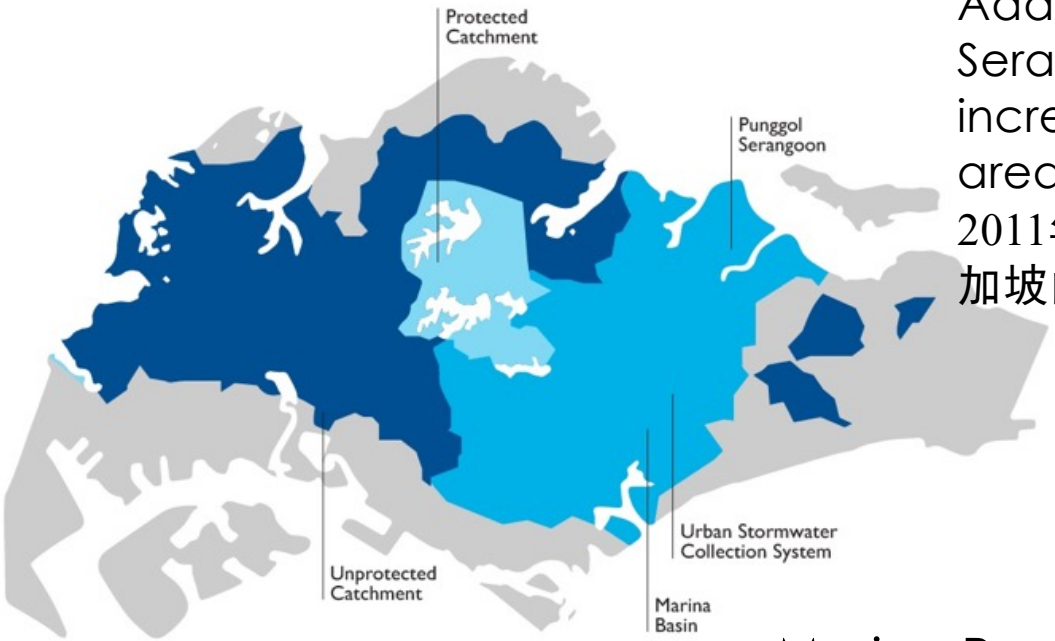


Desalination Plant

Groundwater地下水
- In other Asian countries其他亞洲國家

MEWR (206). https://www.nccs.gov.sg/docs/default-source/publications/a-climate-resilient-singapore-for-a-sustainable-future.pdf
PUB (2019). NEWater. https://www.pub.gov.sg/watersupply/fournationaltaps/newater
https://en.wikipedia.org/wiki/Bedok_Reservoir

SINGAPORE'S CATCHMENT新加坡的流域



Addition of Punggol and Serangoon Reservoirs in 2011, increase Singapore's catchment area from half to two-third
2011年新增榜鵝站和實龍崗水庫，將新加坡的流域面積從一半增加到三分之二

Coherently with residential housing & industrial development

Marina Reservoir – 1st Reservoir in the city collects rainwater from the highly urbanized catchment濱海水庫– 1st 城市中水庫，從高度城市化流域收集雨水

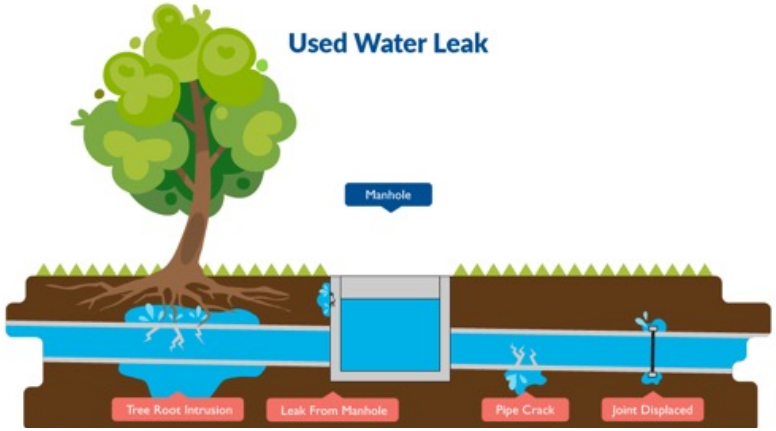
Original map source: https://www.pub.gov.sg/watersupply/fournationaltaps/localcatchmentwater
Marina Barrage: http://www.greenroofs.com/projects/pview.php?id=1212

CATCHMENT MANAGEMENT流域管理

Public Sewer Rehabilitation 公共下水道修復

preventive approach to minimize pollution to waterways

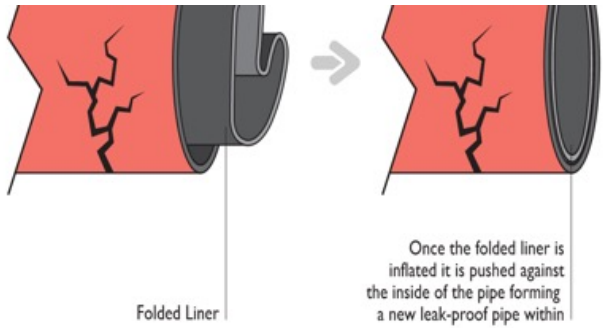
減少河道污染的預防方法



Damage of sewer pipes may be caused by wear and tear, ground movement and tree root intrusion
磨損、地面移動和樹根侵入可能導致污水管損壞

Trenchless technology minimizes disruption and inconvenience to public, owners and residents **非開挖技術盡量減少對公眾、業主和居民的不便干擾**

An example of one of the commonly employed trenchless technology



Fold and Form Pipe Lining Method

https://www.pub.gov.sg/usedwater/sewerrehabilitation/publicsewers

CATCHMENT MANAGEMENT流域管理

Bioretention System for Managing Stormwater Runoff
管理雨水徑流的生物滯留系統

A collaboration between NUS and PUB

Fig. 1: Pilot-scale bioretention unit to assess the impact of filter media depth and plants on effluent water quality

Bioretention site filled with engineered soil[1]

Pollutant	Expected Removal of Engineered soil[1,2]	Treatment objectives in ABC designs[3]
Total Phosphorus	> 80 %	45%
Total Nitrogen	> 45 %	45%
TSS	> 85 %	80%
Copper	> 80 %	-
Zinc	> 80 %	-

Critical for successful functioning and cost-effective bioretention system生物滯留系統的成功運行和成本效益至關重要

- Use of locally available and/or recycled materials 當地可用和可回收材料
- Support local plant growth支援本地植物生長
- Within the range of infiltration capability based on local rain fall intensity 基於當地降雨強度的滲透能力範圍內
- Achieve the required stormwater runoff pollutant removal 實現雨水徑流污染物清除的需求

[1] **Patent:**
AN ENGINEERED SOIL COMPOSITION AND A METHOD OF PREPARING THE SAME (SG2013082722A)

[1] Engineered soil for use in bioretention system or equivalent and a method of producing the same, United States, 61/723,369.
[2] An engineered soil composition and a method of preparing the same, Singapore, 201308272-2.
[3] https://www.pub.gov.sg/Documents/ABC_Waters_Design_Guidelines.pdf

Innovation in Water Singapore, Vol. 7, June 2015, pg 14

Pilot test sites for Engineered soil 工程土壤的測試地點

Nanyang JC

NUS High

[1] Guo et al. 2014. Desalination and Water Treatment: 1-7.
[2] Engineered soil for use in bioretention system or equivalent and a method of producing the same, United States, 61/723,369.
[3] An engineered soil composition and a method of preparing the same, Singapore, 201308272-2.

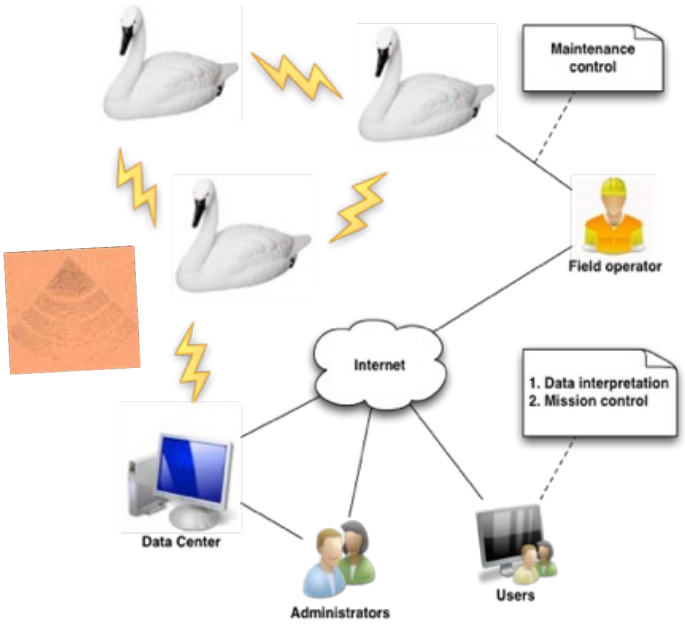
CATCHMENT MANAGEMENT 流域管理

Smart Water Assessment Network (SWAN) collects real time data for continuous water quality monitoring in the reservoirs **智慧水評估網路 （SWAN） 收集水庫水質連續監測的實時數據**

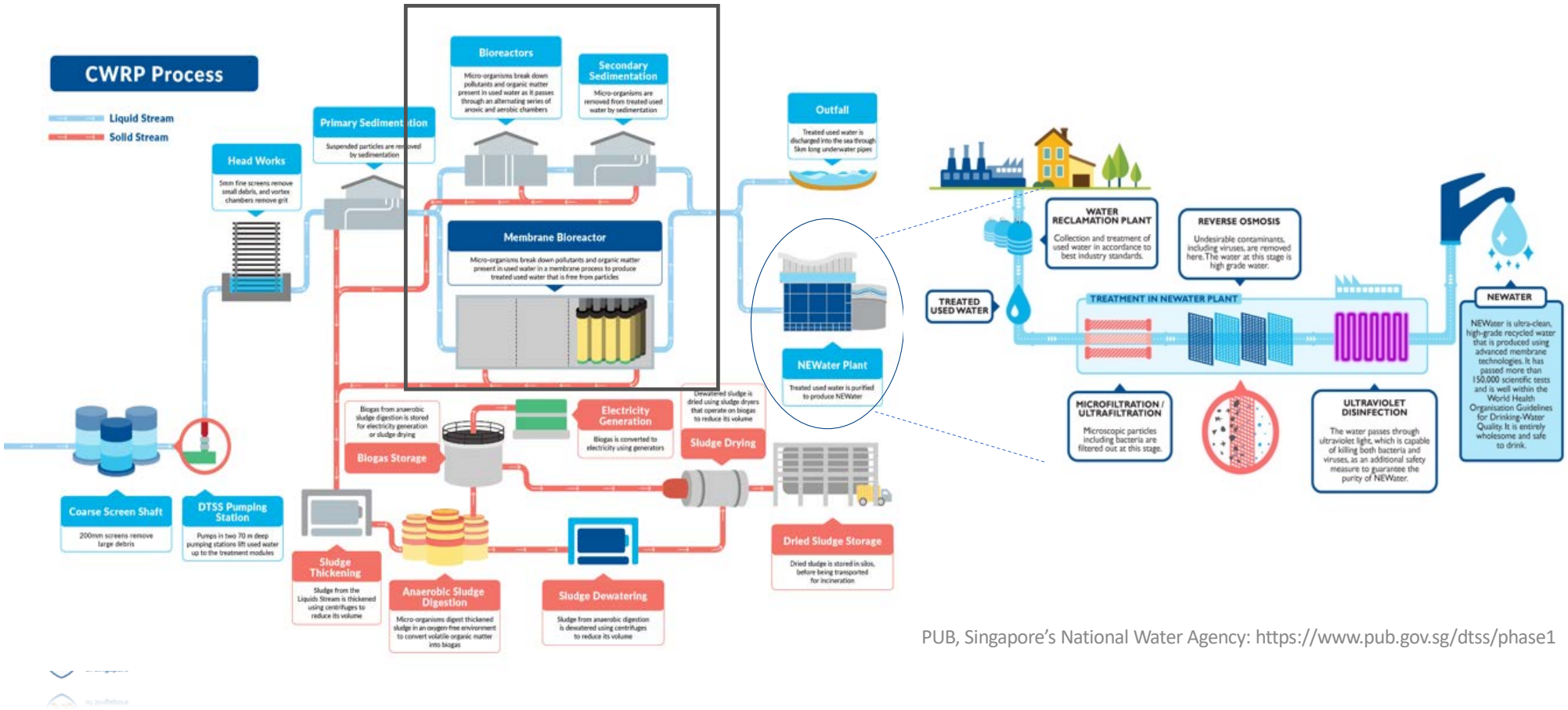
A result from collaboration between NUS and PUB

Five robotic swans will be used at various reservoirs in Singapore to monitor raw water quality, announced national water agency PUB on Monday (Jan 15).

https://www.channelnewsasia.com/news/singapore/robot-swans-reservoirs-monitor-water-quality-pub-9861686



Utilizing Membrane Technology for Water Reclamation
利用膜技術回收水



PUB, Singapore's National Water Agency: https://www.pub.gov.sg/dtss/phase1

Membrane Technology for Water Reclamation
膜技術在水資源回收中的應用

MBR Using Ceramic Membranes使用陶瓷膜的 MBR

- Offers higher mechanical, stability, relatively narrow membrane pore size distribution, and higher chemical stability
  具有較高的機械性能和穩定性，膜孔徑分佈較窄，化學穩定性較高
- Requires more performance data for its wider application需要更多的性能數據以實現更廣泛的應用

Average MBR filtrate quality for Ceramic MBR Case Studies 陶瓷MBR的平均MBR濾液品質案例研究 (extracted from Koh et al., 2017)

Case studies	Ulu Pandan Pilot (Noguichi et al., 2010)	Jurong Demo (Kekre et al. 2015)	Changi MBR Retrofit
Evaluation period	May – Oct 12	Nov – Jan 15	Dec 16 – Jan 17
Turbidity, NTU	0.1	0.19	0.04 (<0.1 max)
Total coliform (CFU/100 ml)	<1	<1	1.3
TOC (mg/L)	6.0	-	3.5
NH_3-N (mg/L)	<0.1	1.6	0.18 (<0.8 max)
pH	6.7	7.4	6.7

Koh et al. (2017). From Pilot to Full Scale: A Review of Flat-Sheet Ceramic MBR Systems for Used Water Treatment/Water Reuse. Proceedings of IWA-MTC2017, Singapore.

- The pilot to full scale plants showed production of ***high filtrate quality*** for industrial reuse or feed to further advanced water reclamation processes. 大規模工廠的試驗表明，生產的高品質濾液可用於工業再利用或進一步先進的水回收工藝。

Full-scale flat sheet ceramic membrane at Changi WRP

- Full scale Changi MBR could meet the guarantee calculated specific energy value of ***<0.5 kW/h per m^3*** of product water (operated at 10 days SRT) with optimized chemical cleaning regime and operating parameters. 完整規模的樟宜MBR在優化的化學清洗制度和運行參數下，能夠滿足計算比能值<0.5 kW/h/m3的產品水（SRT為10天）的保證。

WATER QUALITY MONITO RING 水質監測

Fish Activity Monitoring System (FAMS) 魚類活動監測系統

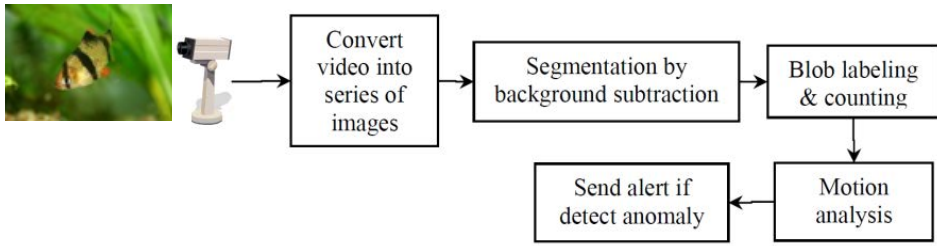


Figure 2. Software architecture of FAMS

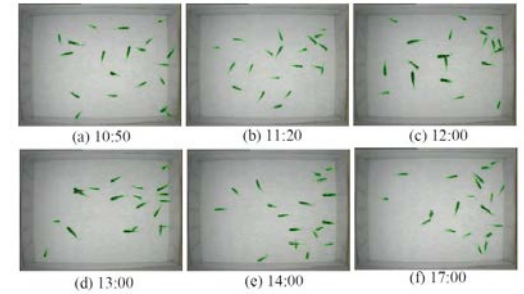


Figure 3. Shows consistent segmentation results over a long hour of operation.

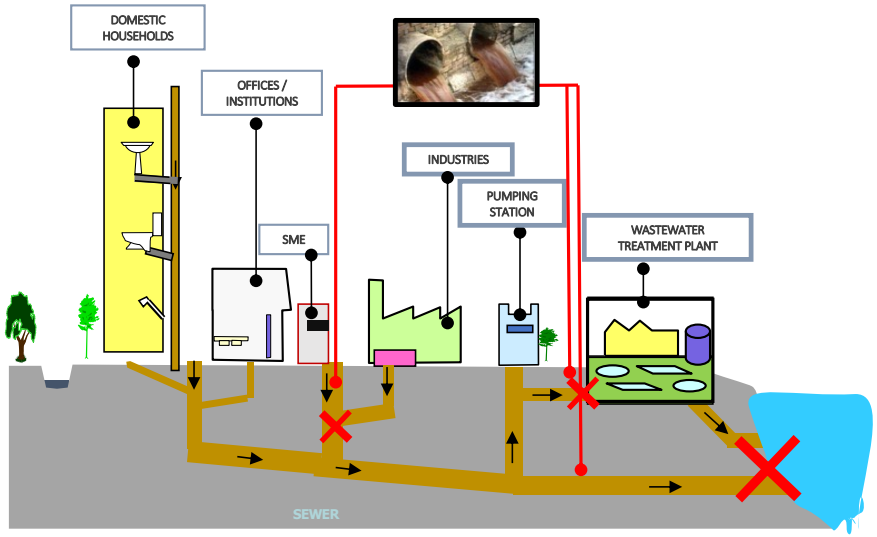
- Live fishes, i.e., tiger barbs are used to monitor the quality of raw water and treated drinking water. 活魚，即虎刺，被用來監察原水及經處理的飲用水的水質。
- Abnormal swimming patterns or fatality in the fish indicates change in water quality. 魚類的異常遊動模式或死亡表明水質發生了變化。
- CCTV with telemetry link to 24/7 Operation Centers were employed to remotely monitor the well-being of fishes. 利用閉路電視與24/7運營中心遙測連接，遠端監測魚類的健康情況。

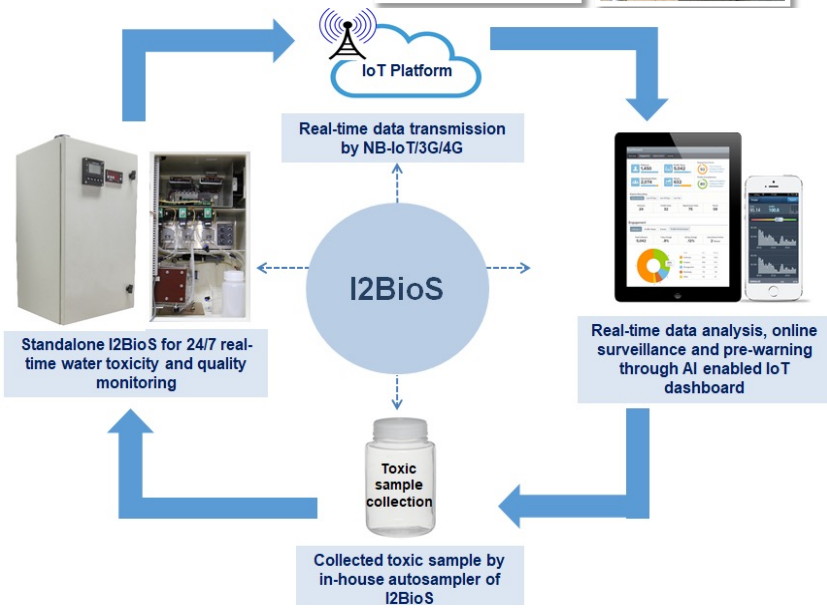
Eng et al. (2008). A Fish Activity Monitoring System for Early Detection of Water Contamination. Singapore International Water Week, 2008.
https://www.eco-business.com/news/fishes-now-the-first-line-of-defence-for-singapore-water-quality/

Protecting NEWater Production – Deterring and Detecting Illegal Discharge 保護再生水生產 - 阻止非法和監測超標排放

- Online 24/7 detecting the presence of heavy metals in trade effluent discharges 全天候在線監測工業污水排放中的重金屬
- I2BioS using IoT technology I2BioS使用物聯網技術
- 175 installed in Singapore. 在新加坡安裝了175台
- Startup初創公司: EnvironSens Pte Ltd.

EnvironSens

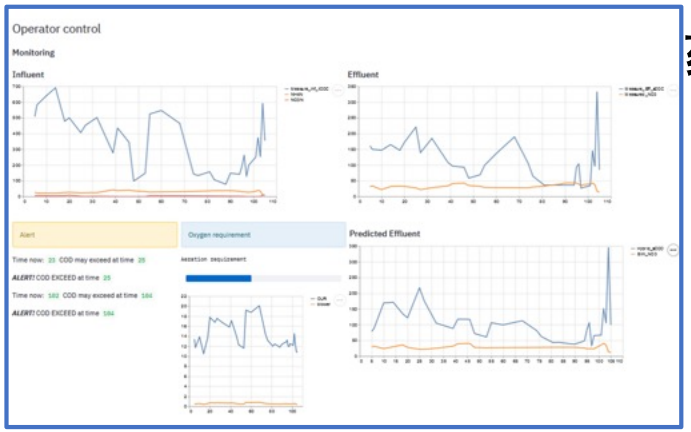


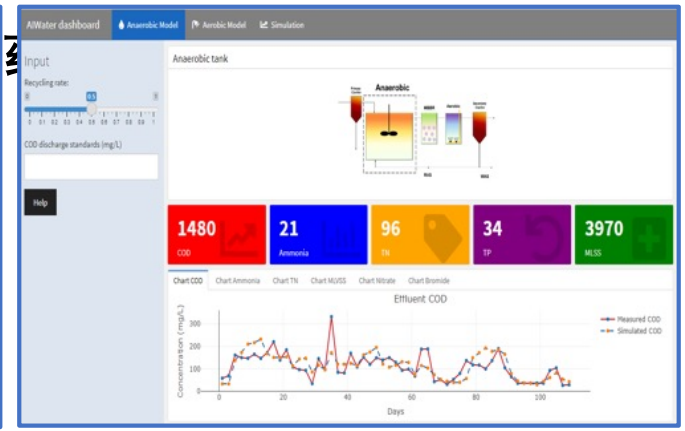


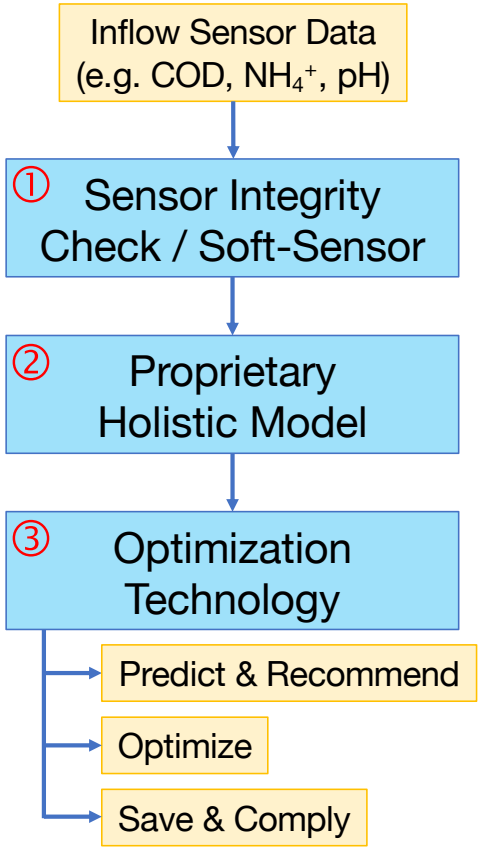
RESEARCH AND DEVELOPMENT IN WASTEWATER TREATMENT AND REUSE
污水處理及回用技術的研究與開發

Reduction of Energy and Chemical Consumption in Wastewater Treatment 污水廠智能化節能降耗

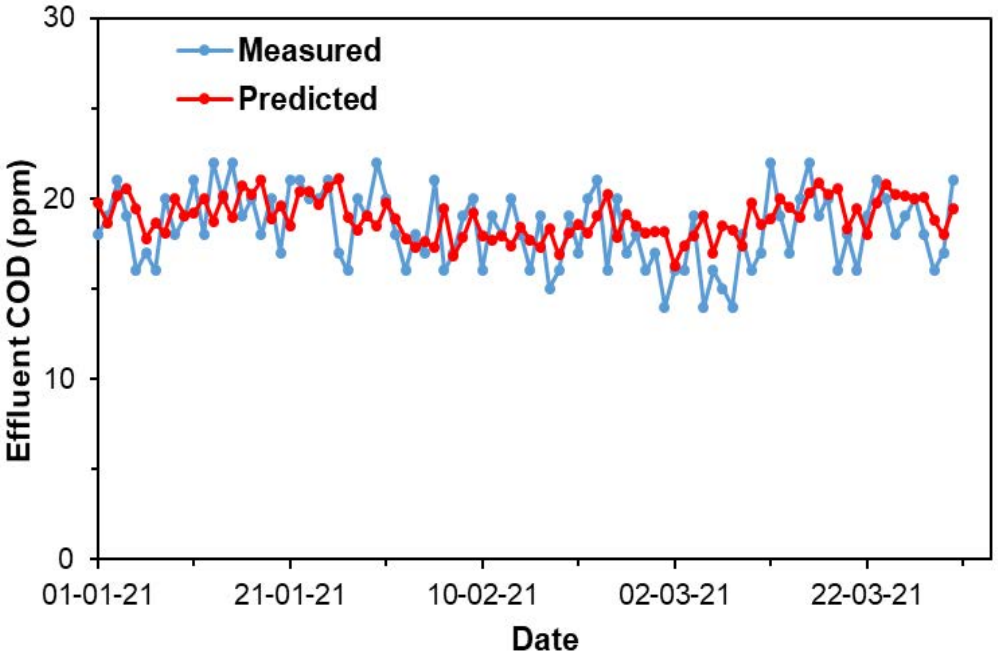
- **Combining biological process equations, big data models and AI optimization techniques to predict effluent quality 結合生物處理模型、大數據和人工智慧技術準確地類比出水的水質**
- Reduction of energy cost of used water treatment plants through process optimisation by up to 30% . **優化風機風量達到好氧池系統的節能降耗，節省20-30%的曝氣能耗**







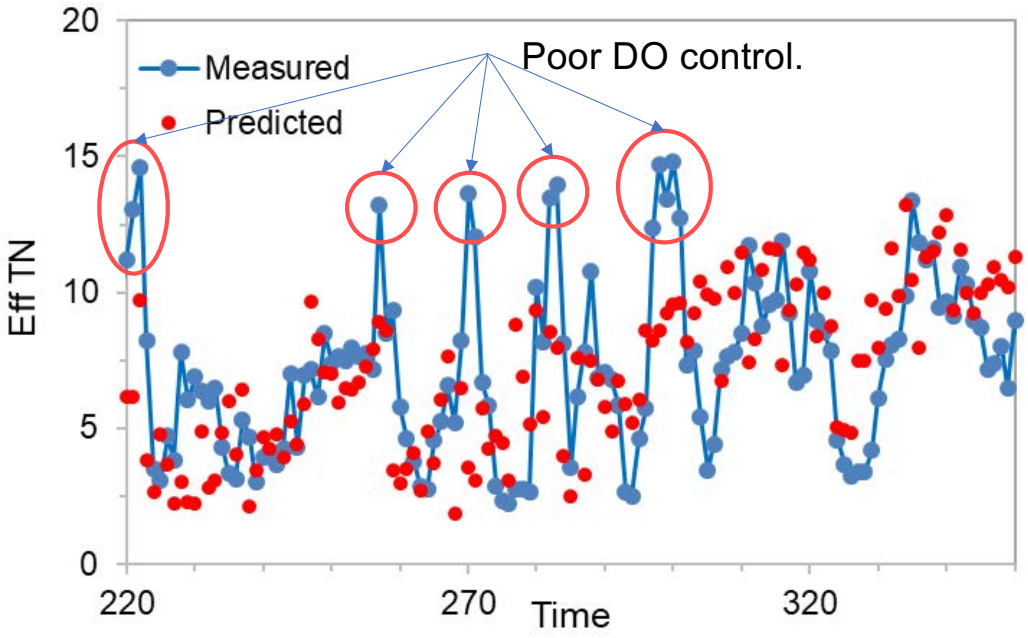
Full-Scale Municipal Wastewater Treatment Plant
全規模市政污水處理廠



	Results
Mean average 平均值	11.6
Percentage error 百分比誤差 (%)	
Correlation	0.80

Model is able to predict effluent COD accurately despite having varying influent parameter 模型能夠準確預測出水COD，儘管進水參數在變動。

Full-Scale Municipal Wastewater Treatment Plant
全規模市政污水處理廠

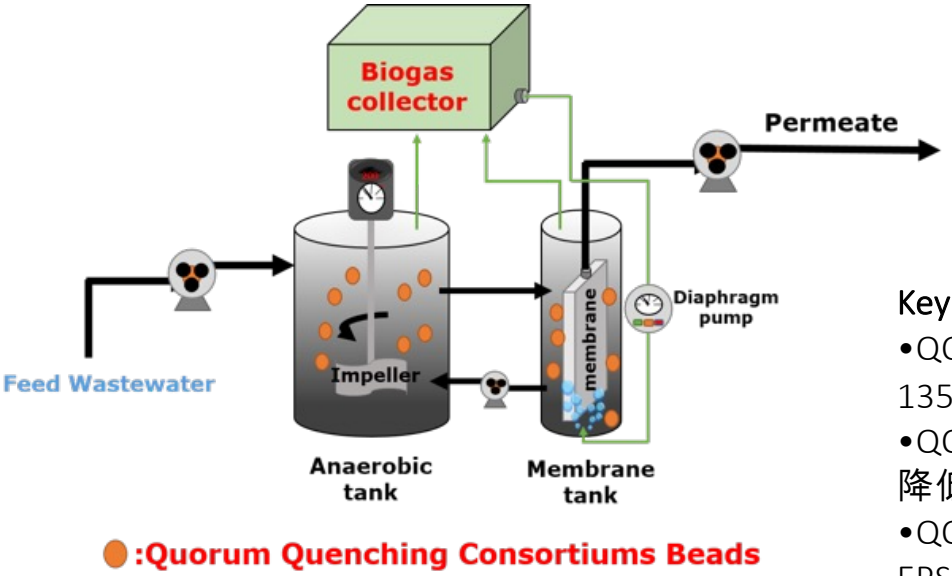


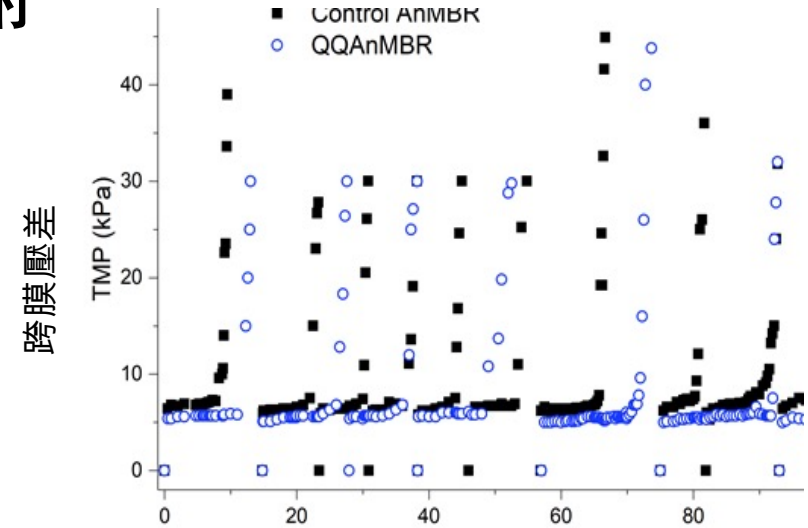
Issue 问题:

- High DO mixed liquor recycled back to anoxic 高溶解氧混合液迴流到 缺氧槽
- Glucose added for denitrification 添加葡萄糖進行反硝化
- High DO resulted in consumption of glucose and reduced denitrification performance 高溶氧導致葡萄糖消耗導致反硝化性能降低
- Chemical consumption can be reduced once aeration optimization is achieved 一旦實現曝氣優化，可以減少化學品消耗。

Quorum Quenching (QQ) to Control Membrane Fouling
利用群體感應淬滅降低膜污染技術

QQ in lab-scale AnMBRs treating domestic wastewater 通過實驗室反應器驗證



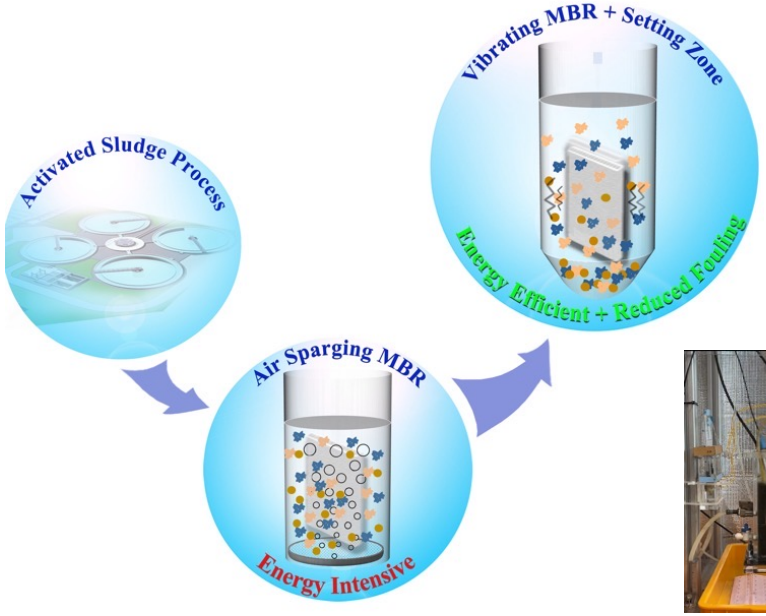


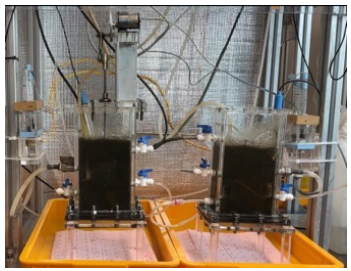
Key findings 主要发现：

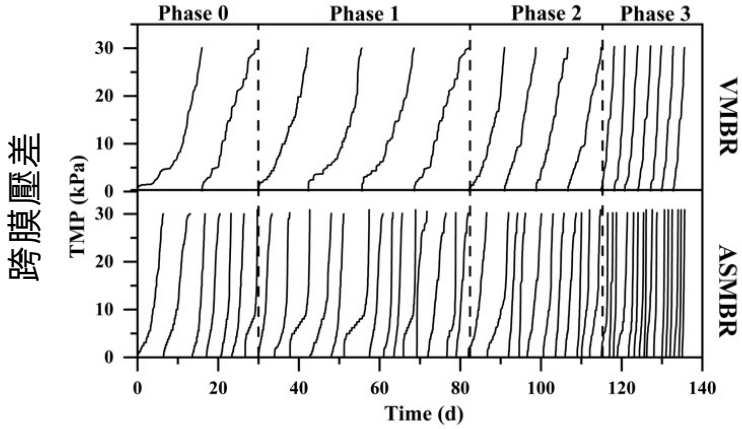
- QQ extended membrane operation service period by 39-135% **延長膜的運行時間，達到39–135%的增加**
- QQ reduced AHLs concentration in AnMBRs
降低反應槽裡的高絲氨酸內酯濃度
- QQ retarded production of key organic matters in EPS 降低EPS中有機物的生產
- QQ was associated to retard production of organic colloids in supernatant of suspended biomass 降低有機懸浮物的產生

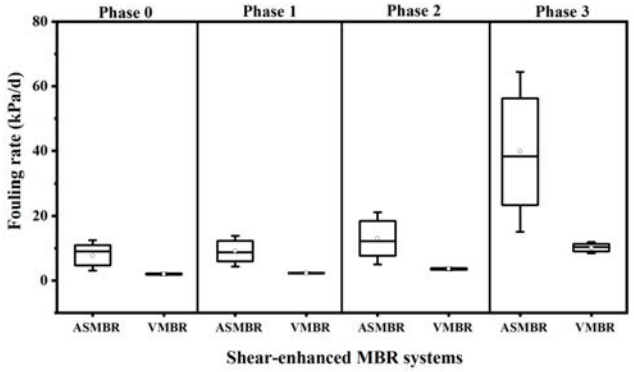
Vibrating Membrane Bioreactor to Reduce Energy Consumption and Membrane Fouling
震動膜好氧膜生物生物反應器降低能耗和膜污染

- No air sparging required 不需要暴氣
- Reduce energy consumption 降低能耗

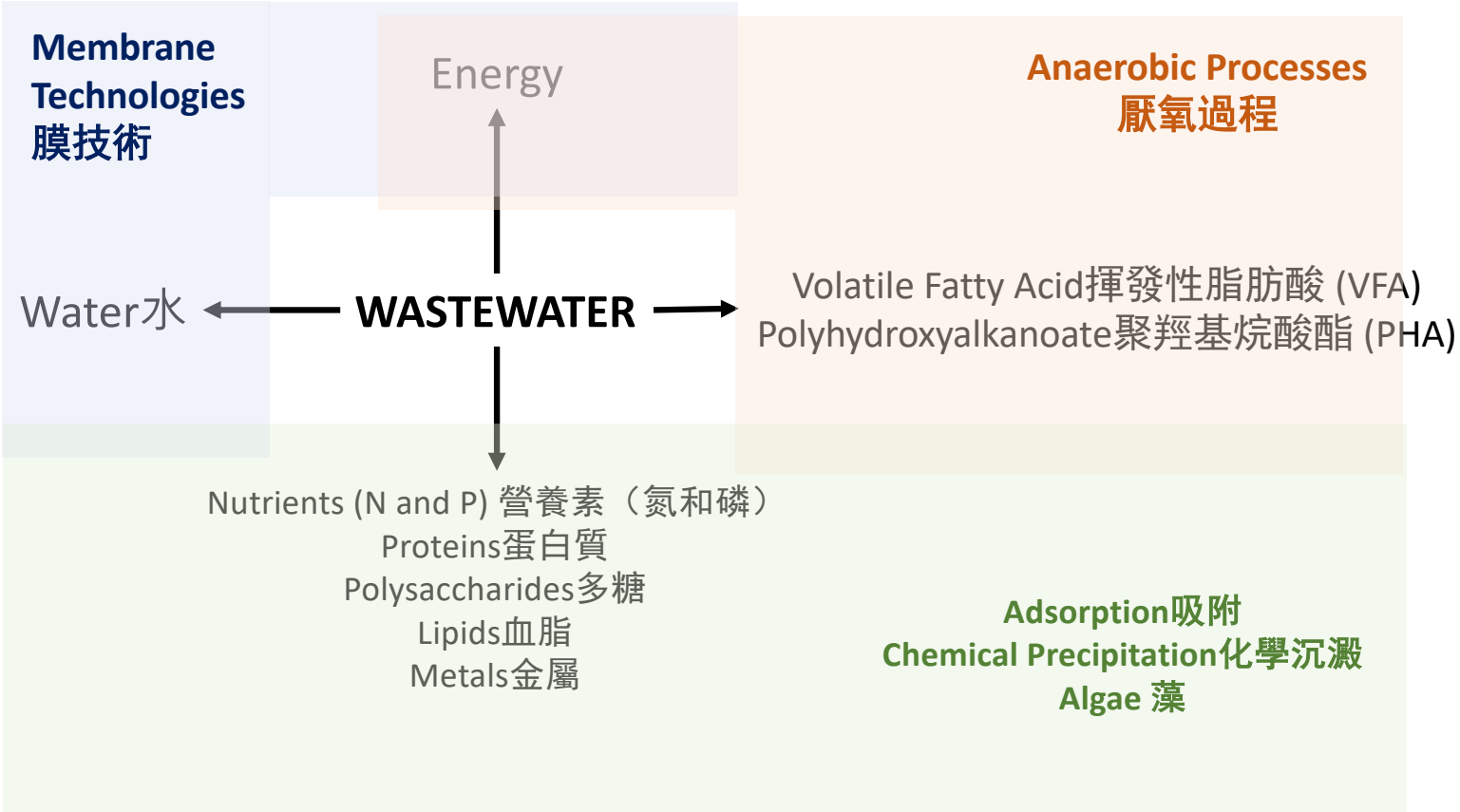








Pathways to Resource Recovery during Water Reclamation Process水資源回收過程中的資源回收途徑



FRESHWATER FROM SEA海水淡化

*From **Early Years** to the **Near Future**…..*

PUB, Singapore's National Water Agency (2022): Desalinated Water: https://www.pub.gov.sg/watersupply/fournationaltaps/desalinatedwater

CHALLENGES IN SEAWATER DESALINATION
海水淡化面臨的挑戰

- More efficient pumps更高效的水泵
- Energy recovery devices能量回收裝置
- **Development of novel technologies 新技術的開展**

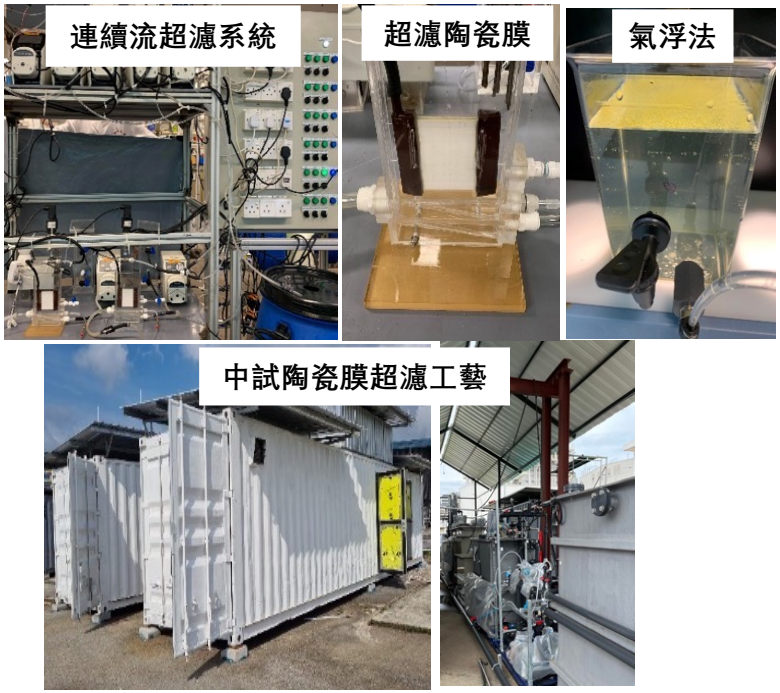
Energy
能耗

- Higher salinity高鹽度
- Increasing pollutants concentrations污染物濃度增加
- Increasing events of algal bloom 藻華事件增多

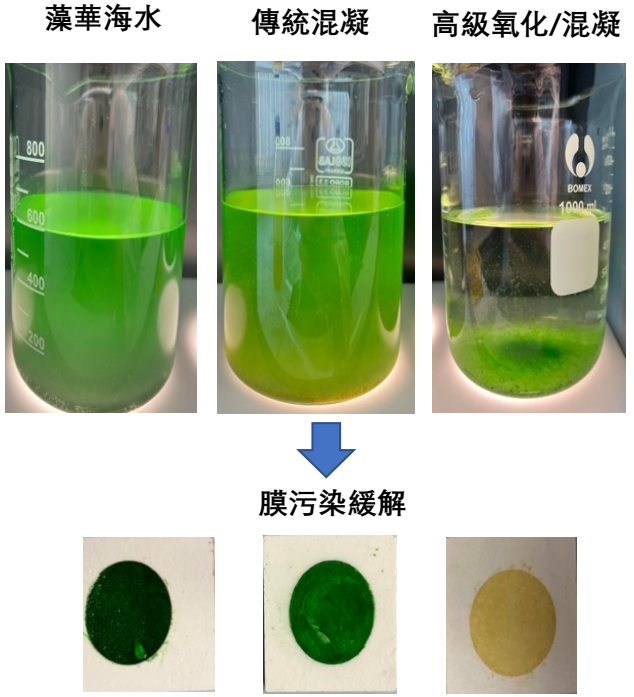
Intake Quality
進水水質

Low Energy Ceramic Membrane Filtration Technology for Pretreatment of Seawater Desalination
低能耗陶瓷超濾膜海淡預處理技術

1. 針對藻華海水，開發了低能耗高通量的陶瓷膜工藝



2. 開發了高級氧化對藻華海水的混凝強化和膜污染緩解的效果



Strategic changes and adaptation towards sustainable freshwater supply可持續淡水供應的戰略變化及適應

Thank you

謝謝聆聽!

再生水未來發展與多元利用趨勢

報告單位：臺南市政府水利局
報 告 人：韓榮華局長
日　　期：111年10月13日

簡報大綱

一 前言

二 國內再生水推動現況

三 臺南再生水推動現況

安平、永康及仁德再生水與其他水源開發

四 水源交換策略

五 推動效益及結語

01

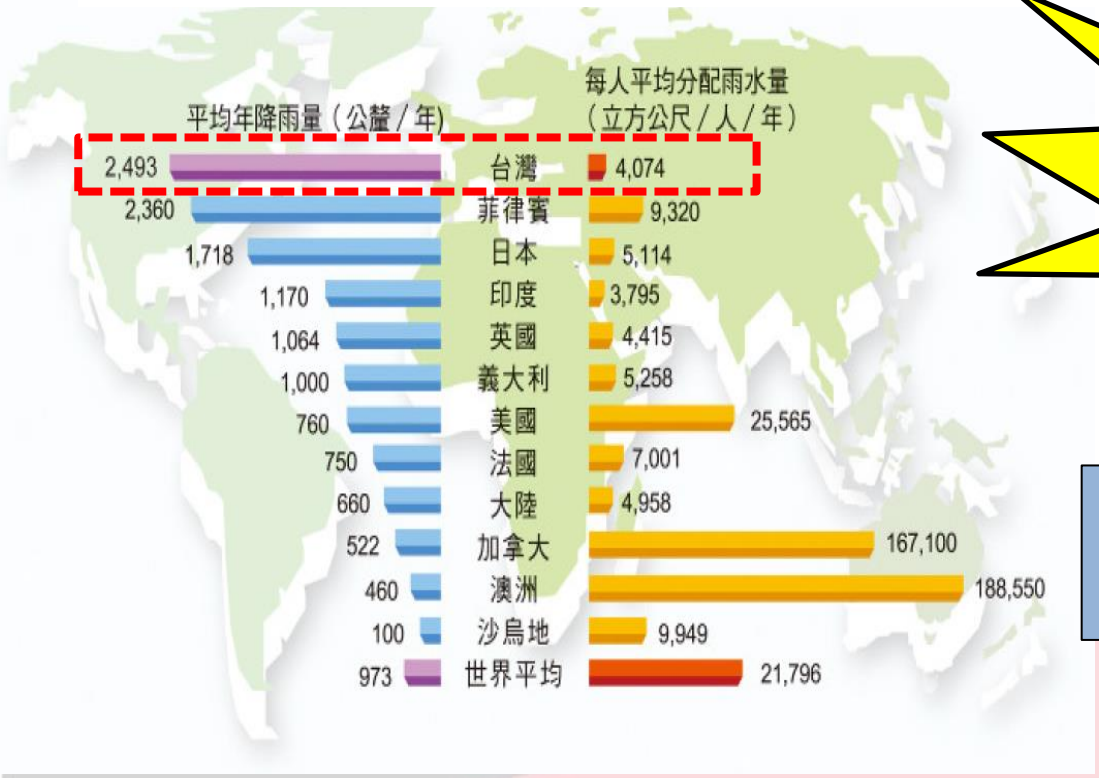
前言

1.1 前言

- 臺灣年均雨量雖豐沛，因氣候變遷，降雨量分佈極為不均，致經常發生區域性缺水問題
- 為因應臺南地區整體發展如南科三期及新市鎮開發，產業及民生用水需求增加，確保產業用水供應穩定，吸引產業投資及根留臺南 ，推動再生水有其必要性

1.2 氣候變遷

- 臺灣年平均降雨量約2,500mm，雨量豐沛，為世界平均值的2.6 倍，但分配雨量卻較世界平均值低
- 降雨分布不均，導致南部地區豐枯水期降雨比率約為9：1

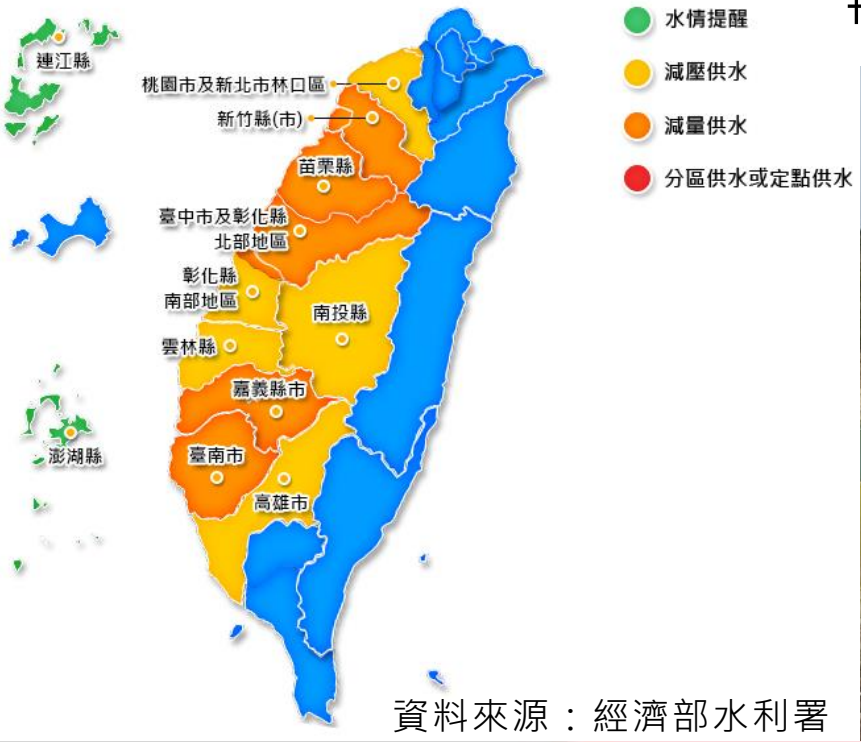


缺水危機

影響農業、民生及產業用水常態使用

1.3 水情吃緊

- 2021年2月25日起，嘉義與臺南的水情燈號由黃燈減壓供水，轉為橙燈的減量供水。
- 南部主要水庫集水區，2021年6月起的累積降雨，不到歷年同期的一半，警覺氣候異常現象，持續推動再生水計畫超前佈署應變。

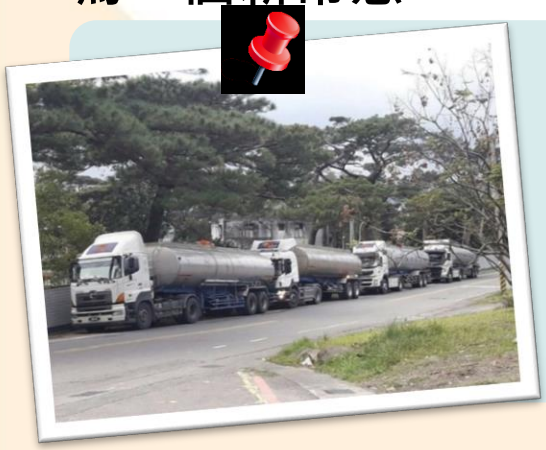


資料來源：經濟部水利署

1.4 再生水發展契機

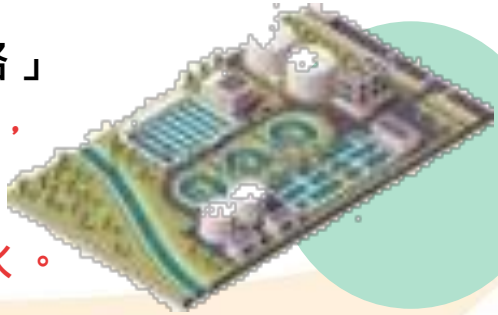
缺水影響半導體生產有多嚴重

這個世紀以來，2002年、2003年、2004年、2005年、2009年、2010年、2011年、2014年、2015年都出現了缺水的危機，缺水已成為一個新常態。



晶圓廠、面板廠必須「包養」水車，簽下長期合約。莊子壽說：「在科學園區這樣的措施是一般性的，不是只有我們，很多廠商都有，台積電總共大概有近300輛水車，幸好這些年有驚無險度過。」然而，科學園區卻是缺水的重災區。

根據經濟部2017年11月7日提出的「產業穩定供水策略」報告，工業用水未來將成長，其中以科學園區成長最快，現在每天供水能力40.3萬噸，到2031年需求會增加到81.3萬噸，如不新增水資源供應，每天將缺41萬噸的水。



生活污水為都市水庫穩定水源，再生水發展契機？

天下雜誌642期(2018-02-27)

02

國內再生水推動現況

2.1 國內再生水推動計畫

- 因應我國整理經濟發展面臨「缺水、缺電、缺人才、缺第、缺工」等五缺問題，經濟部訂定再生水政策願景：民國120年再生水量達132萬CMD。

102年核定

「公共污水處理廠放流水回收再利用示範推動方案」

高雄鳳山及臨海、台中豐原及福田、臺南永康及安平

106年核定

前瞻基礎建設計畫-
水環境計畫(水與發展)再生水推動計畫

台中水湳、臺南仁德、高雄臨海擴大取水管

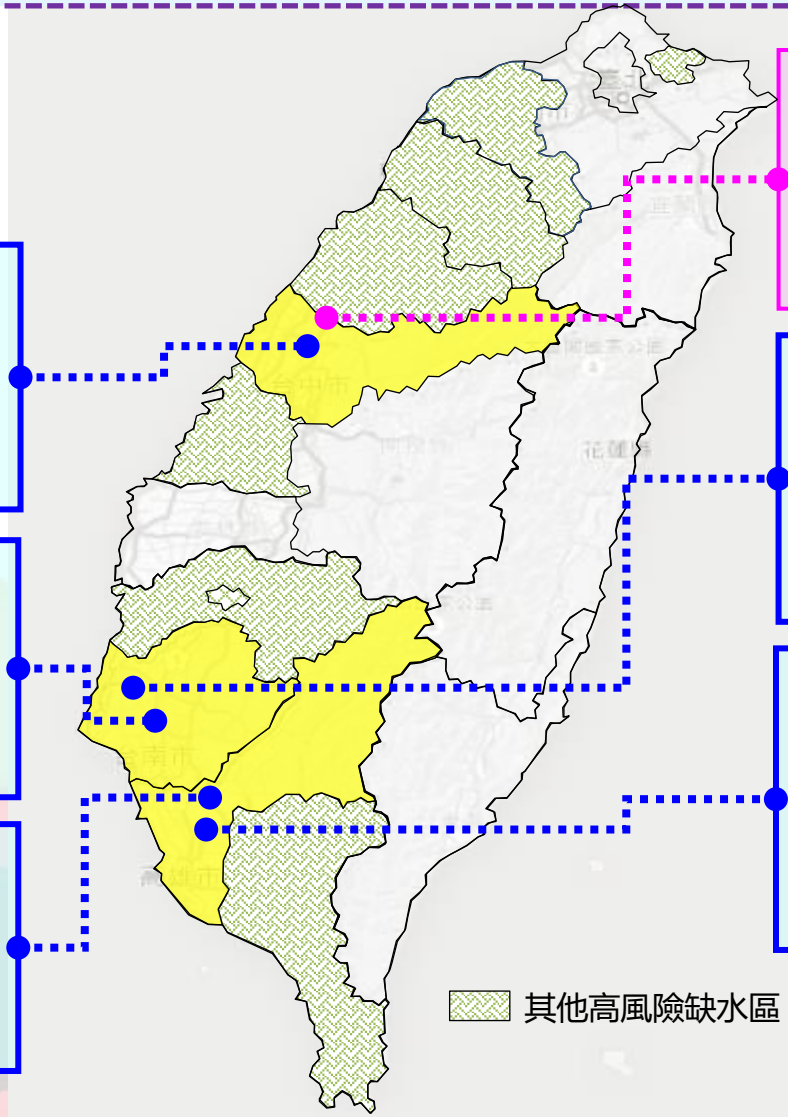
109年核定

公共污水處理廠再生水推動計畫

桃園北區、新竹竹北、高雄橋頭及楠梓

2.2 國內再生水示範案

- 102.10.1奉行政院同意辦理公共污水處理廠放流水回收再利用6座示範案例，總再生水量共28萬CMD。
- 總經費151.63億元（102~109年）



豐原污水處理廠
（建設中）
產1萬CMD再生水
供中科用水
核定經費17.148億元

福田水資源回收中心
（營運中）
產5.8萬CMD再生水
供台中港工業專區用水
核定經費42.39億元

永康水資源回收中心
（試營運中）
產1.55萬CMD再生水
供南科/樹谷園區用水
核定經費33億元

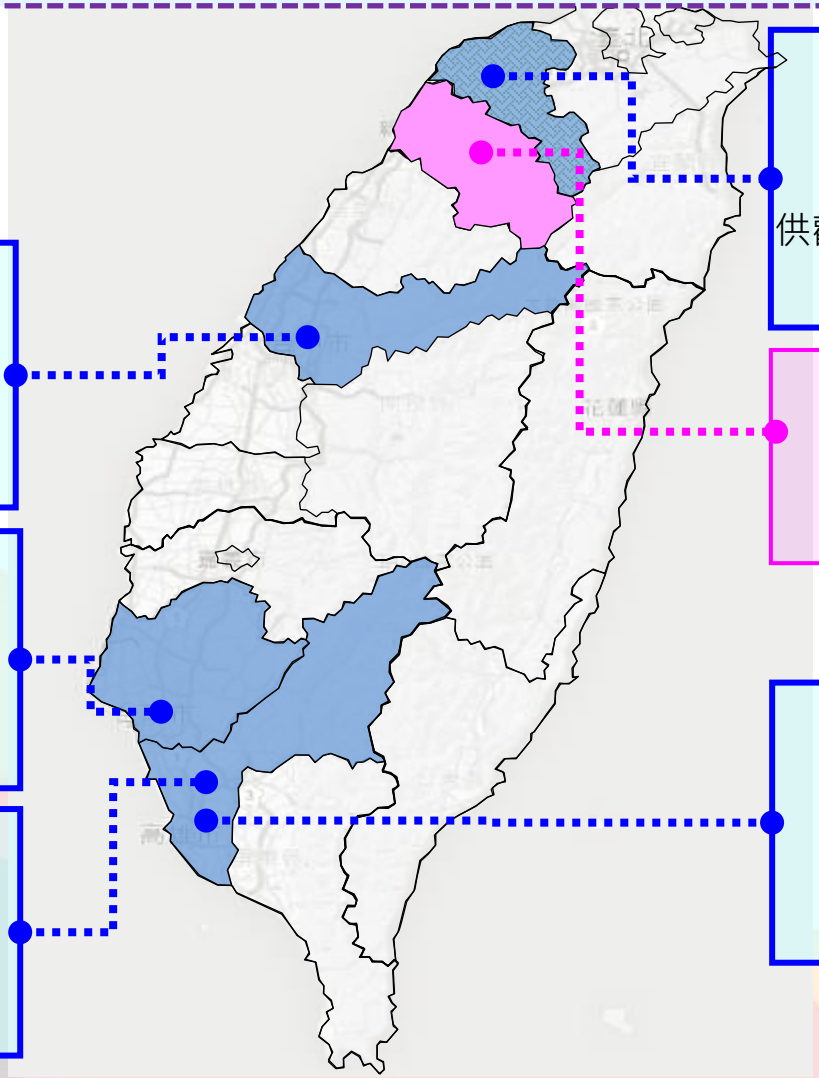
安平水資源回收中心
（營運中）
產3.75萬CMD再生水
供南科/樹谷園區用水
核定經費44.5億元

臨海污水處理廠
（營運中）
產3.3萬CMD再生水
供臨海工業區用水
核定經費45.52億元

鳳山溪污水處理廠
（營運中）
產4.5萬CMD再生水
供臨海工業區用水
核定經費30.88億元

2.3 國內再生水前瞻及新增案

- 106年核定前瞻基礎建設計畫-水環境計畫(水與發展)共3案，總再生水量共1.8萬CMD。
- 109年核定公共污水處理廠再生水推動計畫共3案，總再生水量共7萬CMD。



桃園北區
（設計中）
產4萬CMD再生水
供觀音工業區中油桃煉廠用水
經費金額49.18億元

新竹竹北
預計產1萬CMD再生水
供竹科用水
經費金額評估中

高雄岡橋
（議約中）
產3萬CMD再生水
供橋科用水
經費金額43.26億元

水湳水資源回收中心
（設計中）
1萬CMD再生水
供中科用水
經費金額5.3億元

仁德水資源回收中心
（招標中）
0.8萬CMD再生水
供奇美實業用水
經費金額9.2億元

高雄臨海擴大取水管
（營運中）
供臨海工業區用水
經費金額6.3億元

03

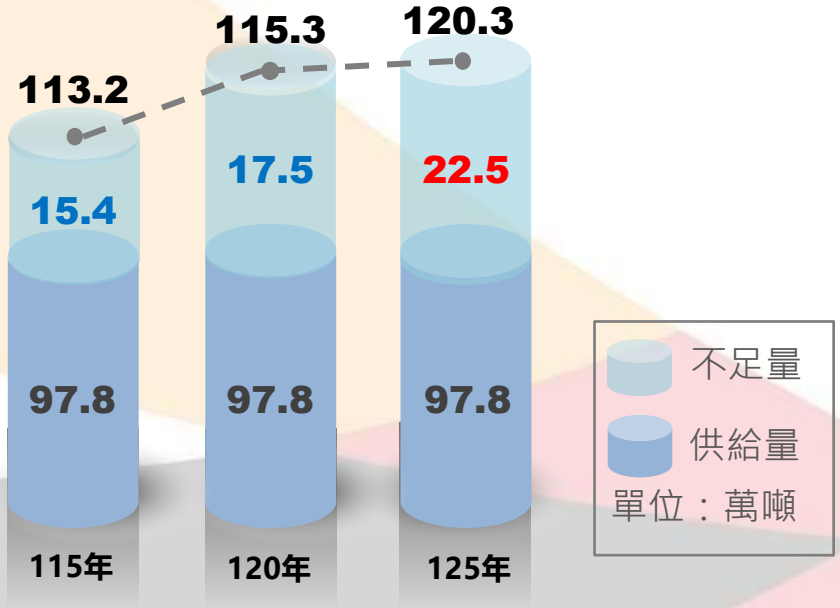
臺南再生水推動現況

3.1 臺南市用水現況

臺南供水現況

- 近年氣候變遷劇，供水穩定需強化
- 產業發展用水增，需開發新興水源

➢ 用水缺口達22.5萬CMD



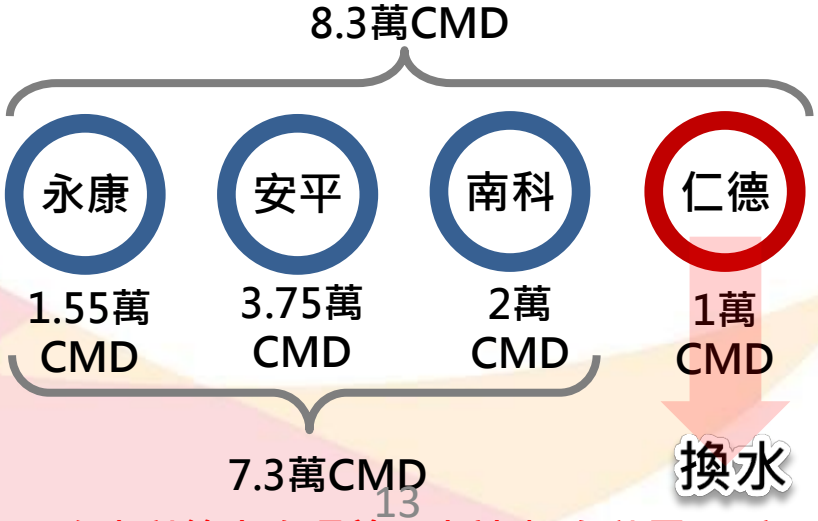
*依據110年2月台灣及離島水資源供水計畫

臺南地區用水供需圖

南科用水需求

- 南科產業發展快，為主要用水大戶
- 自來水供水有限，環評要求再生水

➢ 南科臺南園區用水計畫第二次修正，於113年後每日使用再生水8.3萬CMD



配合南科第十次環差用水計畫(台積電N3廠)

13

3.2 臺南市再生水推動現況

水利署106年核定南科園區用水計畫，115年達到每日32.5萬噸，其中8.3萬噸由再生水供應，其中6.3萬噸由臺南市再生水廠提供予南科園區，再由南科管理局進行調配

3.2-1 安平再生水

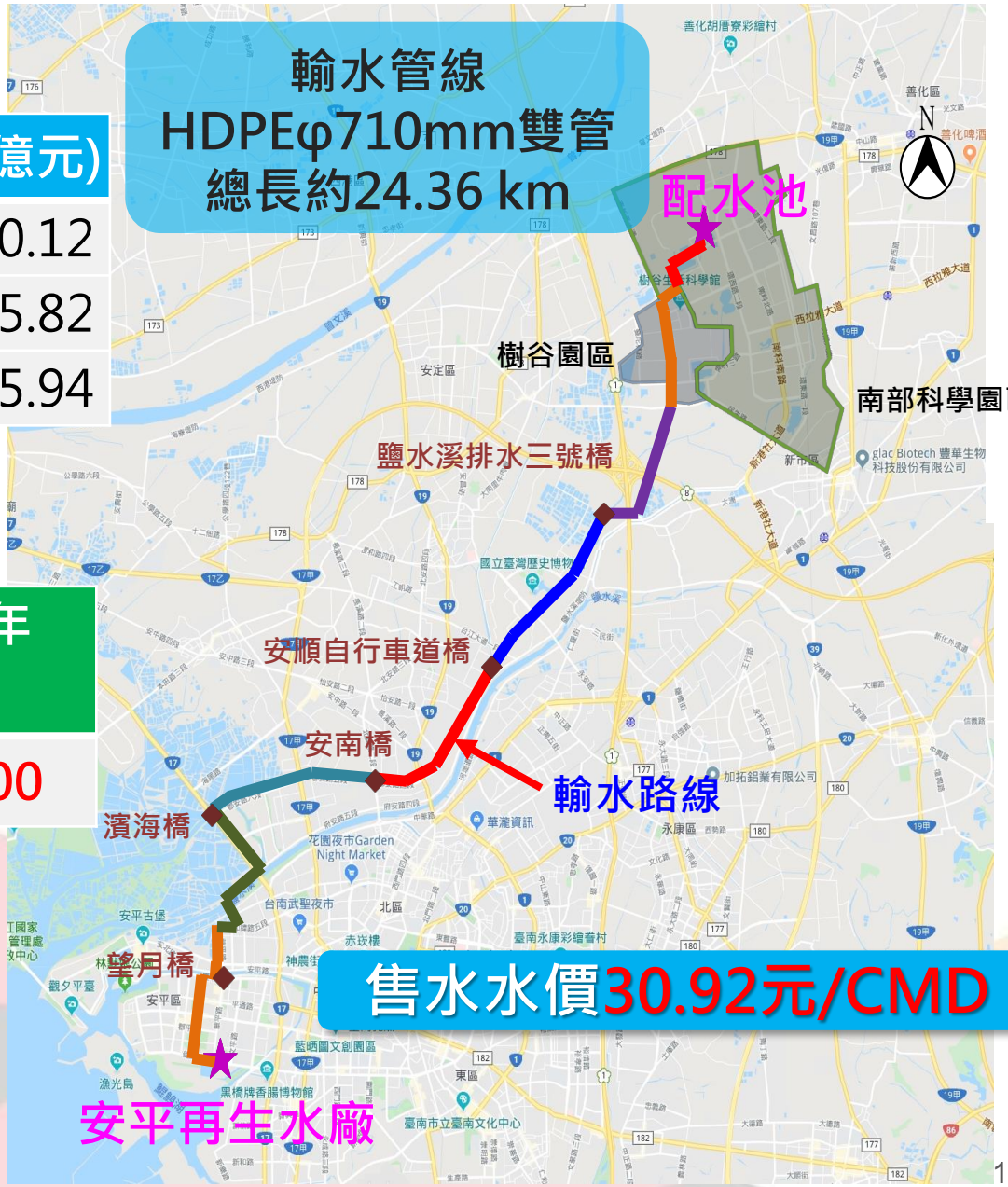
3.2-1 安平再生水計畫說明-計畫概要

預計投入經費

工程項目	經費(億元)
再生水廠+輸水管線	30.12
配水池+配水管線管網	5.82
總計	35.94

預計供水期程

預計供水（CMD）	111年	113年
台積電	10,000	37,500



3.2-1 安平再生水計畫說明-水質要求

- 產水供應標的：南部科學園區臺南園區之台積電
- 供水端需求水質（詳如表），項次1~20為市府供應南科配水池產水，項次1~21為南科配水池供應用水端再生水產水。
- 尿素採用高級氧化處理(溴化鈉)。

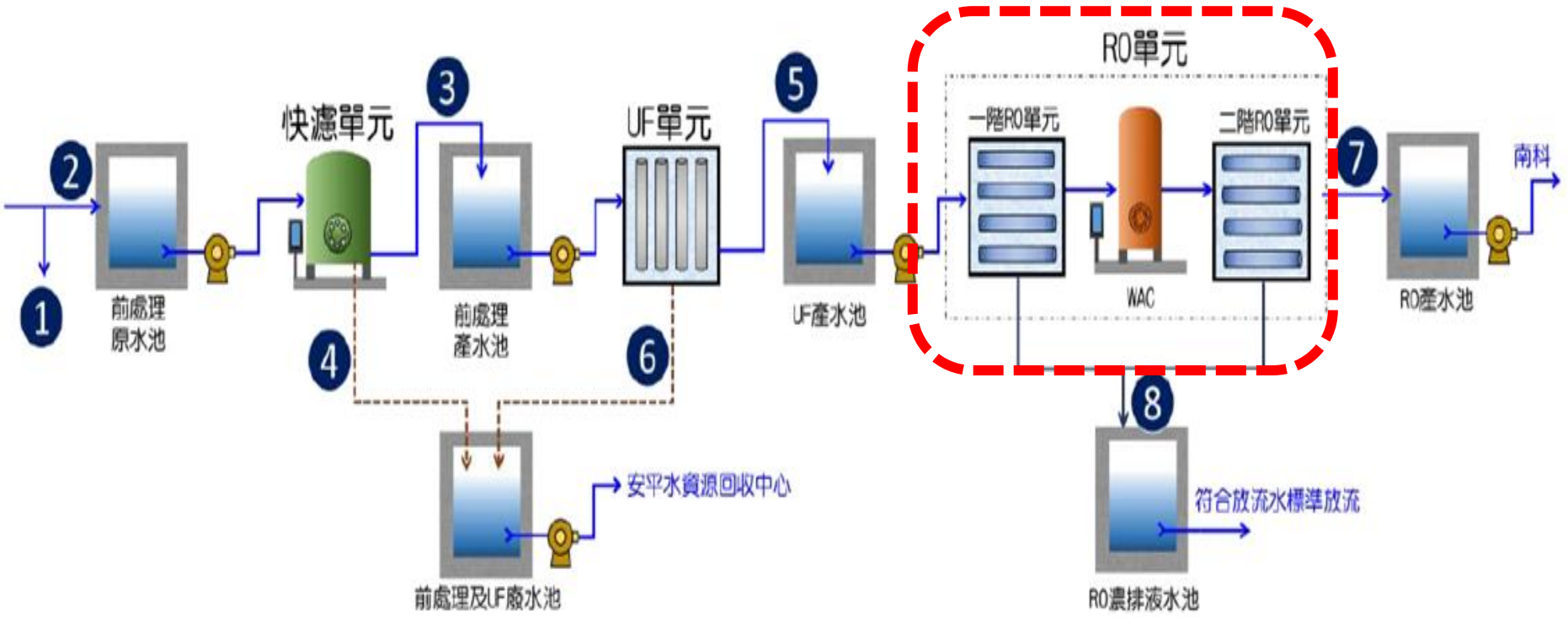
項次	水質項目	水質要求
1	溫度 (℃)	15~35 ℃
2	pH	6.0~8.5
3	比導電度 (μS/cm)	< 250
4	懸浮固體 (mg/L)	< 1.0
5	濁度 (NTU)	< 0.3
6	化學需氧量 (mg/L)	< 4.0
7	總有機碳 (mg/L)	< 1.0
8	氨氮 (mg/L)	< 0.5
9	亞硝酸氮(mg/L)	< 0.1
10	硝酸鹽氮(mg/L)	< 10

項次	水質項目	水質要求
11	硼 (mg/L)	<1.0
12	PO_4^{3-}(mg/L)	<0.5
13	Cl^-(mg/L)	<15
14	總溶解固體物(mg/L)	<150
15	SO_4^{2-}(mg/L)	<45
16	砷(mg/L)	<0.05
17	鎘(mg/L)	<0.005
18	鉻(mg/L)	<0.05
19	鹼度(mg/L)	< 30
20	硬度 (mg/L)	< 50
21	尿素(mg/L)	< 0.005

3.2-1 安平再生水計畫說明-處理單元

- 既設水資中心新建之再生水廠。
- 安平水資中心有海水滲入問題，故導電度及硼離子較其他水資中心高，且用水端為晶圓廠製程用水，因此除硼及尿素為主要課題。
- 處理程序：快濾+超濾+2階RO(+樹脂塔)+高級氧化處理

供高科技產業晶圓製程使用之再生水



3.2-1 安平再生水計畫說明-管線及監測說明

✓710mm外徑，雙管(備援概念)
✓專管供水至南科

1. 輸水管線共24.36公里
2. 跨越5座橋梁
3. 跨越5行政區
(安平、安南、北區、中西區及新市)

智慧水網水壓管理(降低風險)

- 流量計：輸水管線起終點及配水管網用水端引水點。
- 壓力傳訊器： 每1000m設置1處。

智慧水網、雲端回傳
即時監控、穩定供水

✓管線圖資匯入工務局公共管線圖資系統，避免管線道路施工誤挖
✓落實施工品質管控，全民督工，品質雙重把關

3.2-1 安平再生水計畫說明-再生水廠特色

再生水廠建築意象

- 以「水」為主題，採波光嶙峋設計
- 設置結合參訪、休憩的屋頂綠化空間
- 外觀採三明治外牆板系統金屬板，打造再生水廠科技感

用地面積僅0.28公頃，採立體配置，克服用地限制

3.2-1 安平再生水計畫說明-環教中心特色

建築意象

- 呼應再生水意象
- 採水滴狀建築造型
- 流動感弧形外觀

水資再用

沖洗及澆灌使用中水(二元供水系統)

永續教育

- 再生水及下水道設備展示導覽及解說
- 互動式軟硬體
- 紅樹林生態保育解說

節能減碳

- 綠建築
- 深色玻璃遮陽
- 大面積採光
- 自然通風導引

3.2-1 安平再生水計畫說明-目前進度(1/3)

再生水廠

1.目前進行頂樓女兒牆及濃排池結構工項、地下1樓FRP作業、外牆三明治版施作及機電設備安裝配管配線工項

環教中心

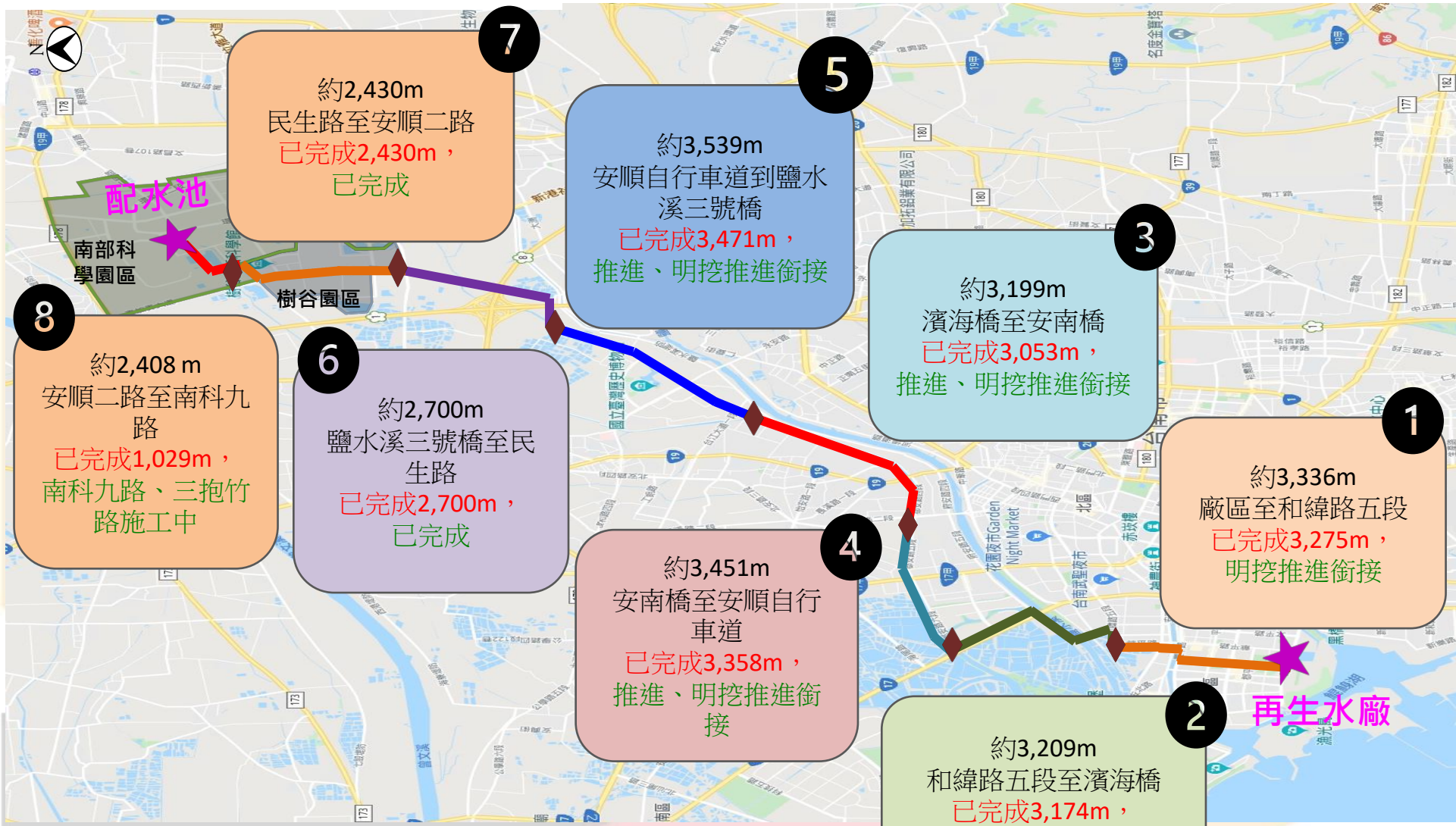
1.目前進行2樓升牆結構工項。

配水池

1.目前進行水池內FRP施作、池頂防水作業、牆面泥作及機電設備安裝配管配線工項

3.2-1 安平再生水計畫說明-目前進度(2/3)

輸配水管線累計已完成22,490/24,272=92.66% (統計至111.09.18)



3.2-1 安平再生水計畫說明-目前進度(3/3)

再生水廠

環教中心

配水池

3.2-2 永康再生水

3.2-2 永康再生水計畫說明-計畫概要

內容經費

工程項目	經費(億元)
水資中心+再生水廠+輸水管線	22.85
配水池+配水管線+配水管網	3.55
總計	26.40

供水期程

供水年	110年	112年
產水規模(CMD)	8,000	15,500

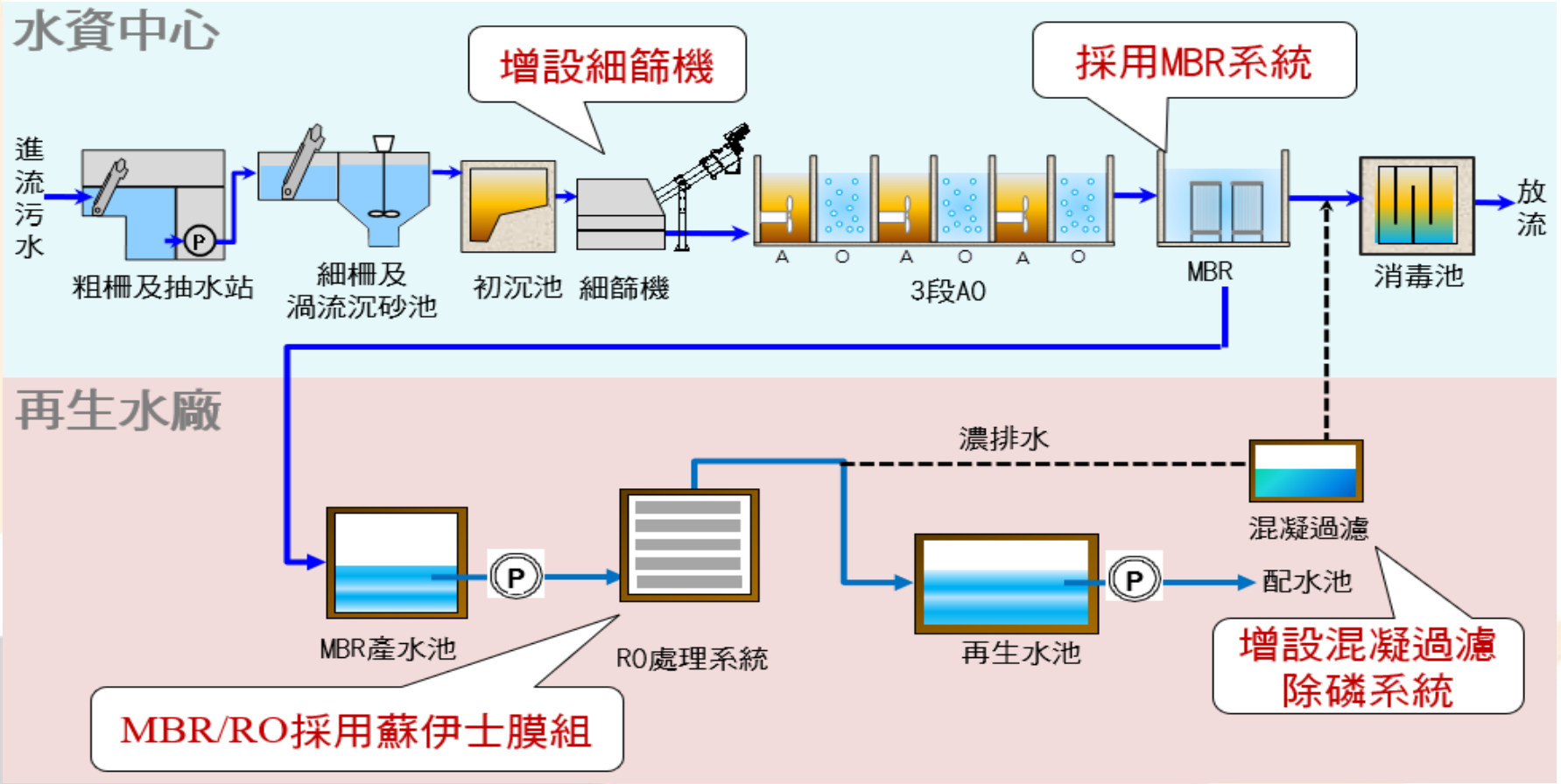
用水需求

需求廠商	需求量(CMD)
台積電(N5)	**9,500**
聯電	3,000
群創	3,000

全國第一座供高科技產業先進製程使用再生水

3.2-2 永康再生水計畫說明-處理單元

- 水資中心與再生水廠為同時新建。
- 水資中心採AO-MBR系統設計，MBR可取代再生水廠前處理單元，故再生水處理流程僅需設RO處理系統。



3.2-2 永康再生水計畫說明-管線及監測說明

工程	永康水資源回收中心	配水池高階處理設施
	水資中心第一期：29,000CMD	配水池及高階處理設施 容量：15,500 m^3
	再生水廠第一階：8,000CMD 第二階：15,500CMD	高階處理設施：添加NaBr+NaOCl
	輸水管線全長約9.3 km (ø500管× 2支)	配水管：約9,277m (ø800管× 2支)

智慧水網水壓管理(降低風險)

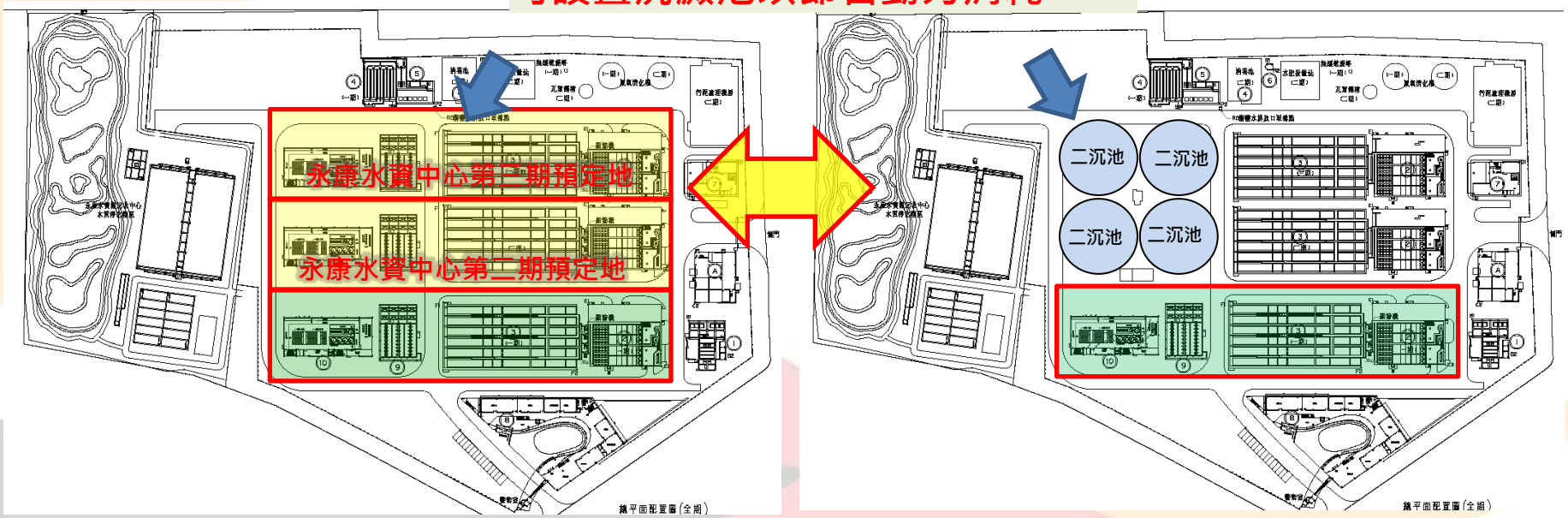
- **流量計**：輸水管線起終點及配水管網用水端引水點。
- **壓力傳訊器**：每1000m設置1處。

3.2-2 永康再生水計畫說明-廠區特色(再生水廠)

處理流程

- 永康水資中心及再生水廠利用MBR處理流程用地面積較小之特性，將水資中心及再生水廠第一期工程用地縮減，維持二、三期用地使用彈性，若水資二、三期建設時仍有再生水需求可設計建造後期再生水廠。

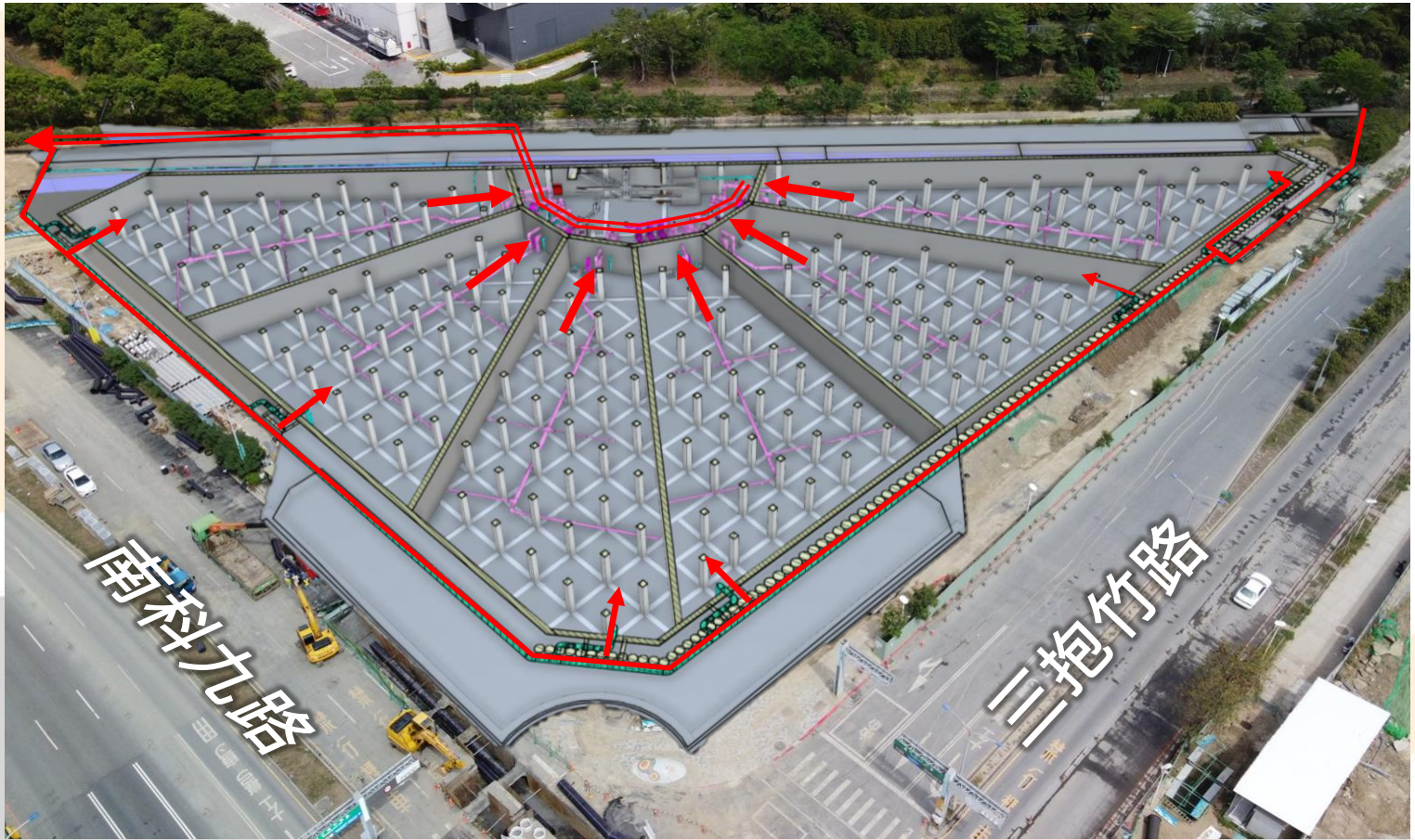
水資中心二期不再設置再生水廠時
可設置沉澱池以節省動力消耗。



3.2-2 永康再生水計畫說明-廠區特色(配水池)

南科配水池採多池批式反應確保水質

- 永康再生水南科配水池採多池批式反應設計，單一水池於進水時即偵測尿素濃度並添加NaBR+NaOCl強制氧化尿素及其他有機物，反應完成經線上偵測檢驗完成才列入待命出水池，每一池再生水都經過2次以上確認水質符合用水戶水質標準才送至用戶手中。



3.2-2 永康再生水計畫說明-目前進度(水資中心)

■ 水資中心已完工，正進行試營運，完成後分二階段供水1.55萬噸(第一階段8000噸/日)再生水至南科科技廠使用。

3.2-3 仁德再生水

3.2-3 仁德再生水計畫說明-計畫概要

背景說明

- 配合南科環差用水需求，解決台積電用水缺口
- 採**交換水源**機制使用再生水，每日供8,000 CMD再生水

計畫內容

- 再生水廠新建工程（供水8,000CMD規模）
- 區內外輸水管線工程（ 3.0 KM/HDPE ）

工程及委託代操作經費

- 工程經費(2年)：8.6億元
- 委託代操作營運費用(再生水15年、污水廠17年)：11.6億元
- 總經費：20.2 億元

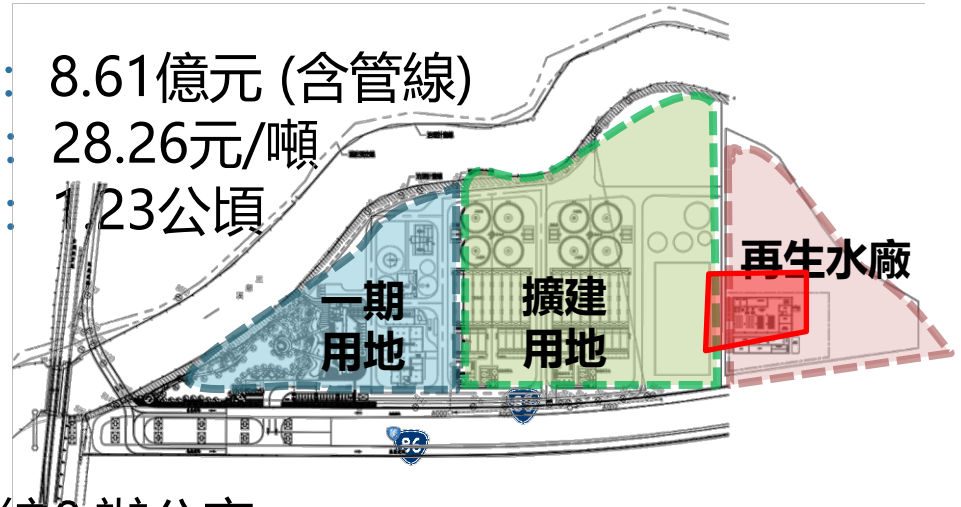
規劃期程

- 111年8月上網公告招標，10月完成統包工程決標
- 預計113年10月完工，**113年年底可正式供水8,000 CMD**

3.2-3 仁德再生水計畫說明-規劃內容

再生水廠規劃成果

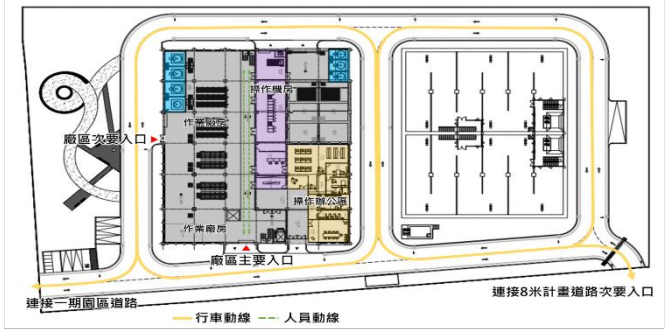
- 產水規模：8,000 CMD
- 處理流程：FF+UF+RO
- 濃排處理：A/O+MBR
- 建設費用：8.61億元 (含管線)
- 售水費用：28.26元/噸
- 用地面積：1.23公頃



再生水廠配置示意

- 採2層設計
  - 地面層：主要處理系統&辦公室
  - 地下層：產水槽&泵浦設備

主要處理系統



產水槽及泵浦區

3.2-3 仁德再生水計畫說明-水質要求

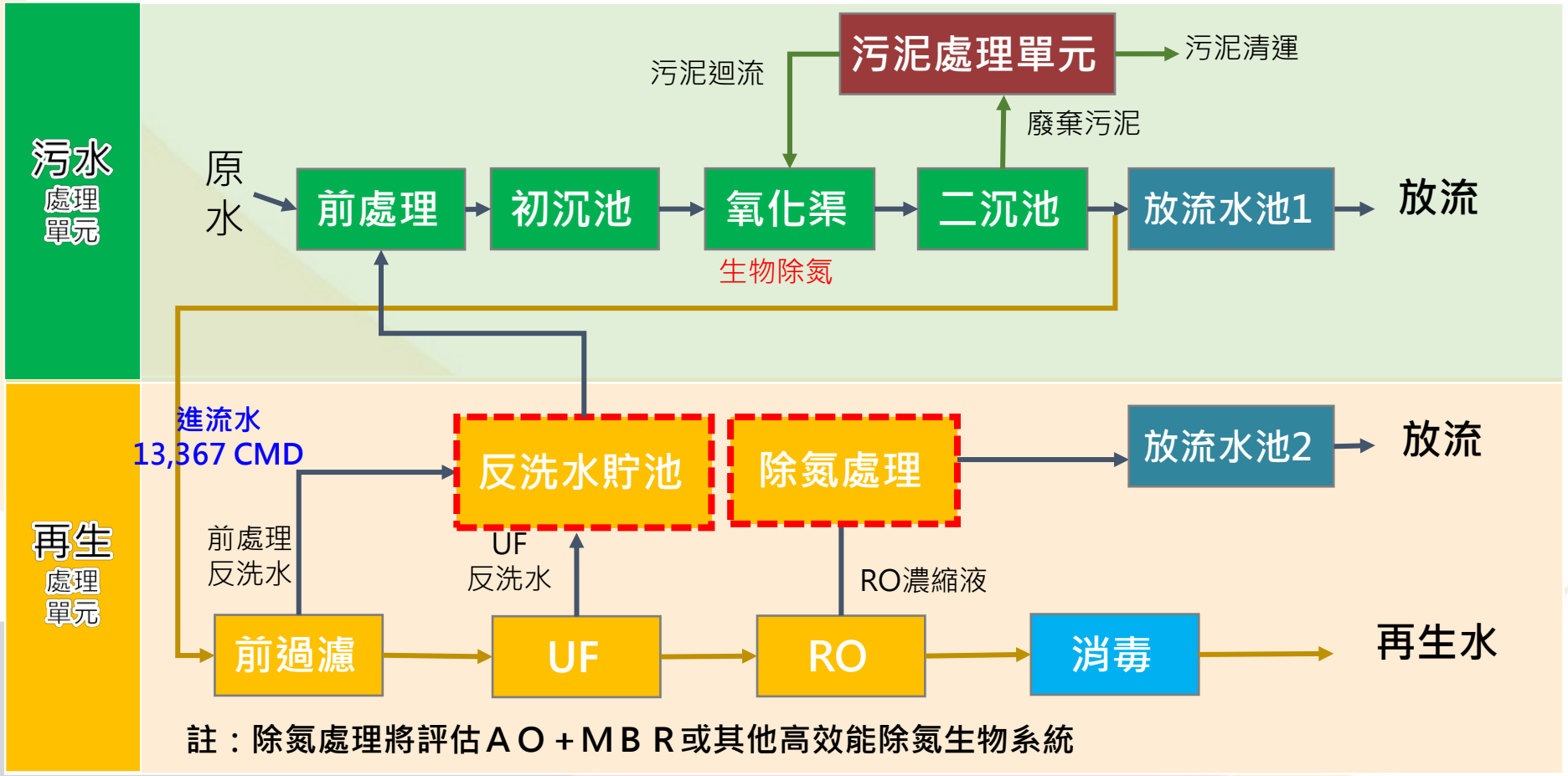
- 奇美再生水水質需求，**無**永康/安平再生水供應南科**尿素規範**
- 經**一階RO回收**處理可符合用水需求

項次	水質項目	再生水標準限值	奇美	南科
1	溫度 (℃)	< 32℃	< 32	15-35
2	pH	6.0~8.5	6.0~8.5	6.0~8.5
3	**比導電度** (μS/cm)	< 250	<250	<250
4	**懸浮固體** (mg/L)	< 3.0	**< 3.0**	<1.0
5	濁度 (NTU)	< 0.3	< 0.3	<0.3
6	化學需氧量 (mg/L)	-	-	<4.0
7	**總有機碳** (mg/L)	< 2.0	**< 2.0**	<1.0
8	**氨氮** (mg/L)	< 0.5	<0.5	<0.5
9	亞硝酸氮(mg/L)	< 0.1	<0.1	<0.1
10	硝酸鹽氮(mg/L)	< 10	<10	<10

項次	水質項目	再生水標準限值	奇美	南科
11	**硼** (mg/L)	<1.0	**<1.0**	<0.1
12	PO_4^{3-}(mg/L)	<0.5	<0.5	<0.5
13	Cl^-(mg/L)	<15	<15	<15
14	總溶解固體物 (mg/L)	<150	<150	<150
15	SO_4^{2-}(mg/L)	<45	<45	<45
16	砷(mg/L)	<0.05	<0.05	<0.05
17	鎘(mg/L)	<0.005	<0.005	<0.005
18	鉻(mg/L)	<0.05	<0.05	<0.05
19	鹼度(mg/L)	< 30	<30	<30
20	硬度 (mg/L)	< 50	<50	<50
21	總菌落數	<100	<100	-

3.2-3 仁德再生水計畫說明-處理單元

- 於既設水資中心新建再生水廠。
- 依用水端水質要求，經一階RO回收處理可符合需求。
- 處理程序：前過濾+超濾+1階RO



3.2-3 仁德再生水計畫說明-輸水管線

路線多為鄉間道路，地下管線少，交通影響小

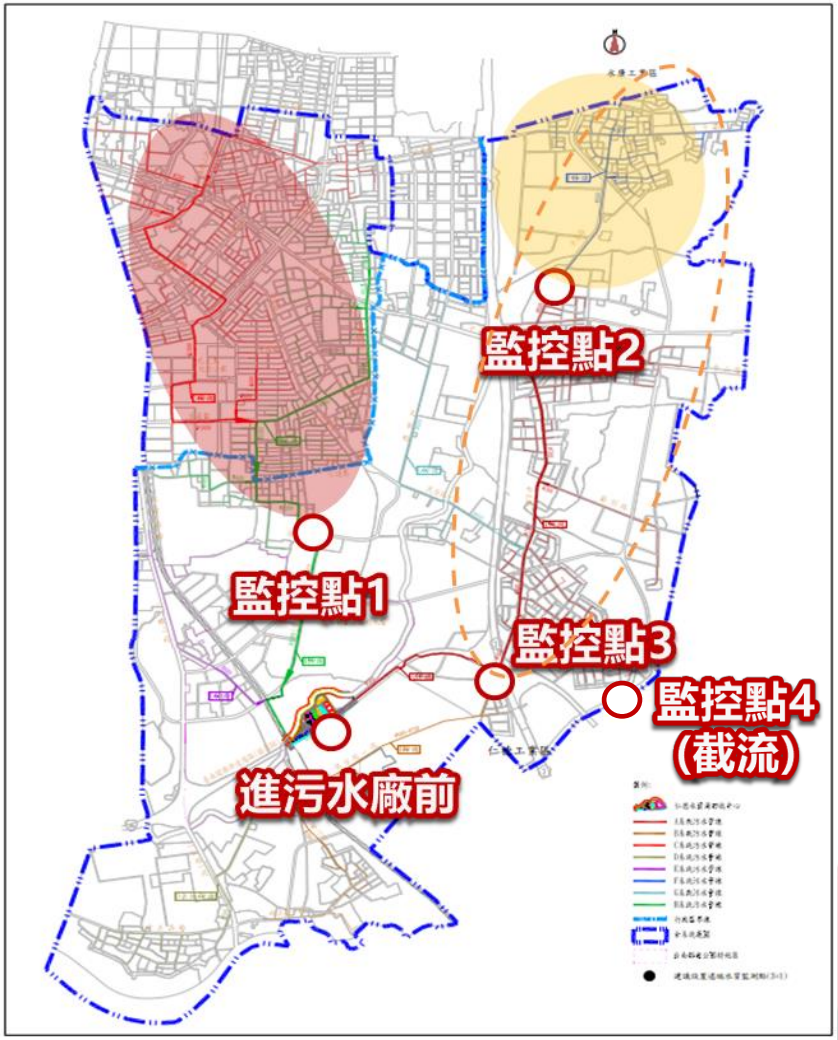
- 管徑大小：
  HDPE-355mm ；
  採雙管佈設
- 建議路線：
  中正路一段→國道1號旁廠區進水點
- 管線距離：3km

管線單位會勘協調

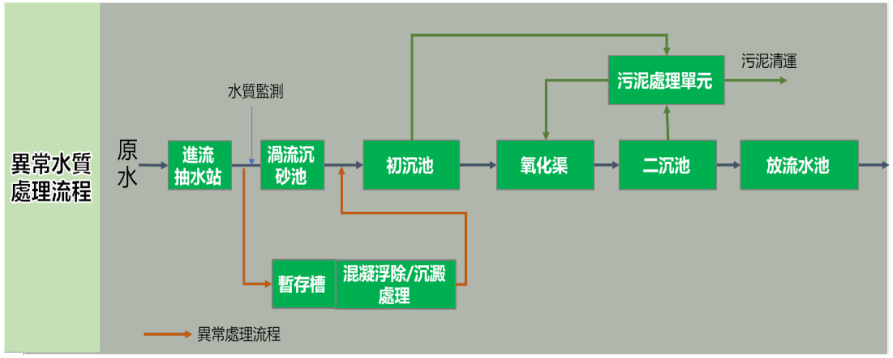



3.2-3 仁德再生水計畫說明-水質異常應變措施

仁德污水下水道之遠端水質監控建議位置

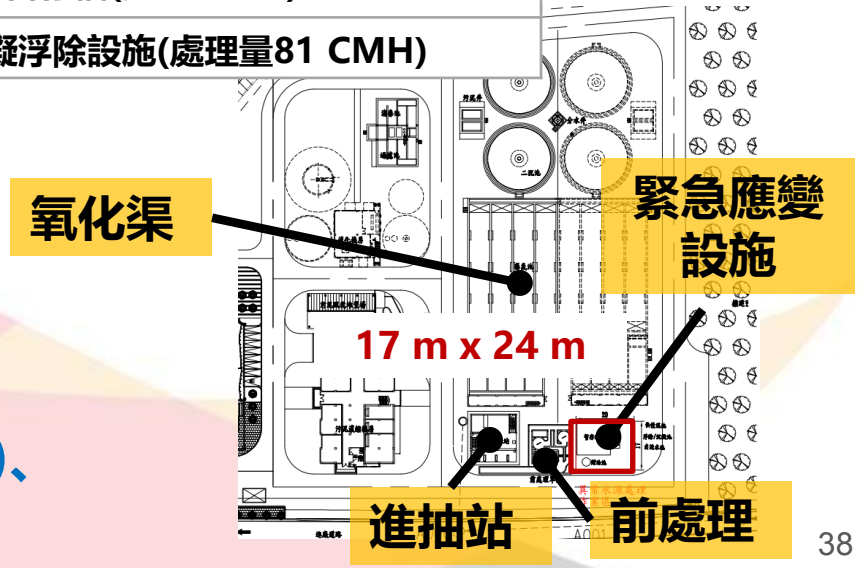


異常水進入處理設施



以異常水源發生時間為**1小時**，混凝設施處理**分批處理時間為8小時**作為規劃基準

異常水入流處理設施
1. 渦流沉砂池前後緊急繞流管線及其附屬設施
2.1座暫存槽(約660 m3)
3.混凝浮除設施(處理量81 CMH)



每處導電度計(EC)、總有機碳分析儀(TOC)、異丁烷等三種監測儀器

04

水源交換策略

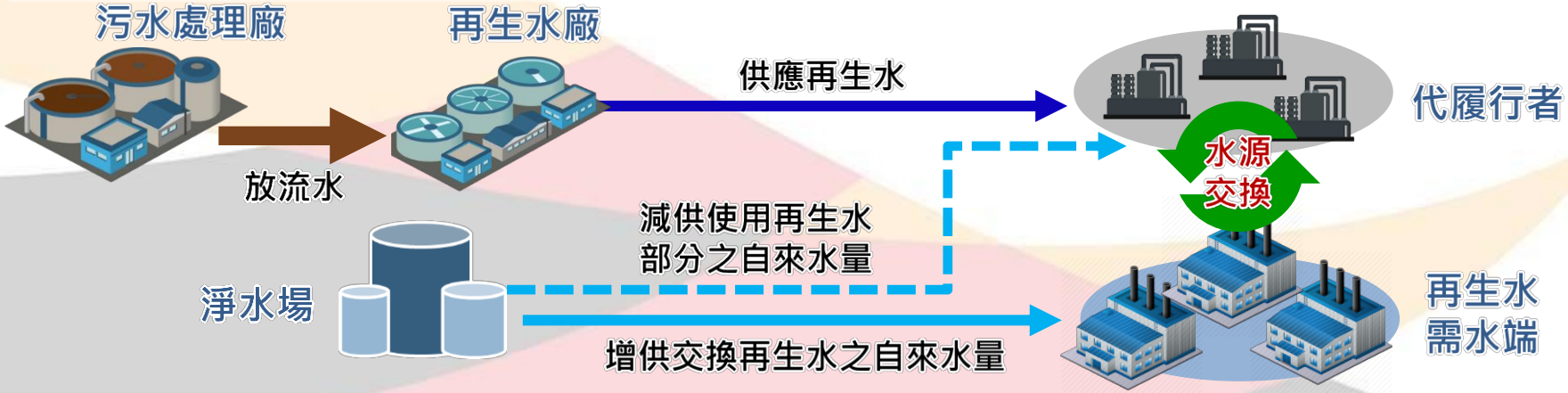
4.1 再生水供應方式

專管供應

- 系統再生水過往案例推動方式都是由再生水廠產製再生水後直接專管輸送供應予再生水用水端使用
- **管線建設費及售水價格**，往往決定於用水端距再生水廠距離遠近

水源交換

- **系統再生水需水端**與**再生水廠鄰近代履行者**雙方合意於一定期間內**交換水源使用**，並於用水計畫書備註送主管機關審查核定
- **節省管線建設費**並可**降低售水價格**，以提高計畫推動的可行性

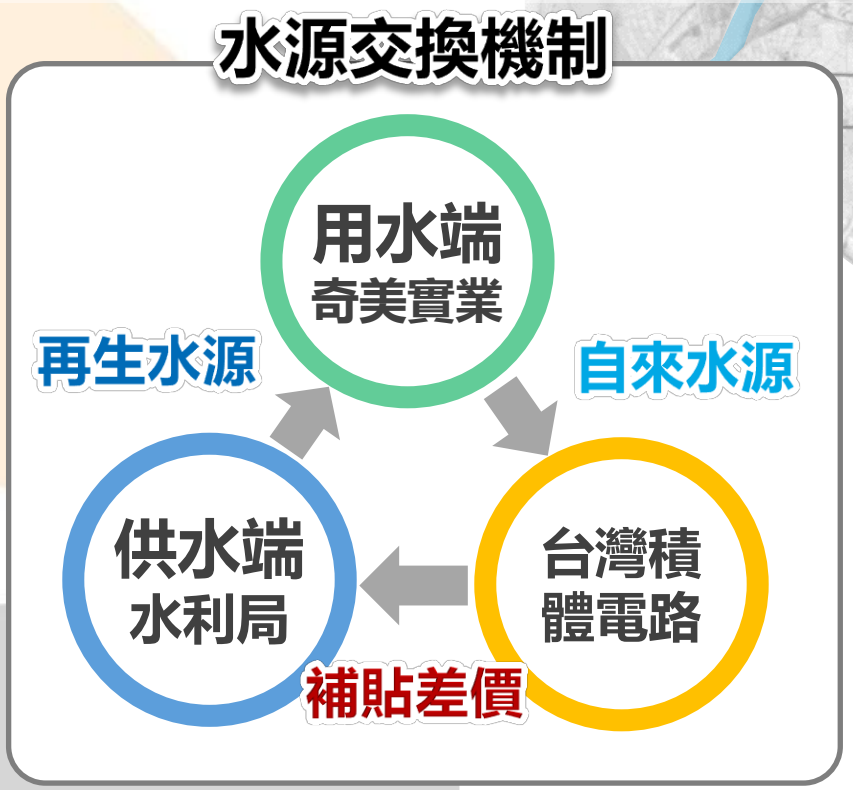


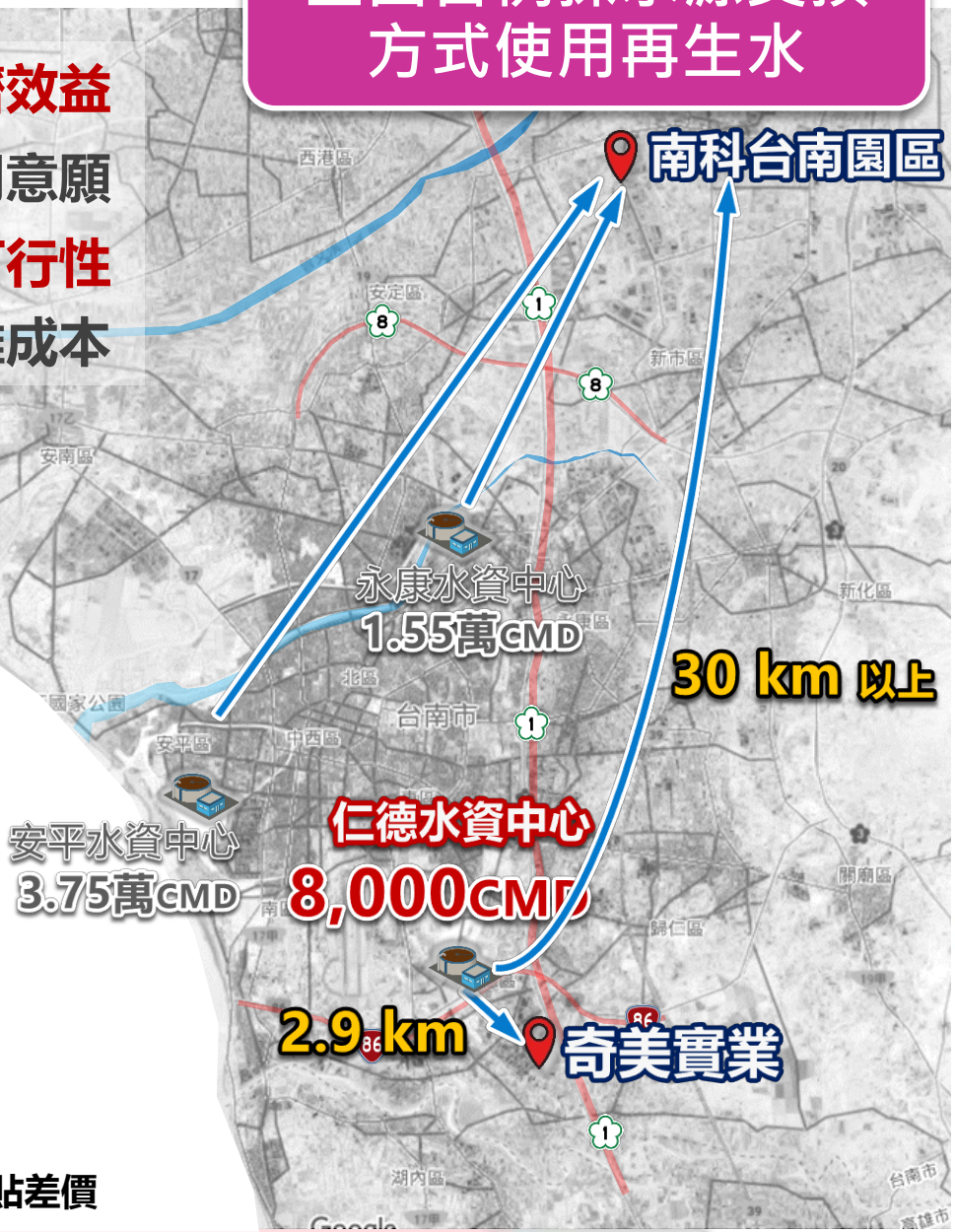
4.2 仁德再生水水源交換機制

採用水源交換緣由

- 直供南科管線長費用高，**不具經濟效益**
- 再生水廠鄰近**奇美實業**，且有使用意願
- 就近供應，補貼差價，提高**推動可行性**
- **淨零減碳**，節省初設費，降低操維成本

全國首例採水源交換方式使用再生水





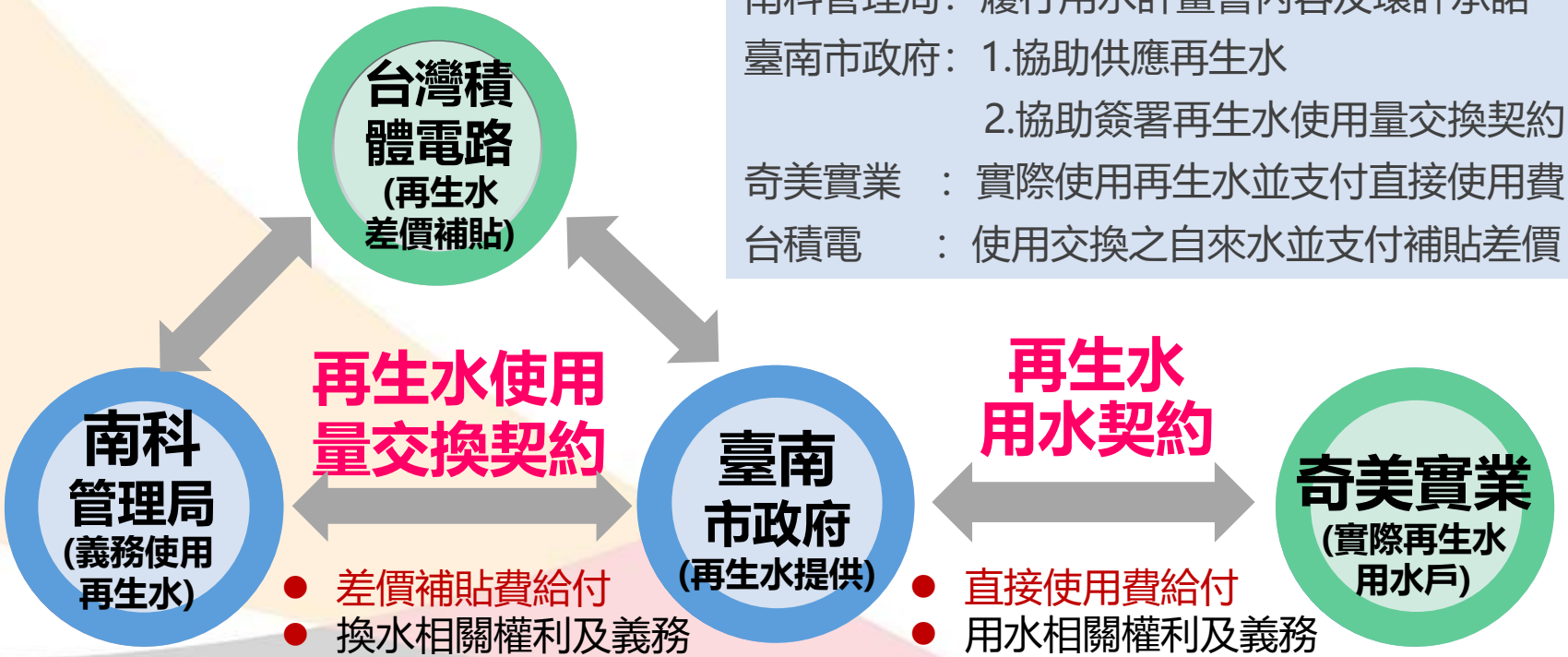
南科環差報告：承諾園區廠商將使用替換之自來水並補貼差價

4.3 仁德再生水水源交換權利義務

用水&水源交換契約簽訂方式

- 依109.7.17研商結議，配合奇美訴求契約簽訂方式採用水契約(二方)、再生水使用量交換契約(三方)分開簽訂

南科管理局：履行用水計畫書內容及環評承諾
臺南市政府：1.協助供應再生水
2.協助簽署再生水使用量交換契約
奇美實業　：實際使用再生水並支付直接使用費
台積電　　：使用交換之自來水並支付補貼差價



- 由南市府作橋梁，於110年10月29日簽訂雙方用水契約與三方再生水使用量交換契約

4.4 水源交換水價支付

水價支付方式

- 再生水使用費：直接使用費+差價補貼費
- 直接使用費：代履行者過往使用自來水之價格
- 差價補貼費：再生水與代履行者使用自來水價之差價

範例：

- 再生水使用費(28元/m^3)
  - 代履行者(奇美實業)支付12元/m^3 (直接使用費)
  - 再生水需水端(台積電)支付16元/m^3 (差價補貼費)

水源交換優勢

- 減輕政府輸水管線建設費的投入，且避免管線施工困難度，增加計畫推動的可行性
- 降低操作維護費，達到淨零碳排目標
- 可滿足再生水供應目的，且代履行者亦可實踐企業ESG

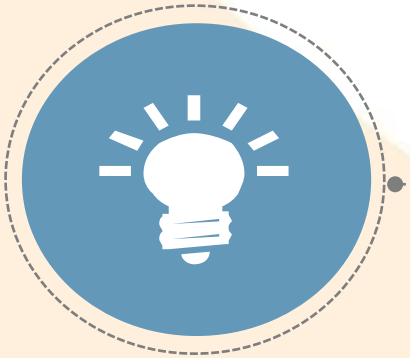
05

推動效益及結語

5.1 結語

綠色產業 永續創新

環教綿延



- 紅樹林生態保育解說
- 再生水設備導覽
- 校外輔導教學活動
- 結合環保團體辦理教育宣導

水資永續

- 開闢新水源
- 創造產業與民生雙贏
- 水資源有效再利用

創新產業

- 推動國家高科技產業發展
- 落實產業扶持政策
- 拓展再生能源商業契機

5.2 推動效益(1/2)

滿足南科用水需求，將高科技產業根留台南

廠商家數:130家

就業人數69,191人

積體電路17家

UMC tsmc

光電產業31家

INNOLUX 群創光電 HannStar

生物科技35家

台灣神隆股份有限公司 ScinoPharm Taiwan, Ltd.

精密機械28家

MEC HMI HERMES MICROVISION

周邊廠商19家

2019年營業額：6,865億元

南科先進製程5奈米與3奈米投資案預期效益：

- 合計投資額約1兆1,500億元，可創造就業人數約9,000人
- 將有利吸引全球頂尖廠商，打造全球規模最大半導體產業聚落

5.2 推動效益(2/2)


降低傳統水源開發壓力
擴增產業產值及發展
中央、地方合作，增加就業及投資效益
再生水缺水時之救命水
確保供水穩定及降低缺水風險
滿足南科園區用水需求
壓力供水確保水質

感謝聆聽
敬請指教

台灣國際水週
Taiwan International Water Week

Capacitive deionization as an energy-efficient approach to reclaim wastewaters for diversifying water sources

Chia-Hung Hou, Ph.D.

Professor

Graduate Institute of Environmental Engineering

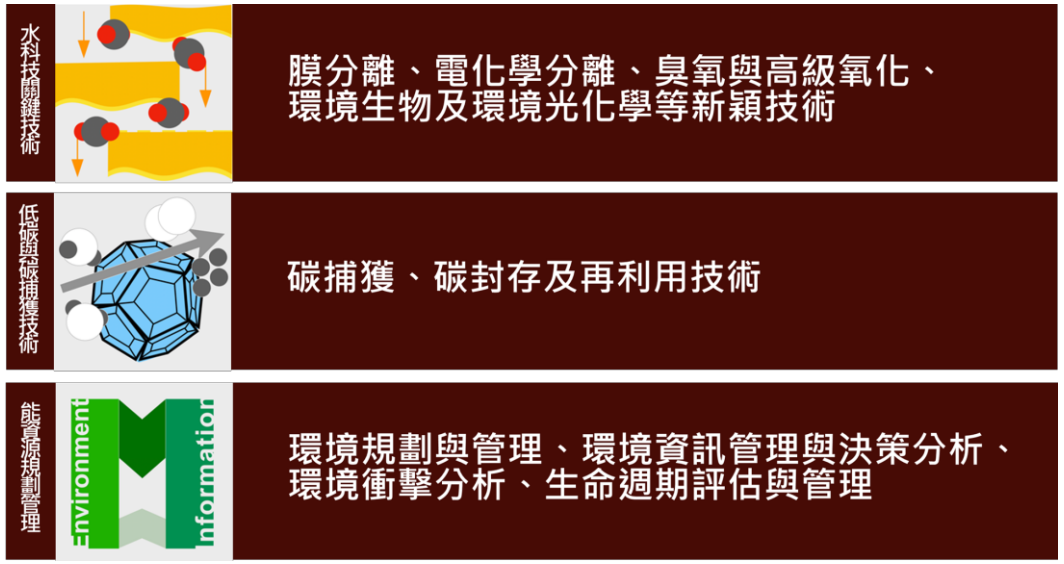
National Taiwan University

October 13, 2022

水科技與低碳永續創新研發中心(WInnER)

Cross-discipline research

- Chemical engineering
- Civil engineering
- Environmental engineering
- Geosciences



Water-Related Challenges: Water-Energy Interactions

SUSTAINABLE DEVELOPMENT GOALS

6 CLEAN WATER AND SANITATION

ENSURE AVAILABILITY AND SUSTAINABLE MANAGEMENT OF WATER AND SANITATION FOR ALL

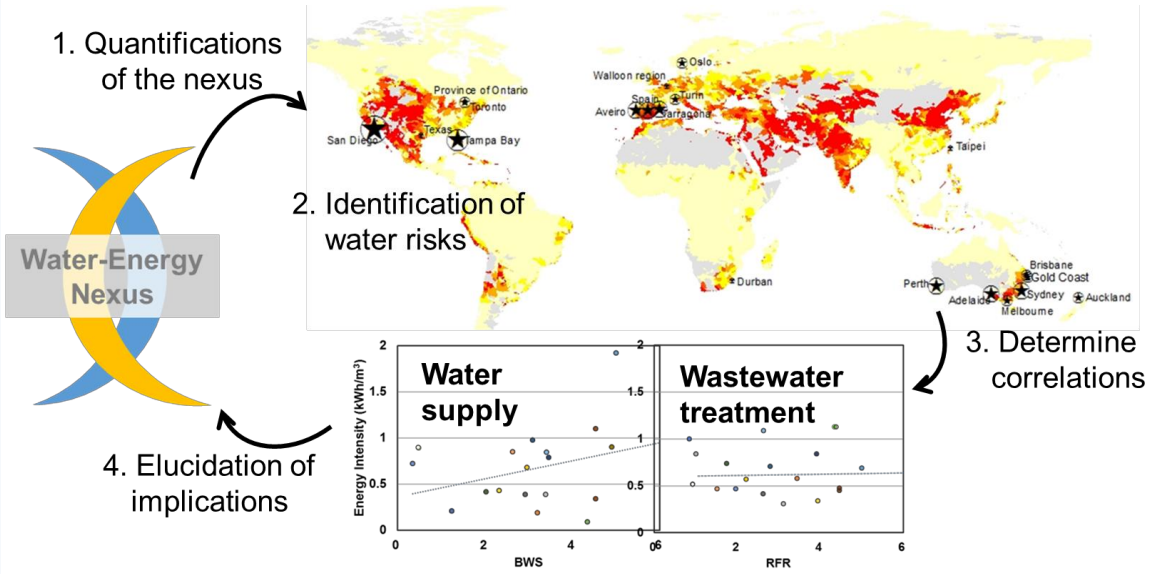
6 CLEAN WATER AND SANITATION

Target

6.4

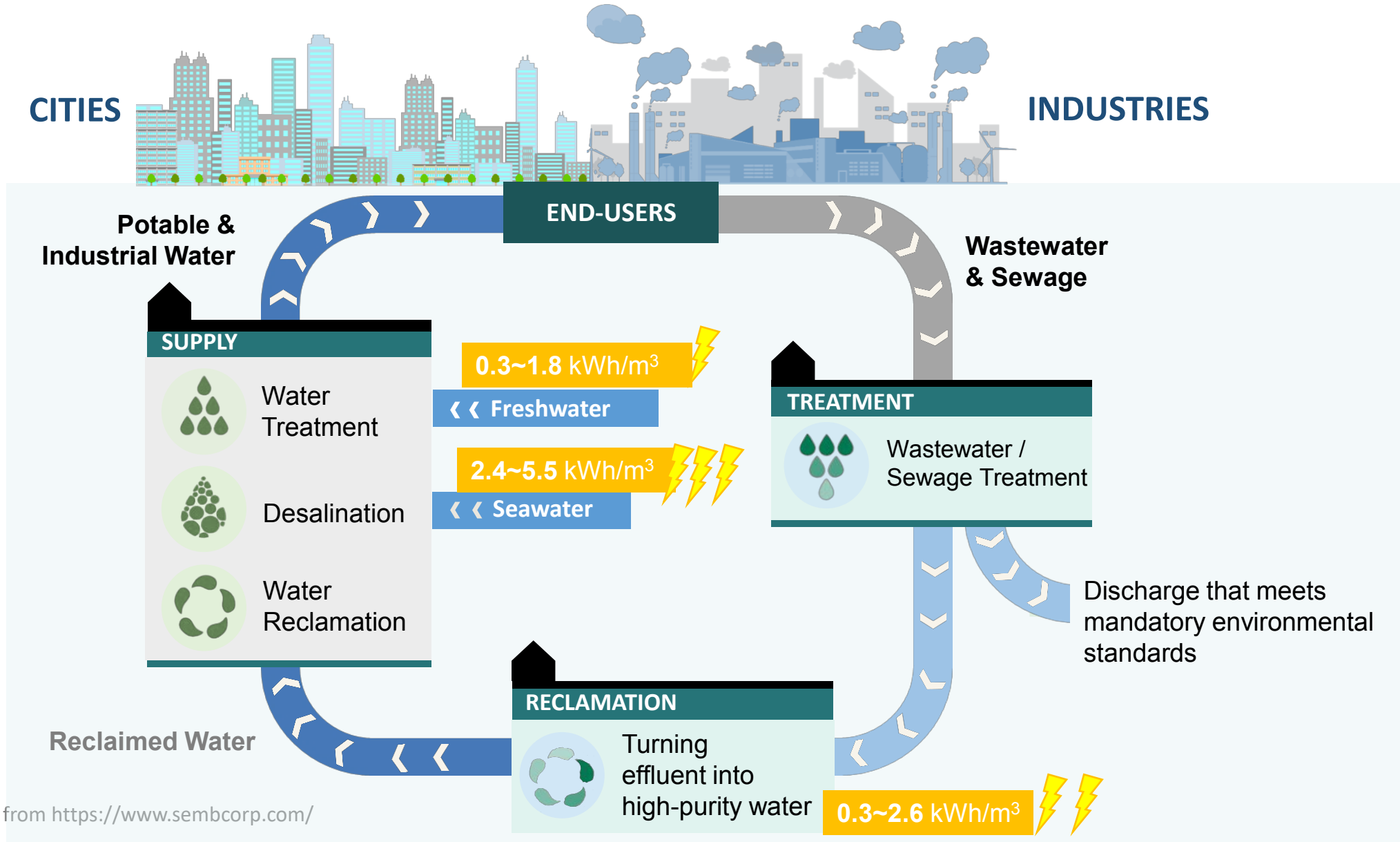
By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

Water-Energy Nexus for Water and Wastewater Systems



(Lee et al., Applied Energy, 2017)

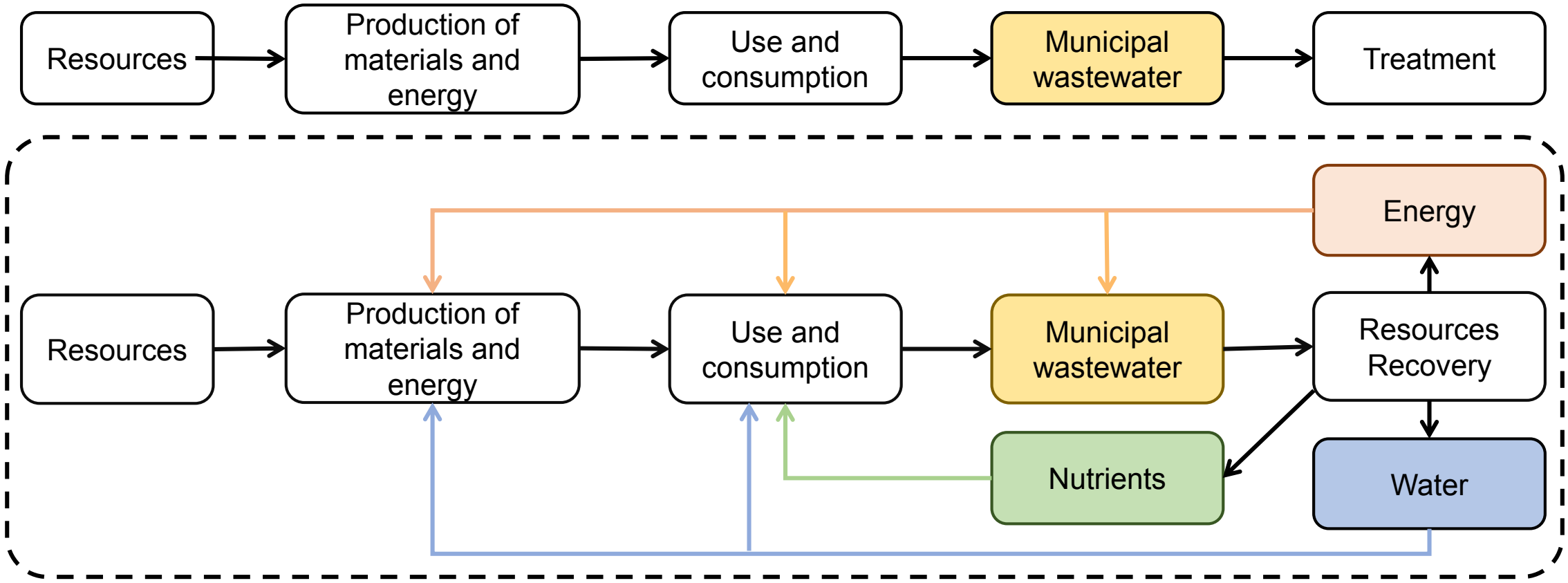
Water Cycle: Water-Energy Interactions



Adopted from https://www.sembcorp.com/

Low-Carbon-Emission Water Treatment Technology

- The trend of change: from ***linear relationship*** to ***circular economy***



- The need of **life cycle thinking**

Taiwan: The Water-starved Island
How Big is the Impact on the Industry (semiconductor)?

Taiwan has faced serious water threats in 2002, 2003, 2004, 2005, 2009, 2010, 2011, 2014, 2015, 2021.

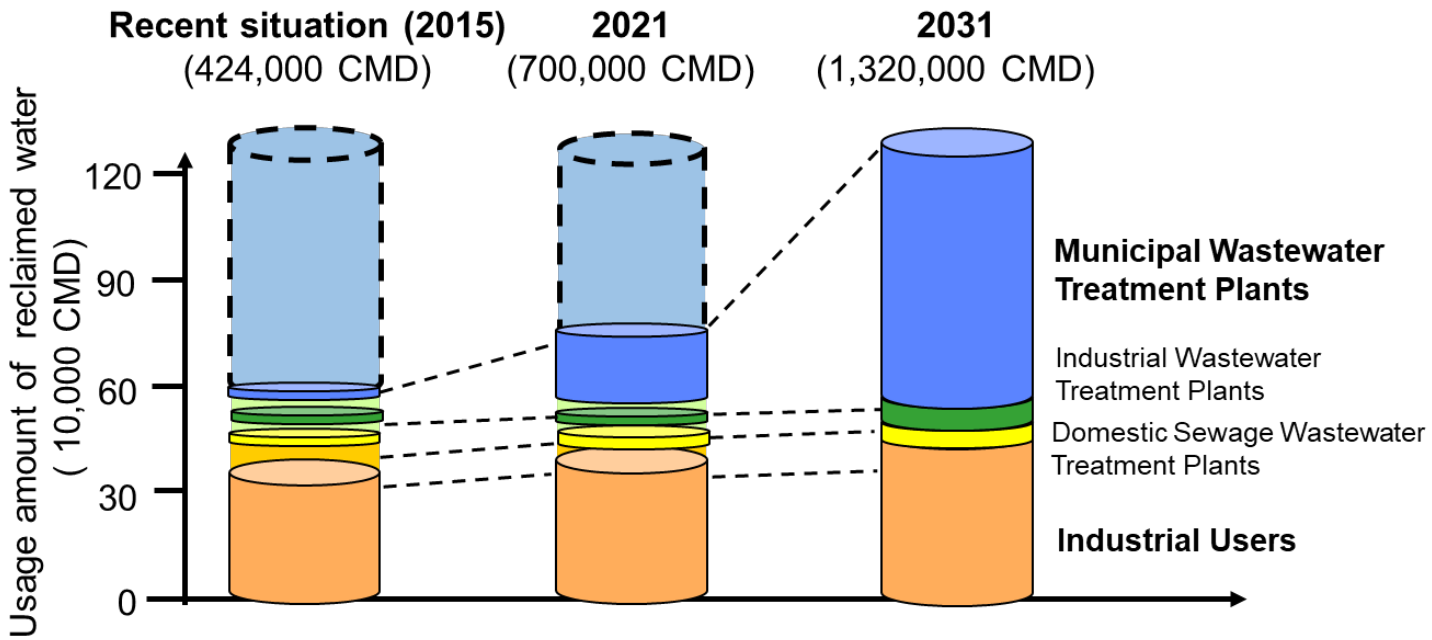
Water Reuse to Meet Booming Demand of High-Tech Industry

Water Policies for the New Century

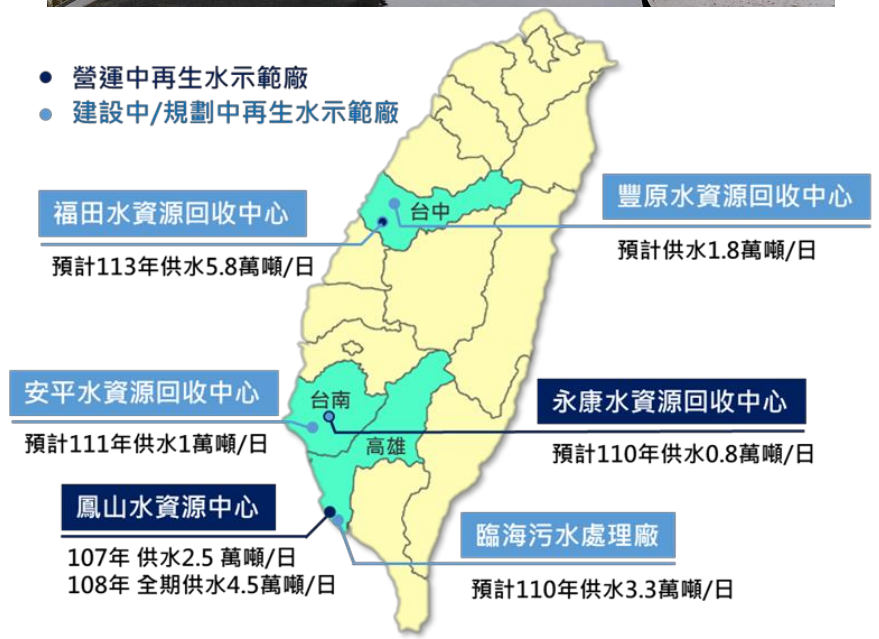
- Water reclamation, recycle and reuse

經濟部水利署 Water Resources Agency, MOEA

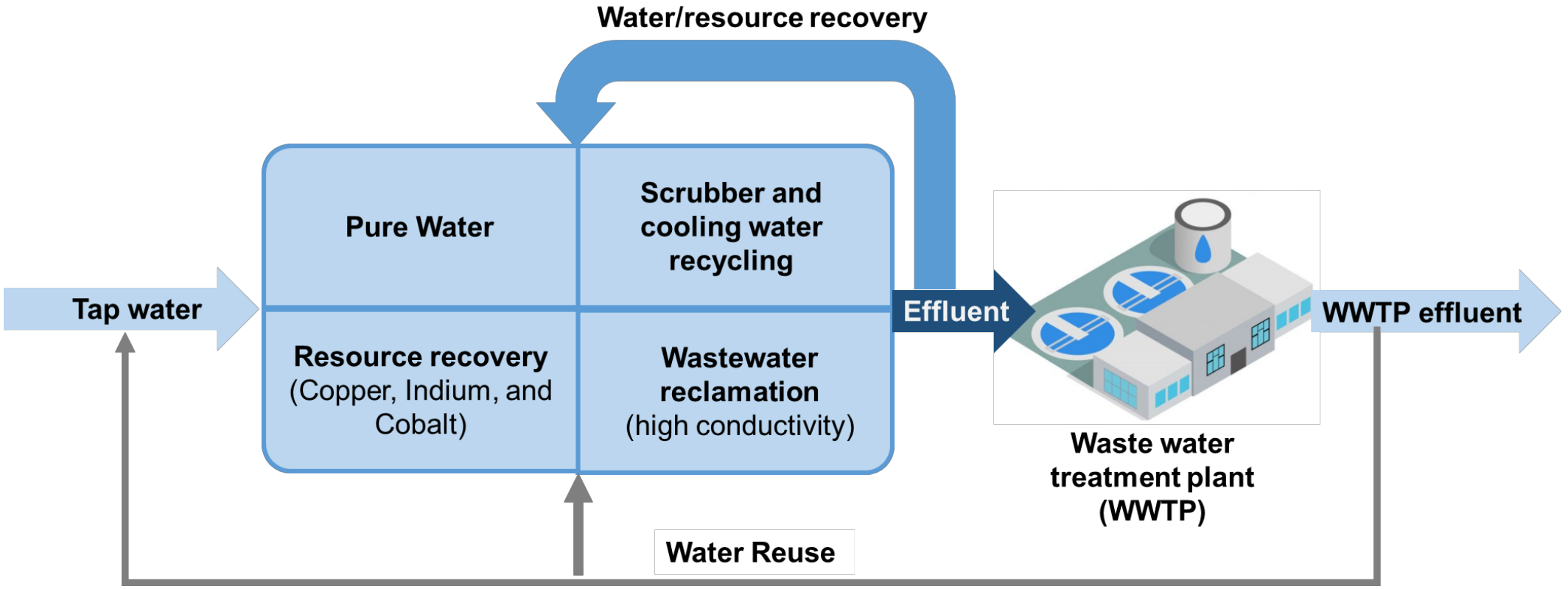
內政部營建署 Construction and Planning Agency Ministry of the Interior



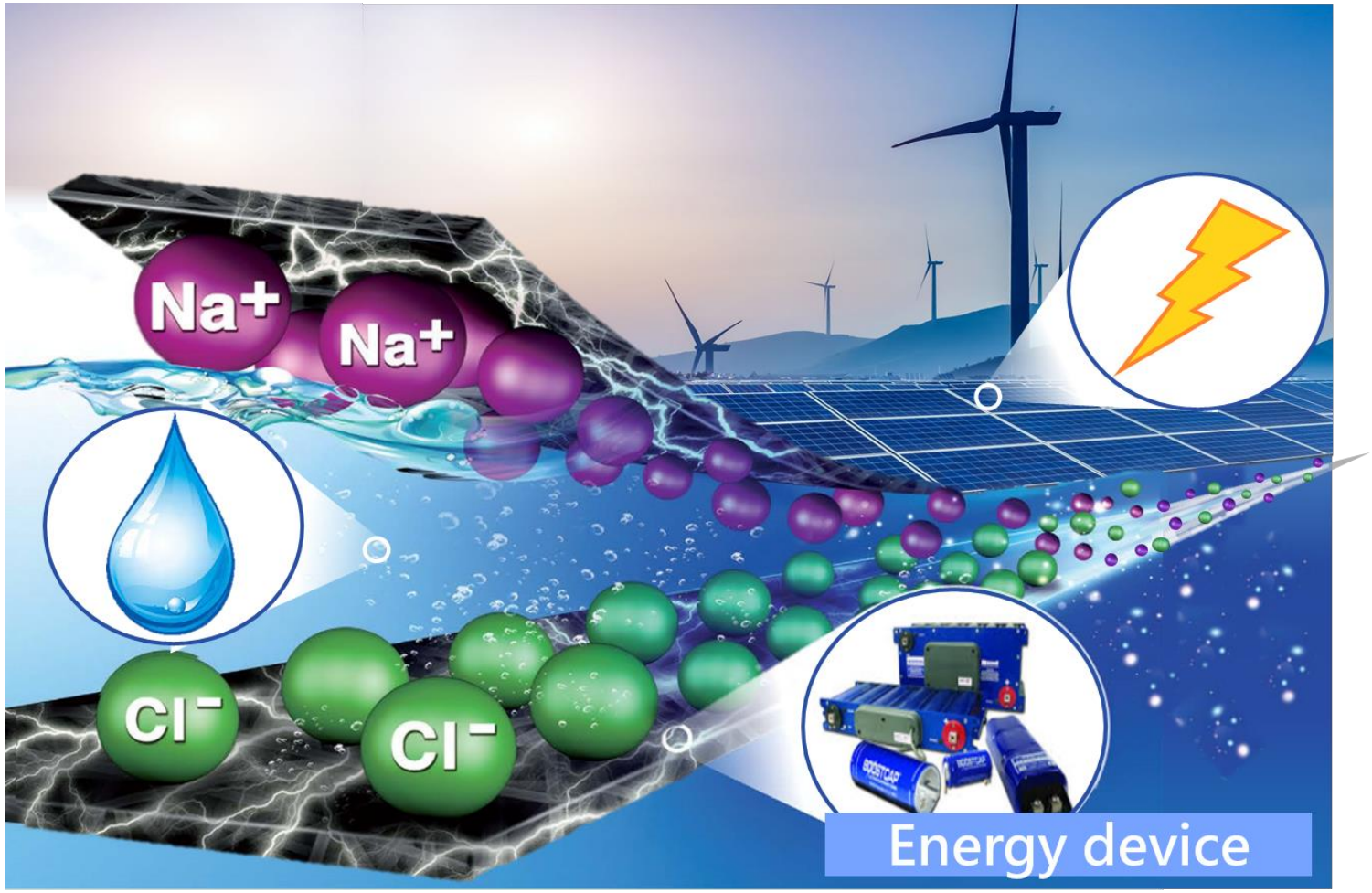
(資料來源：財團法人中興工程顧問社)



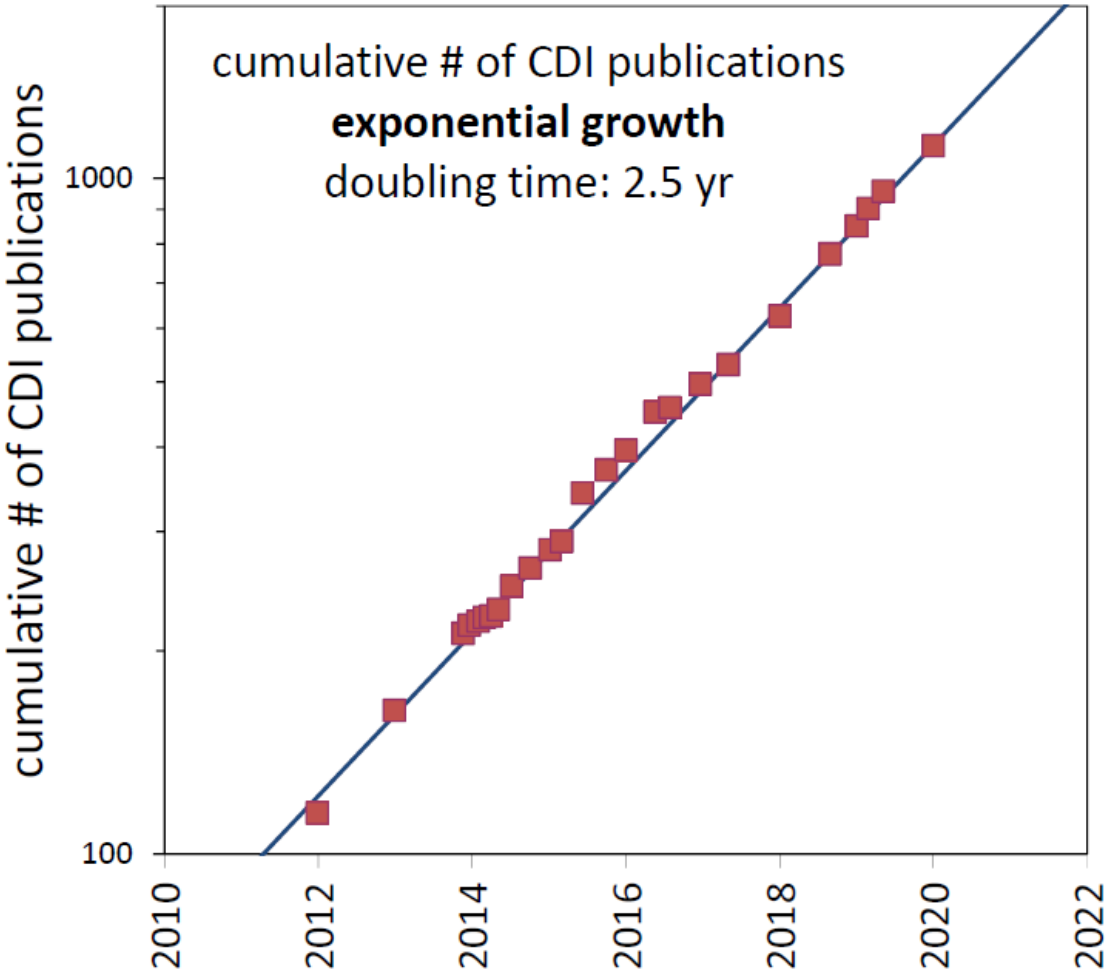
Water Reuse & Ion Separation in High-Tech Industry



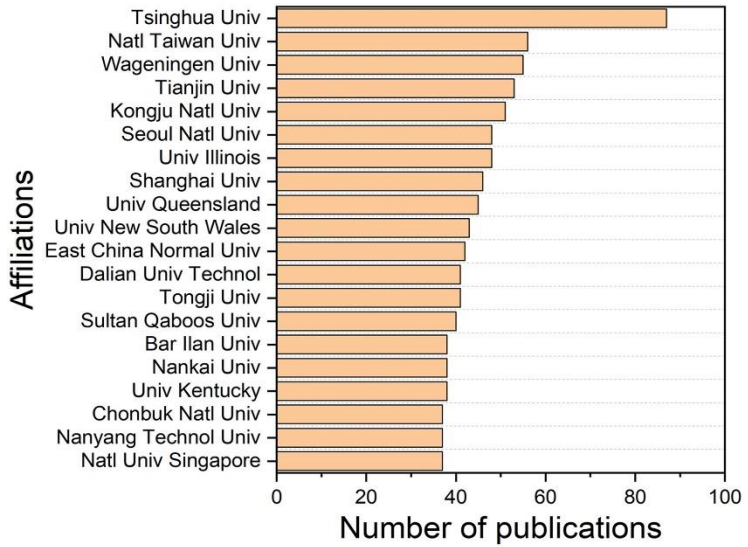
(Membrane) Capacitive Deionization

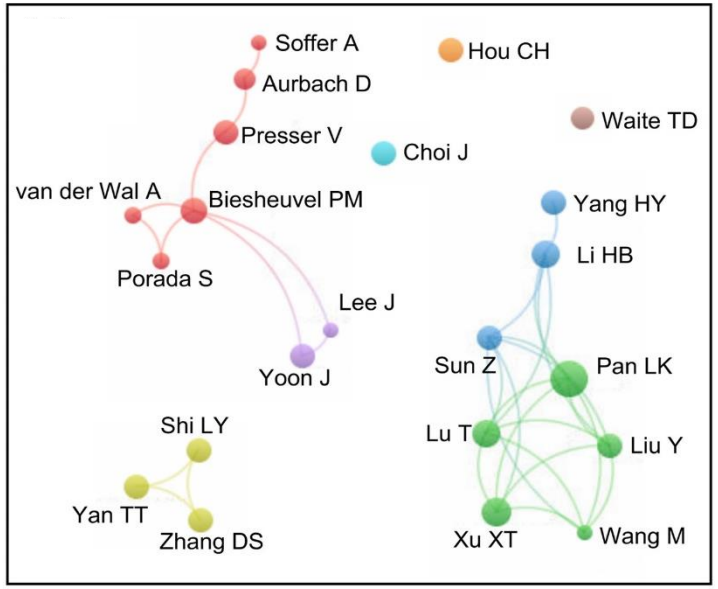


CDI Keeps Growing Exponentially !



(Maarten Biesheuvel • January 7, 2020)





(Pang and Shen, Desalination 2022)

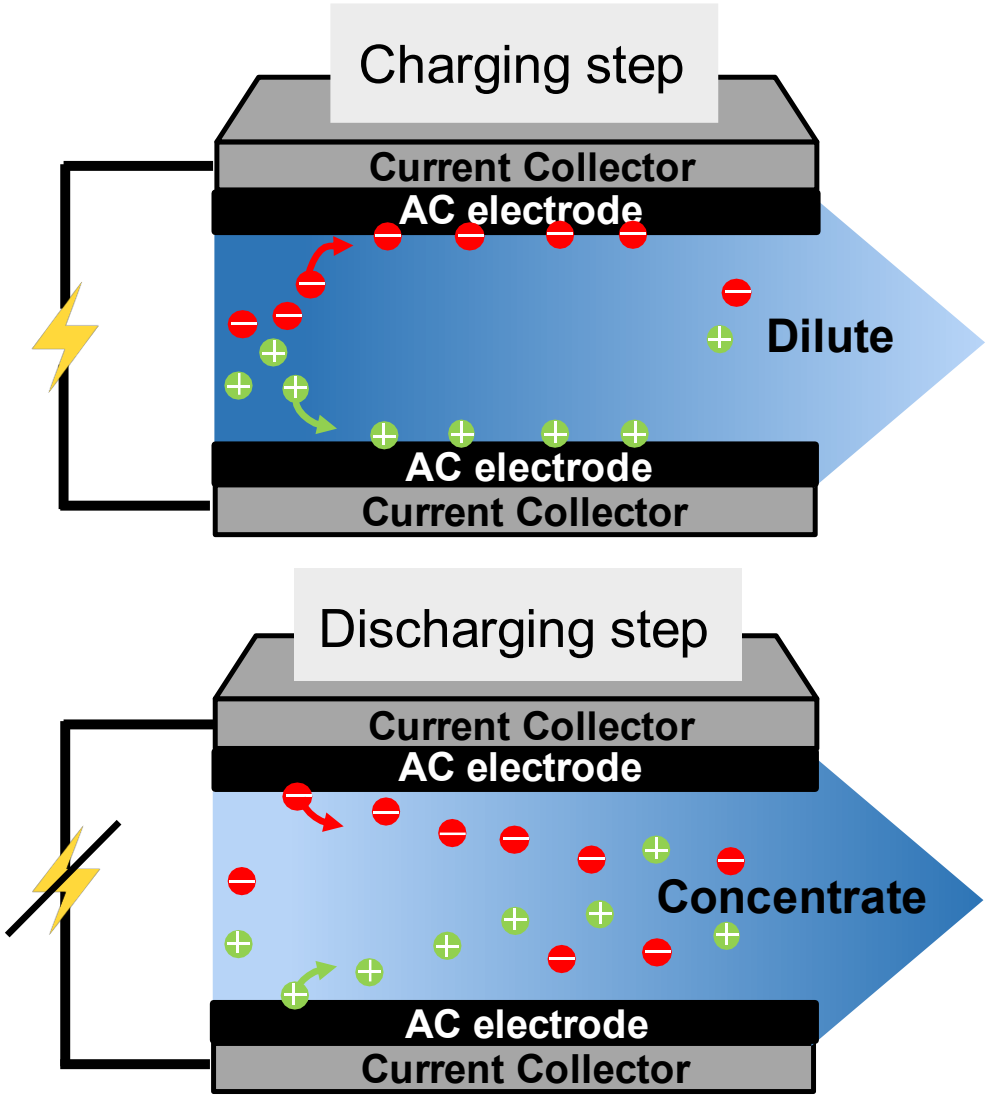
Capacitive Deionization (CDI)

Electrosorption of ions

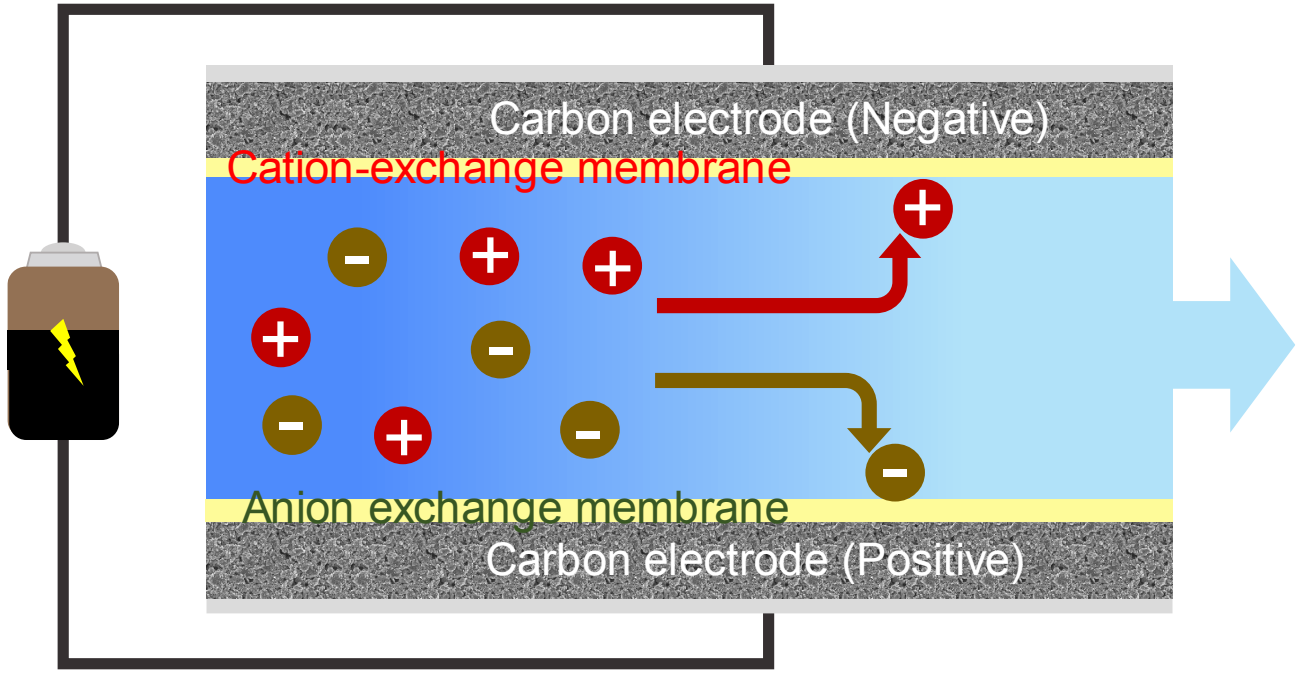
- Highly porous carbons for electrical double-layer charging
  - Activated carbon
  - Carbon aerogel
  - Templated carbons

Operation

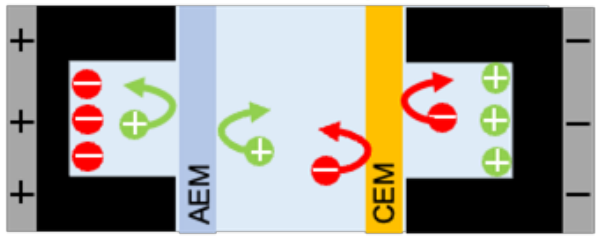
- Low applied voltage
- Direct energy recovery
- High water recovery
- Low chemical usage
- Environmental friendliness



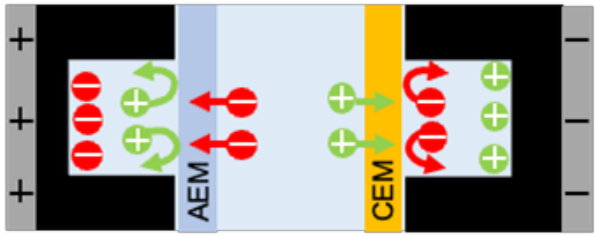
Membrane Capacitive Deionization (MCDI)



Block co-ion repulsion

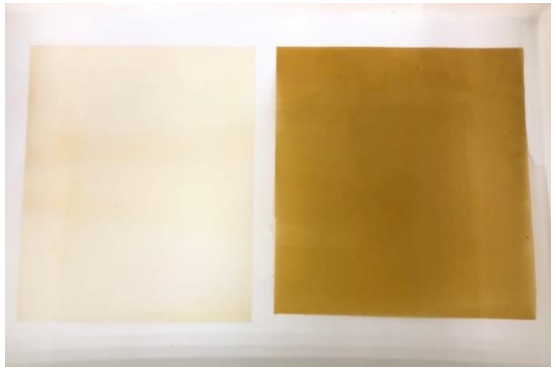


Accumulate local co-ion



Compensate excess charge

Homogeneous ion exchange membrane (IEM)



MCDI v.s. CDI

- Co-ion effect ↘
- Salt adsorption capacity ↗
- Charge efficiency ↗
- Energy consumption ↘

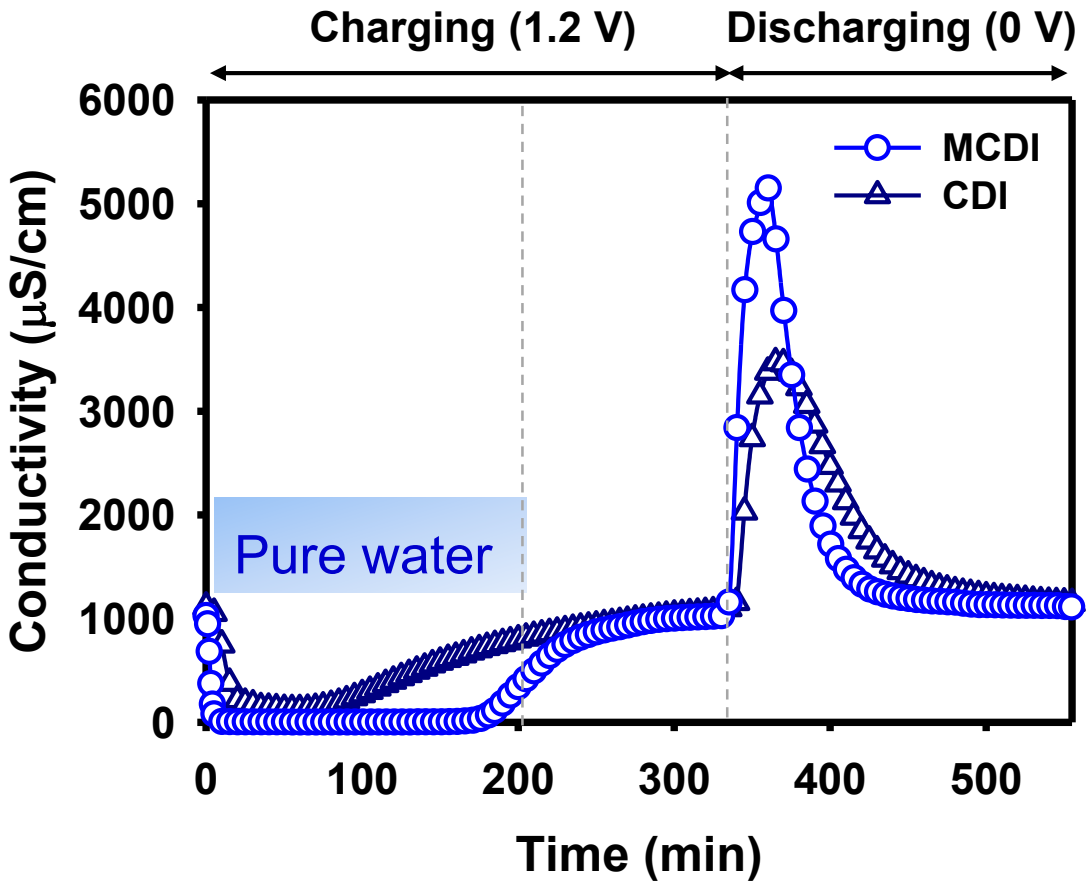
CDI *v.s.* MCDI

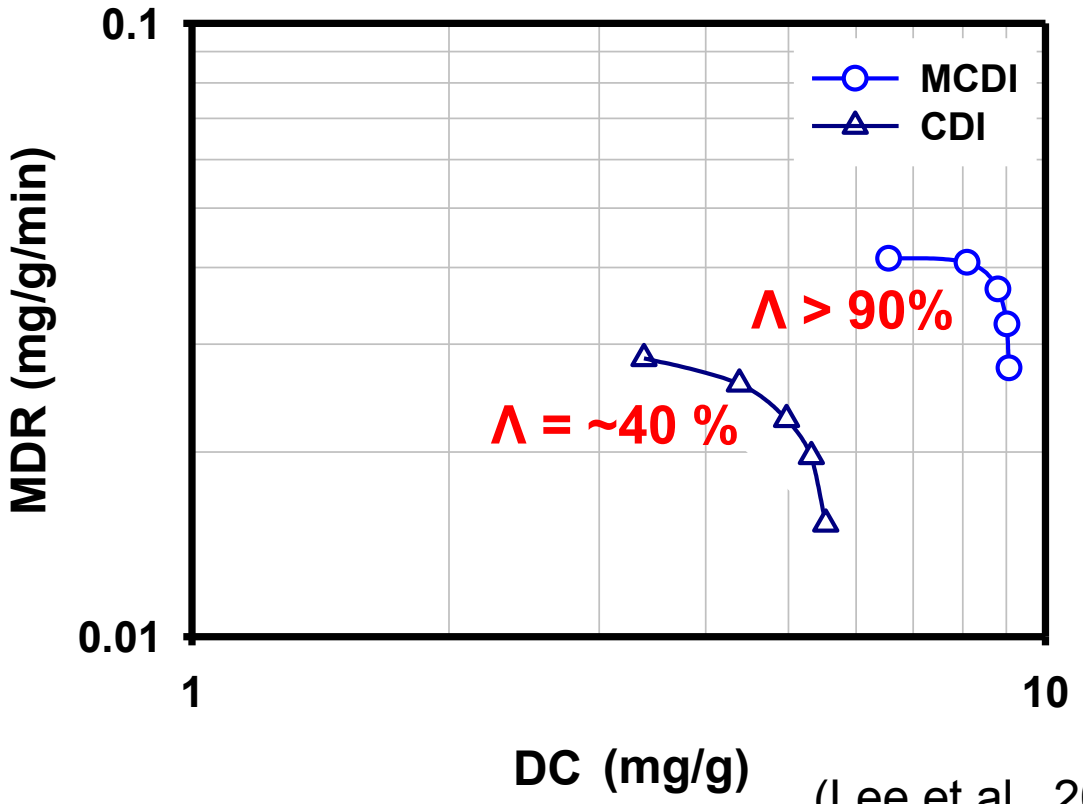
Desalination performance of MCDI

DC = 9.1 mg/g; MDR=0.0274 mg/g-min

E_v = 0.323 kWh/m^3; E_m = 0.05 kW/mol;

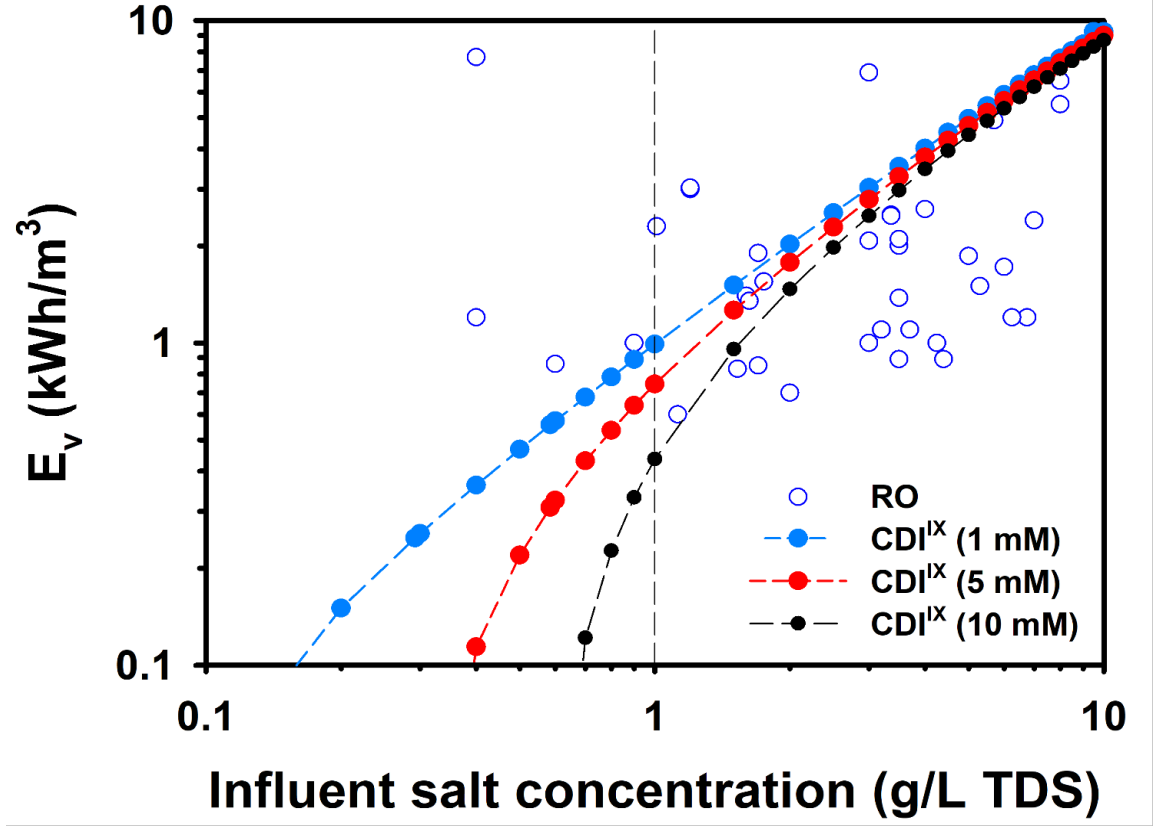
10-pair AC electrodes





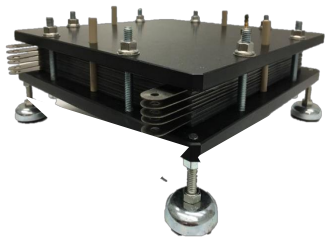
(Lee et al., 2019)

Energy Considerations in MCDI



*Energy consumption (2000 mg/L salty water)
RO: 2.25 kWh/m^3
EDR: 2.03 kWh/m^3
CDI : 0.59 kWh/m^3
(Welgemoed and Schutte, 2005)

*CDI could be competitive technology at NaCl concentrations below 5000 mg/L.
(Anderson et al., 2010)



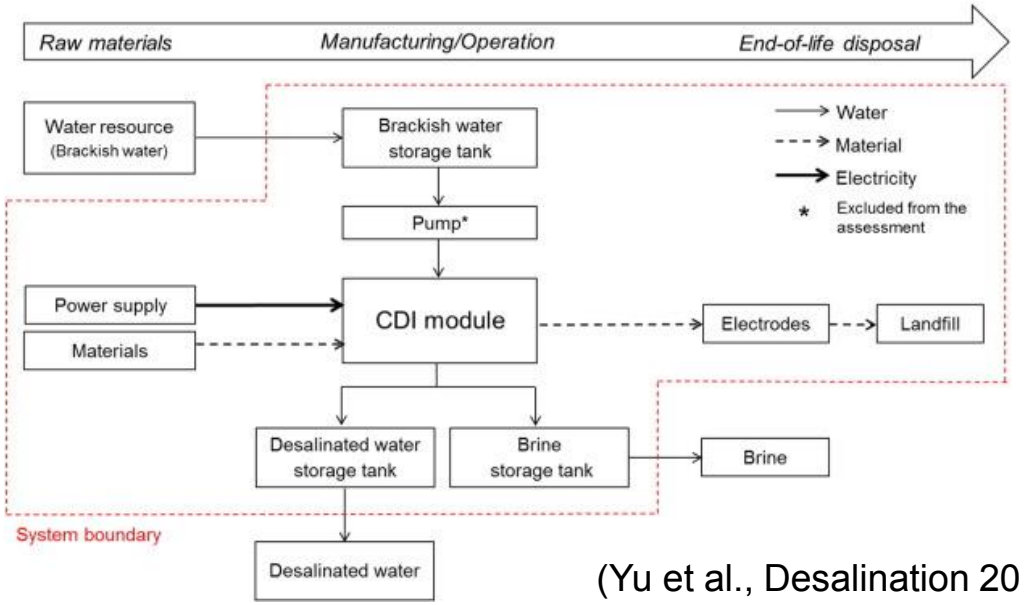
Energy consumption is calculated based on the experimental data of CapPure module.

- MCDI could have lower energy consumption for desalination of brackish water or low-salinity solutions (TDS < 5000 mg/L).

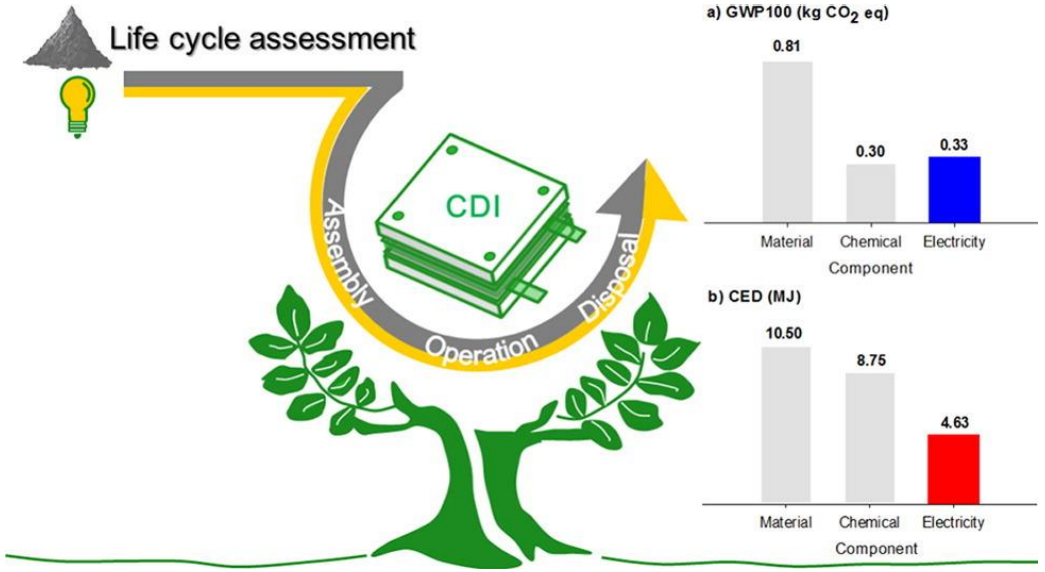
Life Cycle Assessment of (M)CDI

Analysis of environmental impacts cumulative energy demand.

- Energy-related environmental impacts were lowest for electricity consumption.
- Material and chemical uses contributed to most of the environmental impacts.

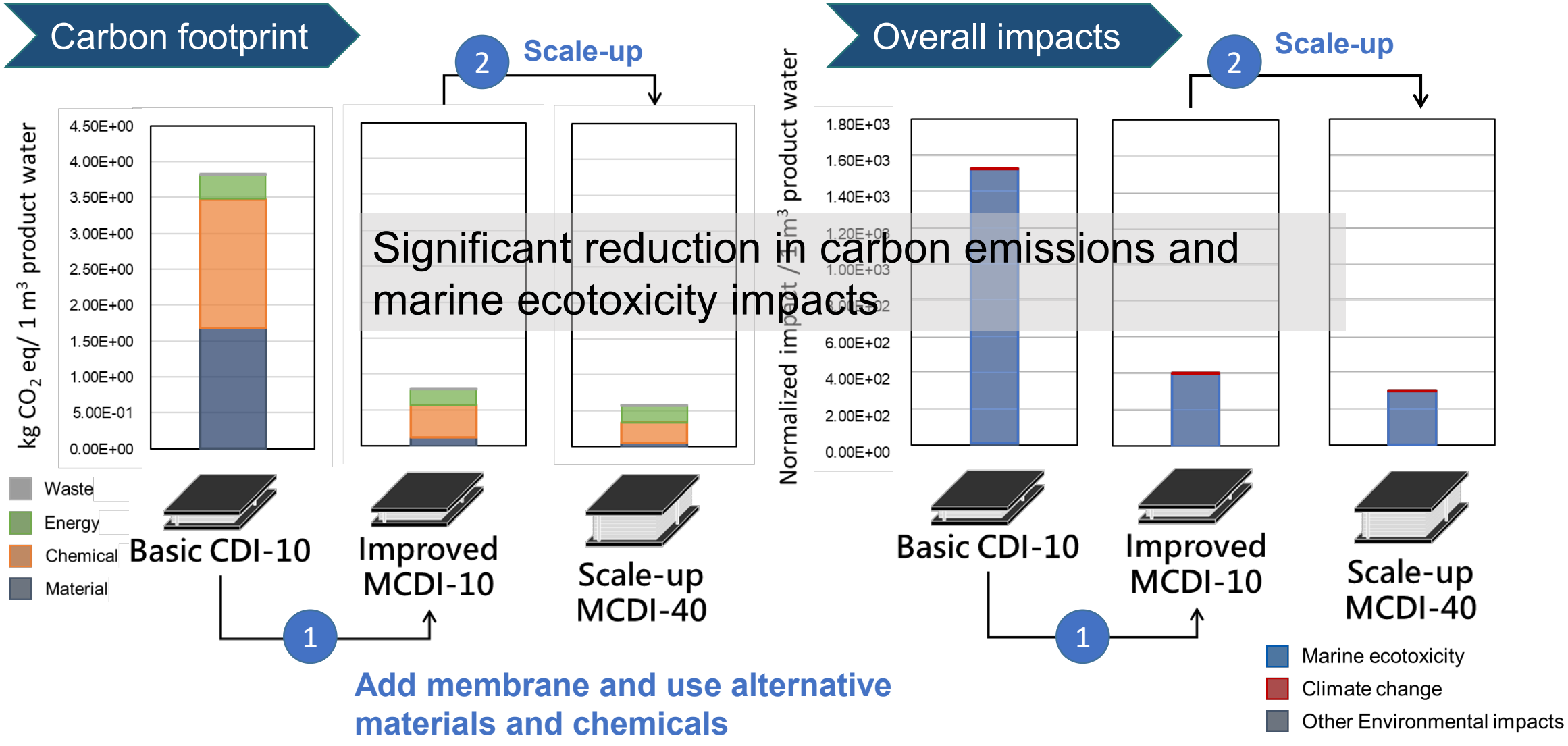


(Yu et al., Desalination 2016)



Life Cycle Assessment (LCA) is commonly used in corporate carbon footprint verification to thoroughly and systematically quantify direct and indirect carbon emissions.

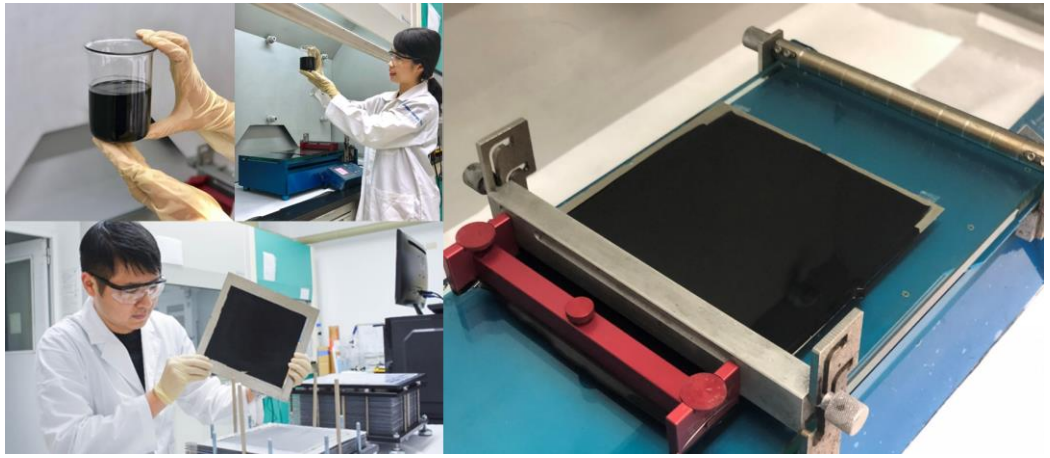
Advancement of MCDI in Improving its Environmentally Friendliness

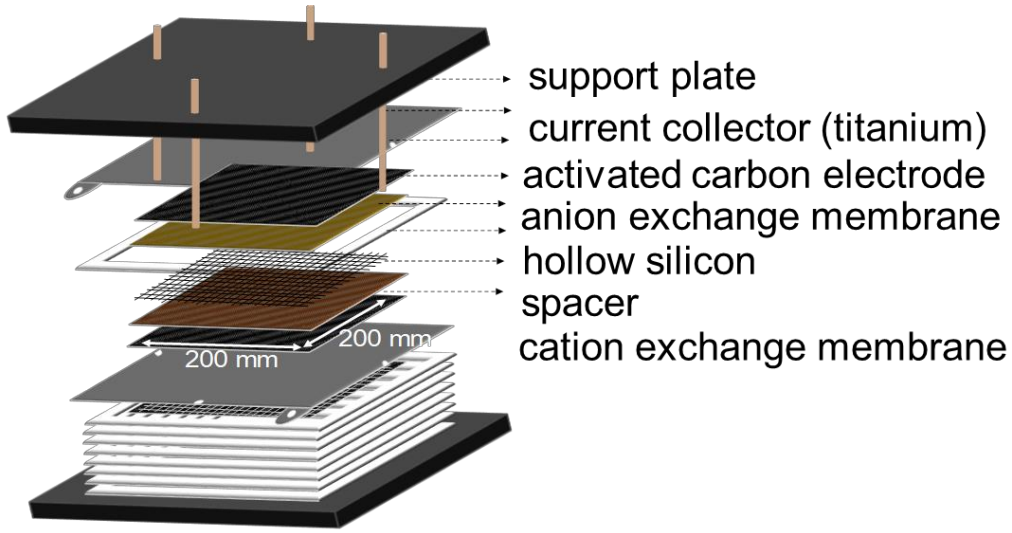


Significant reduction in carbon emissions and marine ecotoxicity impacts

Technology Demonstration:
Scale-up MCDI stack for water reclamation

Prototype of the MCDI system



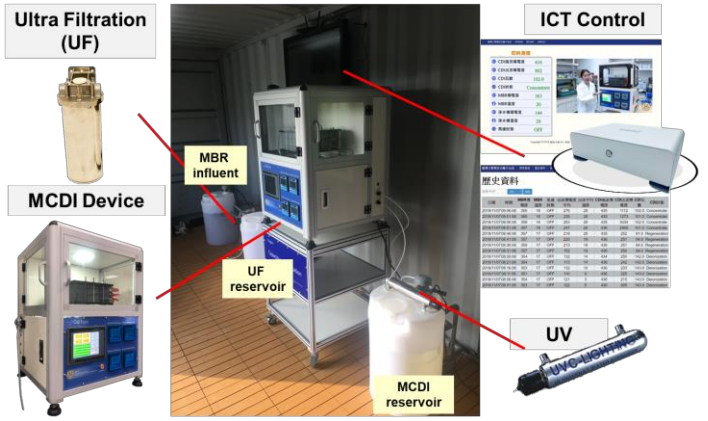


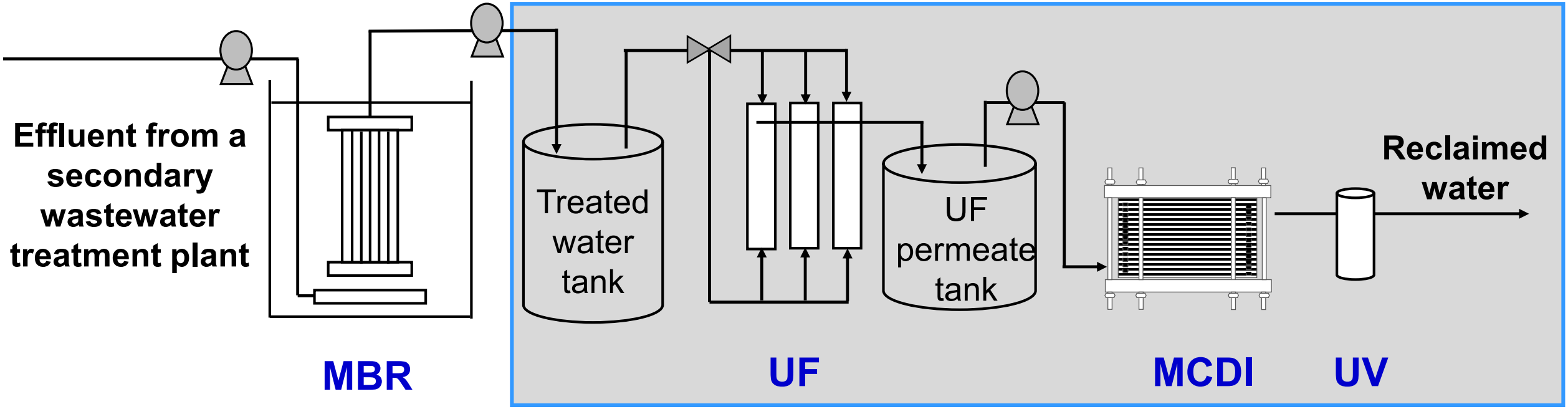
MCDI-Based System for Water Reuse

經濟部水利署 Water Resources Agency, MOEA

Technology Demonstration

- Water Resources Recycling Center, North District Taoyuan

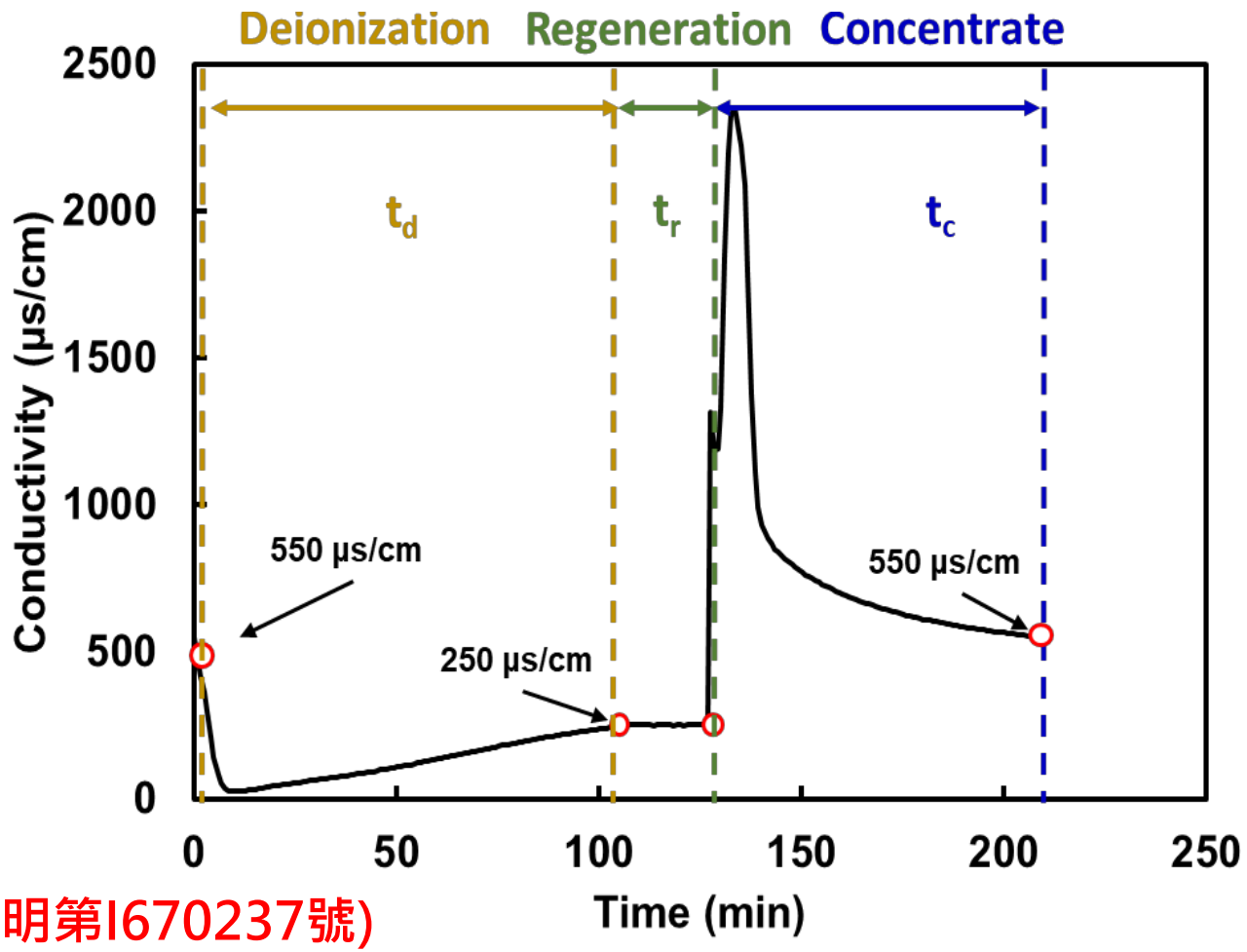




Operation Mode

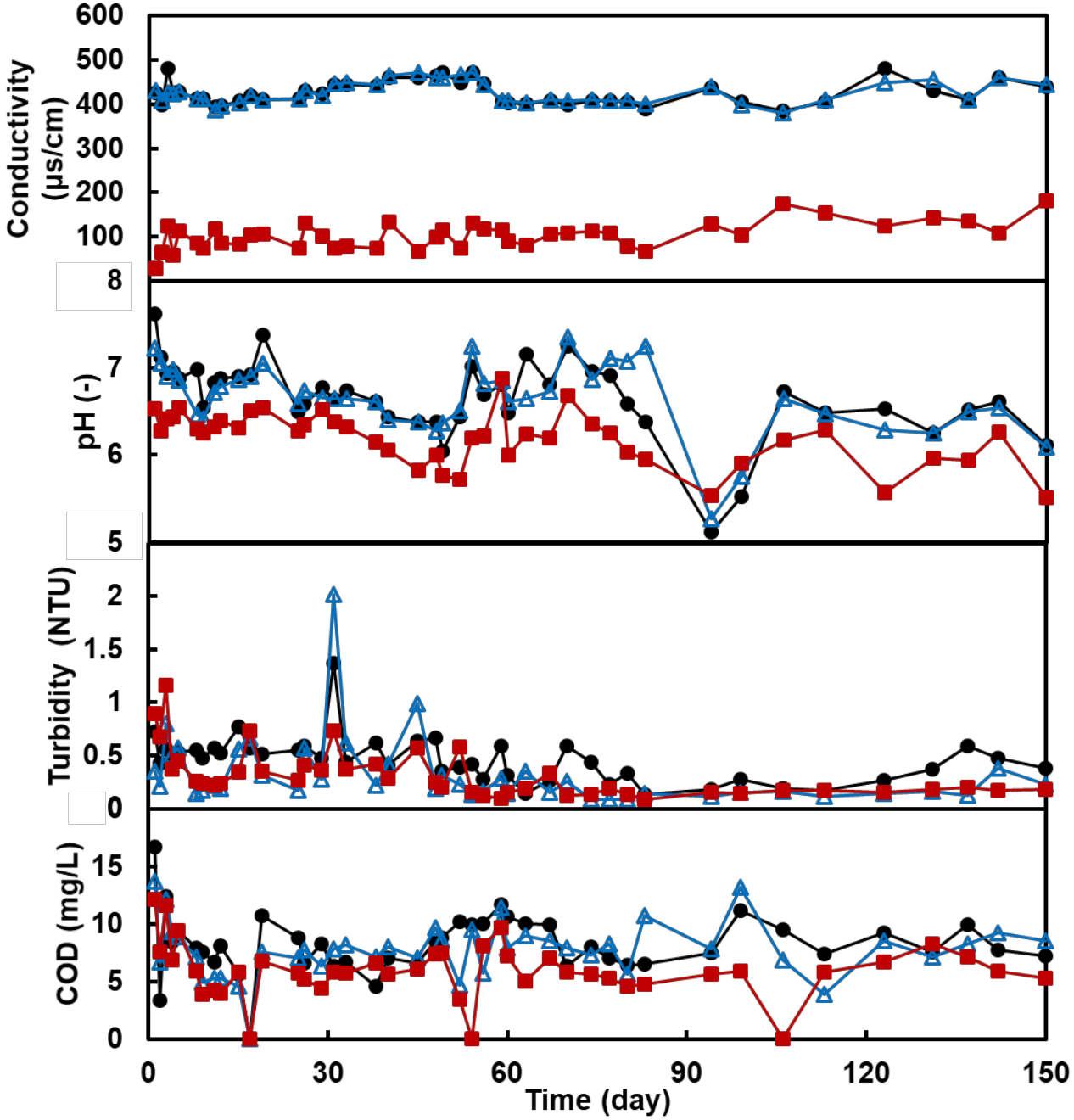
MCDI stack with
40-pair activated carbon electrodes

Deionization		Concentrate
Pump-on	Pump -off	Pump-on
Charging (1.2 V)	Discharging (0 V)	



發明專利：
電容去離子控制方法及其自動控制伺服器(發明第I670237號)

Water Quality

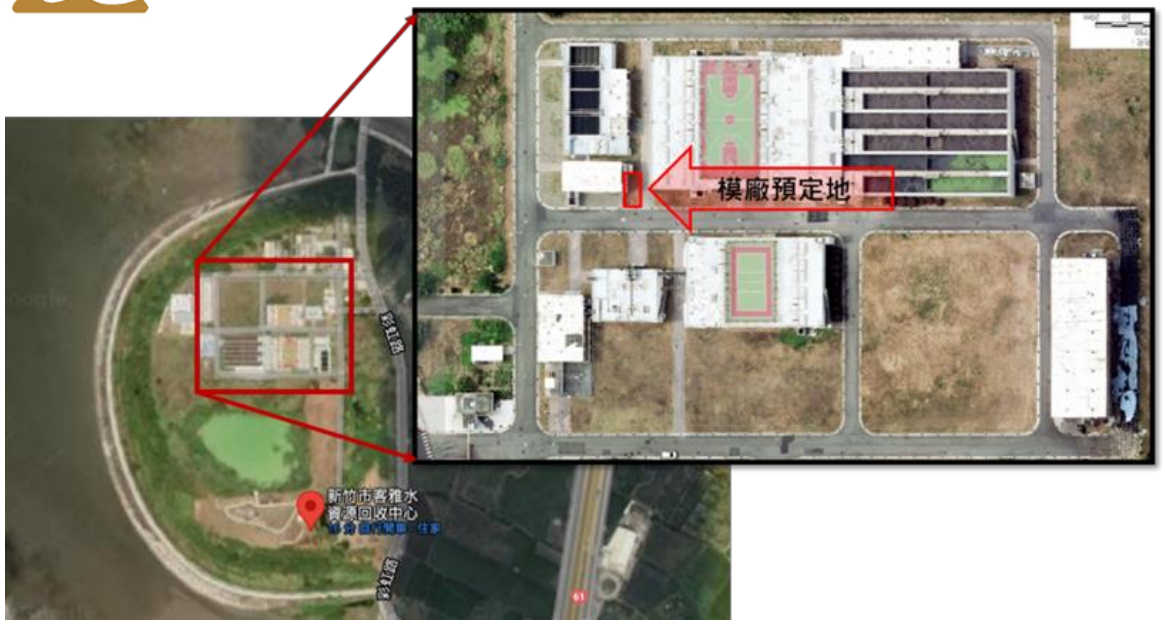


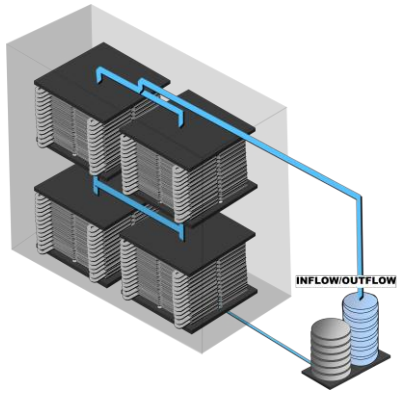
(Shen et al., Desalination, 2021)

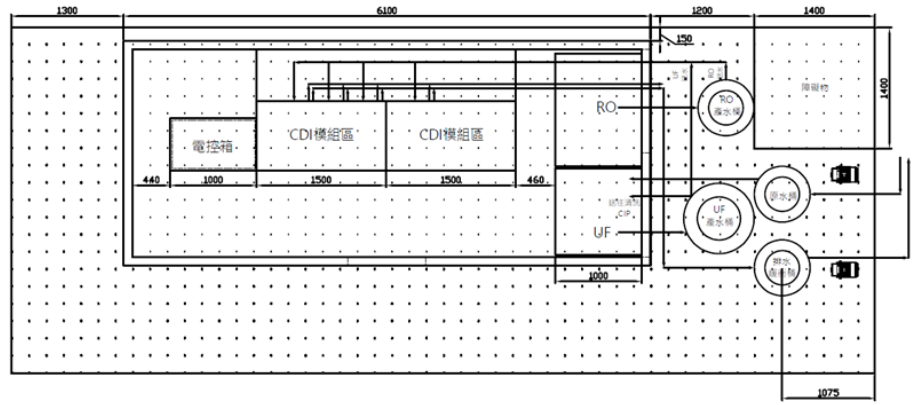
A Pilot-Scale MCDI to Reclaim WWTP Effluents

- EC < 250 μS/cm
- Energy consumption < 0.3 kWh/m^3
- Productivity > 20 CMD
- Water recovery: ~80%

內政部營建署
Construction and Planning Agency
Ministry of the Interior

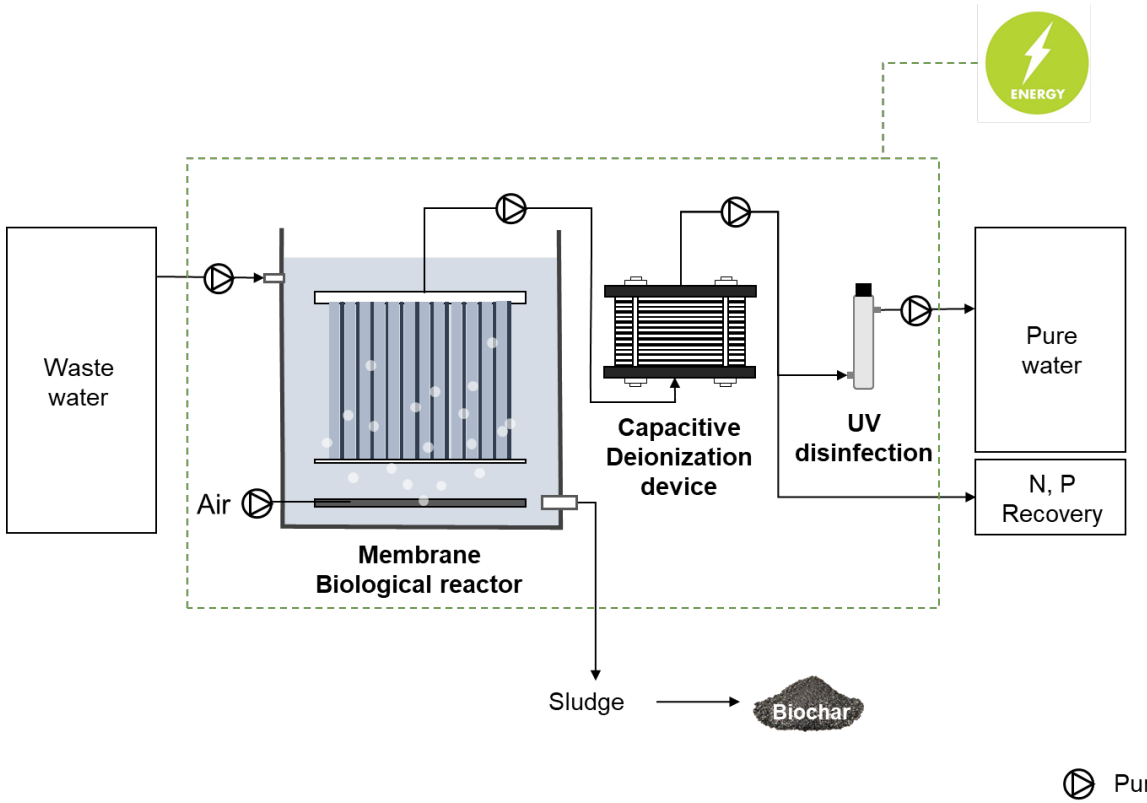






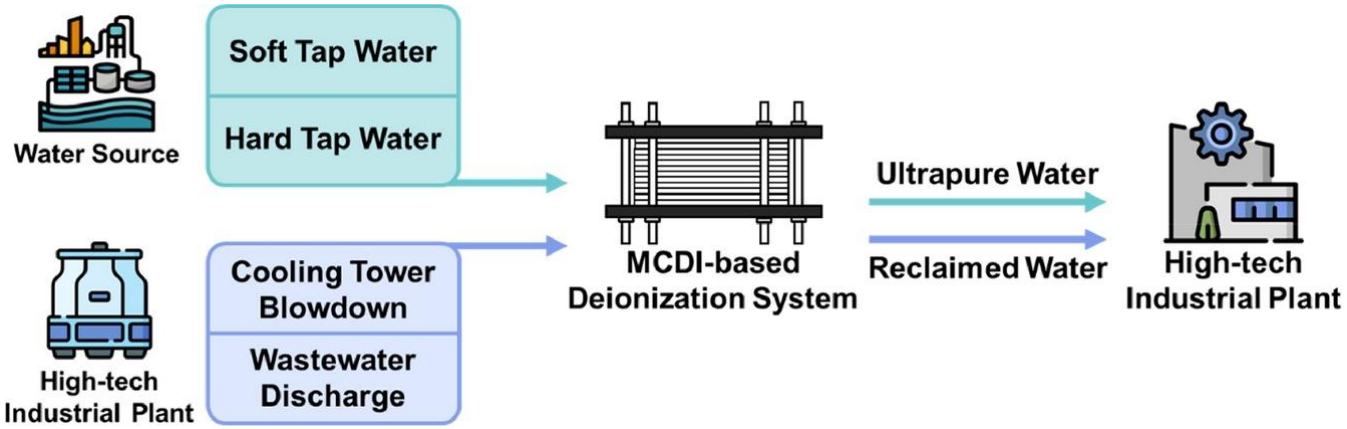
Modular, Decentralized MBR-MCDI System

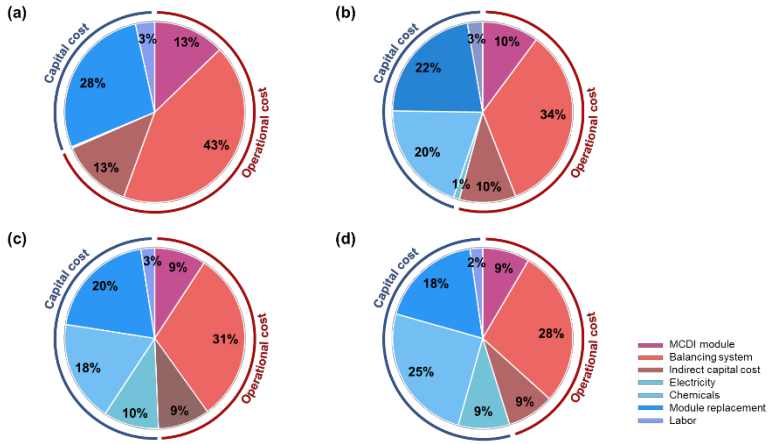
- NTU demo site for water reclamation
- Incorporating MBR and MCDI

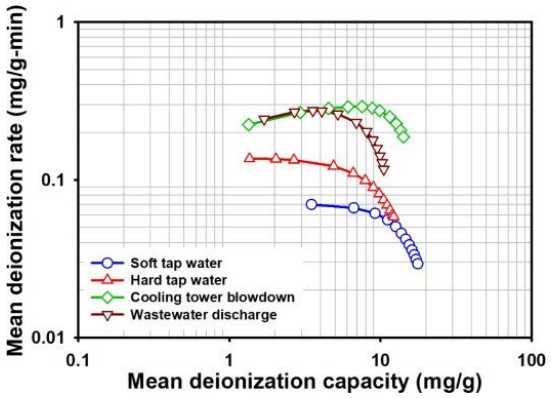


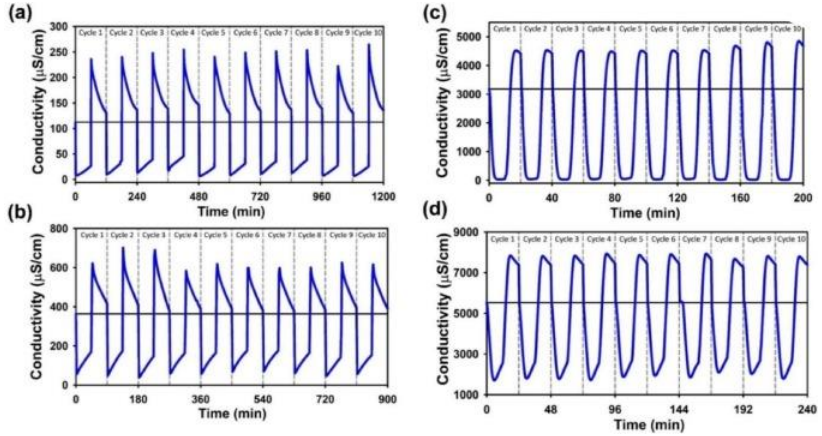
Technological and Economic Perspectives of MCDI

From tap water purification to wastewater in high-tech industries







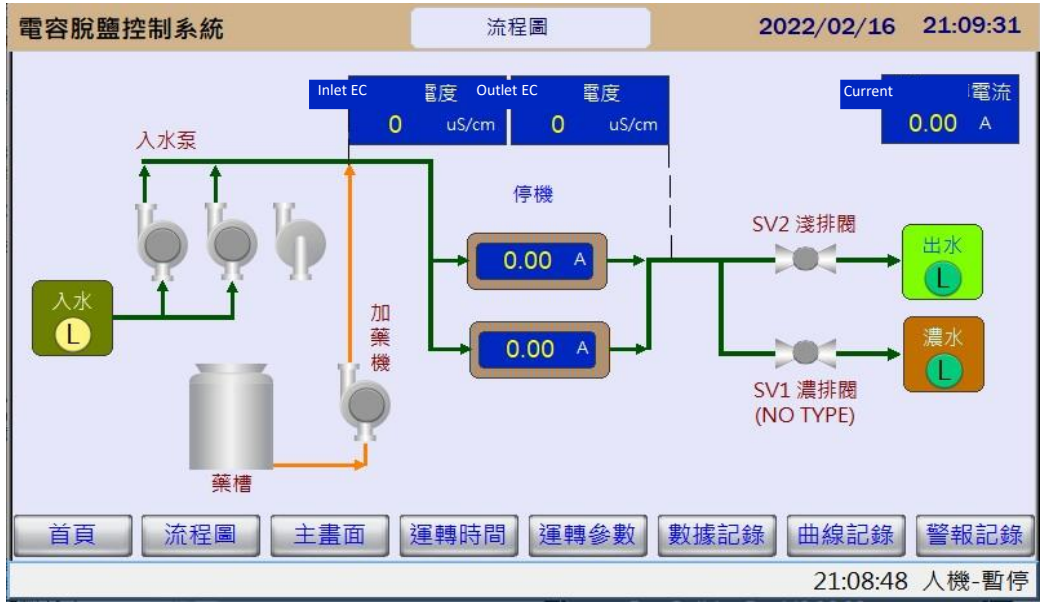


(Chen et al, Resources, Conservation and Recycling, 2022)

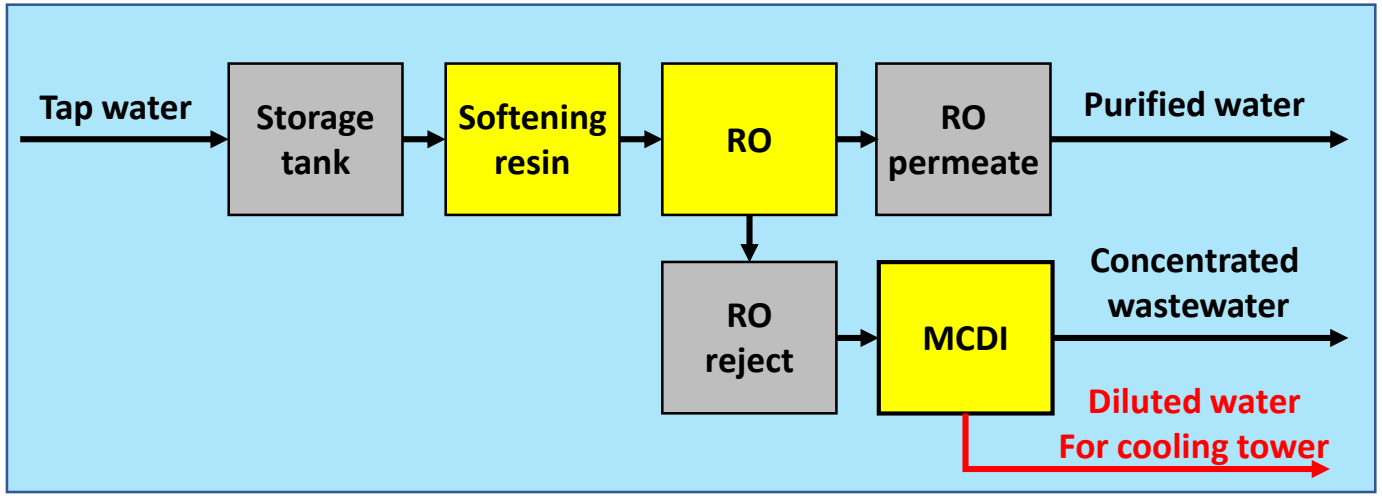
Modular MCDI System in Industry Application

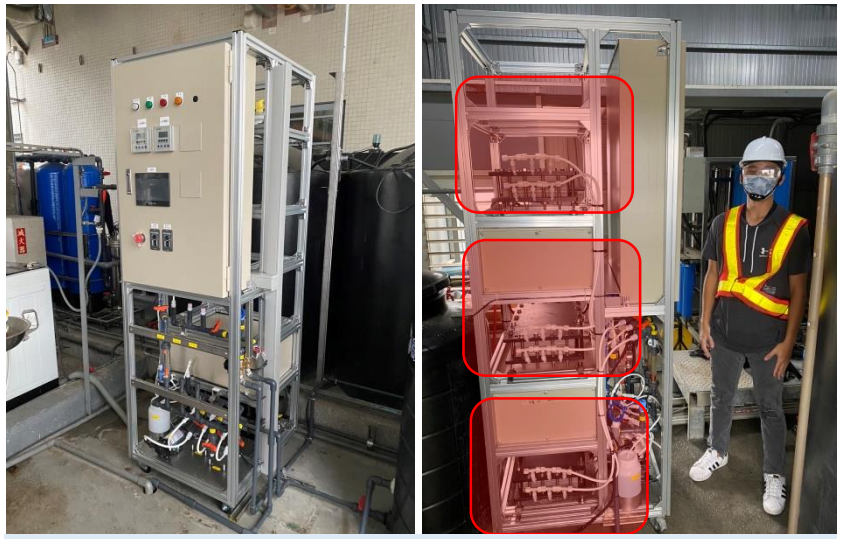
Case: Merck
Targeted wastewater: ROR
Application: Reclaimed water for (1) RO inlet; (2) Cooling tower water

- Inlet EC: 1000-1200 μS/cm
- Outlet EC: 200-300 μS/cm (for cooling tower/ RO Inlet)



Reclaimed Water for Cooling Tower Water Supply (5 CMD)



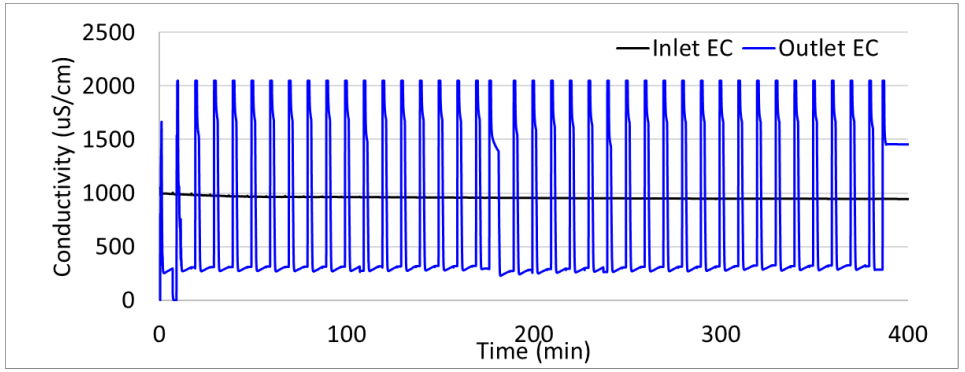


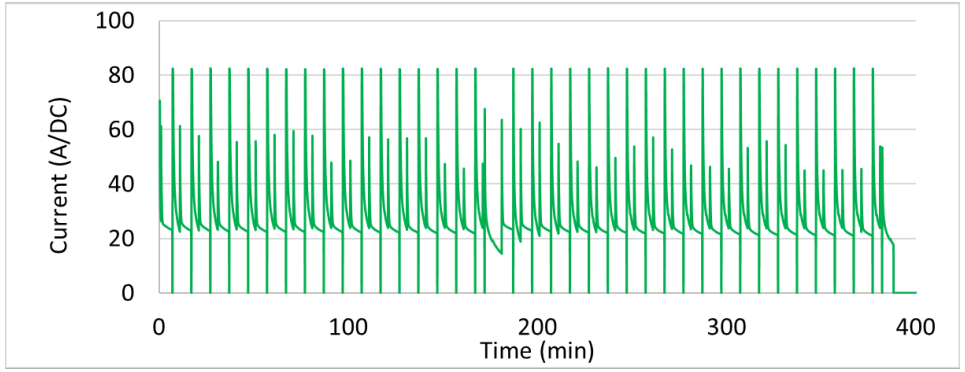
Module design with flexibility adaptability.

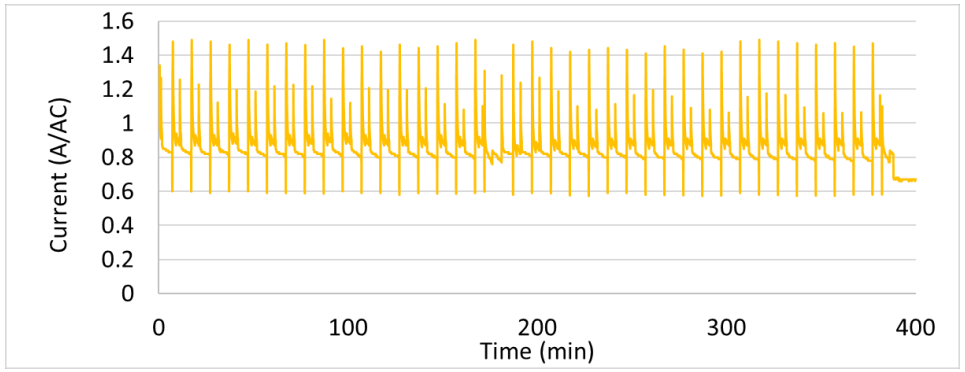
Real-time monitoring:

- Inlet and outlet EC
- Energy consumption of MCDI module
- Energy consumption of system

The peak power of system is 660 W (3 A@220V)







Take Home Message

- (M)CDI is a promising technology for low-energy desalination and water reclamation.
- A scale-up MCDI stack has been successfully developed to reclaim wastewaters with low-energy input and environmental friendliness.
- Future work will be conducted:
  - Develop flow battery desalination for seawater desalination
  - Design CDI with selectivity for resource recovery

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經濟部水利署
Water Resources Agency, MOEA

內政部營建署
Construction and Planning Agency
Ministry of the Interior

行政院環境保護署
Environmental Protection Administration
Executive Yuan, R.O.C.(Taiwan)

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Thank you for your attention.