NUS National University of Singapore

ELECTROCHEMICAL WATER TREATMENT GROUP

Department of Civil a Environmental Engineering - National University of Singapore

EWaT

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

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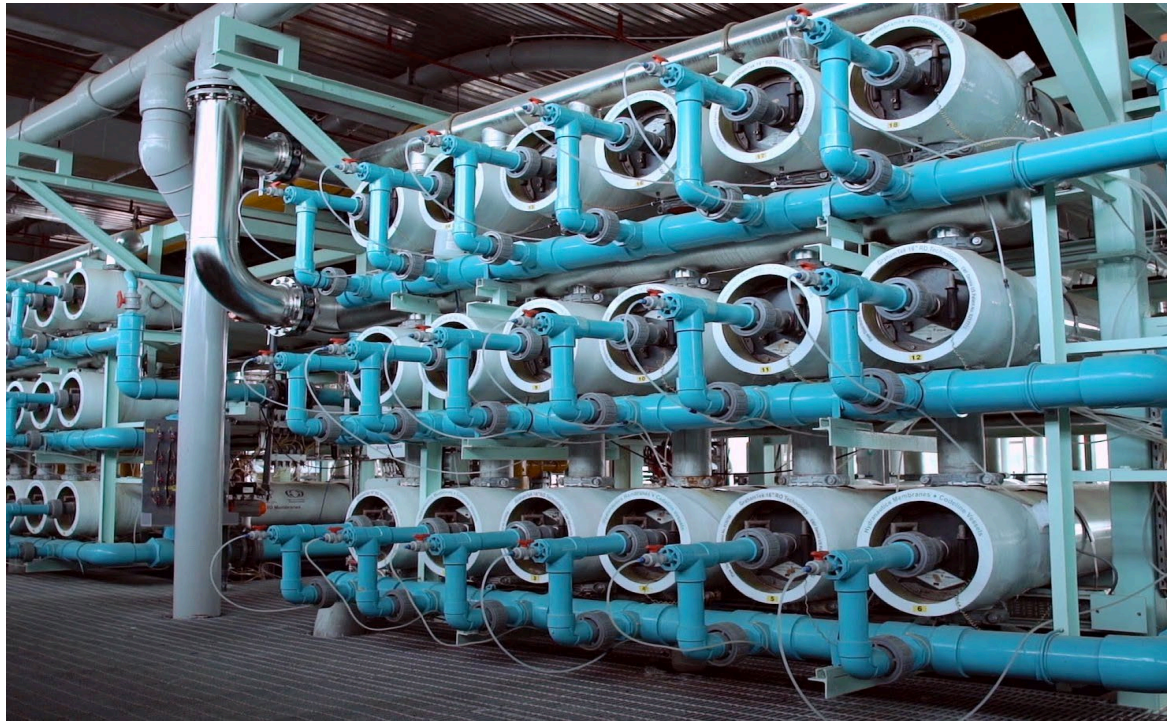
https://www.google.com/maps/place/Singapore/@-40.8315726,102.6988031,3.01z/data=!4m5!3m4!1s0x31da11238a8b9375:0x887869cf52abf5c4!8m2!3d1.352083!4d103.819836

A NIGHTSOIL CARRIER IN THE 1970_S

USED WATER RECYCLING INTO NEWATER



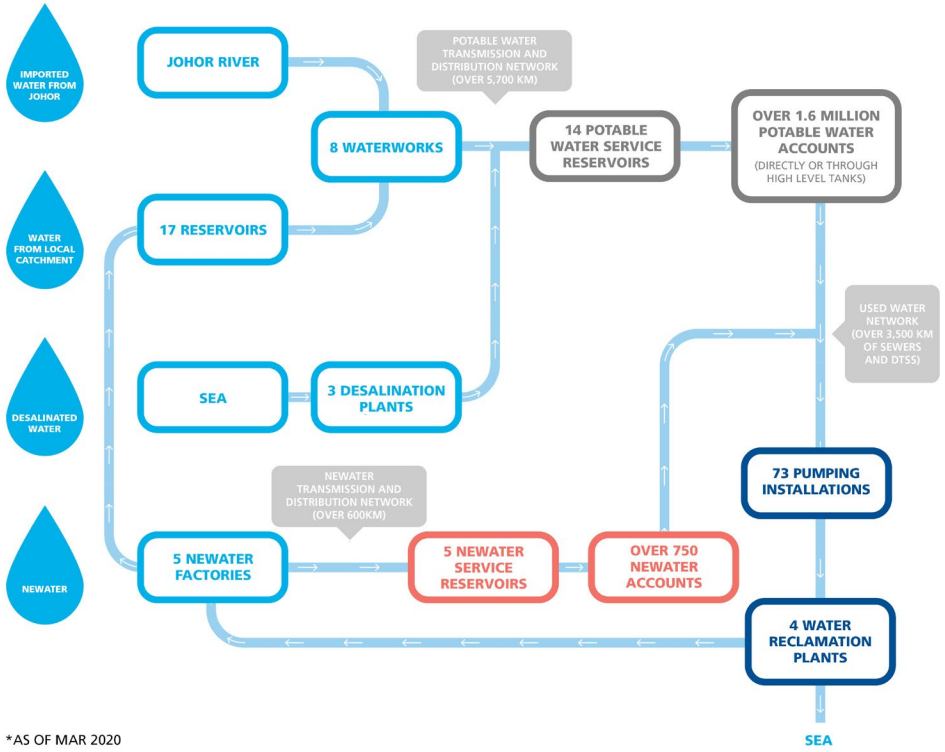
SINGAPORE

JORDAN

Renewable freshwater resources < 110 m^3 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

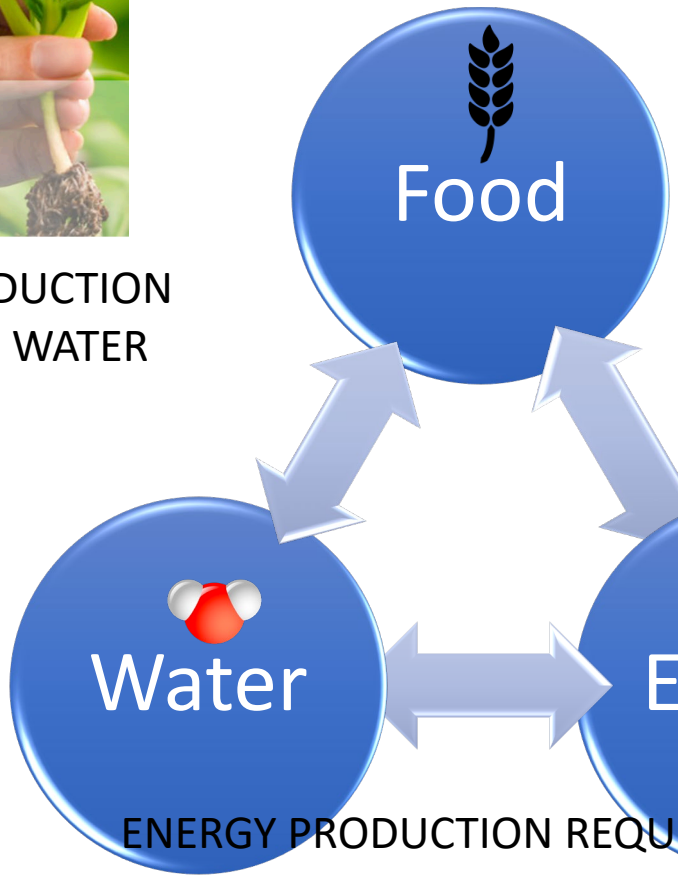
Some examples

Singapore Marina Reservoir

Incorporating water in the city (ABC water programme)

THE WATER-FOOD-ENERGY NEXUS

FOOD PRODUCTION REQUIRES WATER



FOOD PRODUCTION REQUIRES ENERGY

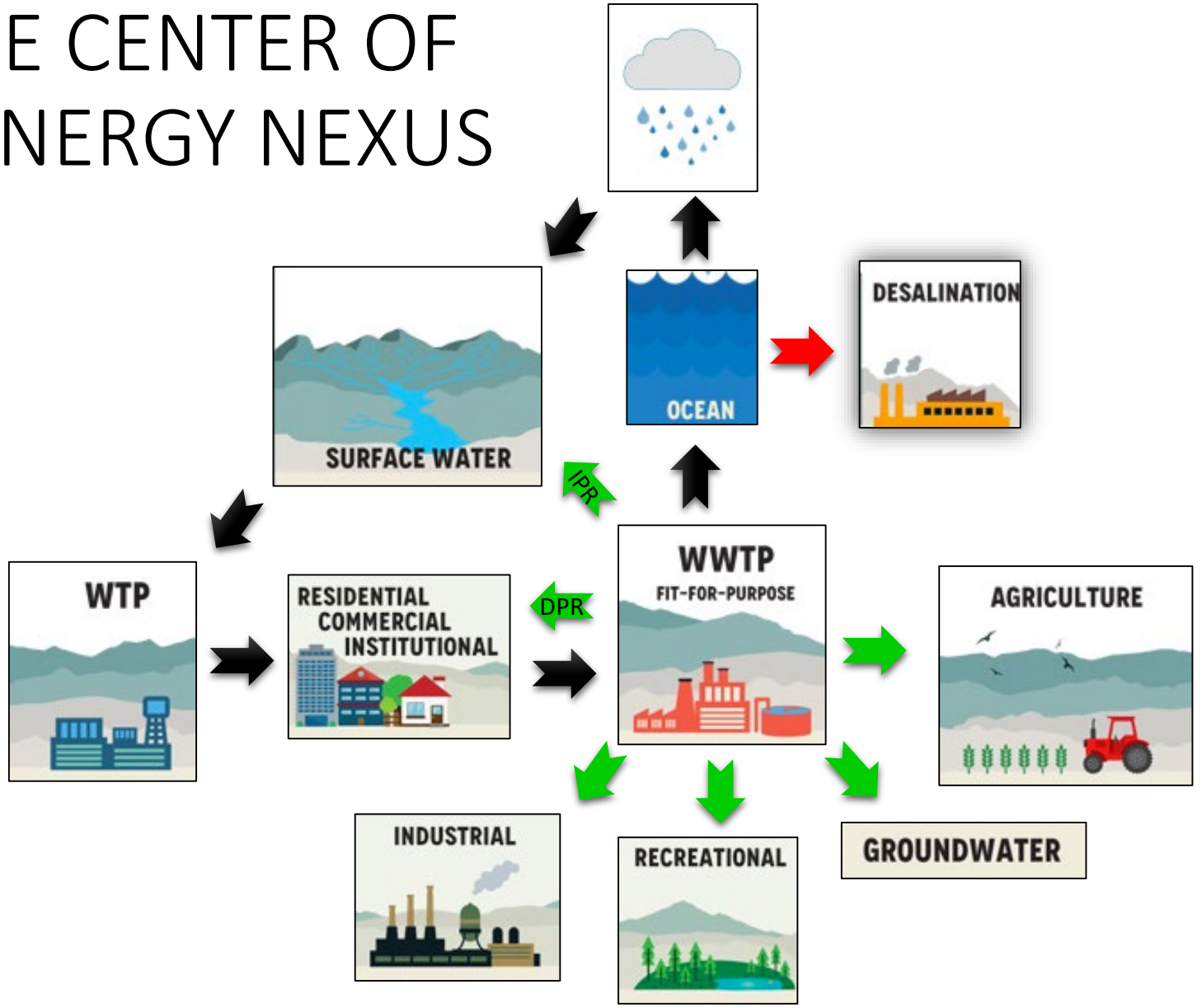
SOME FOOD IS DIVERTED TO PRODUCE ENERGY TOO (ENERGY CROPS)

ENERGY PRODUCTION REQUIRES WATER

CLEANING AND DISTRIBUTING WATER IS ENERGY INTENSIVE

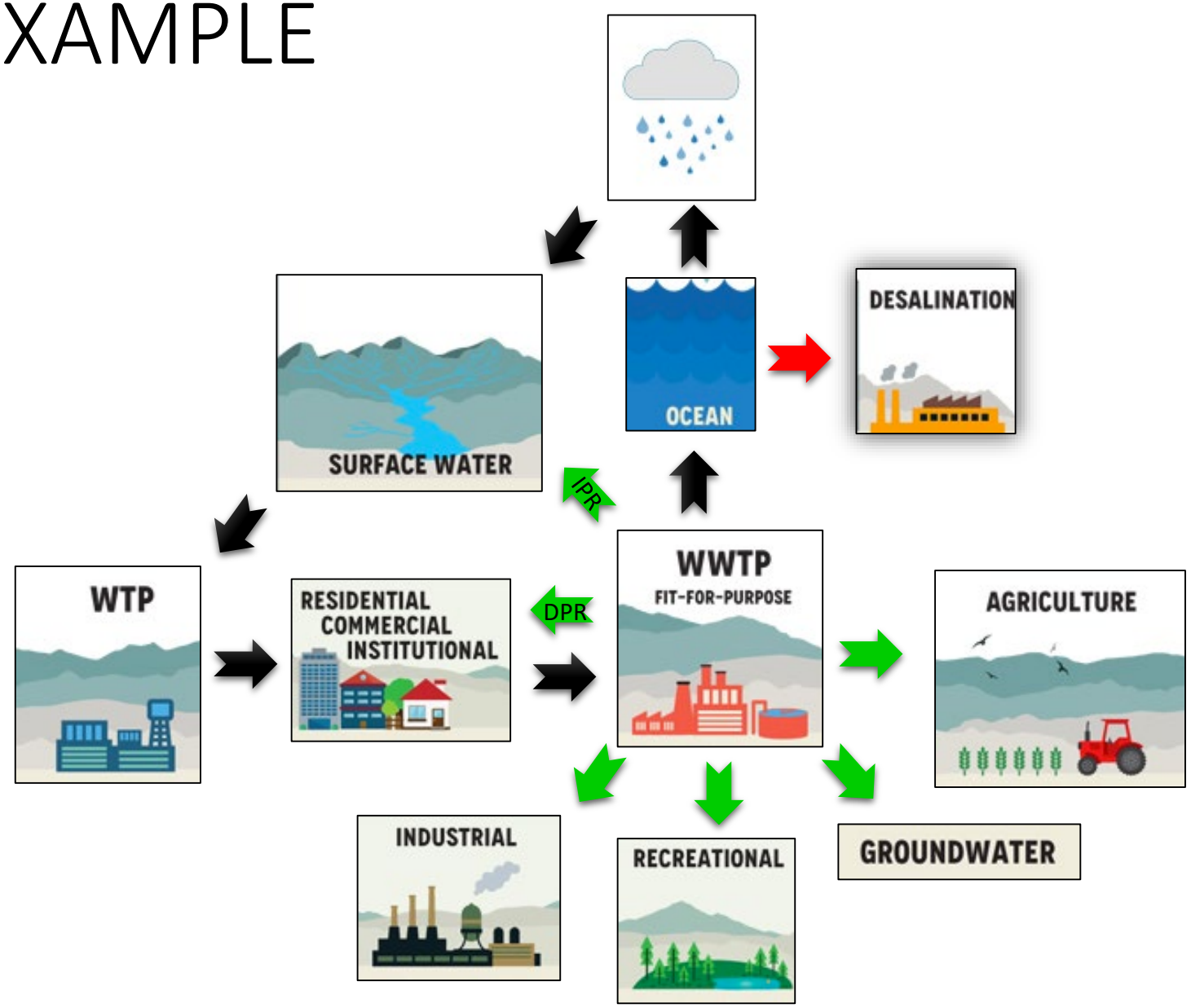
WATER REUSE AT THE CENTER OF THE WATER-FOOD-ENERGY NEXUS

- 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)

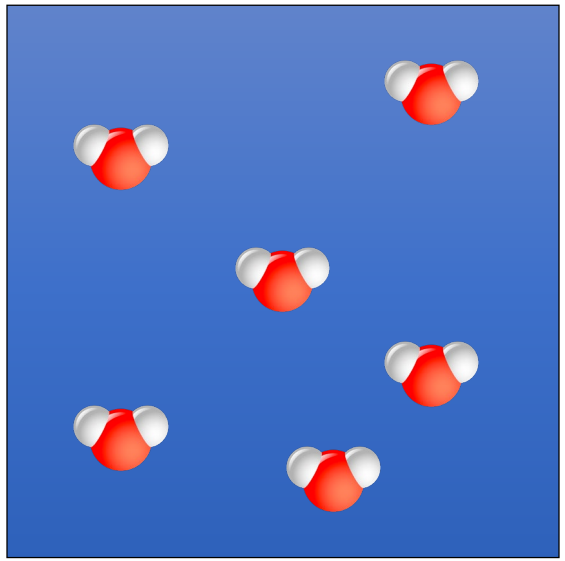


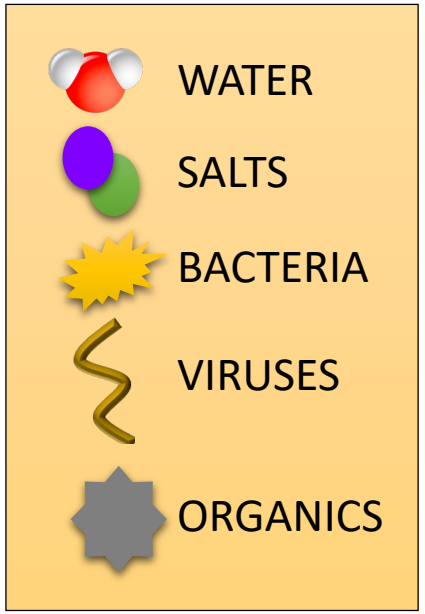
THE SINGAPORE EXAMPLE

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



MAKING NEWATER: EXPLOITATION OF A NATURAL PHENOMENON





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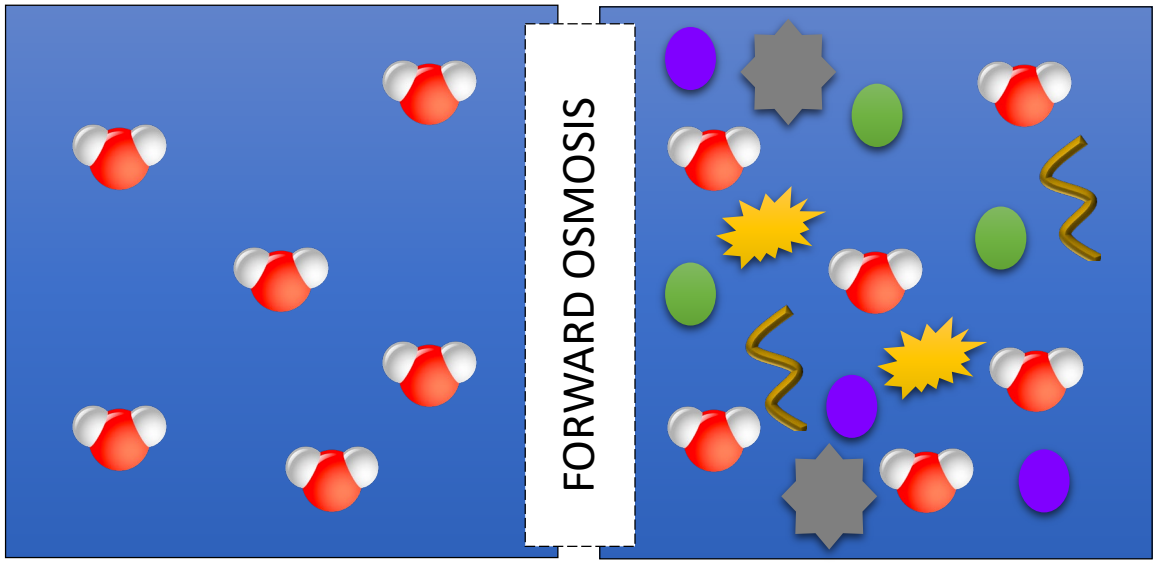
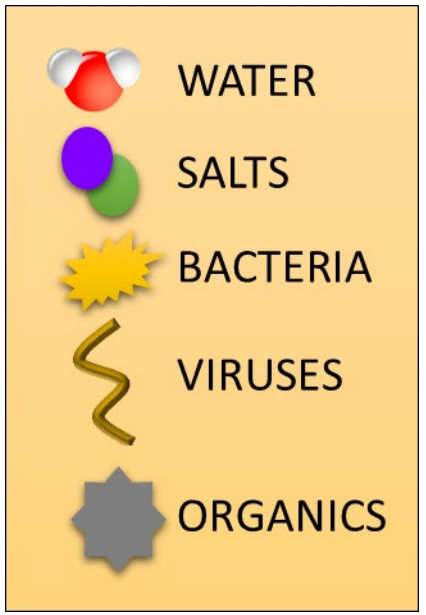
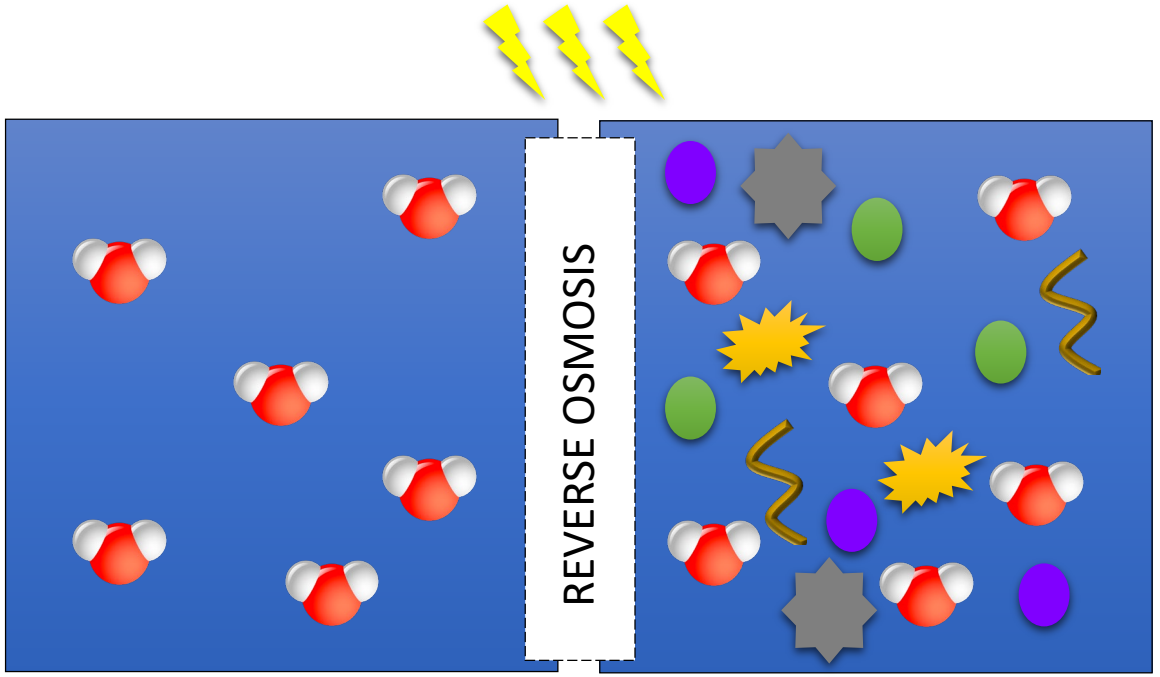
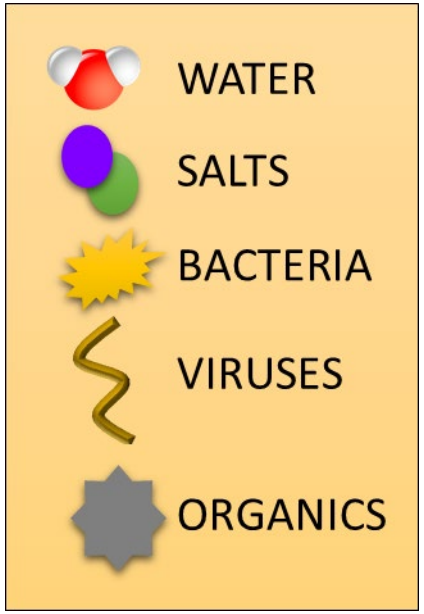




MAKING NEWATER: **REVERSAL** OF A NATURAL PHENOMENON





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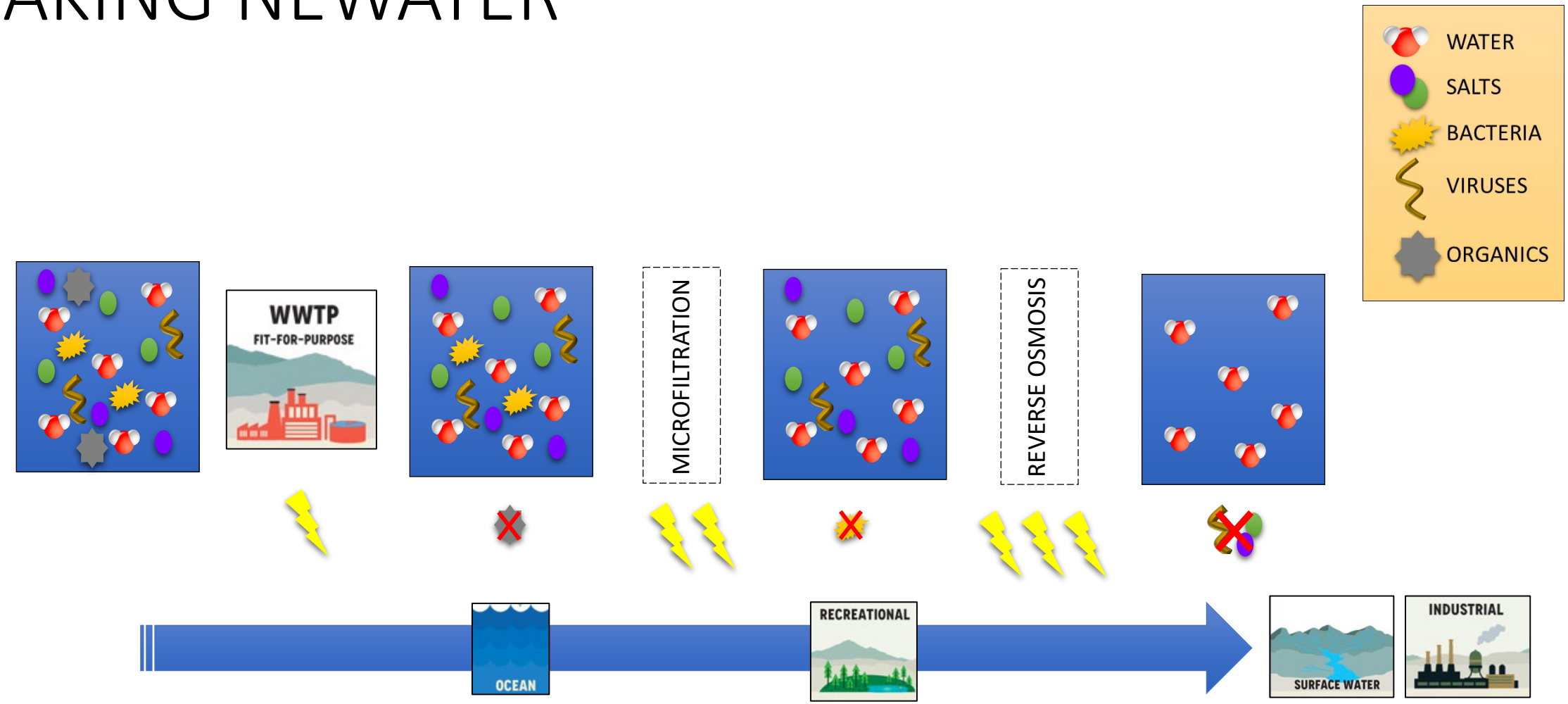
MAKING NEWATER



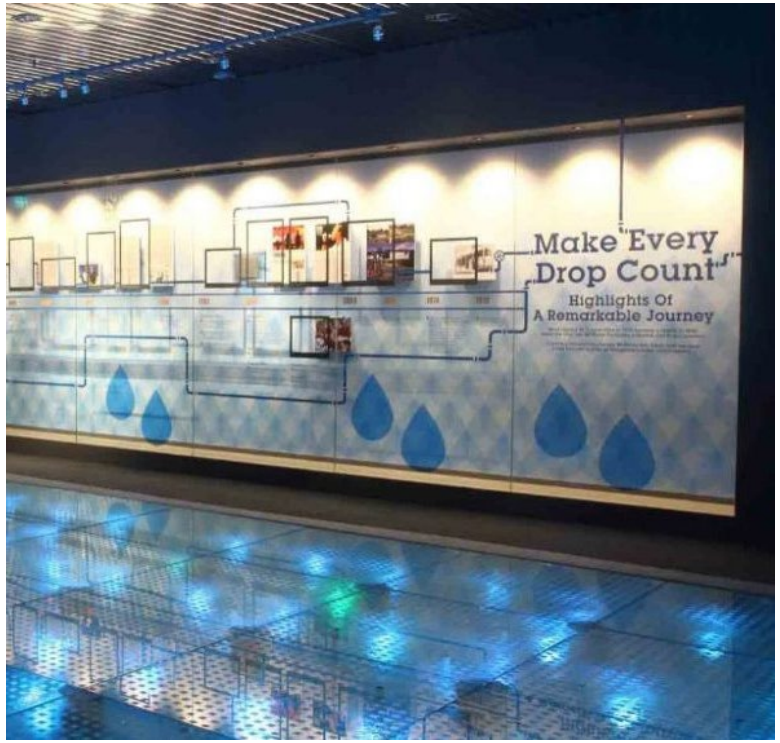
ANALYSIS OF A SUCCESS STORY

- 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^3 (approx. 1.4 Euro/m^3) vs. S$2.7/$m^3$ for potable water
- Expected to rise to 55% by 2060 = 440 mgd (> 1.6 hm^3/d)

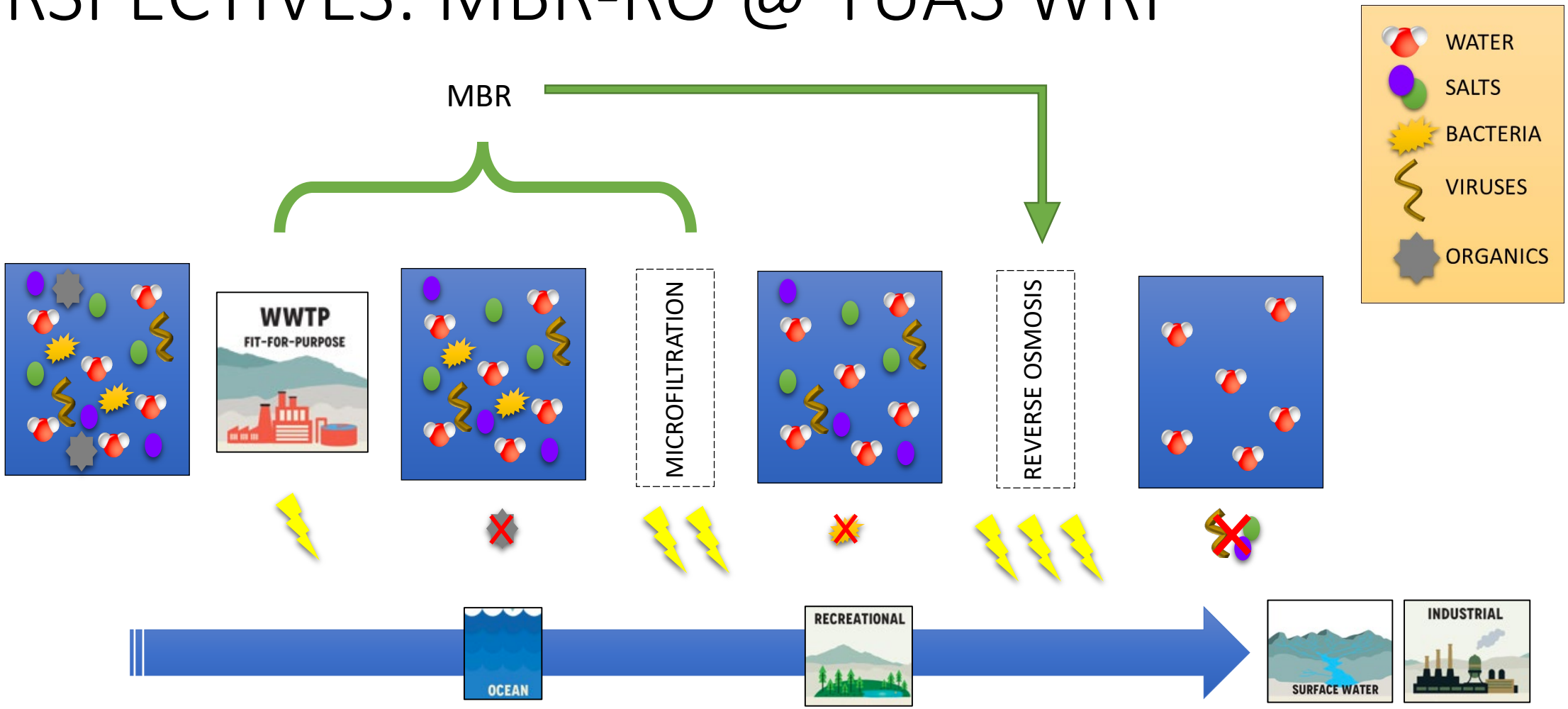
More examples

NEWater Visitor Centre

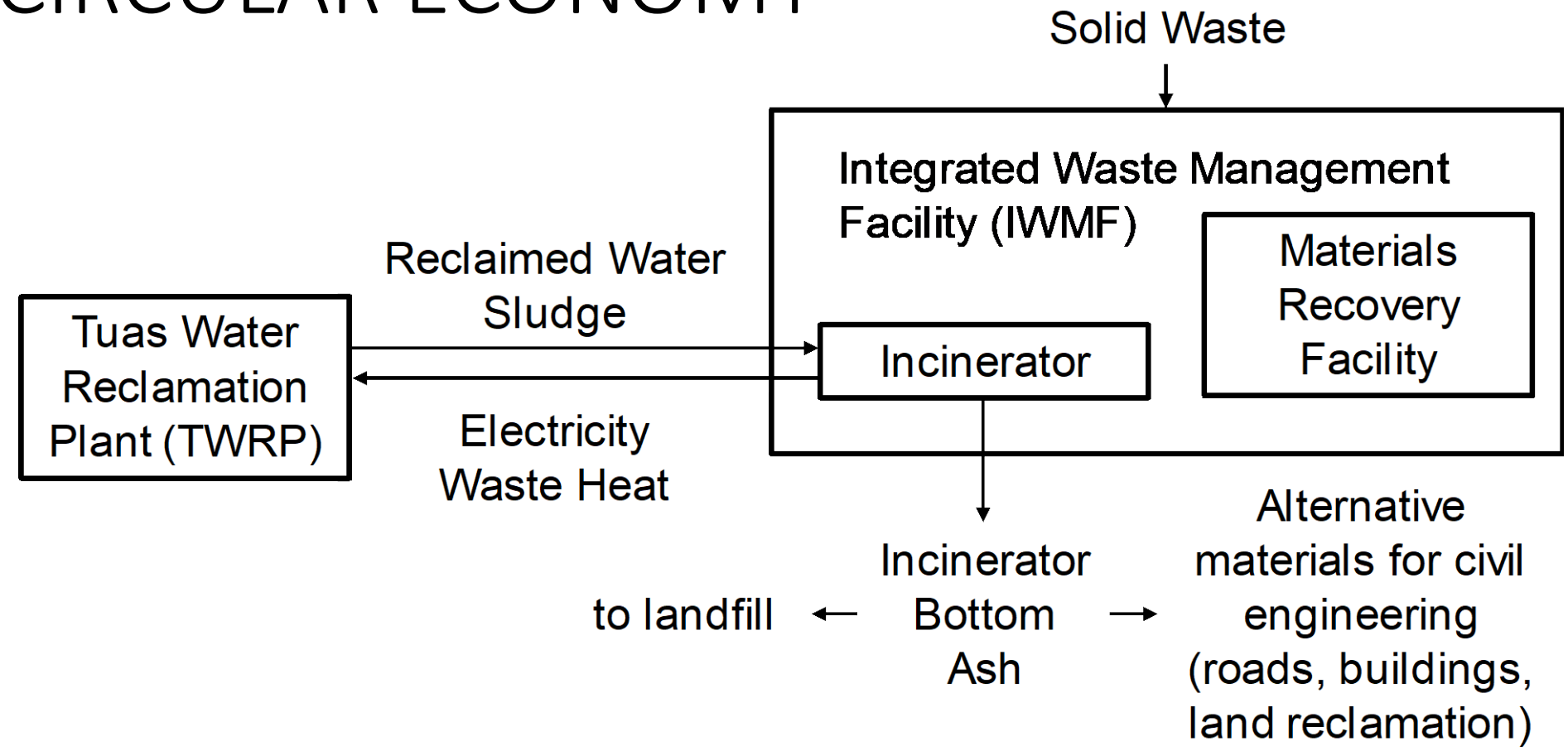


NEWbrew

PERSPECTIVES: MBR-RO @ TUAS WRP



WATER REUSE AS A COMPONENT OF CIRCULAR ECONOMY

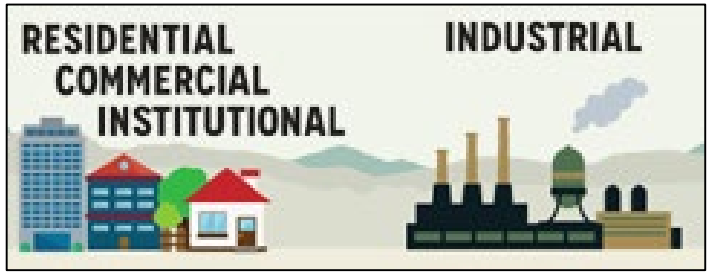


IS DPR AN OPTION IN S'PORE?

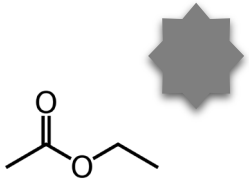
- Not considered but Singapore has several advantages that would make that option viable
- Public Utility Board (PUB) already manages the whole water cycle from drinking water to wastewater treatment
- Trust in technology, experts and government: over 300 persistent organic pollutants are already routinely 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

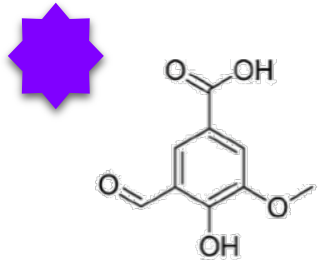
CHALLENGES AHEAD…

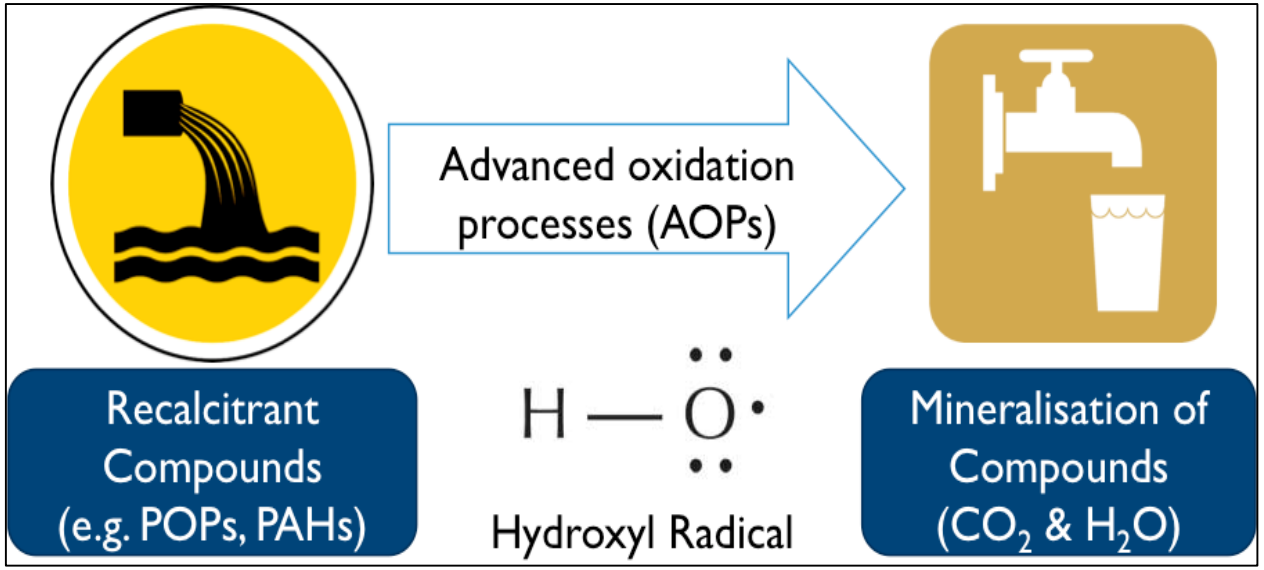
EVOLUTION OF WATER USAGES



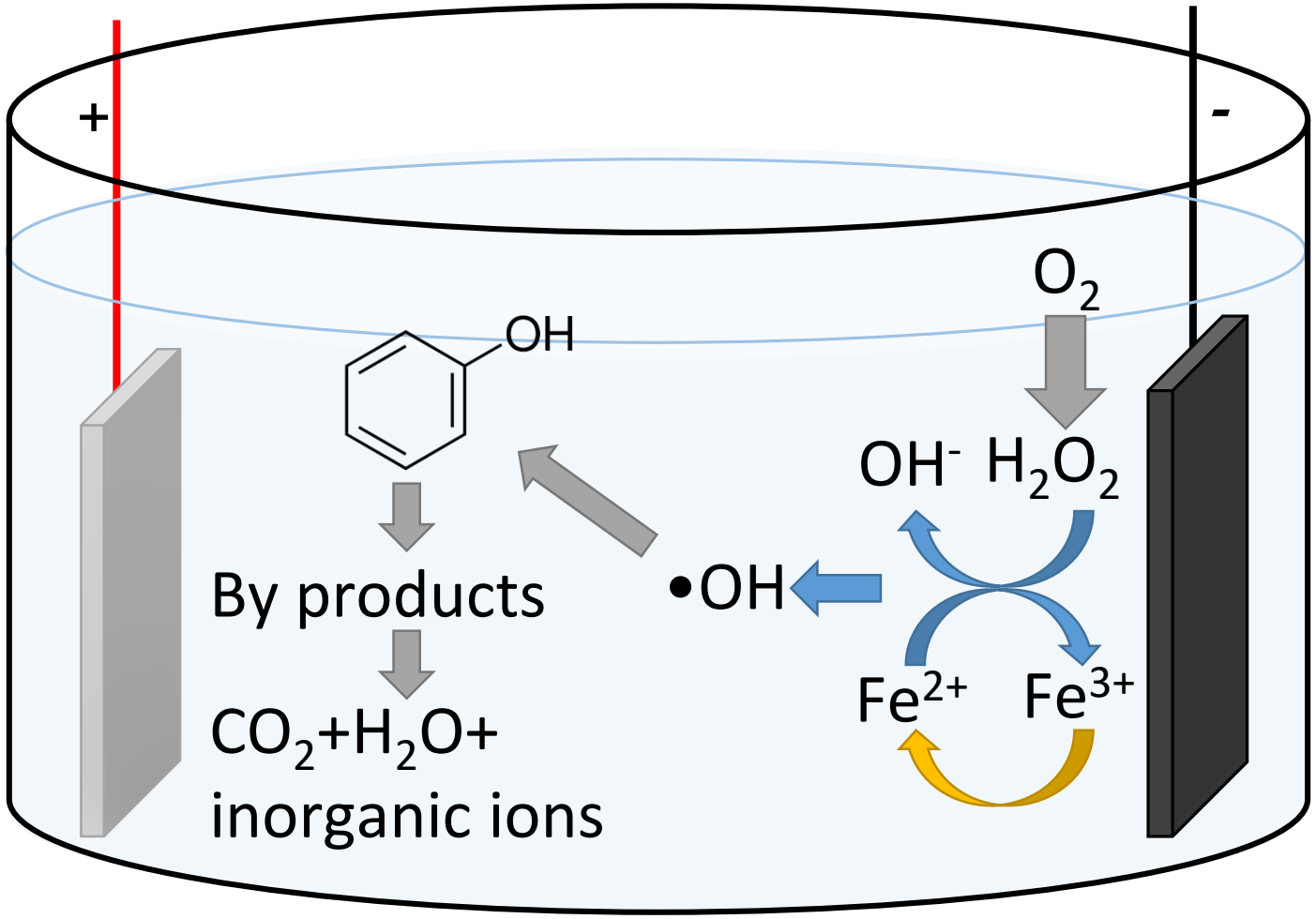
2011	45%	55%
2060	30%	70%

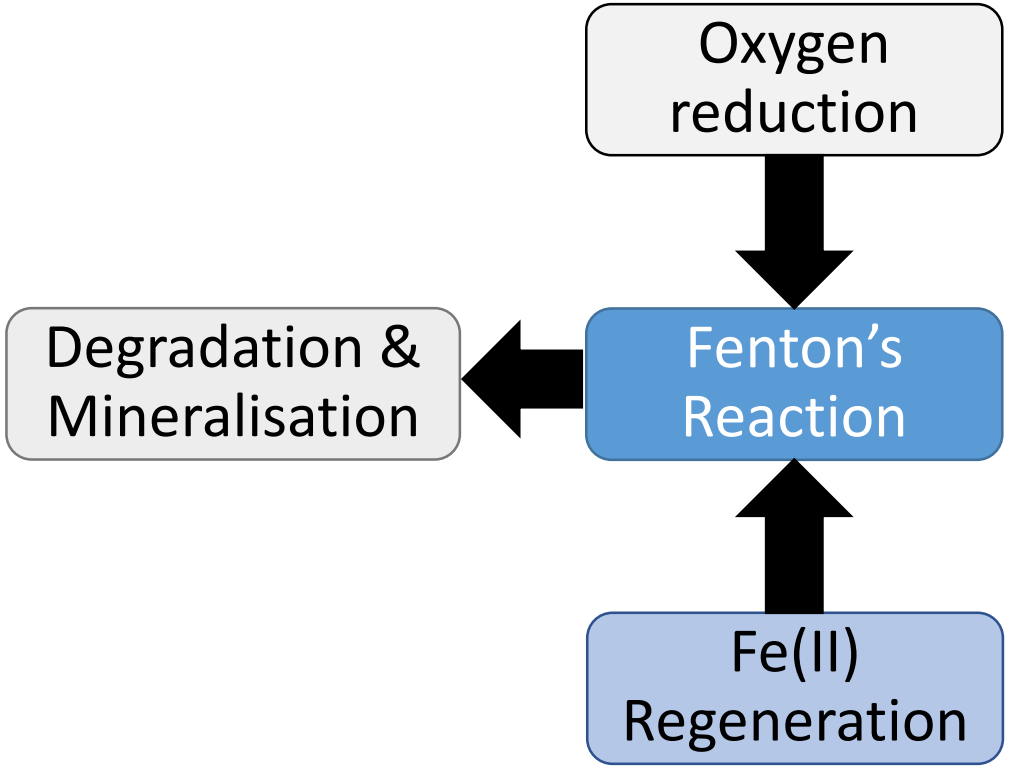




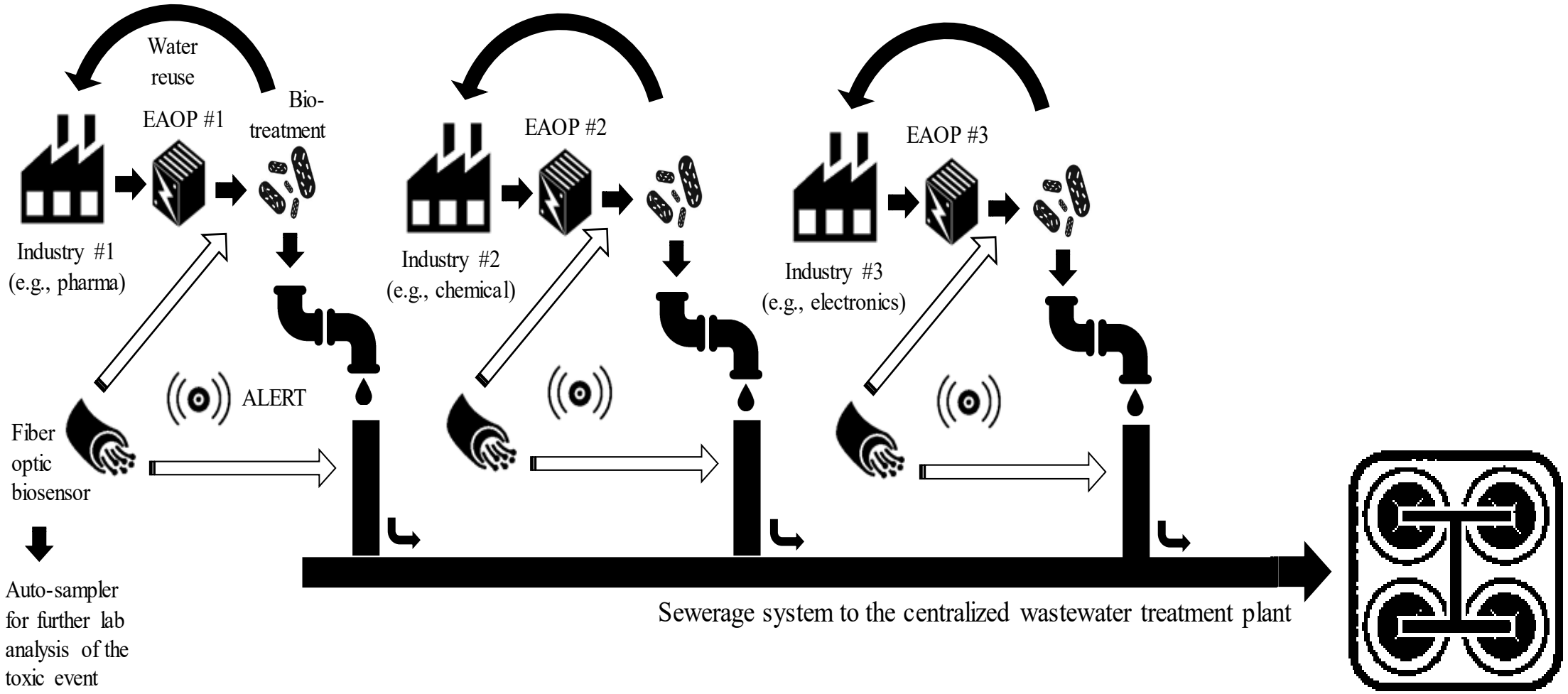


ELECTRO-FENTON



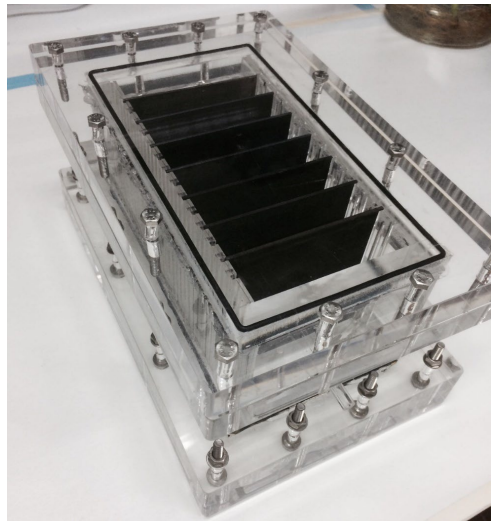


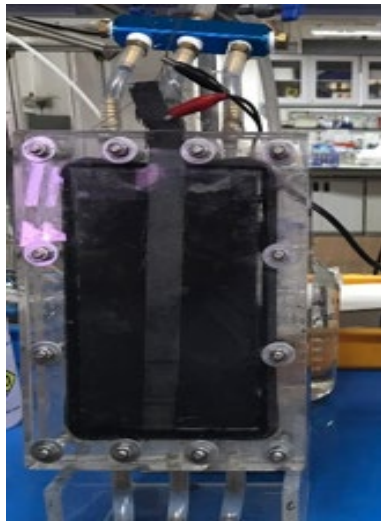
ELECTRO-FENTON FOR DECENTRALIZED INDUSTRIAL WATER REUSE

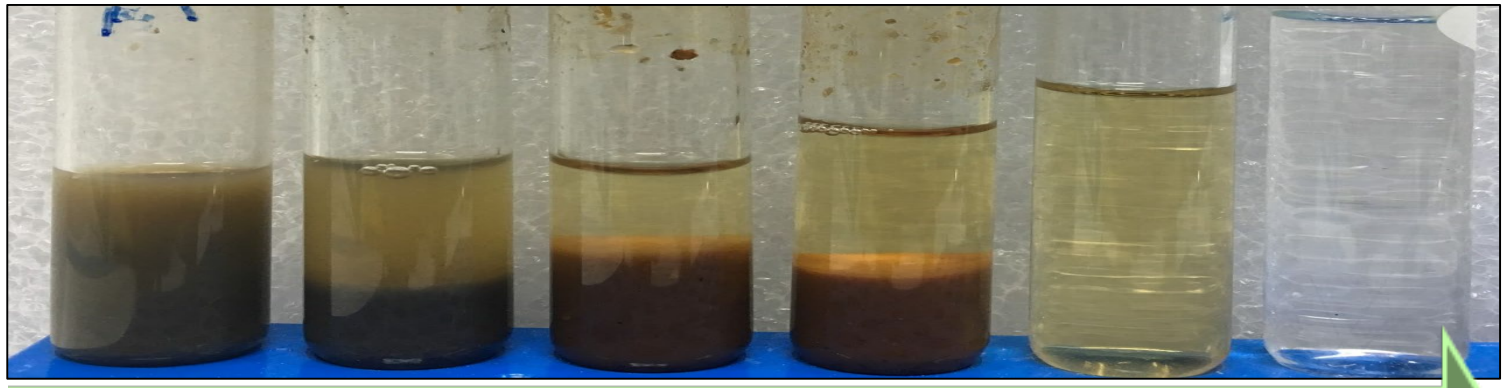


APPLICATIONS AT NUS

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

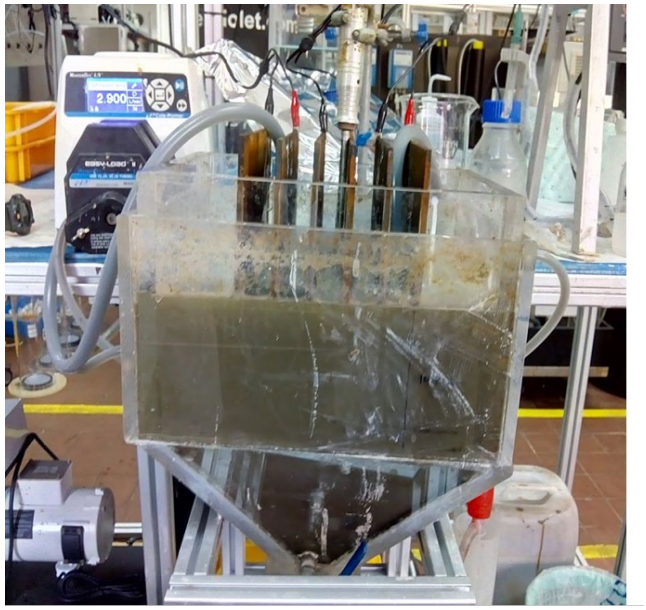




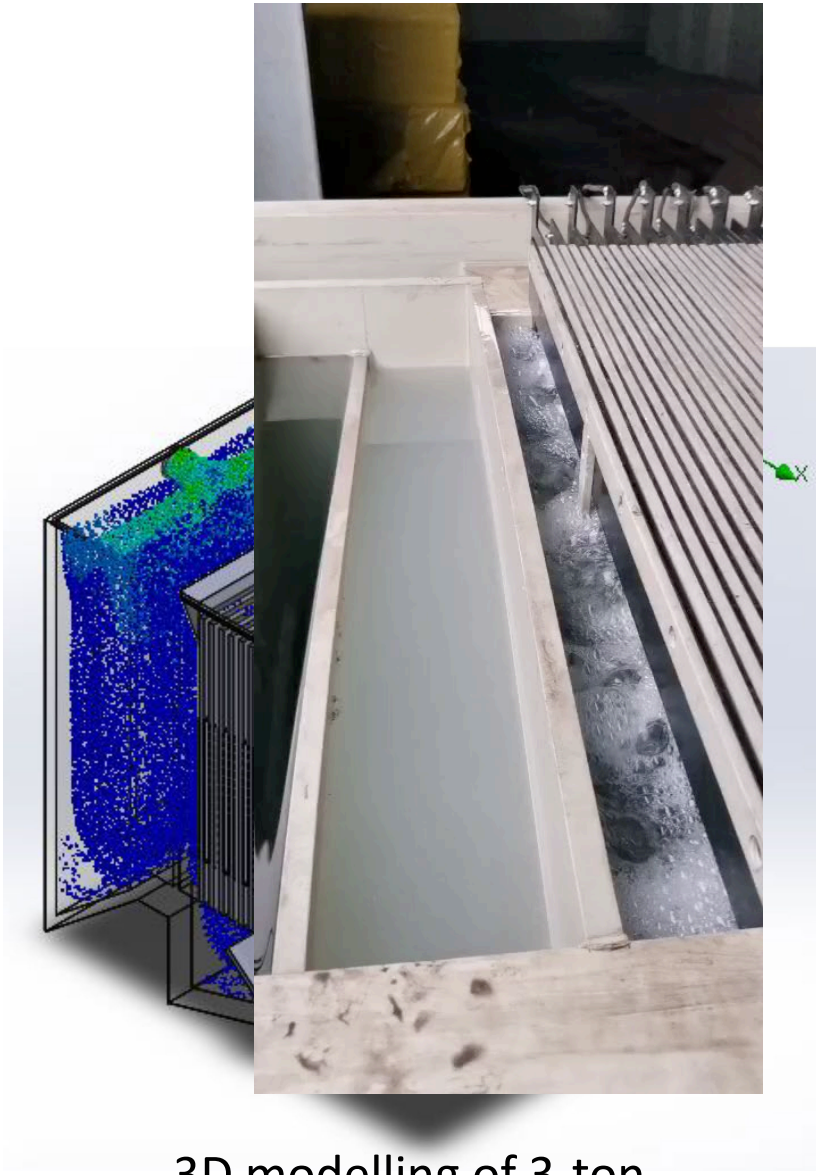


THE PATH TO SCALING UP

Successful 0.4L
Lab-scale test

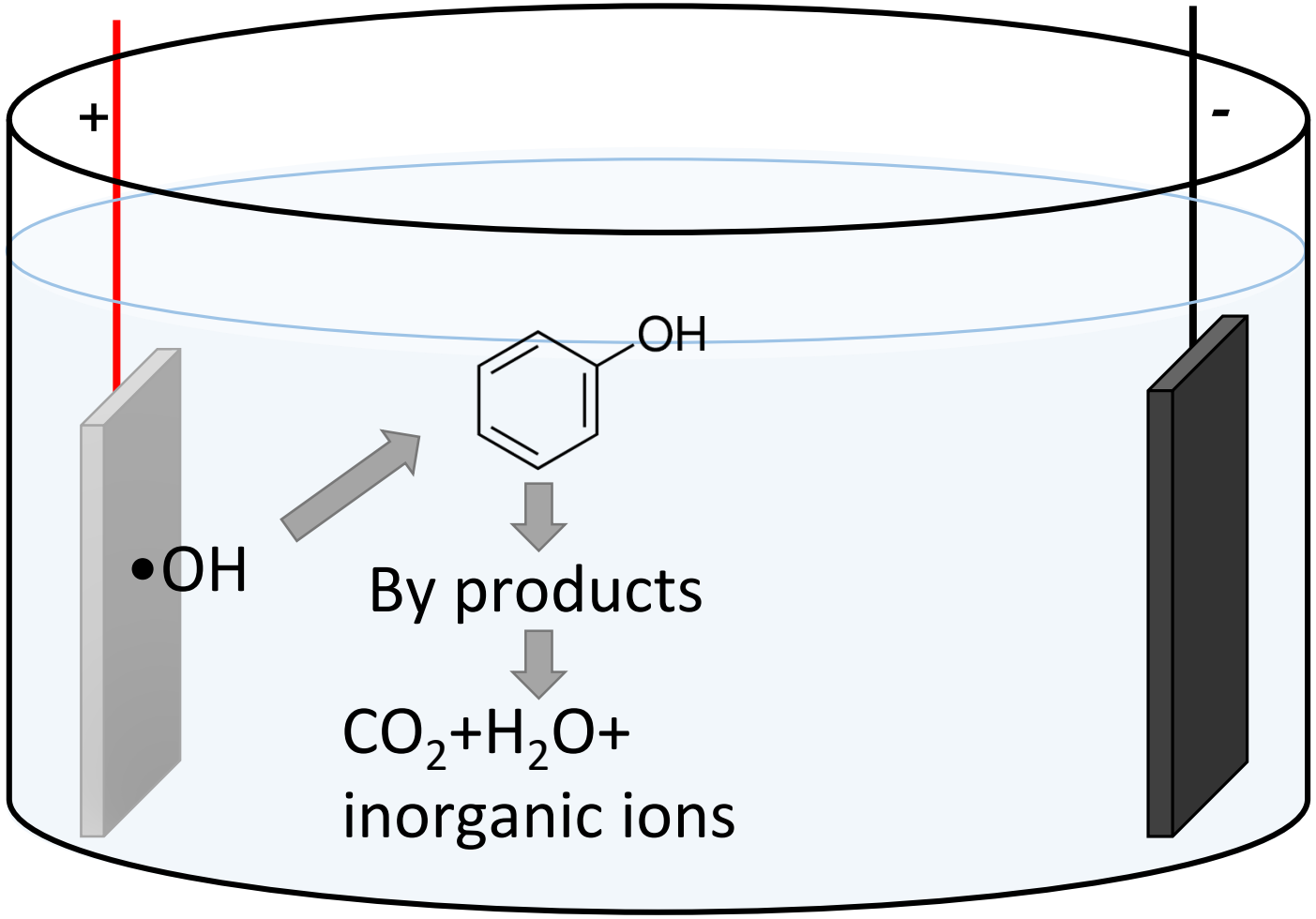


Successful
10L Bench-scale test



3D modelling of 3-ton
pilot

ANODIC OXIDATION



Degradation & Mineralisation ← ANODIC OXIDATION

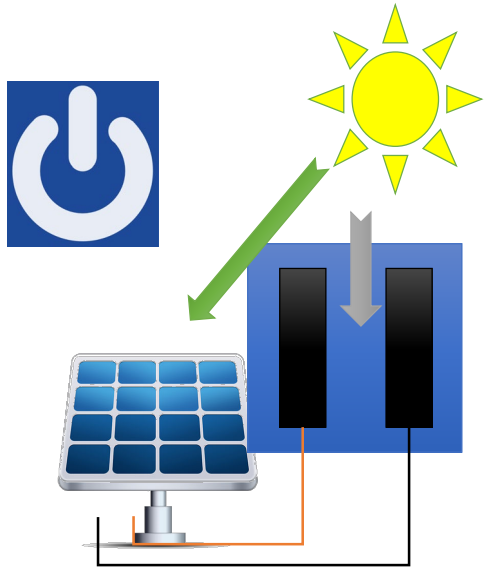
APPLICATIONS AT NUS

- Outdoor use in natural environment
- Combination with solar power

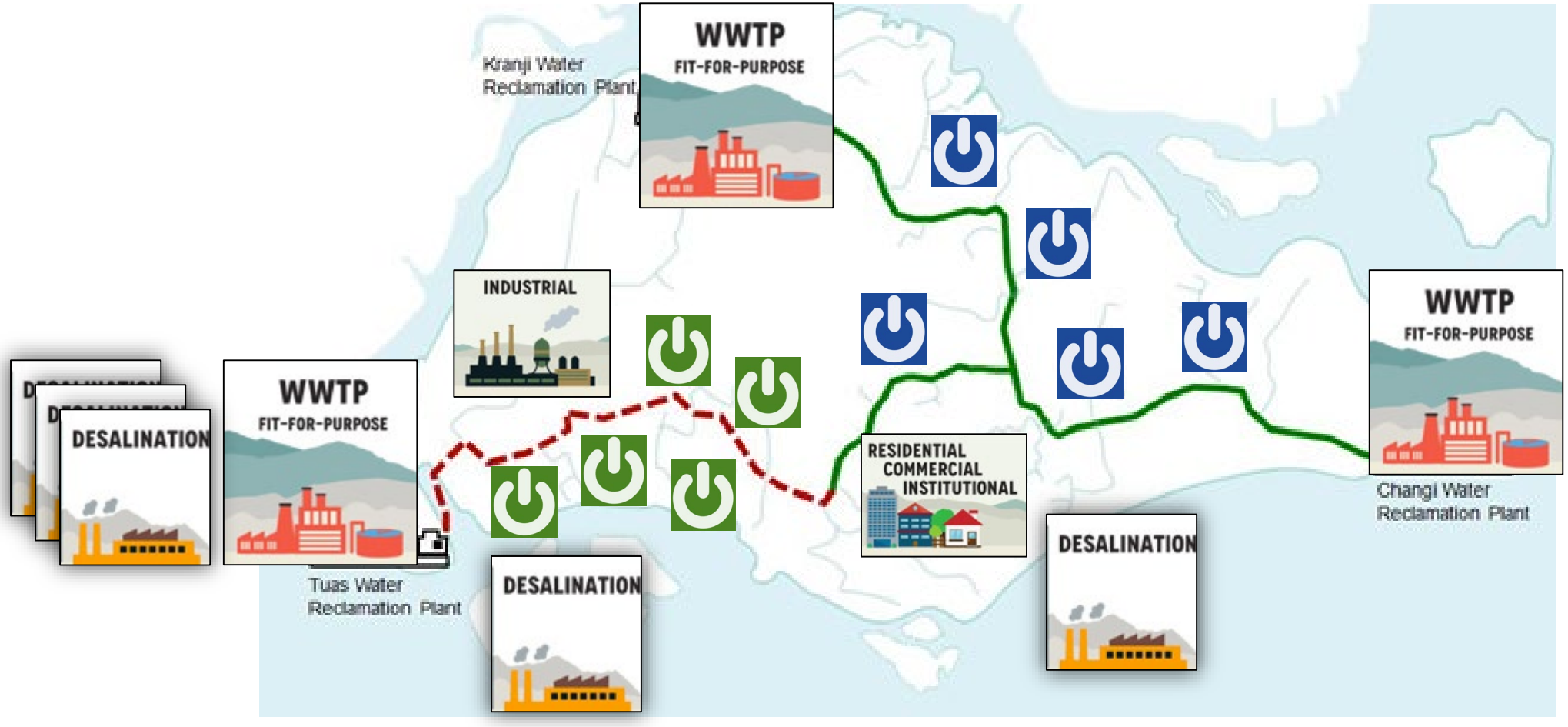
Freshwater reservoirs

Marine environment

Green buildings

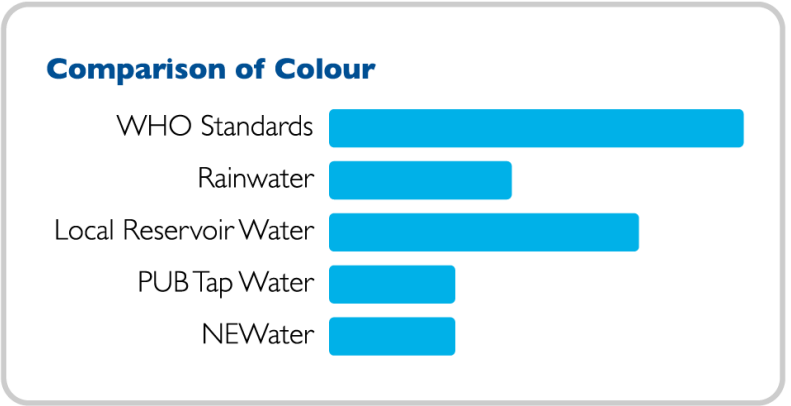


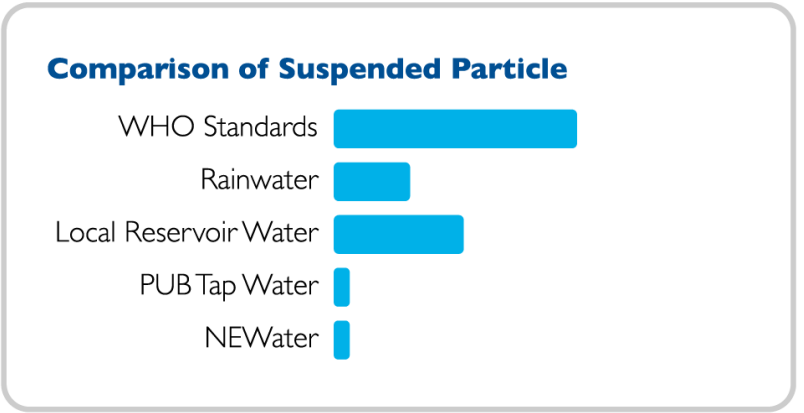
A LOOK INTO THE FUTURE

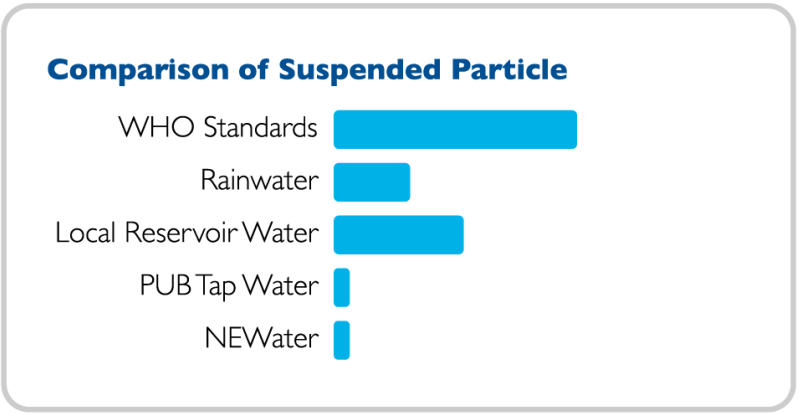


TAKE AWAYS

- 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







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 a **key player** in developing water technologies in the XXIst century

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