



# WATER REUSE IN SINGAPORE: OPINION AND TRENDS WITH PAST, PRESENT AND FUTURE PERSPECTIVES

Olivier Lefebvre



A NIGHTSOIL CARRIER IN THE 1970s



USED WATER RECYCLING INTO NEWATER



## SINGAPORE



## JORDAN

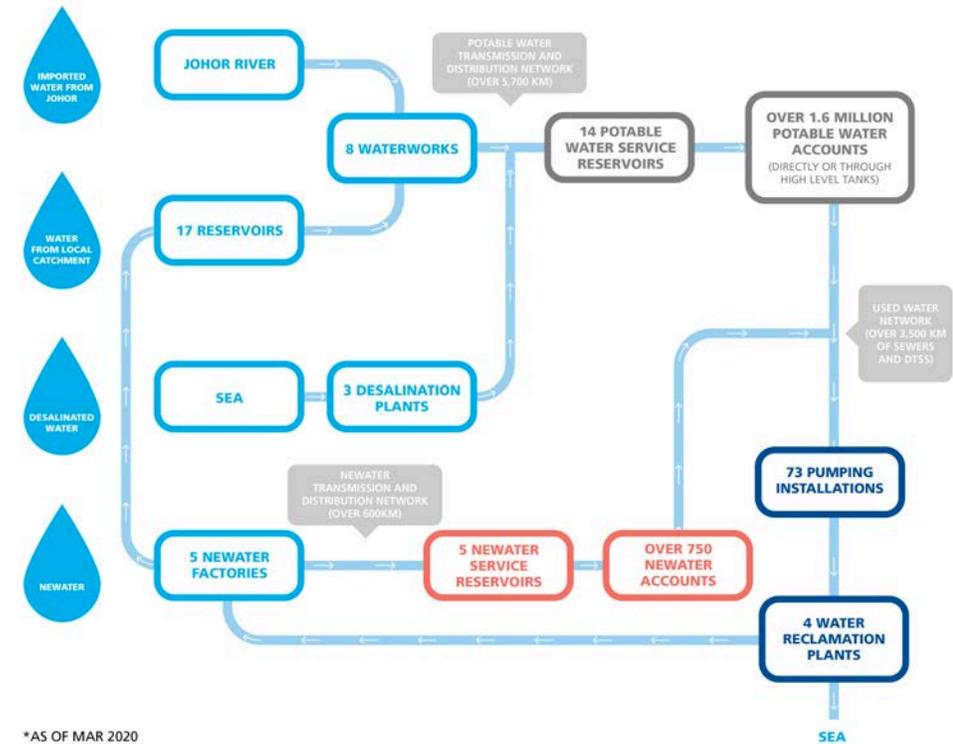


**Renewable freshwater resources < 110 m<sup>3</sup> per capita**

# The 4 national taps



Lee Kuan Yew (1923-2015): “every other policy has to bend at the knees for water survival”



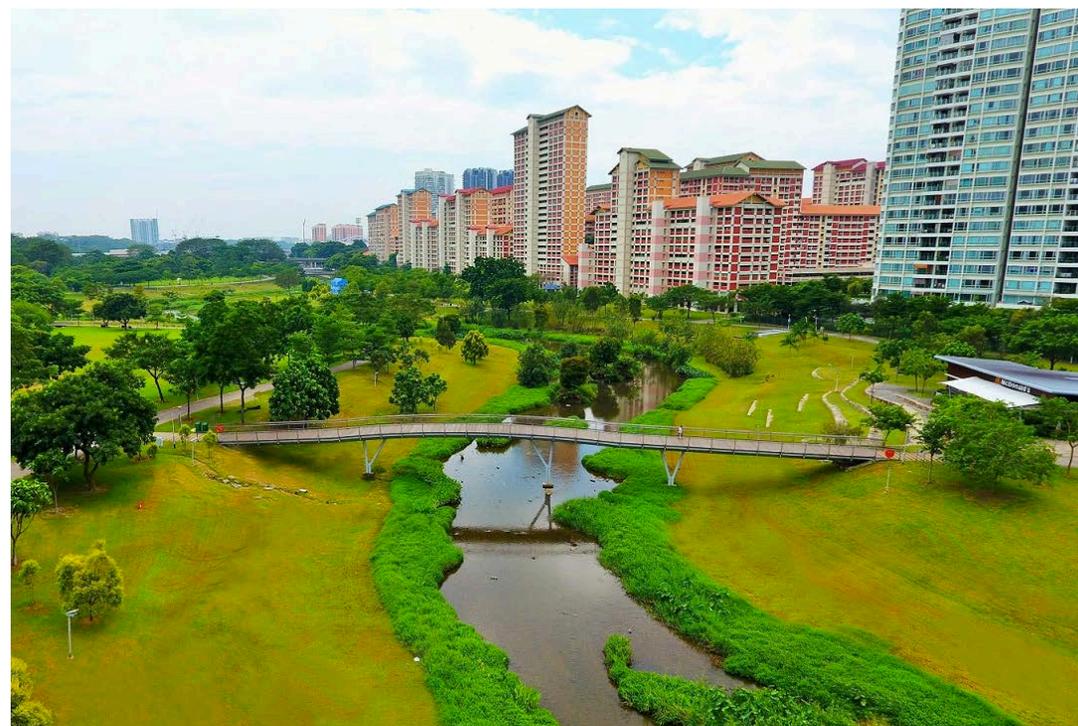
Source: PUB

# Some examples

## Singapore Marina Reservoir



## Incorporating water in the city (ABC water programme)



# THE WATER-FOOD-ENERGY NEXUS



## Food Farming 30 by 30

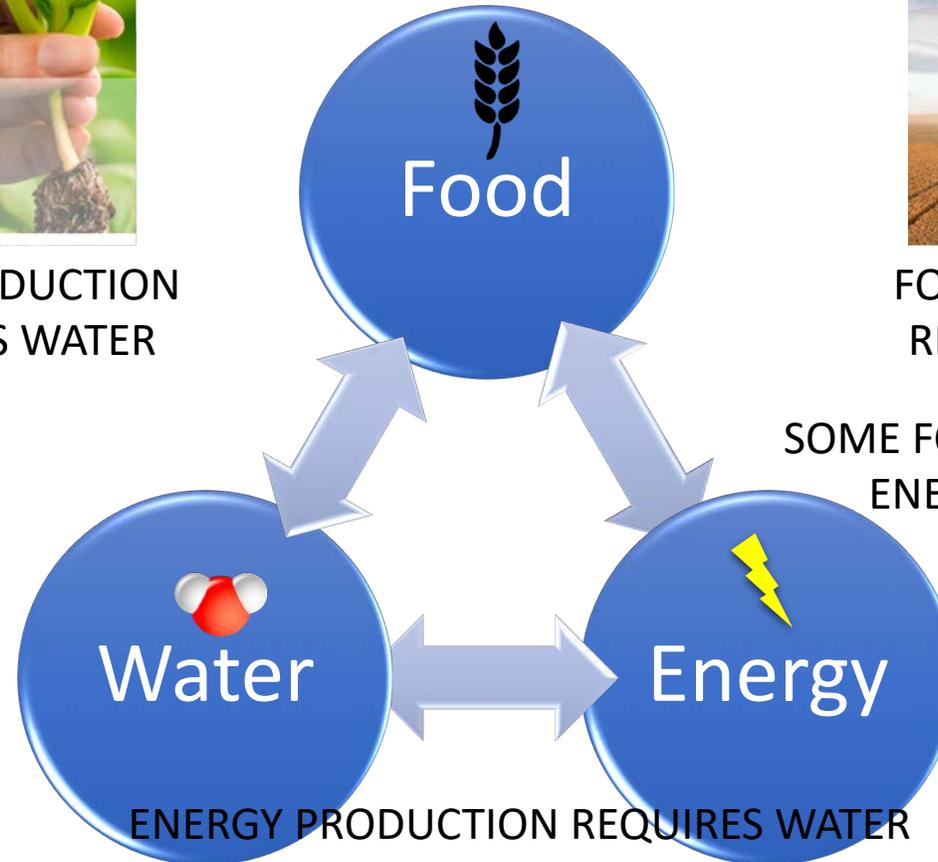
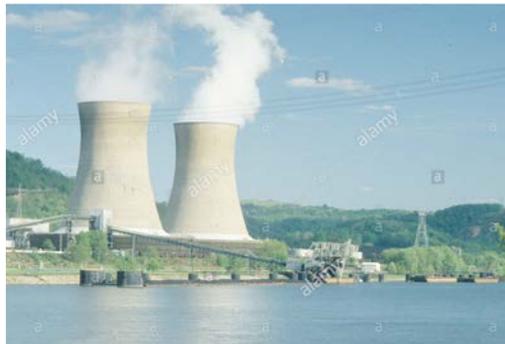
To effectively buffer from supply disruptions, Singapore aims to produce 30% of its nutritional needs by 2030. Through funding and technology transfers, SFA helps local farmers transform and adopt technology to intensify output.

FOOD PRODUCTION  
REQUIRES WATER



FOOD PRODUCTION  
REQUIRES ENERGY

SOME FOOD IS DIVERTED TO PRODUCE  
ENERGY TOO (ENERGY CROPS)



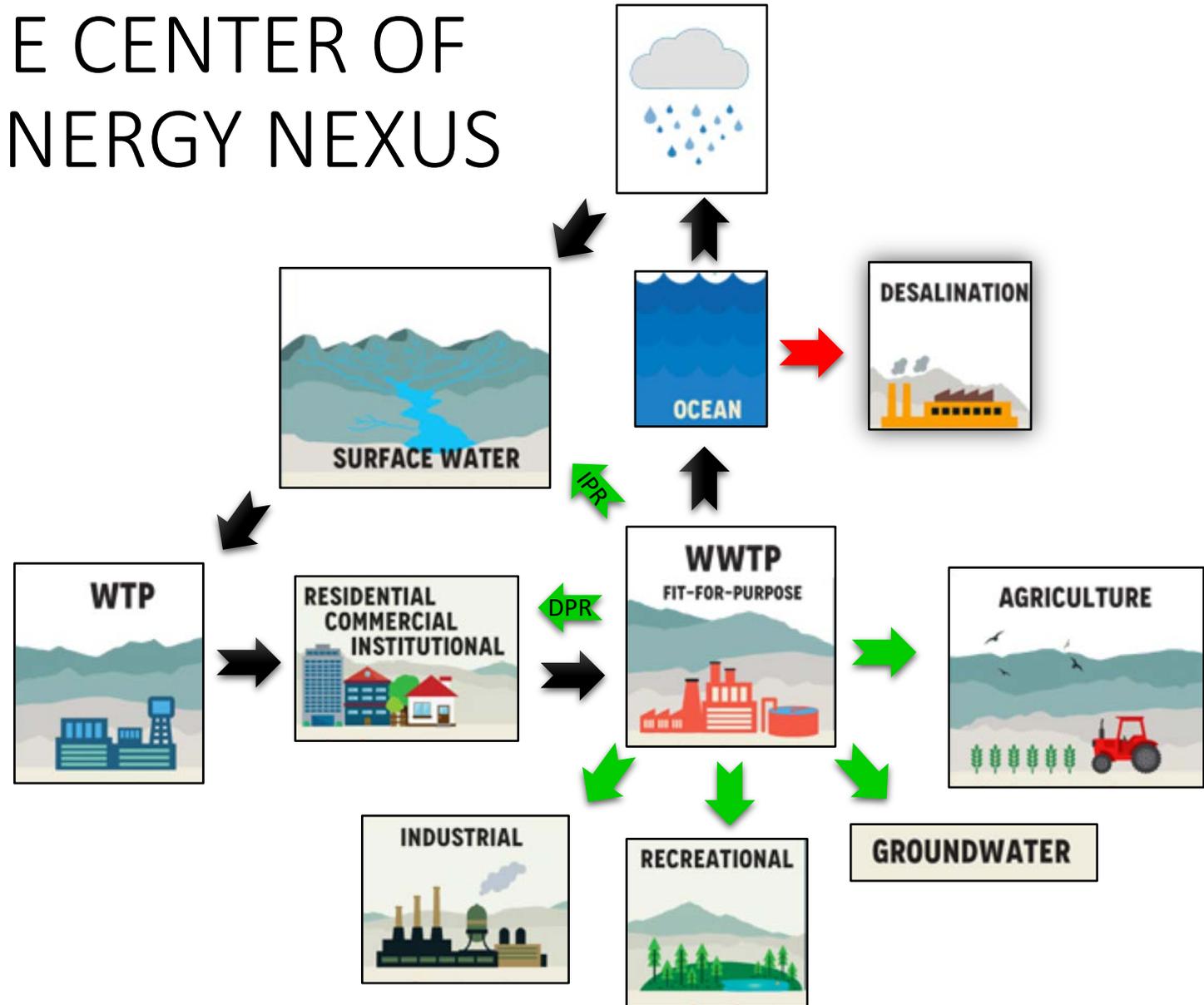
ENERGY PRODUCTION REQUIRES WATER



**CLEANING AND DISTRIBUTING WATER IS ENERGY INTENSIVE**

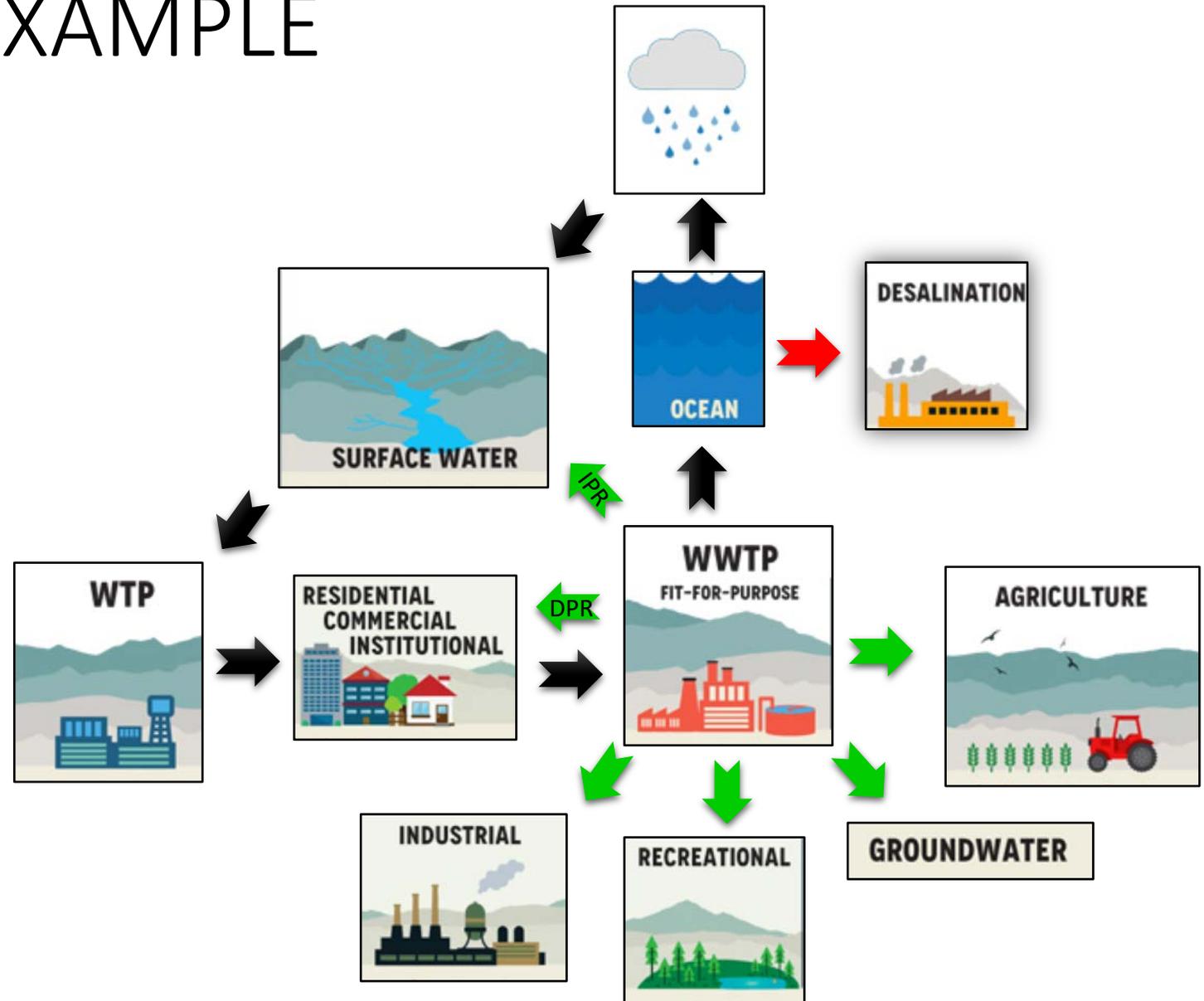
# WATER REUSE AT THE CENTER OF THE WATER-FOOD-ENERGY NEXUS

- Cheaper to clean than other unconventional water sources (mostly seawater desalination)
- Can be used for a variety of purposes (irrigation, industries, drinking) at various costs and with different qualities needed (fit-for-purpose)

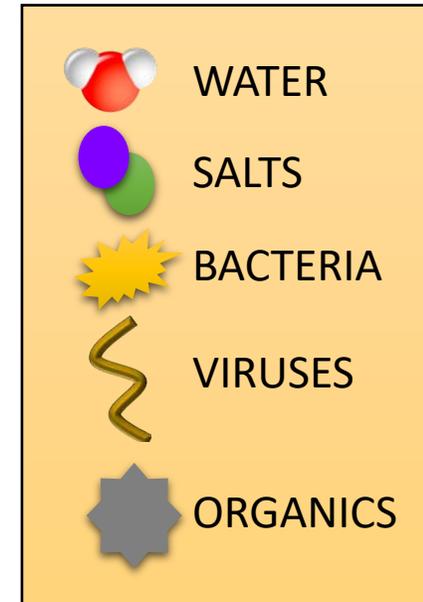
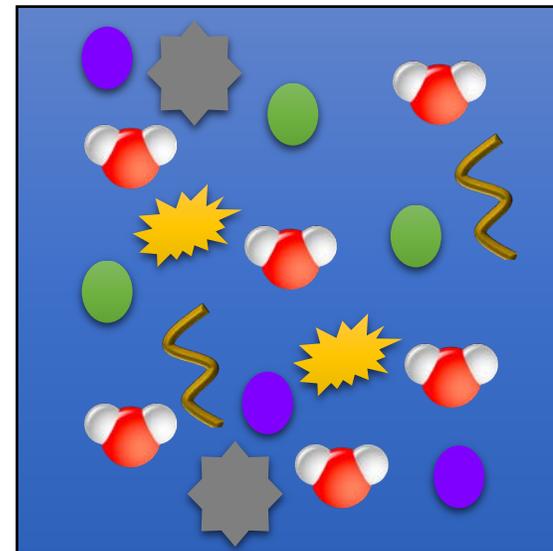
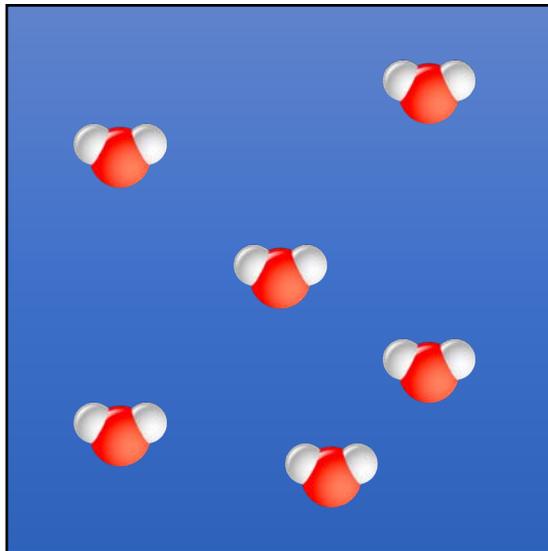


# THE SINGAPORE EXAMPLE

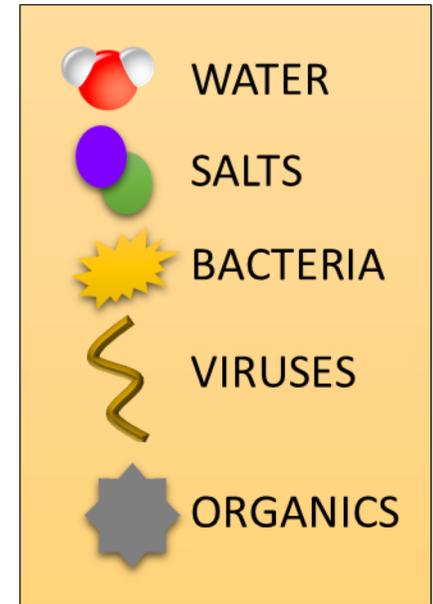
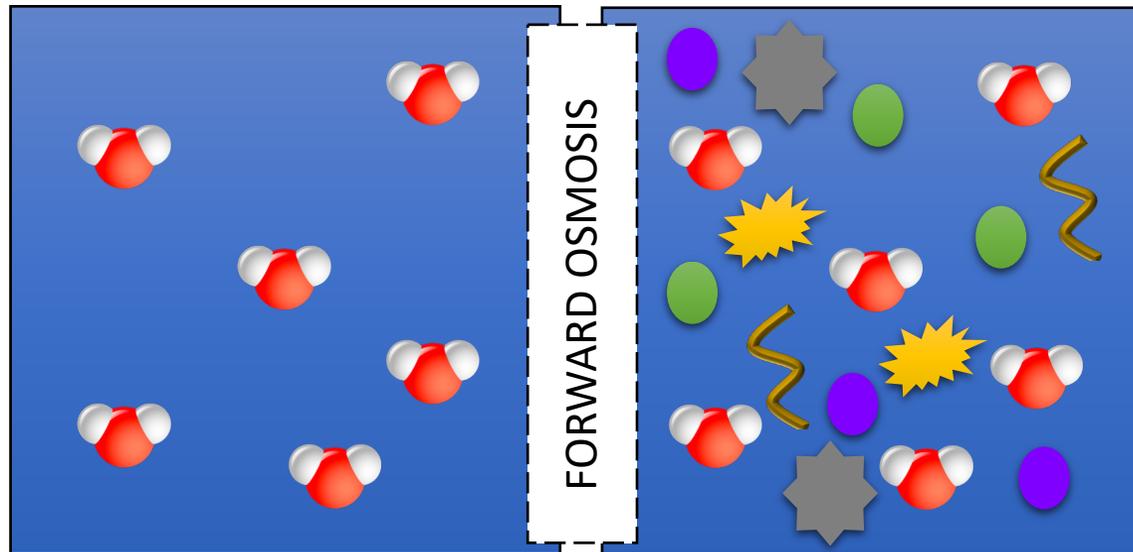
- More restrictions
- Fewer options
- Biggest user = industry
- Also IPR during dry weather



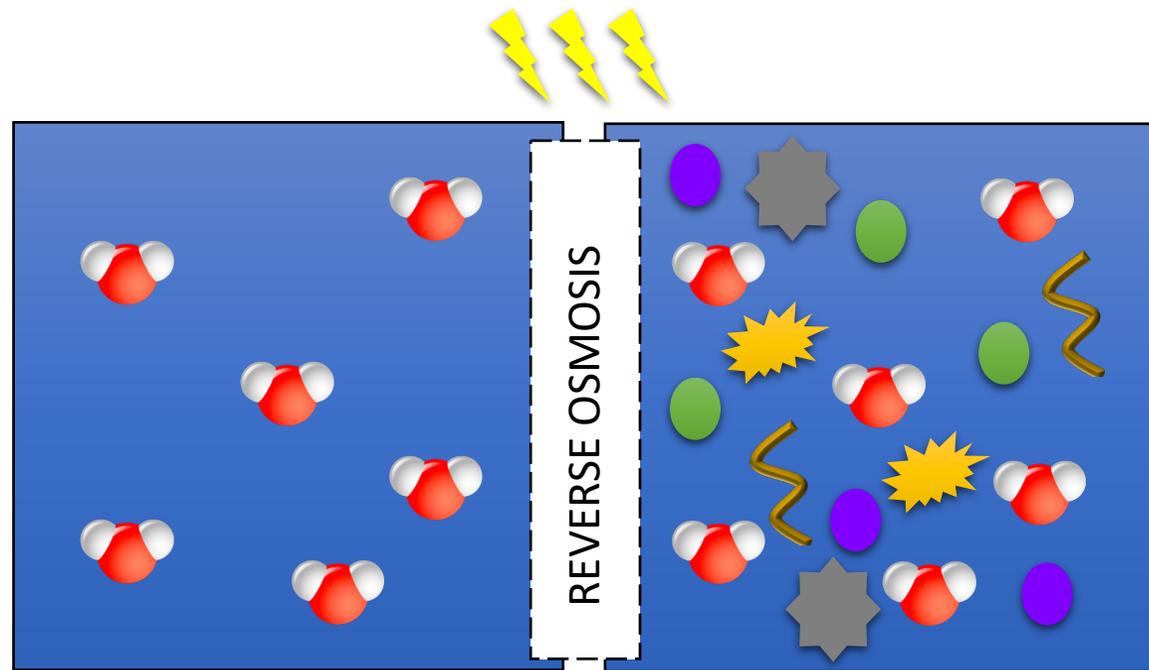
# MAKING NEW WATER: EXPLOITATION OF A NATURAL PHENOMENON



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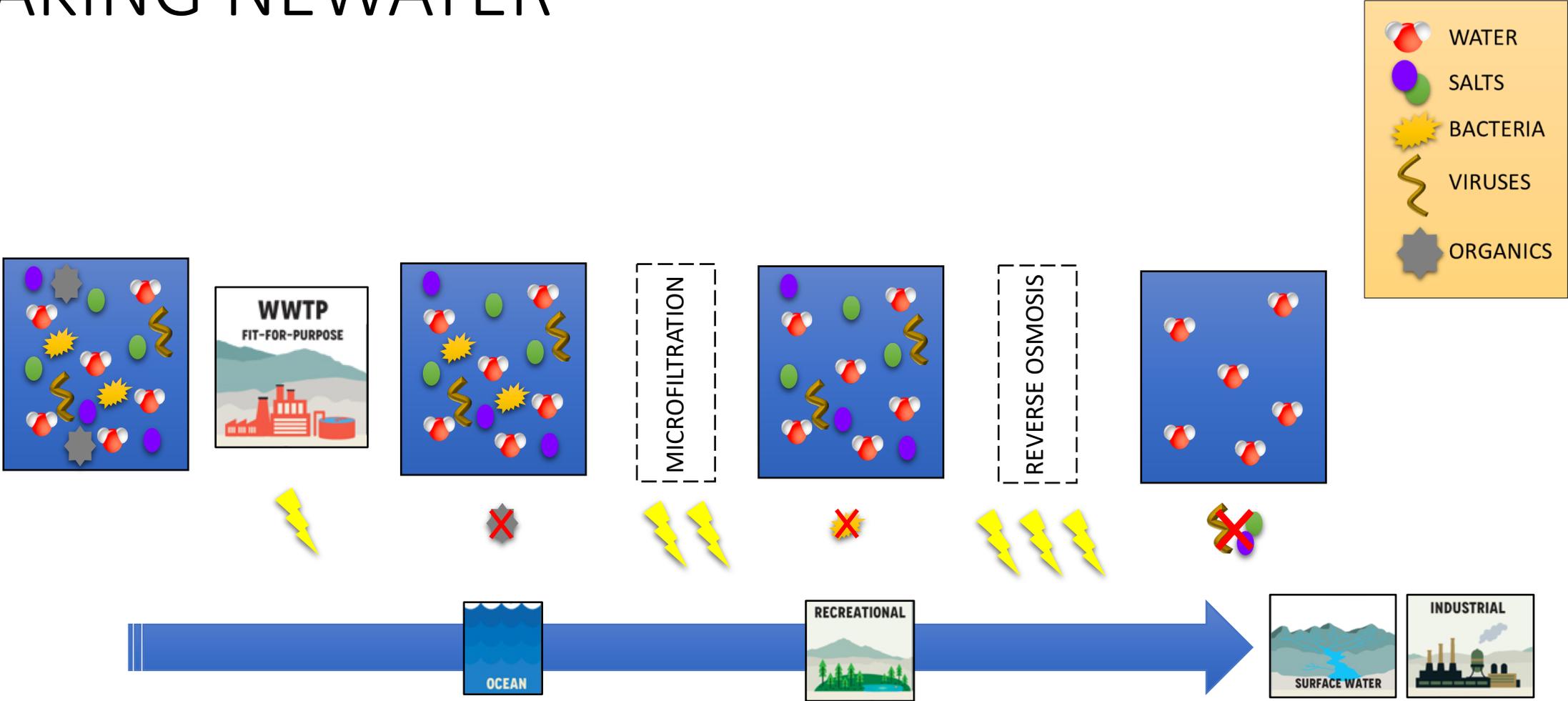


# MAKING NEW WATER: REVERSAL OF A NATURAL PHENOMENON



	WATER
	SALTS
	BACTERIA
	VIRUSES
	ORGANICS

# MAKING NEWATER



# ANALYSIS OF A SUCCESS STORY

- A Seal of quality
  - Trust in technology, experts and government
  - Positive discourse from the media
  - Development of a thick narrative, emphasizing the imperative to reuse water for strategic / security reasons
- 
- As a result, water reuse provides in average 30% of the nation's water demand at a cost of S\$ 2.3/m<sup>3</sup> (approx. 1.4 Euro/m<sup>3</sup>) vs. S\$2.7/m<sup>3</sup> for potable water
  - Expected to rise to 55% by 2060 = 440 mgd (> 1.6 hm<sup>3</sup>/d)

# More examples

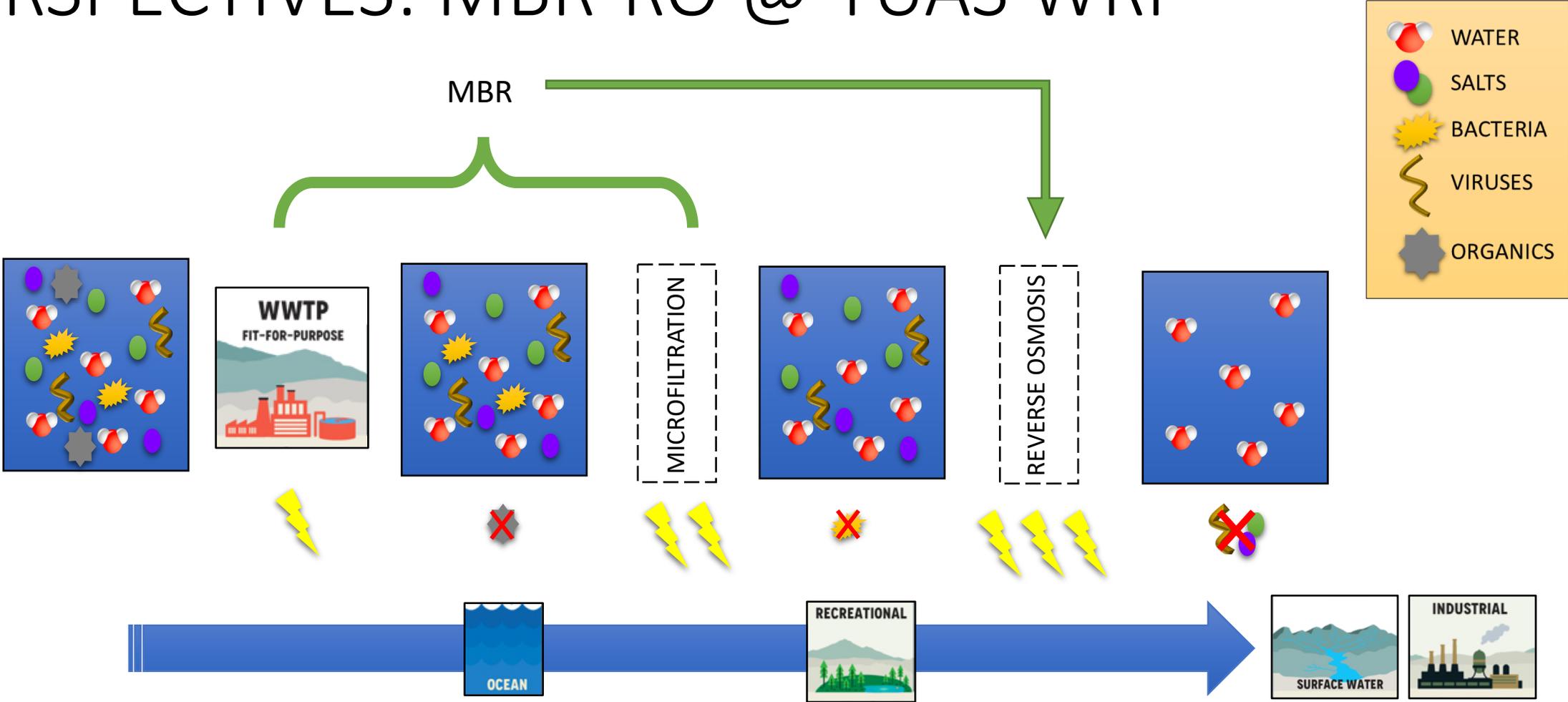
## NEWater Visitor Centre



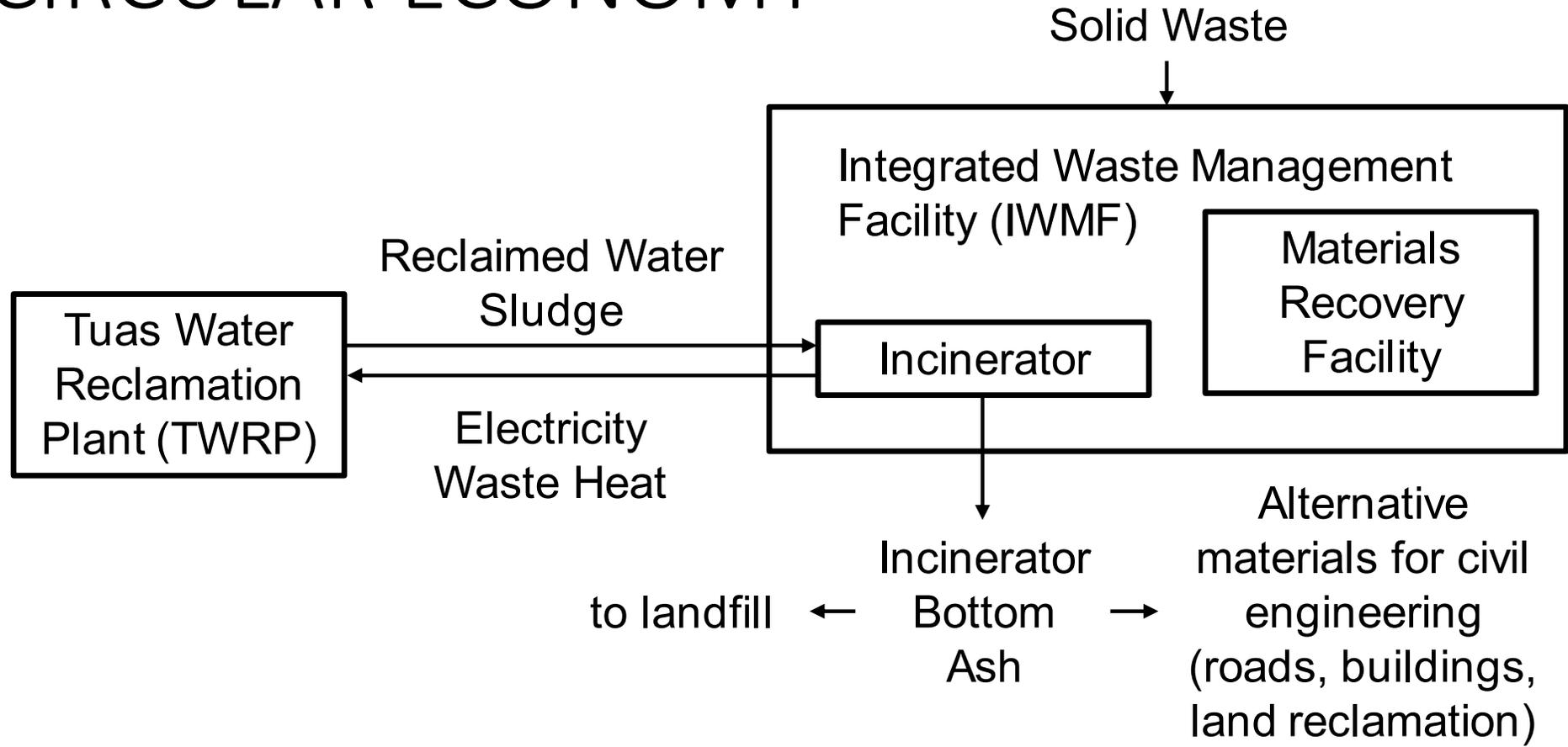
## NEWbrew



# PERSPECTIVES: MBR-RO @ TUAS WRP



# WATER REUSE AS A COMPONENT OF CIRCULAR ECONOMY

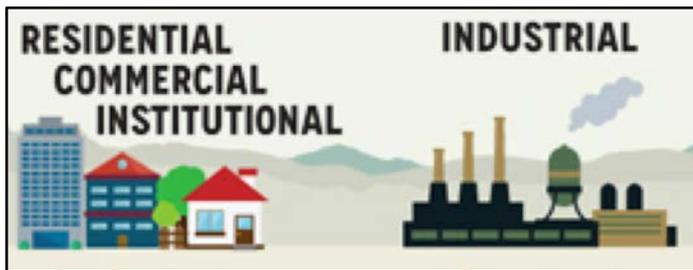


# IS DPR AN OPTION IN S'PORE?

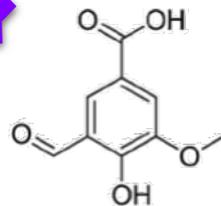
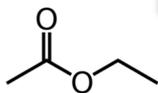
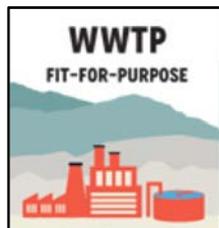
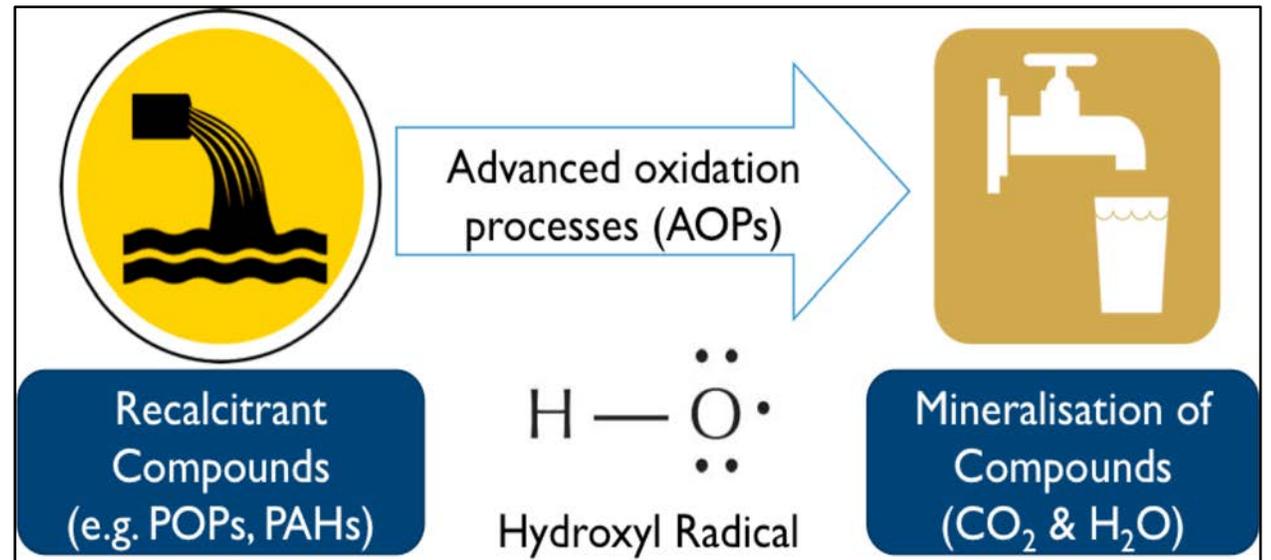
- Not considered but Singapore has several advantages that would make that option viable
- Public Utility Board (PUB) already manages the whole water cycle from drinking water to wastewater treatment
- Trust in technology, experts and government: over 300 persistent organic pollutants are already routinely monitored at concentrations as low as ng/L
- Unnecessary concern? ultimately the quality of water from a DPR scheme should be compared to that of a conventional drinking water scheme, in order to avoid unnecessary cost escalation

# CHALLENGES AHEAD...

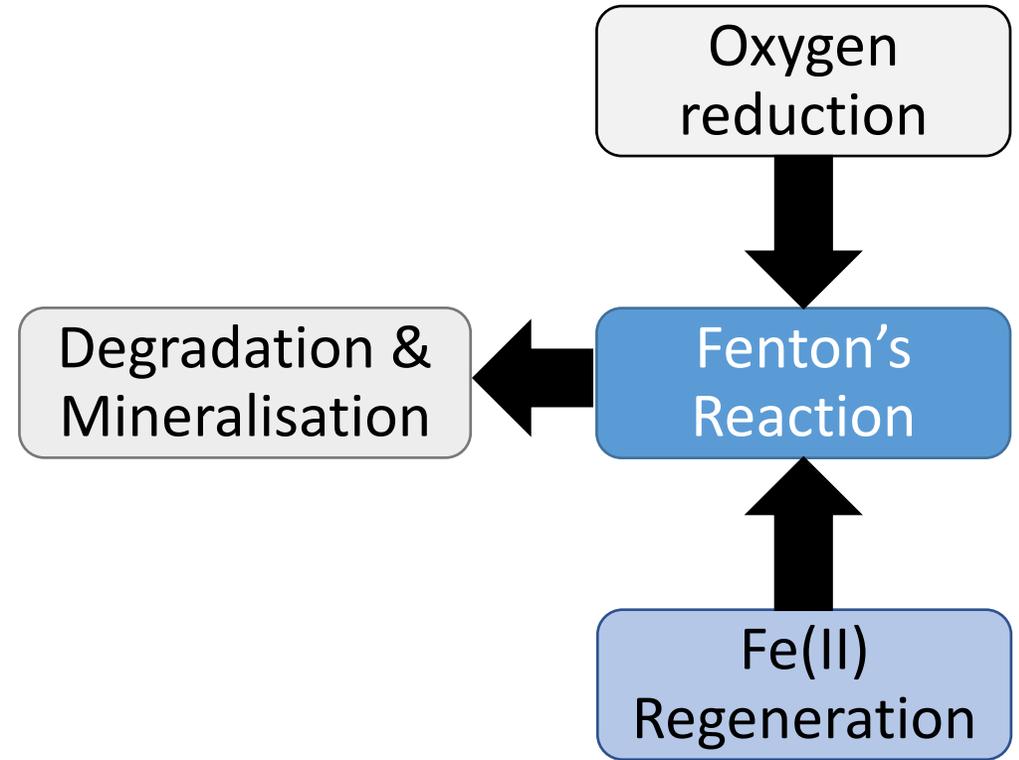
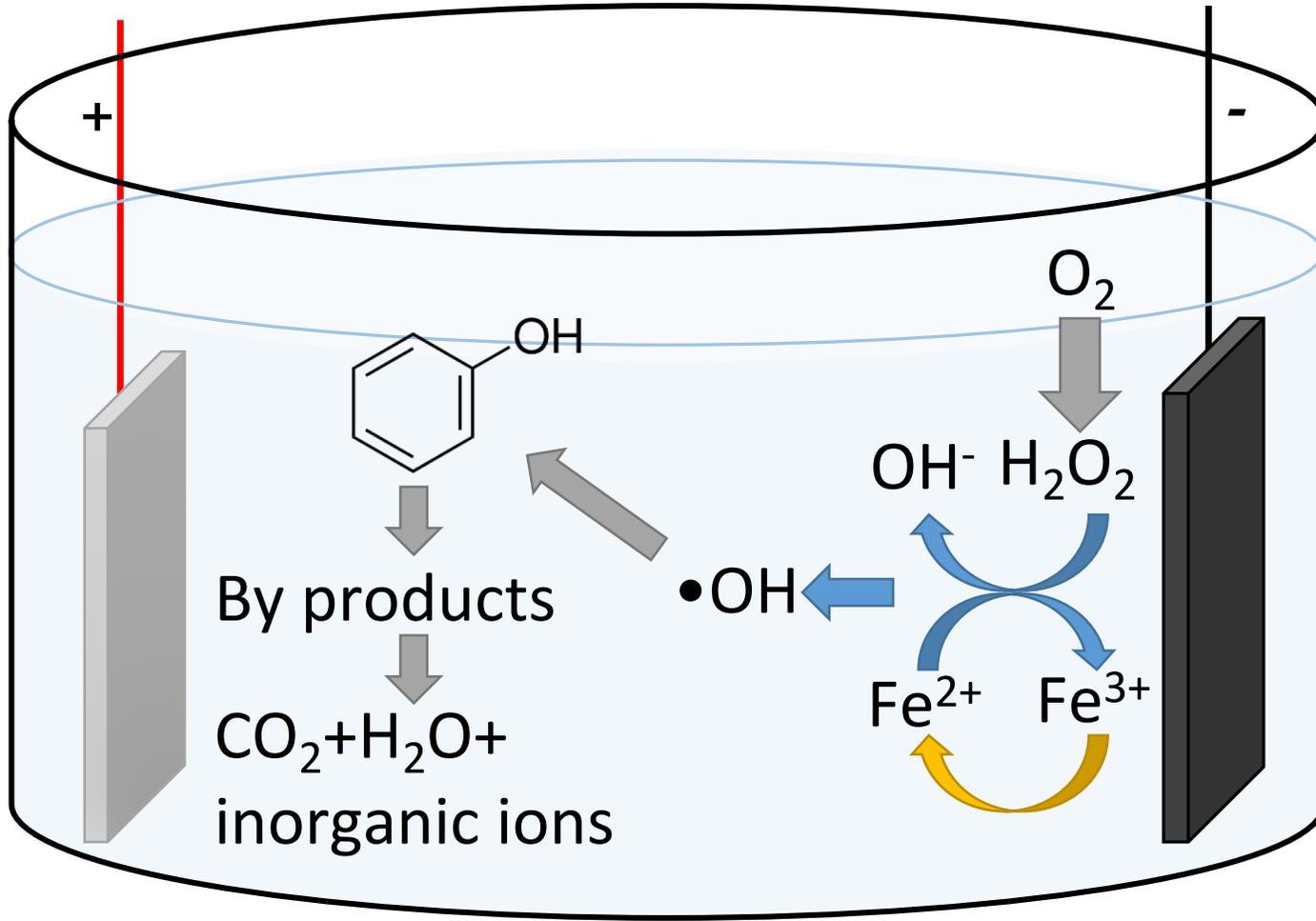
## EVOLUTION OF WATER USAGES



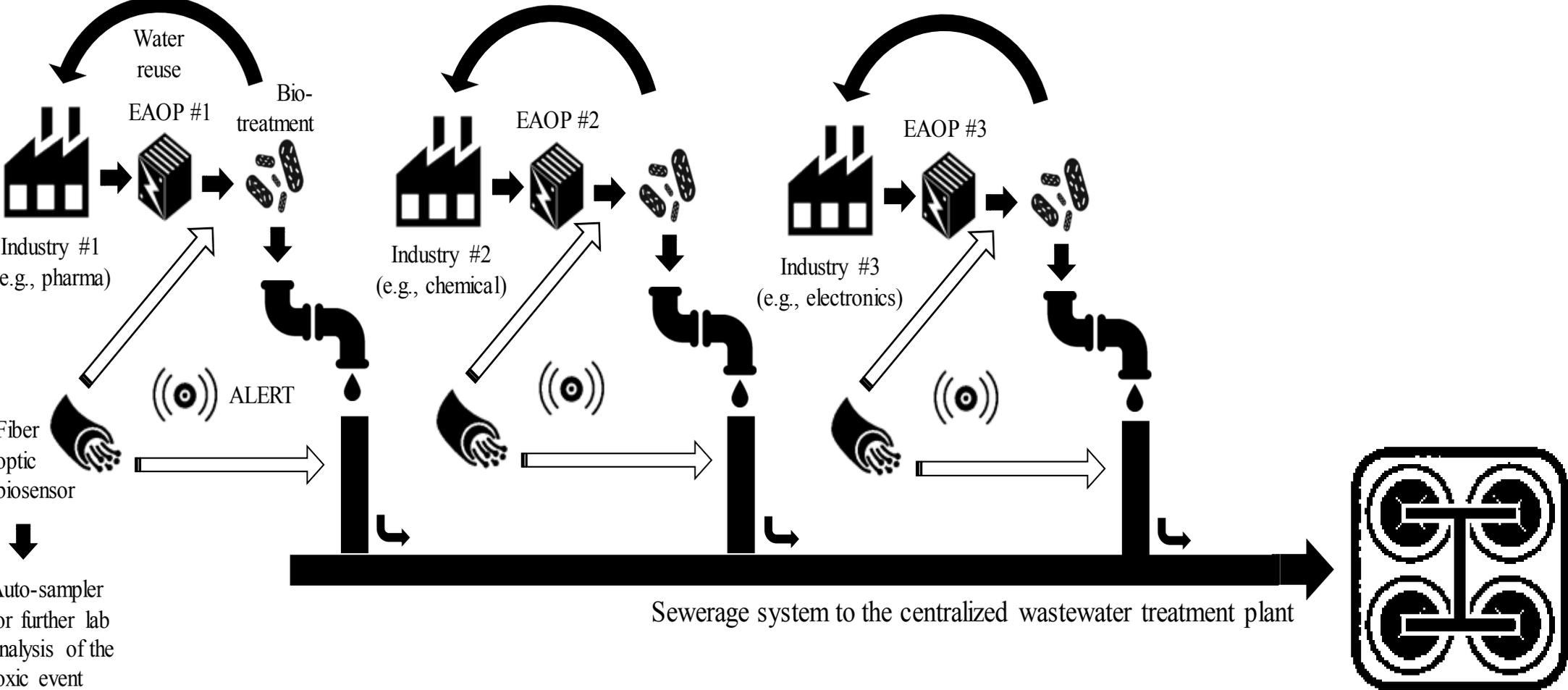
<b>2011</b>	<b>45%</b>	<b>55%</b>
<b>2060</b>	<b>30%</b>	<b>70%</b>



# ELECTRO-FENTON



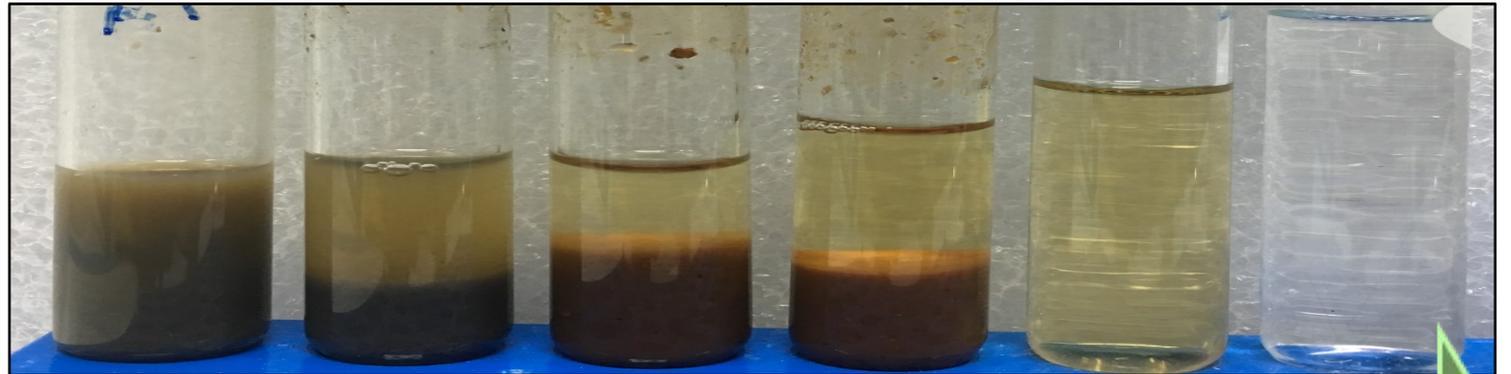
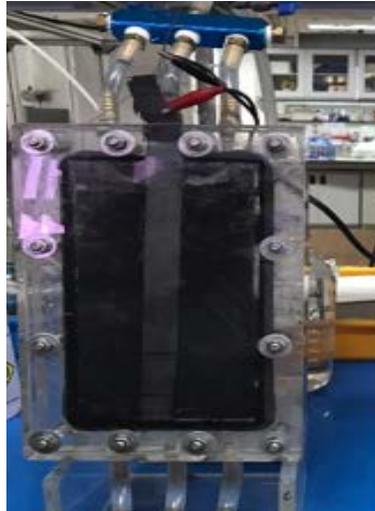
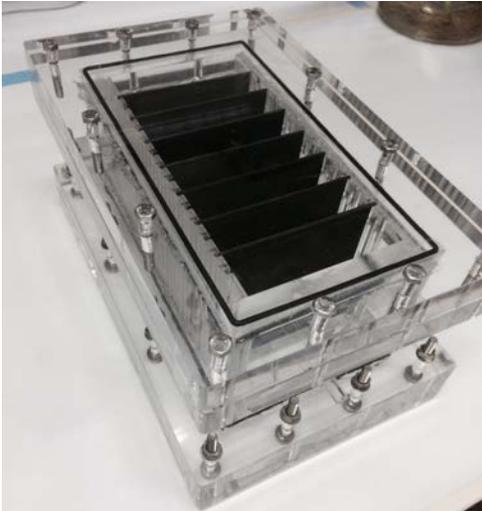
# ELECTRO-FENTON FOR DECENTRALIZED INDUSTRIAL WATER REUSE



# APPLICATIONS AT NUS



- Treatment of electronics wastewater
- Treatment of sludge from a poultry farm
- Scale-up systems



Initial

ECP-1h

ECP-2h

Filtration

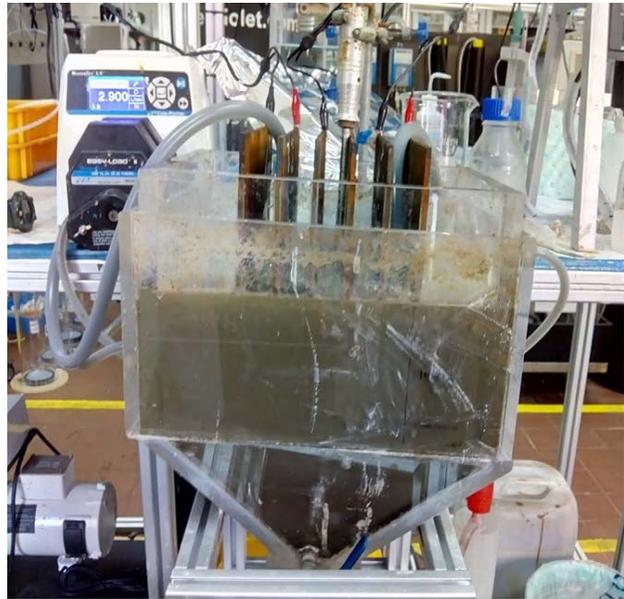
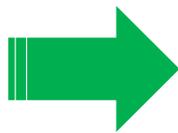
EF-Initial

EF-4h

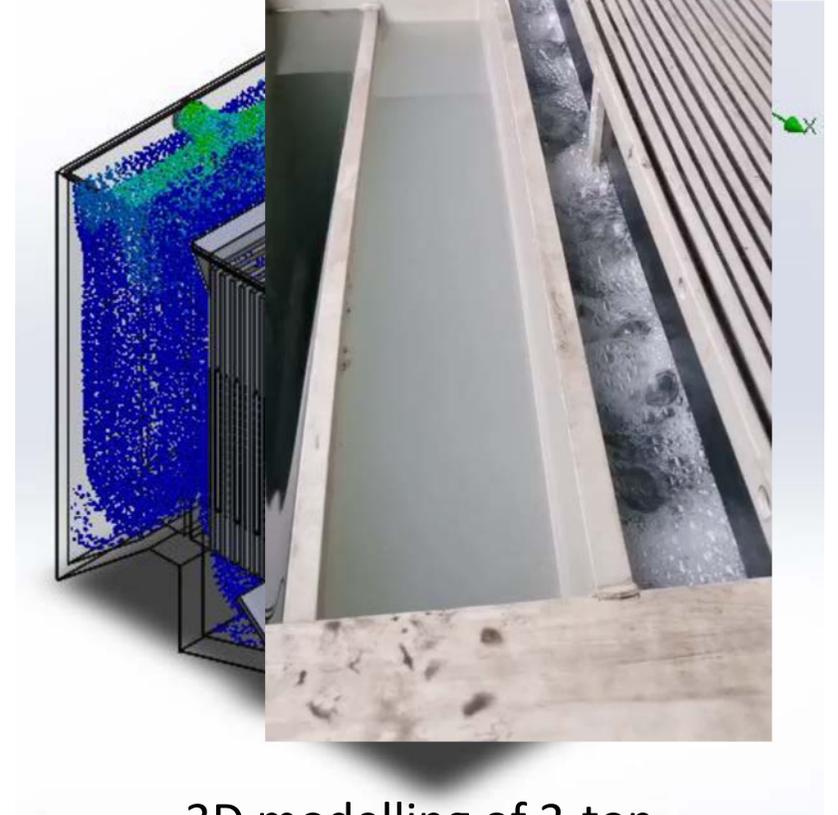
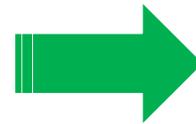
# THE PATH TO SCALING UP



Successful 0.4L  
Lab-scale test

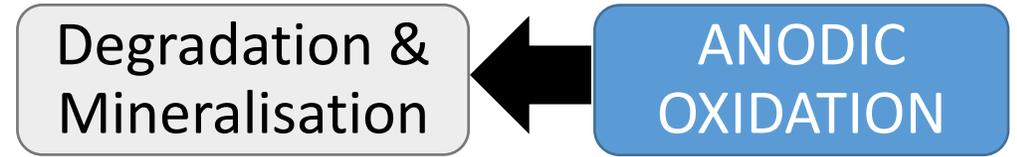
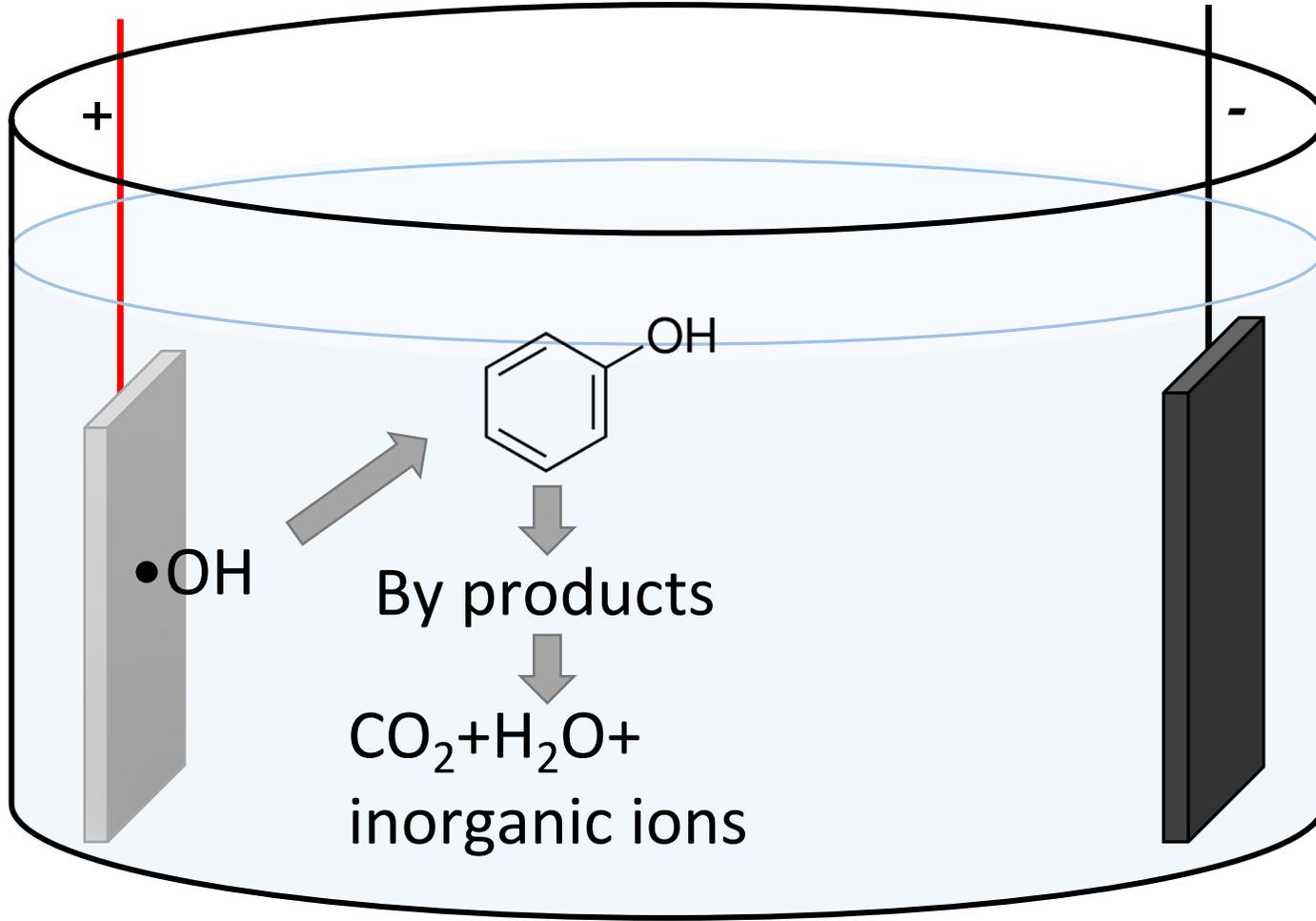


Successful  
10L Bench-scale test



3D modelling of 3-ton  
pilot

# ANODIC OXIDATION



# APPLICATIONS AT NUS



- Outdoor use in natural environment
- Combination with solar power



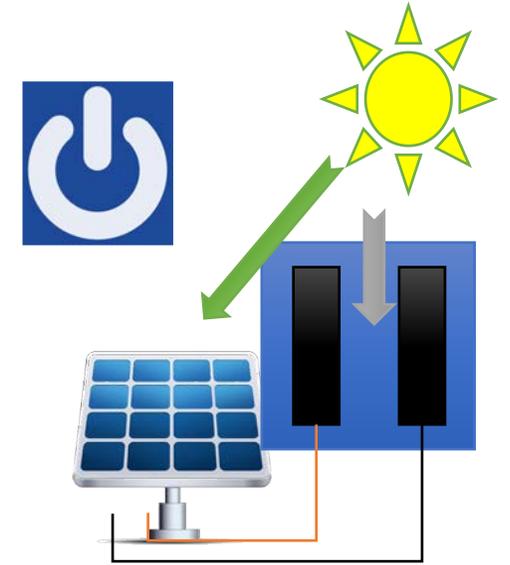
Freshwater  
reservoirs



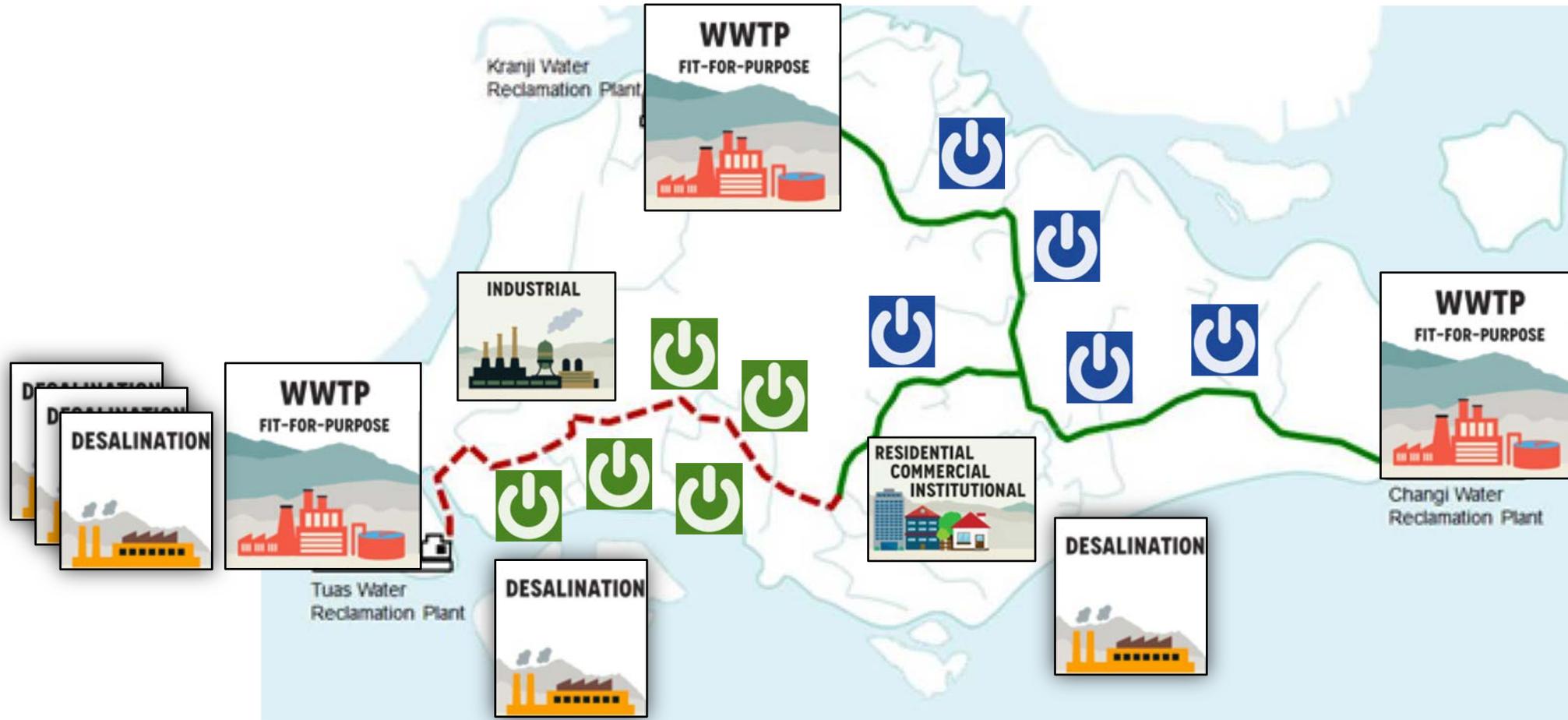
Marine  
environment



Green  
buildings



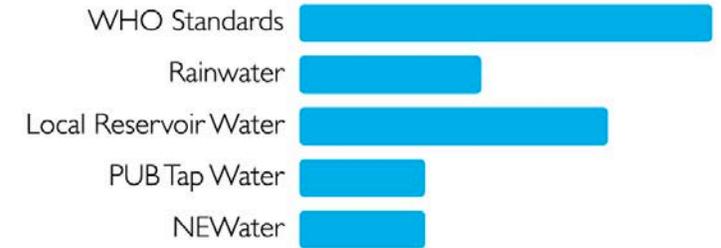
# A LOOK INTO THE FUTURE



# TAKE AWAYS

- A historical decision to promote **integrated management** of water resources
- The success of NEWater was built on **quality control**, regulatory support (**WHO guidelines**), **trust** and recognition of the **strategic** importance to reuse water in Singapore

## Comparison of Colour



## Comparison of Suspended Particle



## Comparison of Suspended Particle



# TAKE AWAYS

- With the new **threats** of climate change, there is further need to address the cost of water treatment in the future to solve **the water-energy-food nexus**
- The key is integration of **tailored integrated solutions** combining advanced **degradation** and **separation** technologies
- Singapore will remain the **key player** in developing water technologies in the XXI<sup>st</sup> century



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