13th sdewes Conference Palermo 2018

September 30 - October 4
Palermo, Italy

UTM UNIVERSITI TEKNOLOGI MALAYSIA

PROSPECT PROCESS SYSTEMS ENGINEERING CENTRE engineering sustainability

Water Minimisation Via Integrated Planning And Management Of Water Supply And Demand

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THE EXPONENTIAL GROWTH OF HUMANITY

worldometers

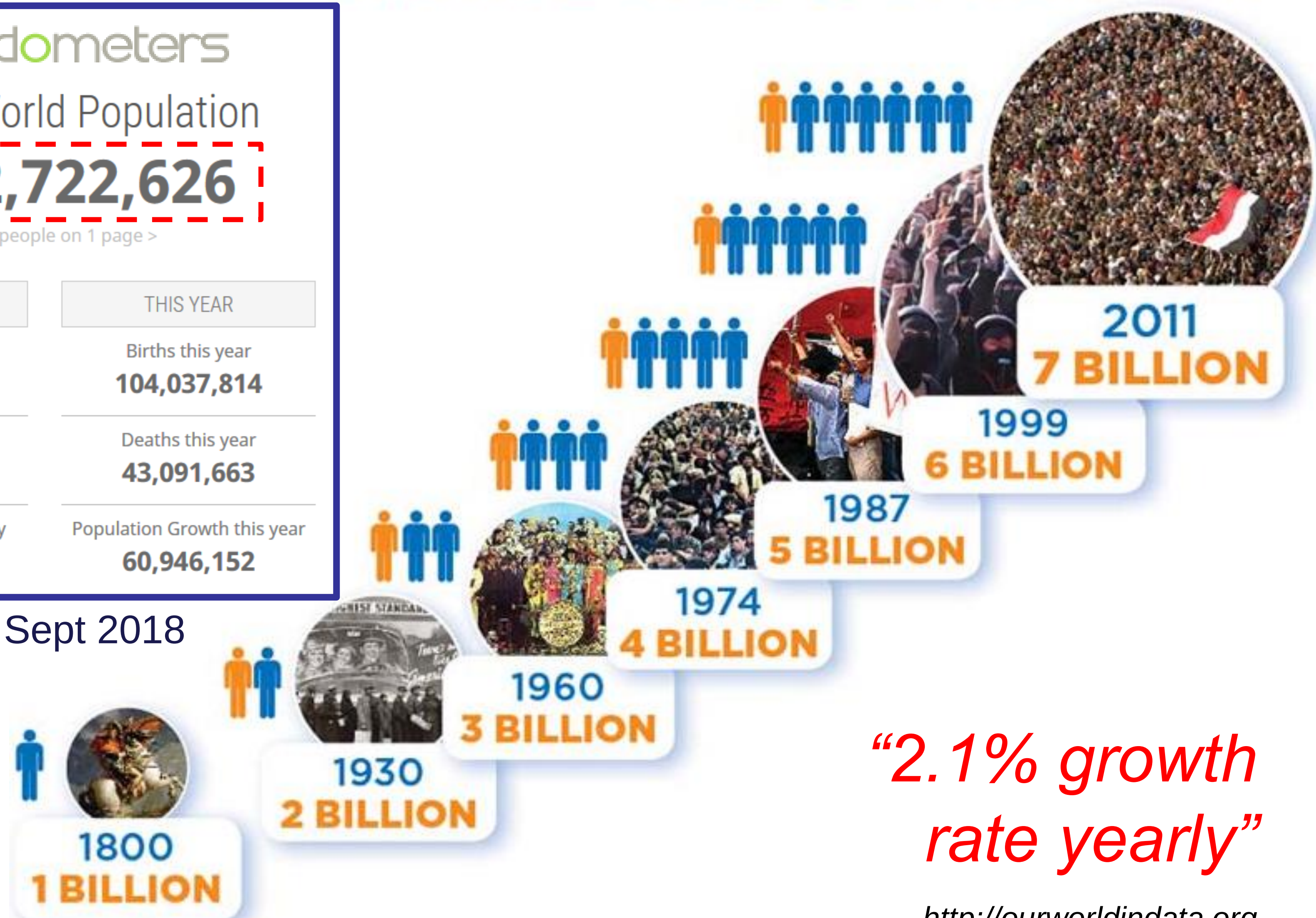
Current World Population

7,652,722,626

view all people on 1 page >

TODAY	THIS YEAR
Births today **245,477**	Births this year **104,037,814**
Deaths today **101,675**	Deaths this year **43,091,663**
Population Growth today **143,802**	Population Growth this year **60,946,152**

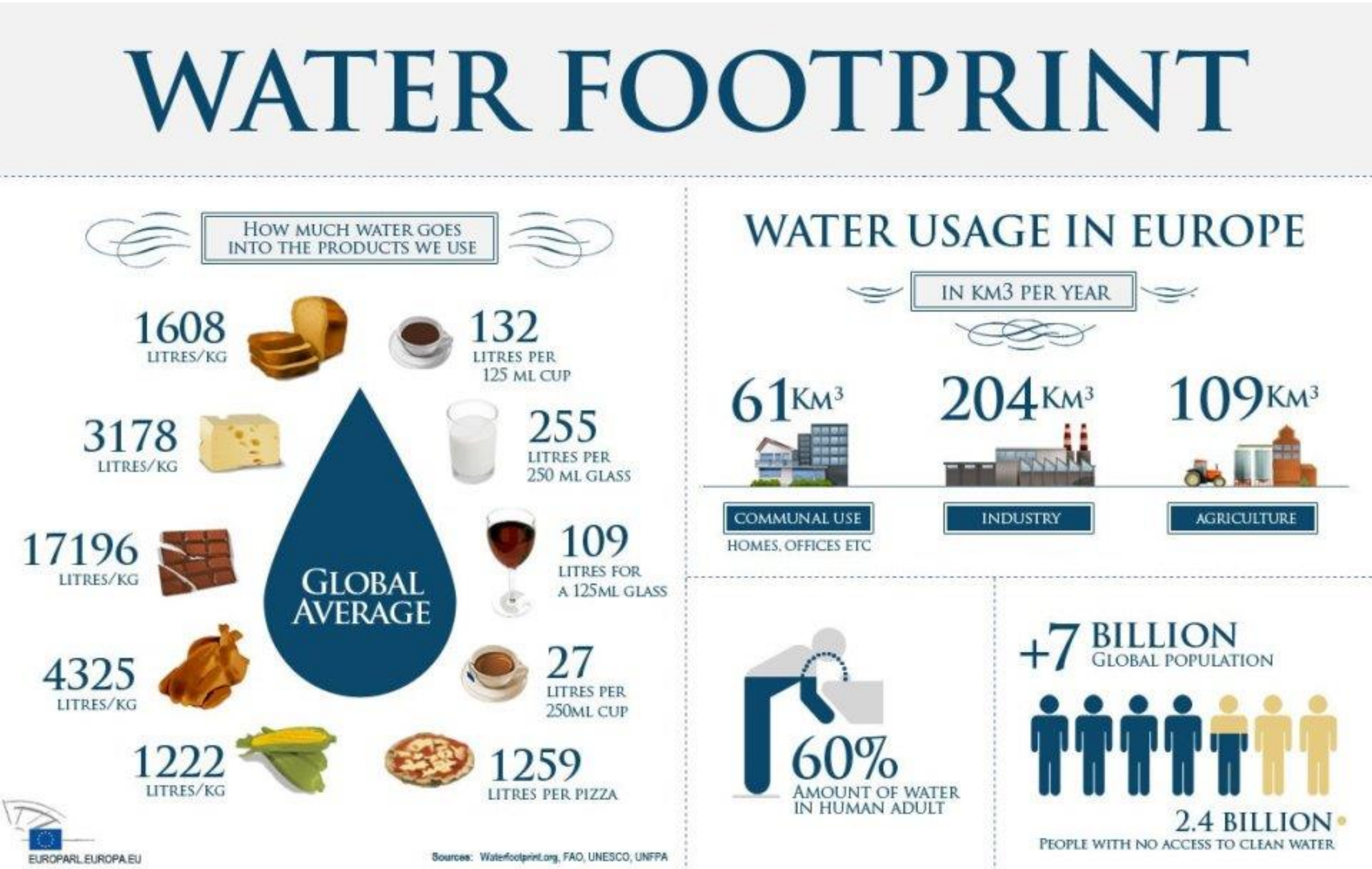
Data on: 26 Sept 2018



"2.1% growth rate yearly"

http://ourworldindata.org

Source: http://theday.co.uk

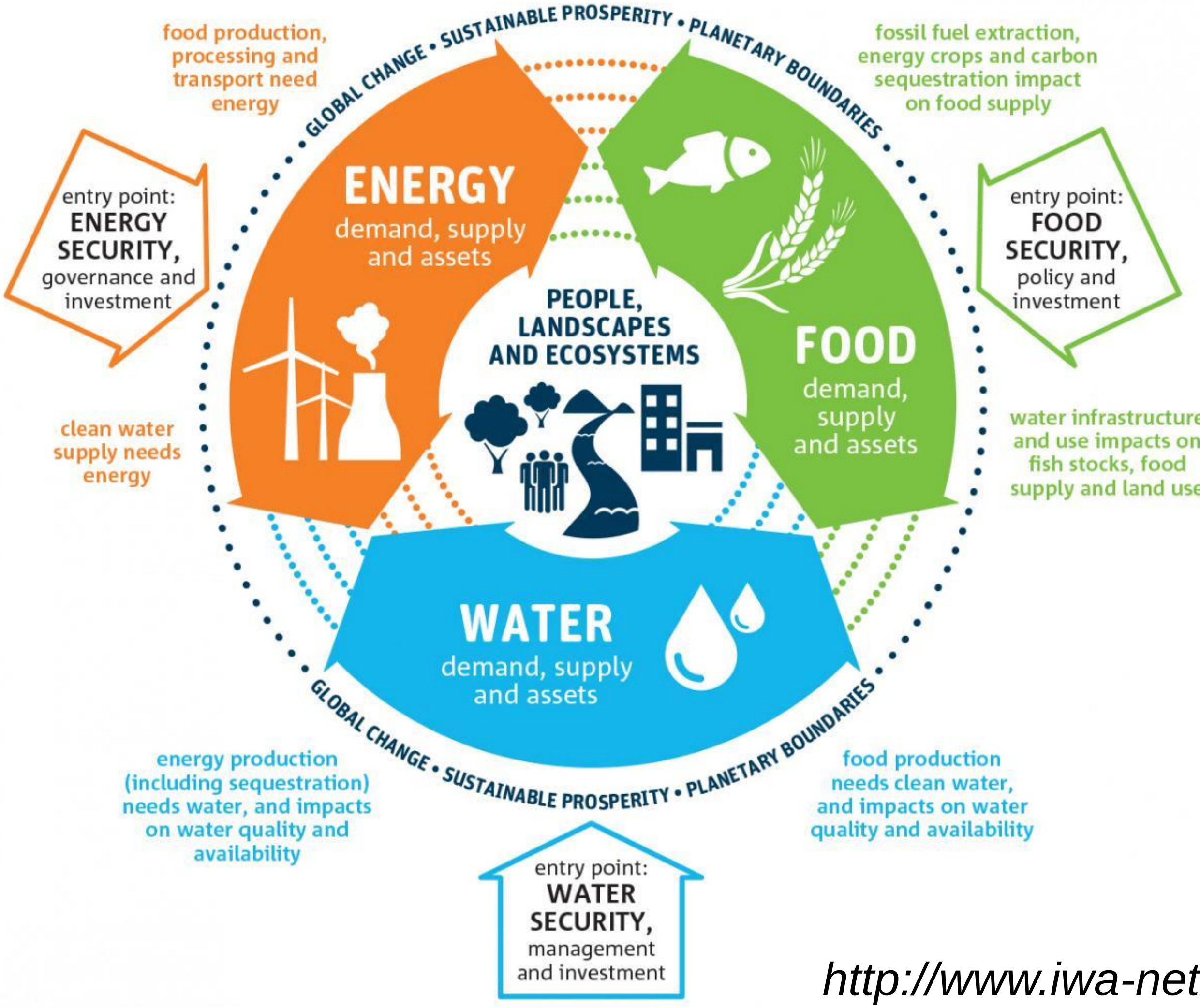

WATER FOOTPRINT
HOW MUCH WATER GOES INTO THE PRODUCTS WE USE
1608 LITRES/KG
132 LITRES PER 125 ML CUP
3178 LITRES/KG
255 LITRES PER 250 ML GLASS
17196 LITRES/KG
GLOBAL AVERAGE
109 LITRES FOR A 125ML GLASS
4325 LITRES/KG
27 LITRES PER 250ML CUP
1222 LITRES/KG
1259 LITRES PER PIZZA
EUROPARL.EUROPA.EU
Sources: Waterfootprint.org, FAO, UNESCO, UNFPA
WATER USAGE IN EUROPE
IN KM3 PER YEAR
61KM³
204KM³
109KM³
COMMUNAL USE
HOMES, OFFICES ETC
INDUSTRY
AGRICULTURE
60%
AMOUNT OF WATER IN HUMAN ADULT
+7 BILLION
GLOBAL POPULATION
2.4 BILLION
PEOPLE WITH NO ACCESS TO CLEAN WATER

Climate Change

“Water shortage is one of highest global risks!”

WEF Global Risk Report, 2014

Food-Energy-Water Nexus

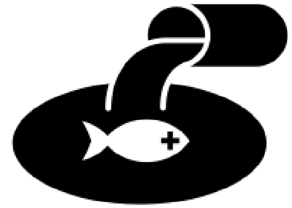


http://www.iwa-network.org

Groundwater

Overextraction

Water pollution



Upstream river
Stormwater

Reduce water demands

Reduce freshwater requirement

Reduce wastewater generated

Public acceptance?

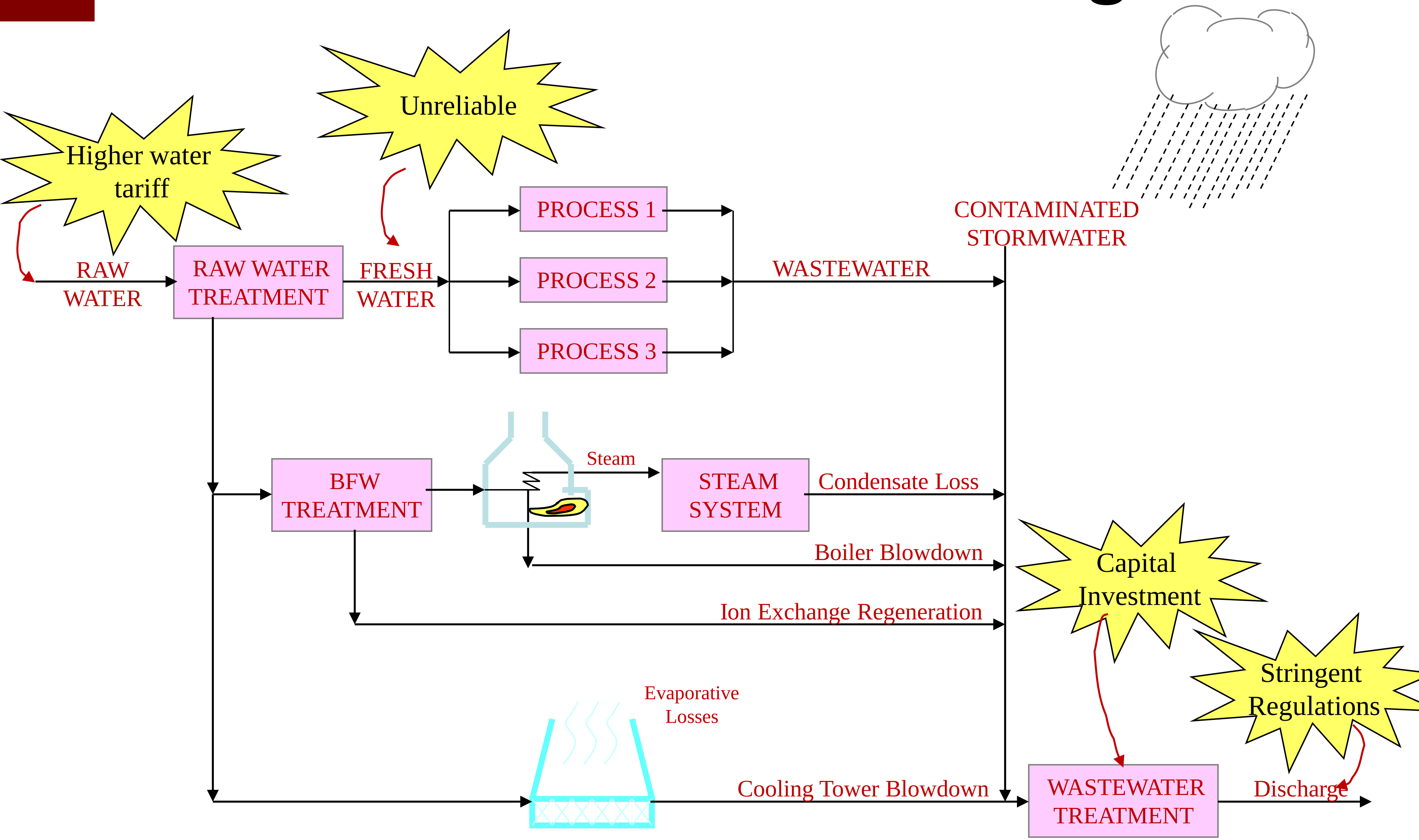
Harder to treat
Expensive treatment

We need more water?

Find more alternative water supplies?

What Can We Do?

Government take charge



User Take Charge

Industry*;
Public & Commercial Facilities;
Domestic & Individuals

Change Behavior!

*Include agriculture

A machine is easier to be controlled than a human…

User Take Charge

Industry*;
Public & Commercial Facilities;
Domestic & Individuals

Change Behavior!

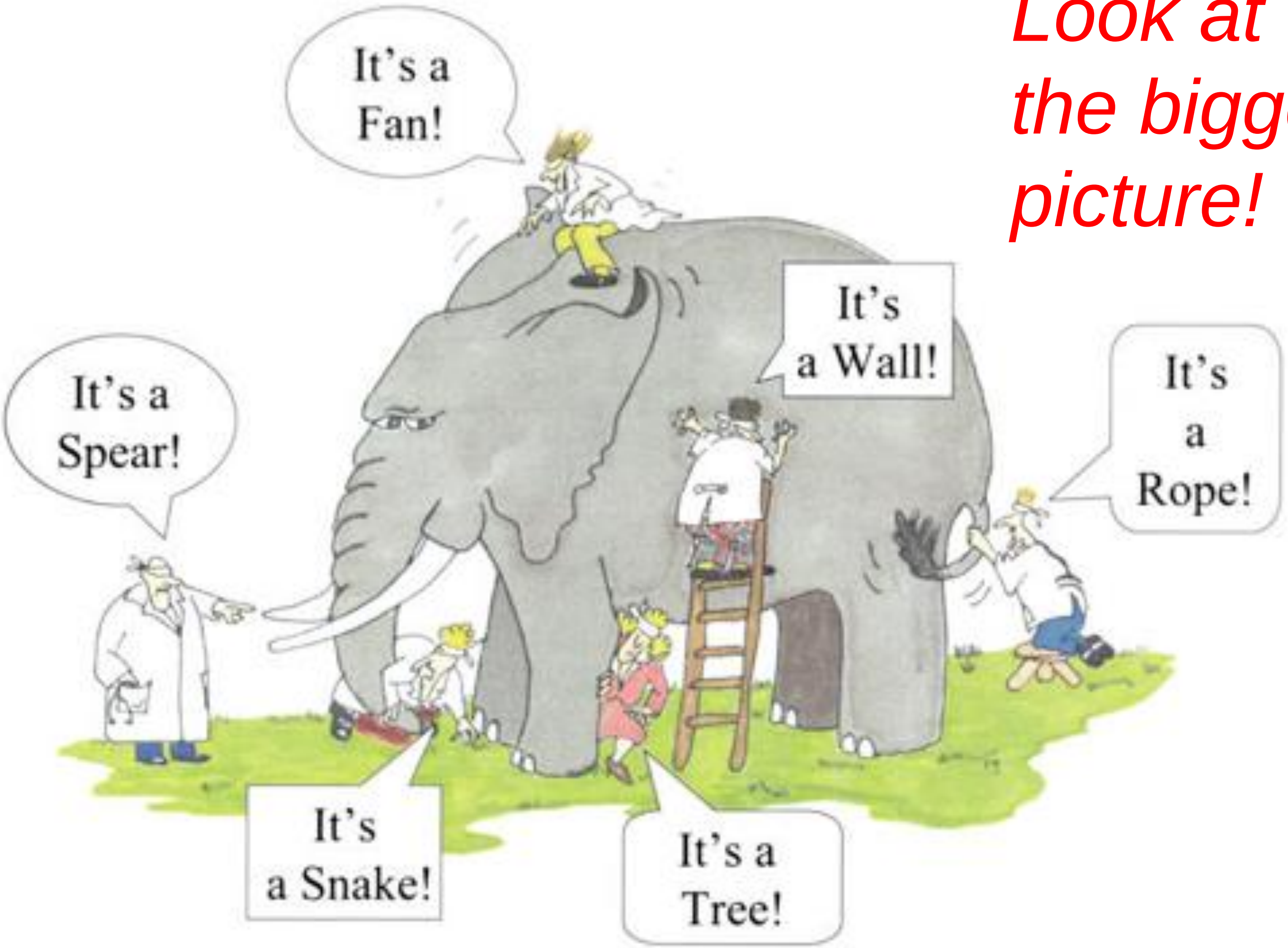
Engineer Sustainable Water Systems!

*Include agriculture

Option 1: Minimise water consumptions in own facility

Greener, and holistic ways?

Look at the bigger picture!



Showcase Project

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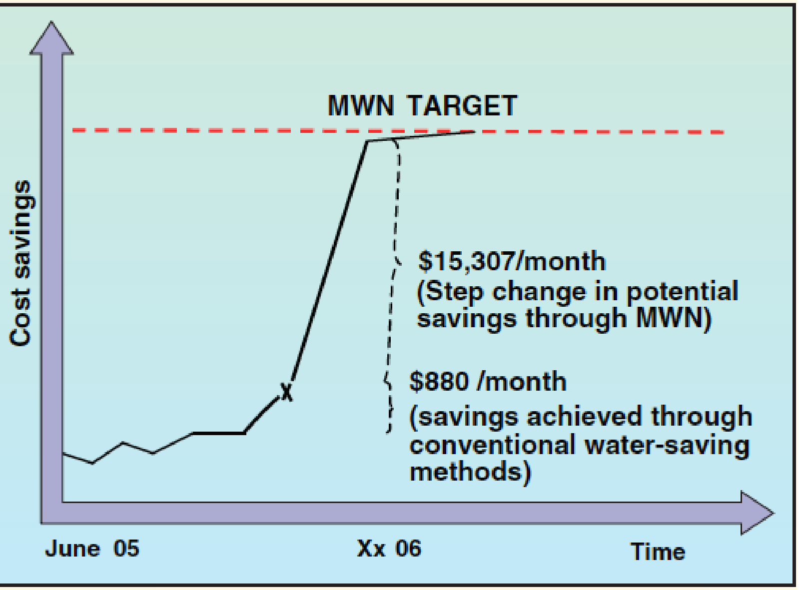
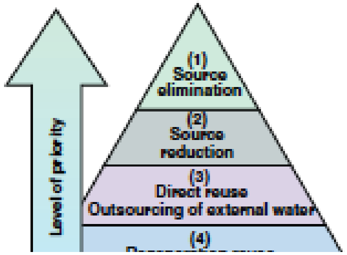
MIMOS

CHEMICAL ENGINEERING



Assess Your Plant's True Water-Savings Potential

Using the minimum water network involves detailed analysis of plant configuration and design, material and energy balances, design and thermodynamic constraints



A CASE STUDY: SETTING TARGETS FOR MINIMUM WATER NETWORK IN A SEMICONDUCTOR FABRICATION PLANT

Water is a major utility for many sectors of the chemical process industries, but for semiconductor manufacturers, it is also a precious commodity. The extreme water demands of a semiconductor fabrication plant — from the ultrapure water required for chipmaking processes to potable water and, increasingly, recycled water for plant operations and maintenance — provide an ideal case study for the application of MWN benchmarking techniques.

In this case, the facility is *MySem*, a semiconductor fabrication plan in Malaysia. ; While the facility's primary activity is research and development (R&D), it produces 6-in. and 8-in. wafers. Figures 3 and 4 show the fab's water distribution network. Water demands indude deionized (DI) process water for solvent processes, acid processes, wet cleaning and tools cleaning; the rest is for plant operations such as abatement, scrubber, cooling tower and wet bench cooling, and maintenance such as toilet flushing, office cleaning, wash basin, toilet pipes and ablution, as shown in **Figure 5**.

Total water consumption varied throughout the year, depending on wafer production and equipment conditions. During the month of the benchmarking study, the fab's estimated total freshwater consumption was 42.6 m^3/h. Of this value, 31.78 m^3/h was used for DI water production and the rest for plant operations and maintenance.

Step 1. Specify the limiting water data

This step involved detailed process survey and line tracing, establishing process stream material balances and conducting water quality tests. Stream flowrates were extracted from data collected by either the plant's distributed control system (DCS) or ultrasonic flowmeters. Depending on the stream audited, tests for total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS) were conducted onsite. For processes that only used ultrapure water, TSS levels were negligible. BOD was absent since no biological contaminants were present. COD was a component of TDS. TDS

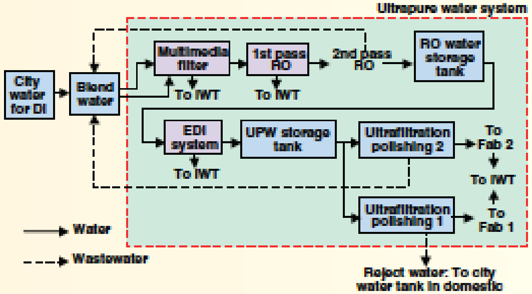


FIGURE 3. Process flow diagram for the ultrapure water system

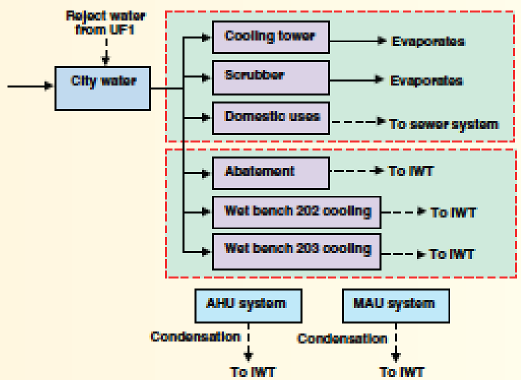


FIGURE 4. Water uses for plant operations and maintenance

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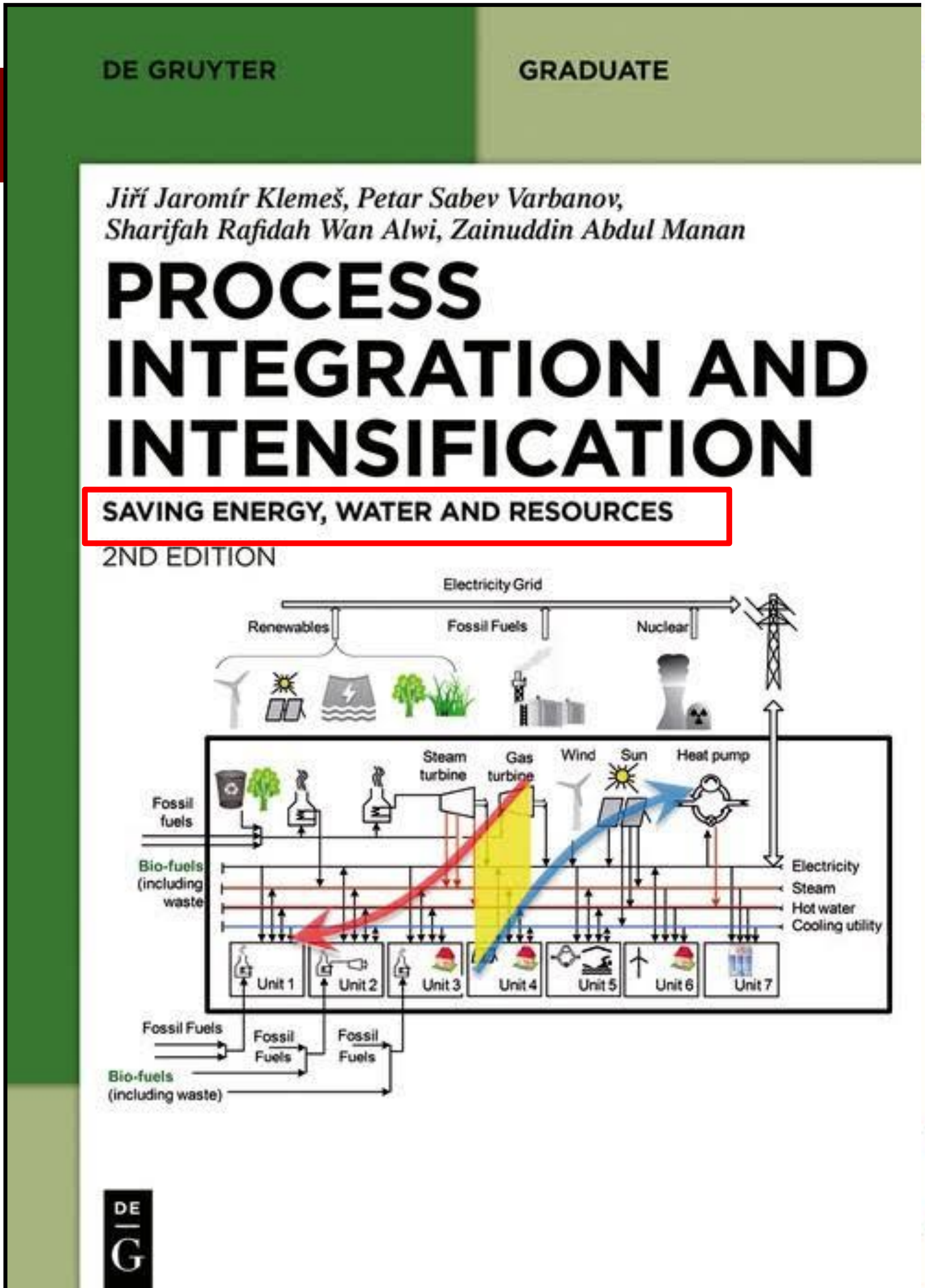
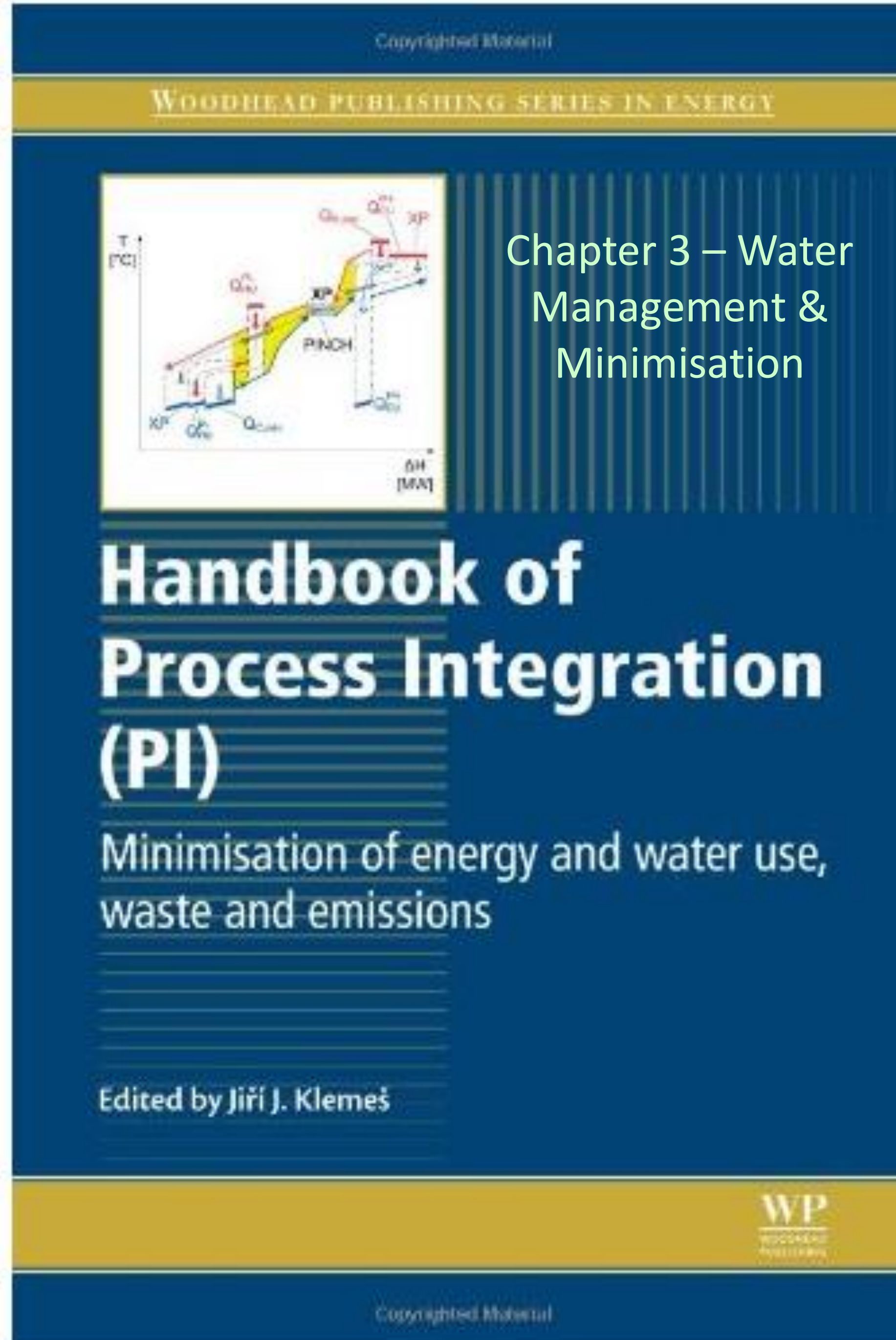
www.utm.my





Chapter 3 – Water Management & Minimisation

The Water Management Hierarchy (WMH)


RESEARCH & DEVELOPMENT

A new look at urban water saving

Cost cutting nitrate r... process

Manan, Wan Alwi & Ujang, Water21 Feb 2006

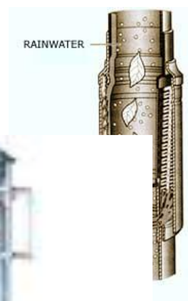
Composting toilet

Normal electrical fan

Dual flush toilet

Vacuum toilet

Aerated Flow Tap



RW Harvesting

Reuse

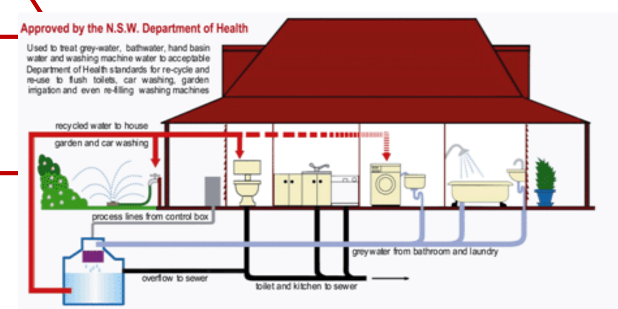
Source & Demand Manipulation

Outsourcing

Regeneration-Reuse

WW Treatment

Increase priority



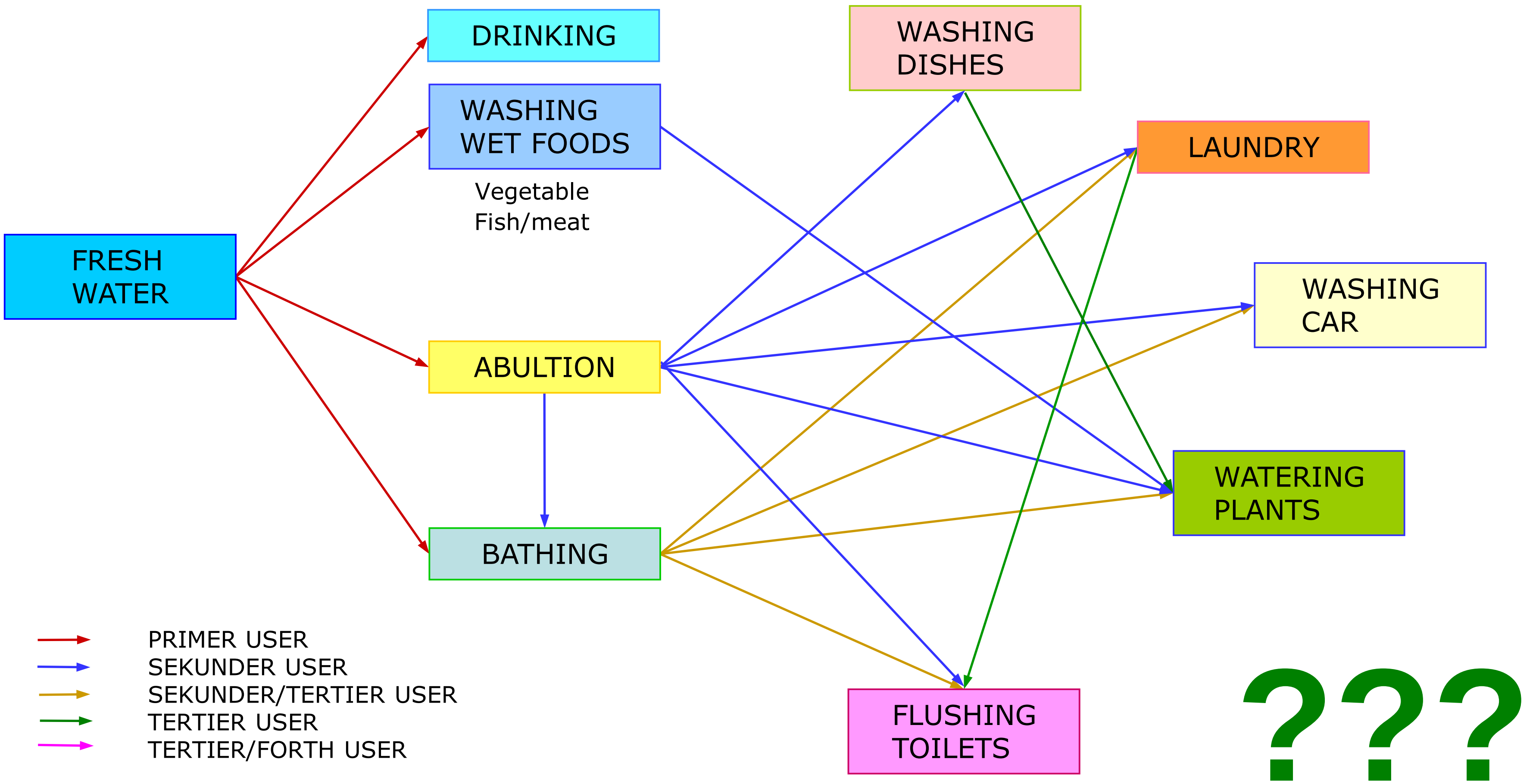
Sand filter with activated carbon

Microfiltration

This is so simple, I can just use common sense

20

Network of Water Reuse Options



Which are the best reuse matches?
How many blending options possible? Water ratios?
How do we ensure contaminants do not affect processes?

WMH	Strategy	Option selected based on NAS	Option selected based on MWN procedure
Elimination	Abatement		
	: Option 2 (decommisioning)	X	X
	WB 202 and 203 cooling	✓	✓
Reduction	WB reduction in Fab 1 and 2	✓	✓
	Heater reduction	✓	✓
	Fab 1 return reduction	✓	✓
	Abatement		
	: Option 1 (0.5gpm during idle)	X	X
	: Option 3 (recirculation)	✓	X
	: Option 4 (on demand)	X	✓
	: Option 5 (pH analysis)	X	X
	Increase RO system recovery/ install 3rd stage	✓	✓
	EDI return reduction		
	: Option 1 (decommissioning)	X	✓
	: Option 2 (run intermittent)	✓	X
	Domestic reduction	✓	X
	Cooling tower reduction using N2	✓	✓
	MMF reduction by NTU analysis	✓	✓
Reuse	Total reuse	✓	✓
Outsourcing	RW harvesting	✓	✓
Regeneration	Treat all WB water	X	✓

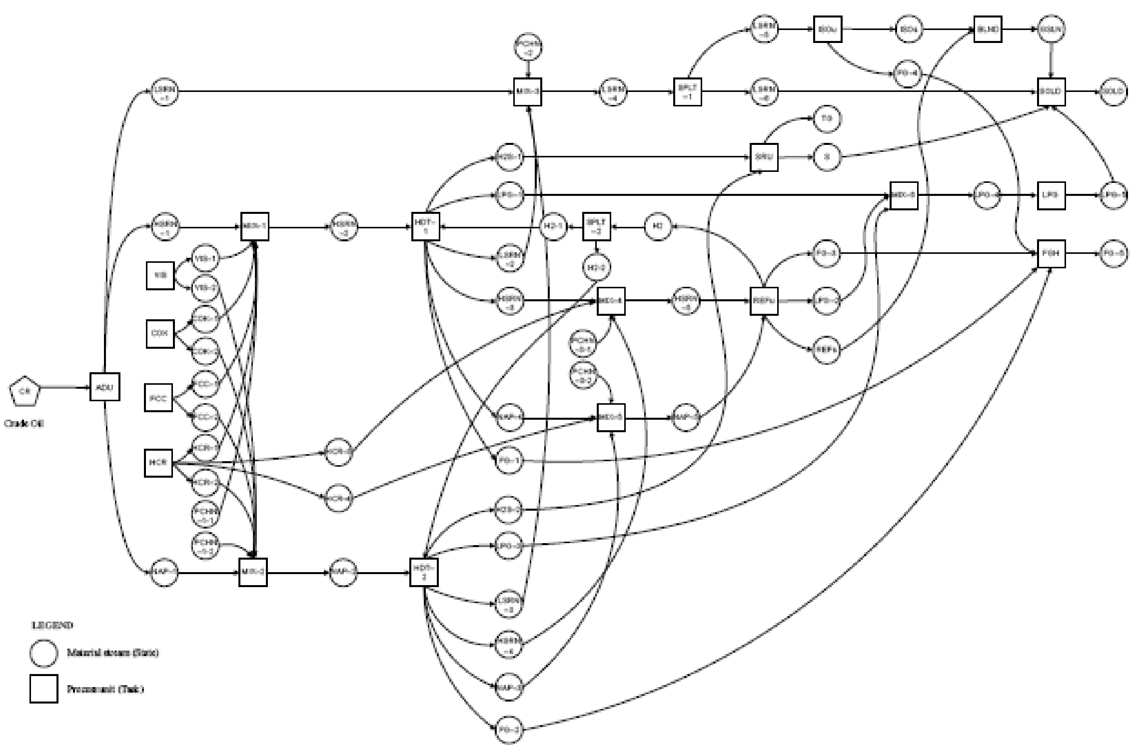
Which water minimisation to choose? What is the interactions with other WMH?

Environment vs Economy?

Engineer sustainable water systems...

Systems Approach

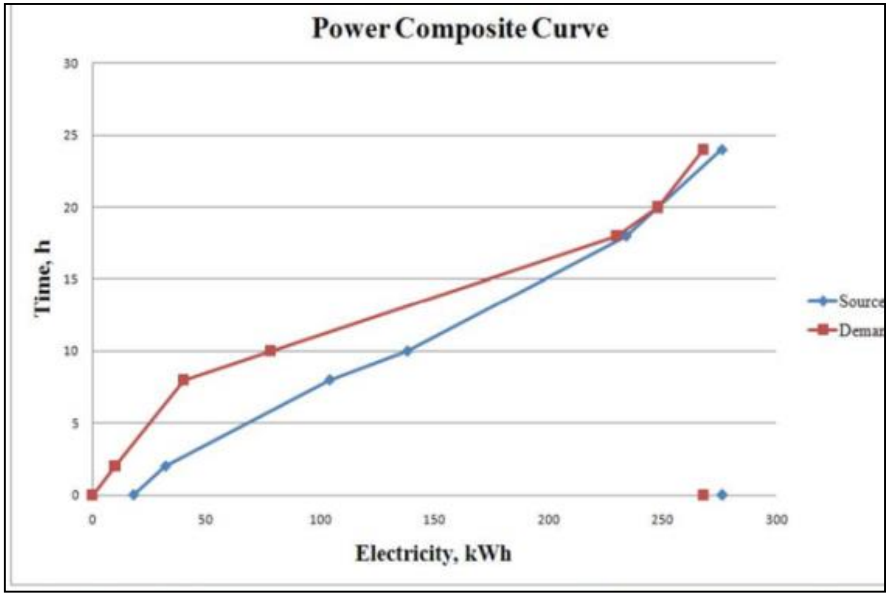
Can help to analyse all the possibilities from all angles before the actual design or committtment. Valuable insights for top management to make decision.



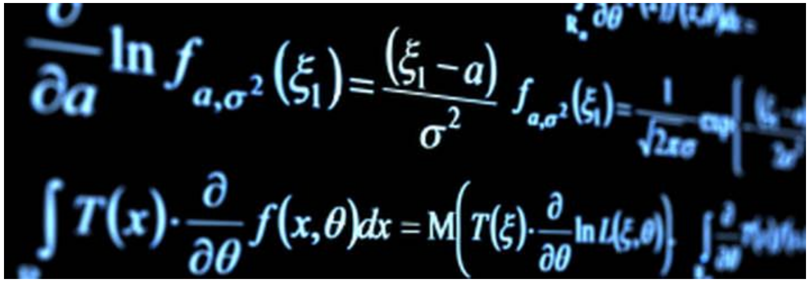
IR4.0

Approaches

Pinch Analysis

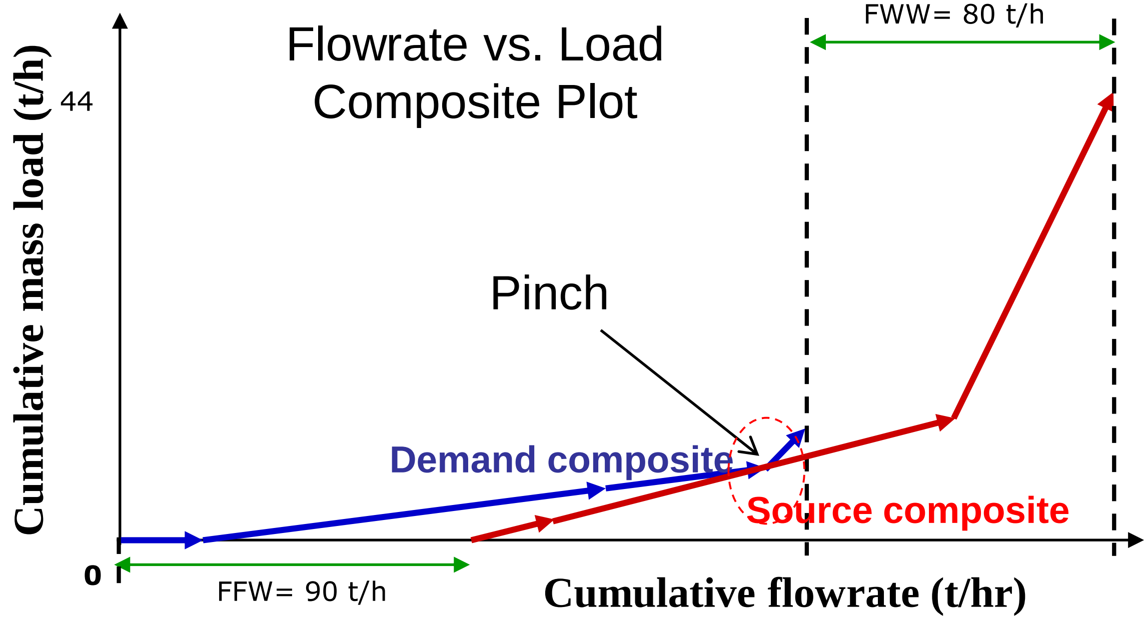


Mathematical Modelling

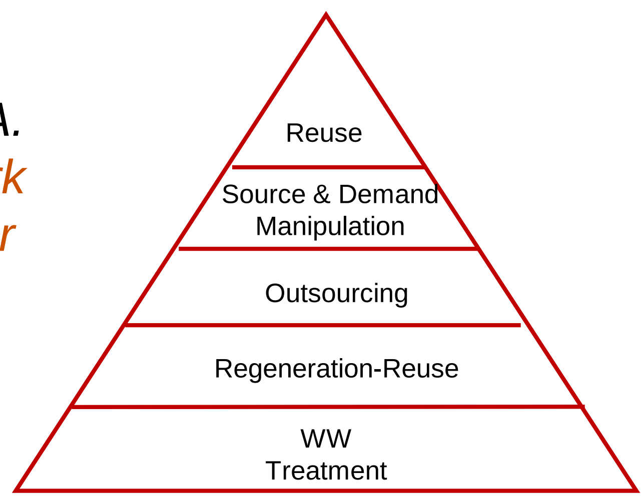


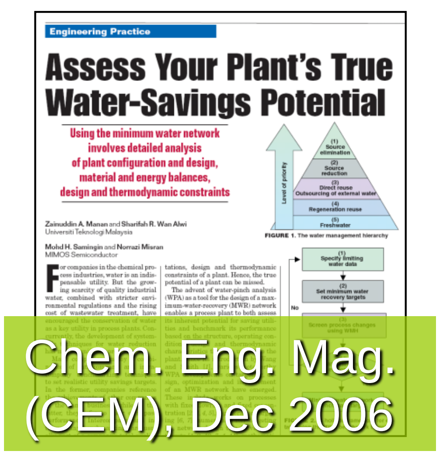
Cost Effective Minimum Water Network (CEMWN) technique

Use the graphical tools to guide where to eliminate, reduce, outsource or regenerate



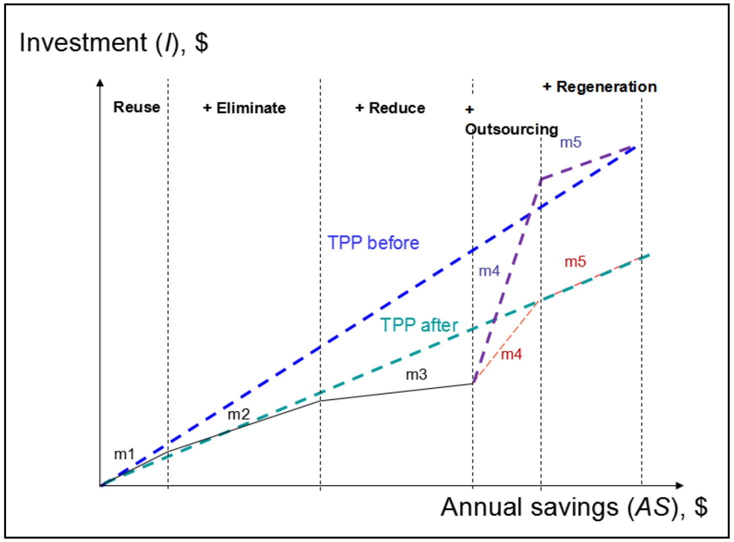
***Wan Alwi, S. R.** and Manan, Z. A. (2008). A New Holistic Framework for Cost Effective Minimum Water Network in Industrial and Urban Sector. Journal of Environmental Management. 88: 219-252.*





Systematic Hierarchical Approach for Resilient Process Screening (SHARPS) technique

IAS Composite Plot



(1) Set *TPPset*

↓

(2) Generate *IAS* composite plot

↓

(3) Draw a straight line connecting the starting point and the end point of the IAS plot to obtain TPP_{BS}

↓

(4) Compare TPP_{BS} with TPP_{set}

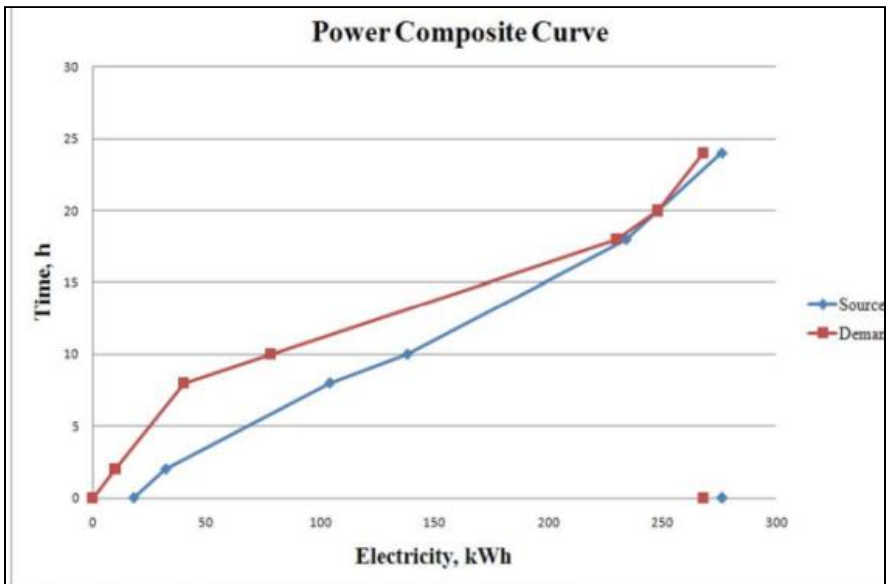
- **If $TPP_{BS} \leq TPP_{set}$** → **(5) Proceed with network design**
- **If $TPP_{BS} > TPP_{set}$** → **(5) Apply SHARPS strategies**

Screen the options based on the budget and investment limits

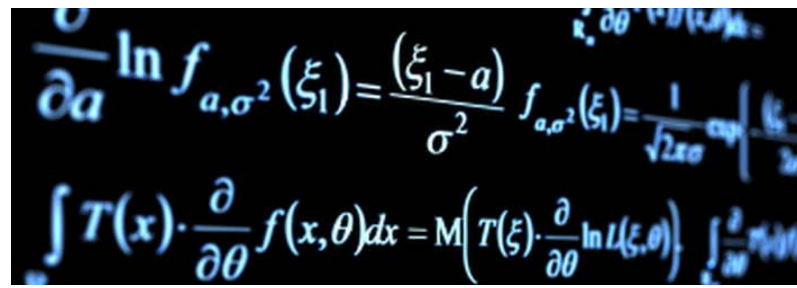
S. R. Wan Alwi and **Z. A. Manan**. (2005) *SHARPS – A New Cost Screening Technique to Attain Cost-effective Minimum Water Network.* AiChe Journal, Vol 52, No. 11, November, 2006.

Approaches

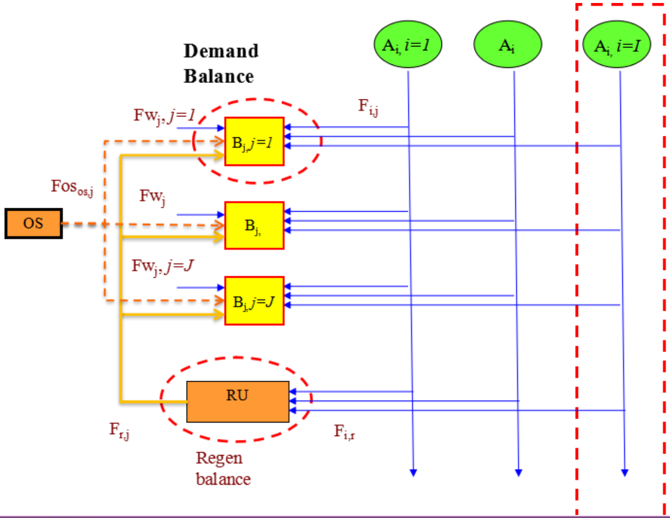
Pinch Analysis

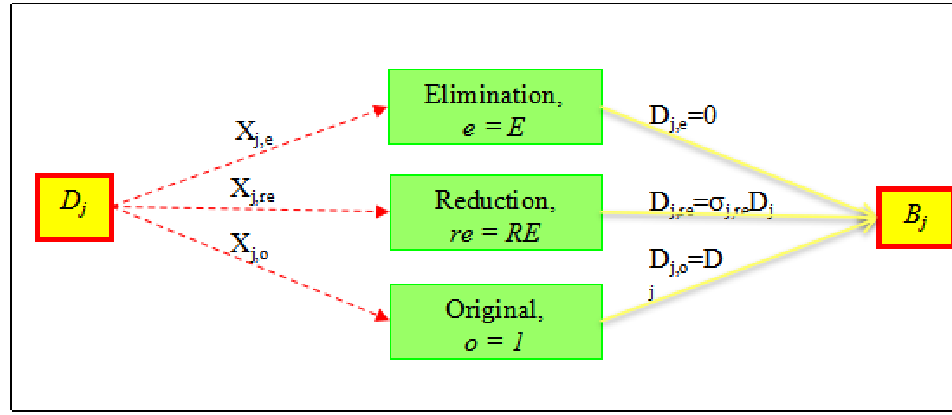


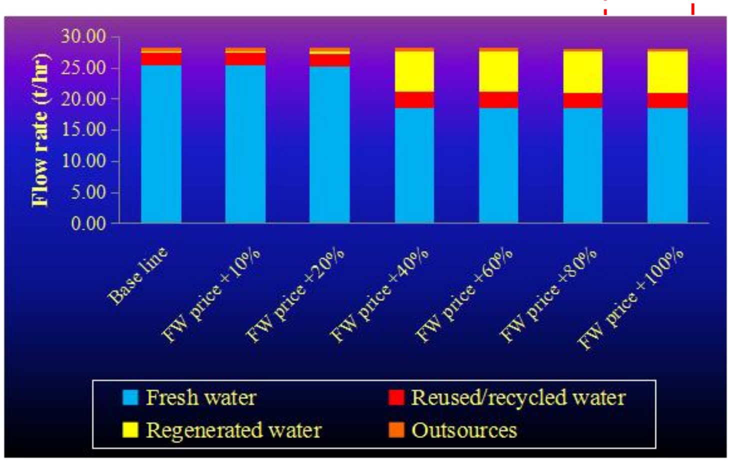
Mathematical Modelling

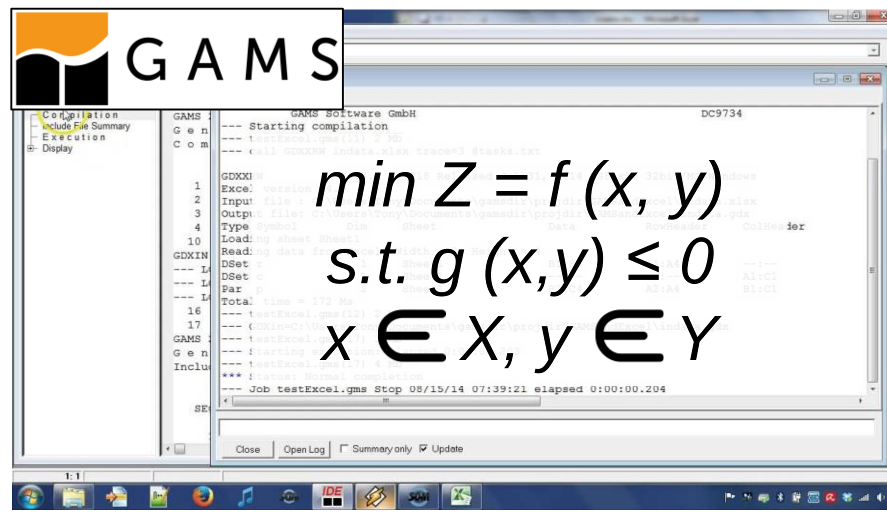


Mathematical Modelling









Handani, Z.B., Wan Alwi, S.R., Hashim, H., ***Manan, Z.A.****, Holistic Approach For Design Of Minimum Water Networks Using The Mixed Integer Linear Programming (MILP) Technique, Industrial and Engineering Chemistry Research, Volume 49, Issue 12, 16 June 2010, Pages 5742-5751.*

Industry & Urban Cases

UNIVERSITI TEKNOLOGI MALAYSIA
FW reduction: 95.3 %
WW reduction: 64.7 %
Net annual savings = USD 5, 400 /year
Payback period = 5 years

MIMOS

SEMI-CONDUCTOR PLANT
FW reduction: 85.1%
WW reduction: 97.7%
Net annual savings = RM 190, 000 /year
Payback period = 4 months

ccm CHEMICAL COMPANY OF MALAYSIA

CHLOR ALKALI PLANT
FW reduction: 35.8%
WW reduction: 100%
Net annual savings = USD 105, 000 /year
Payback period = 1.87 years

mni MALAYSIAN NEWSPRINT INDUSTRIES

PAPER MILL PLANT
FW reduction: 14%
WW reduction: 14%
Net annual savings = USD 150, 000 /year
Payback period = 1.5 years

Minimise water consumption within single plant

- Great to do if possible!
- Shorter pipelines, less energy
- Cheaper if build within own plant

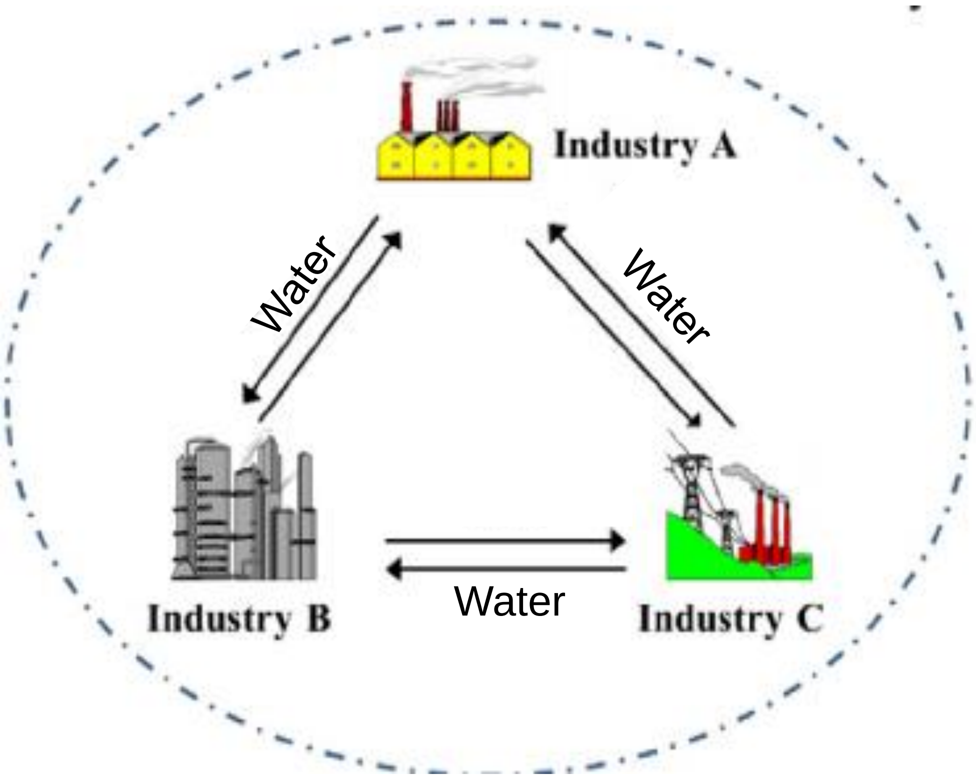
But may not be possible due to certain reasons....

- No economy-of-scale
- No suitable water streams
- No expertise

Can we centralised the water reuse system to a larger network?

Option 2: Centralised water reuse system

How to make water exchange across industries a reality?



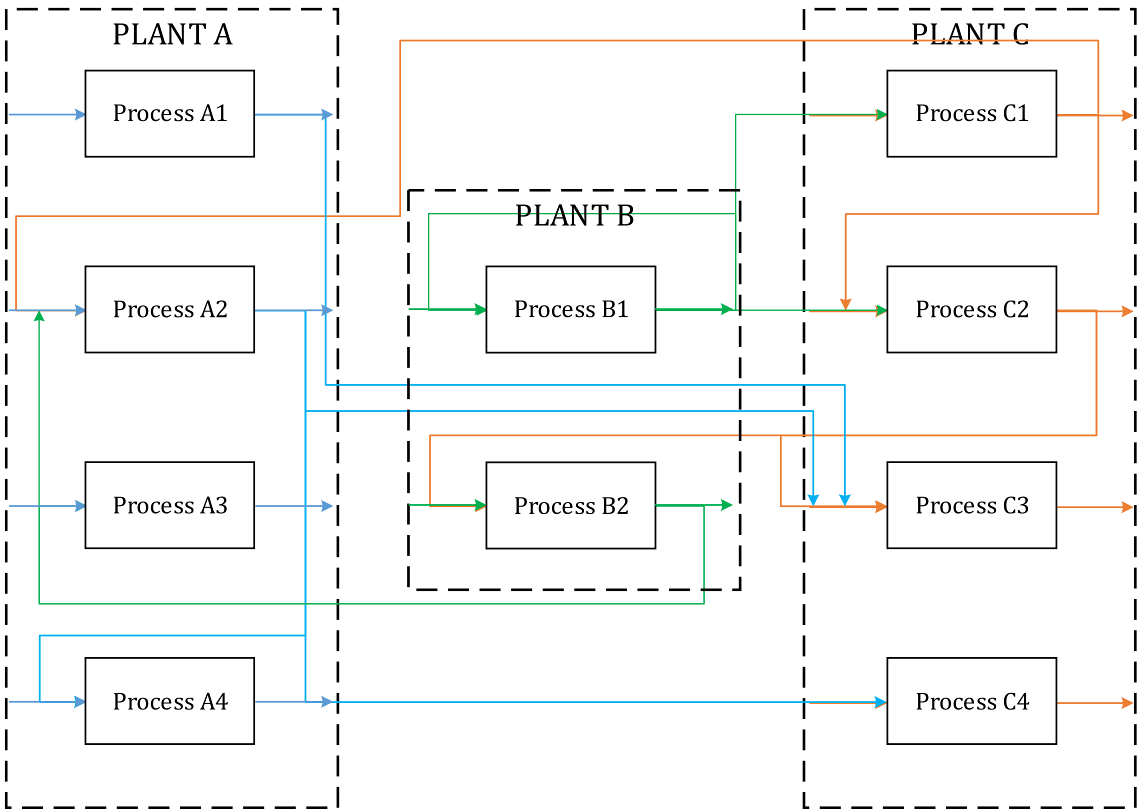
Eco Industrial Park

“Waste” from one company becomes a resource for another company

Industrial symbiosis. Supply Side Planning
Demand Side Planning. End-of-Pipe Solutions

“An eco-industrial park (EIP) is an industrial park in which businesses cooperate with each other and with the local community in an attempt to reduce waste and pollution, efficiently share resources (such as information, materials, water, energy, infrastructure, and natural resources), and help achieve sustainable development, with the intention of increasing economic gains and improving environmental quality.”

Should this be the way?
Interplant Water Integration - Model 1



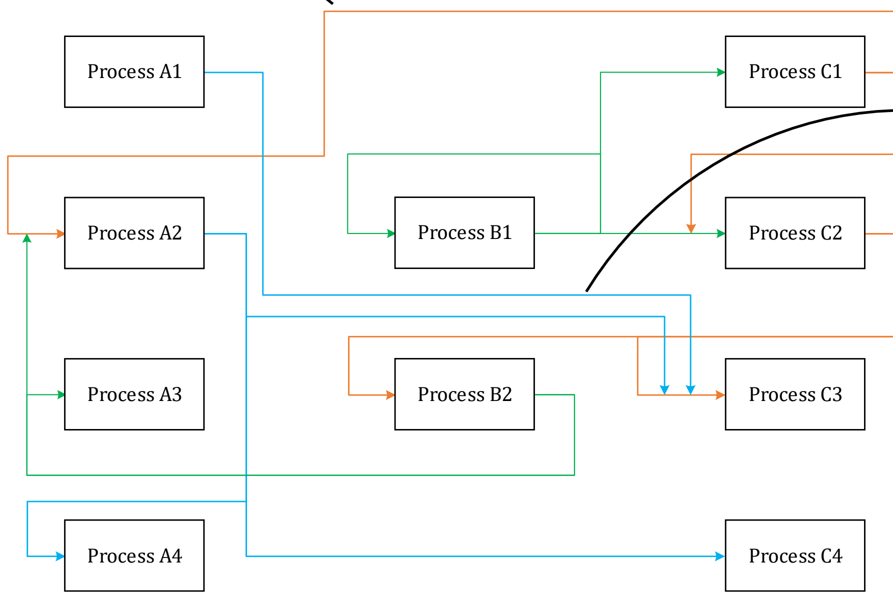
But... How practical is this system?

Interplant Water Integration - Model 1

Who needs to pay for the cost of pipeline and pumping?

Do they have time for data collection for each plants across Total Site?

Does this protects the confidentiality of the plants?



Complexity of the pipeline considering the location of unit process

What about the length of pipeline between plants at Total Site?

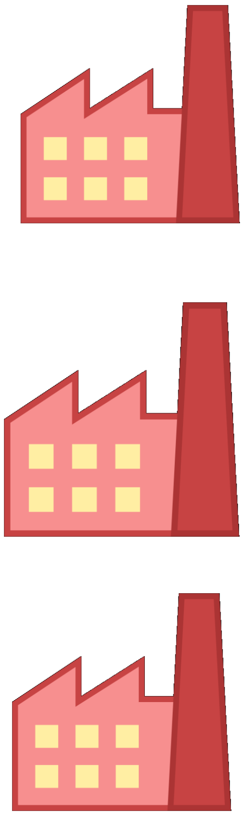
But... How practical is this system?

Interplant Water Exchange - Business model possibilities

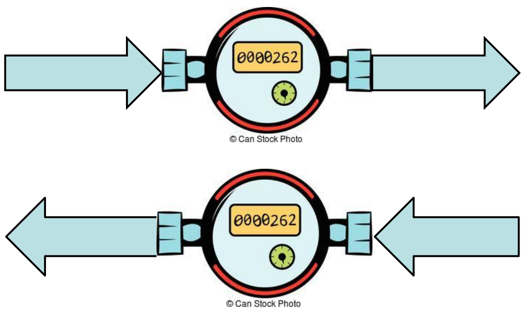
Can the water exchange system be managed by middle man or maybe park managers?

Possible business model

Industries



Sell



Buy

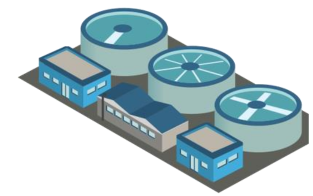
Water reuse tariff

Centralised Water Reuse Header

Middleman

Piping & pumping

Wastewater Treatment Plant



Quality Assurance

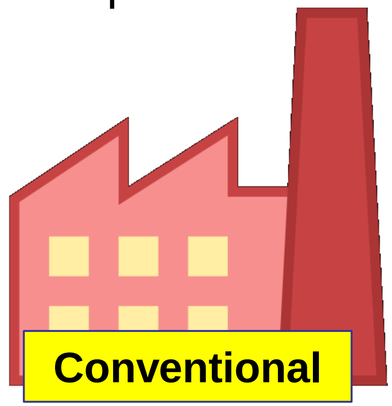
How it works?

SAJ FW non-domestic tariff: RM3.30 per m^3

WH1 tariff (buy): RM2.60 per m^3

WH1 tariff (sell): RM1.30 per m^3

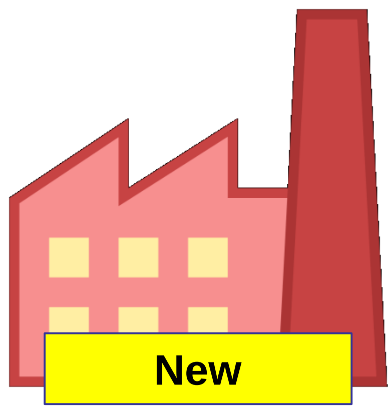
FW = 100k m^3/y
Water Bill = RM330k/y



WW = 100k m^3/y

FW = 80k m^3/y
Water Bill = RM264k/y

WH1 = 20k m^3/y
Water Bill = RM52k/y



WW = 70k m^3/y

WW = 30k m^3/y
WH1 (sell) = RM39k/y

New Water Bill = RM316k/y

5% Water Bill Reduction!

Reduce WWT cost!
Additional income from selling WW!

Interplant Water Exchange Concepts - Model 2

Water reuse are collected and distributed by using one-way centralised header

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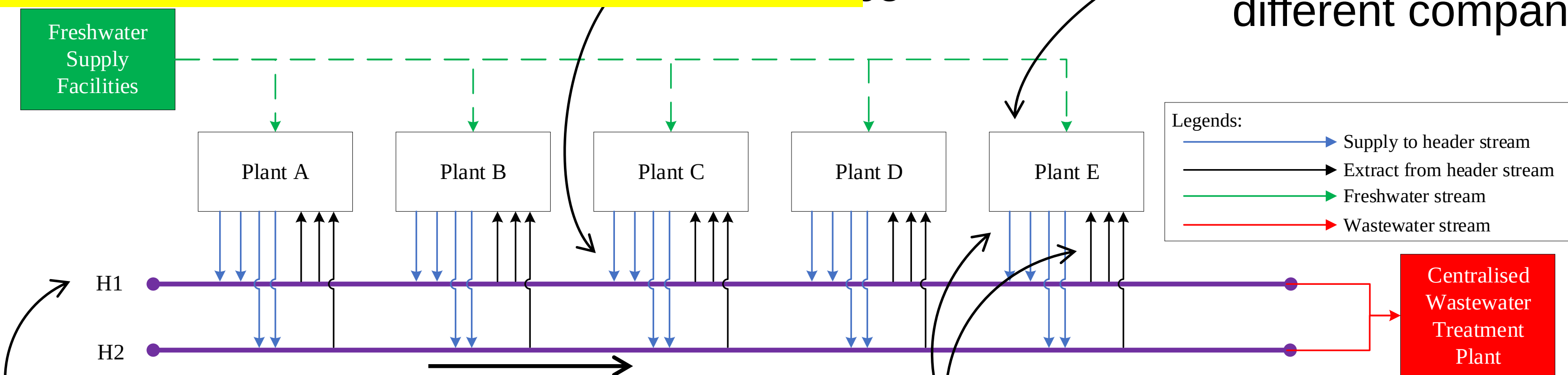
Third-party managing the system protecting the confidentiality of data between different companies



Centralised pipeline simplify the industrial site water network (piping and pumping arrangement)

One-way flow of water source based on the plant sequence at industrial site

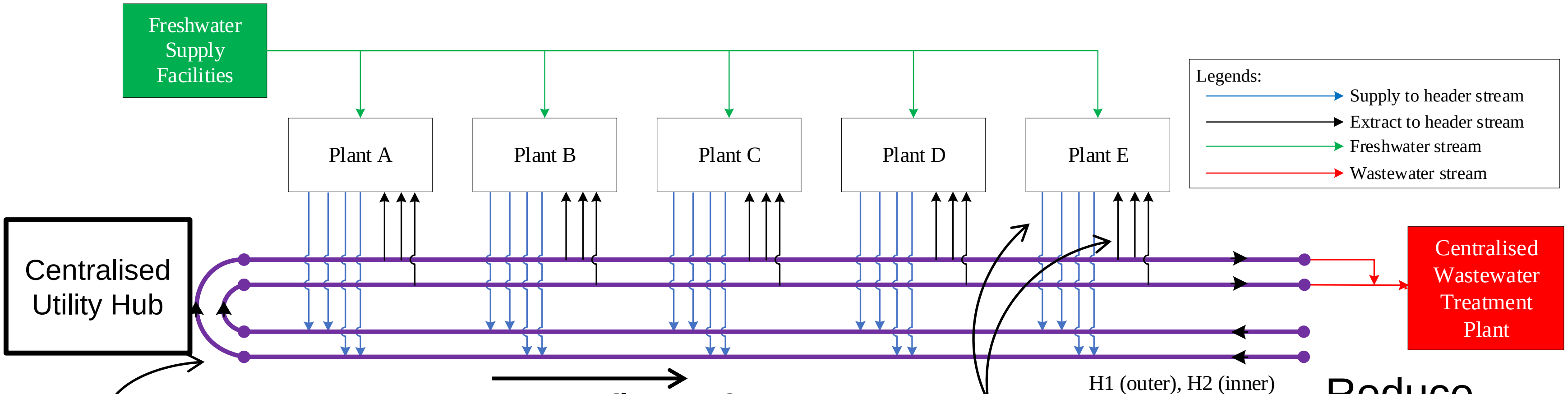
Maximize water exchange between plants at an industrial site through centralised pipeline

Reduce wastewater generation

*Ahmad Fadzil, A.F., **Wan Alwi, S.R.**, Manan, Z.A., Klemeš, J.J.. (2018). Industrial Site Water Minimisation via One-Way Centralised Water Reuse Header. Journal of Cleaner Production. 200: 174-187*

Interplant Water Exchange Concepts - Model 3

Water reuse are collected and distributed by using two-way centralised header



Centralised pipeline simplify the industrial site water network (piping and pumping arrangement)

Two-way flow of water source (act as a reservoir) based on the plant sequence at industrial site

Maximize water exchange between plants at an industrial site through centralised pipeline

Reduce wastewater generation

Fadzil et al. (2018)

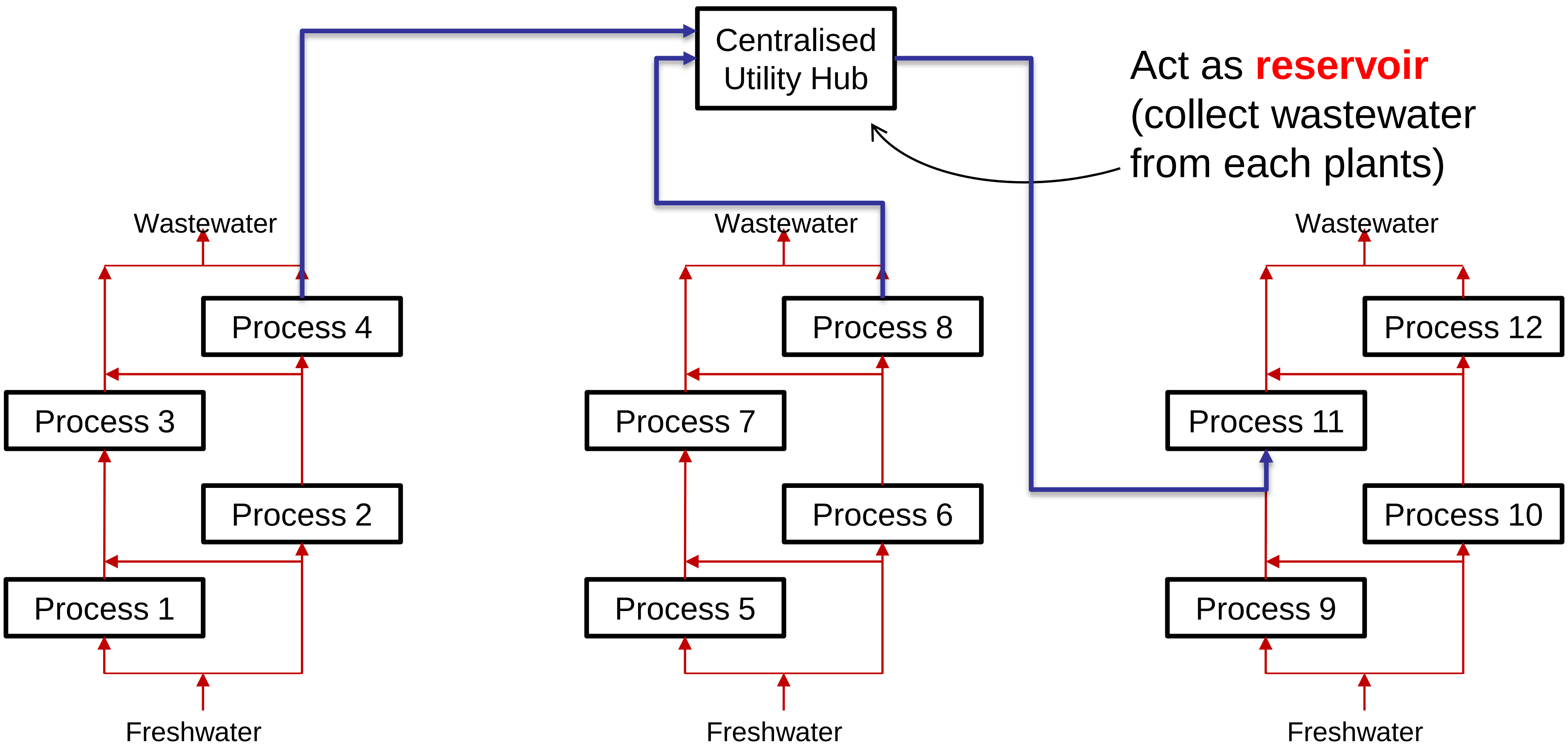
*Ahmad Fadzil, A.F., **Wan Alwi, S.R.**, Manan, Z.A., Klemeš, J.J.. (2018). Maximizing Total Site Water Reuse via a Two-Way Centralized Water Header. ACS Sustainable Chemistry & Engineering 6 (2), 2563-2573.*

Interplant Water Exchange Concepts - Model 4

All WW send to centralised utility hub

Indirect integration via centralised utility hub

Act as **reservoir** (collect wastewater from each plants)



Chew et al. (2009)

Ref: *Chew I.M.L., Foo D.C.Y., 2009, Automated targeting for interplant water integration, Chemical Engineering Journal, 153(1-3), 23–36.*

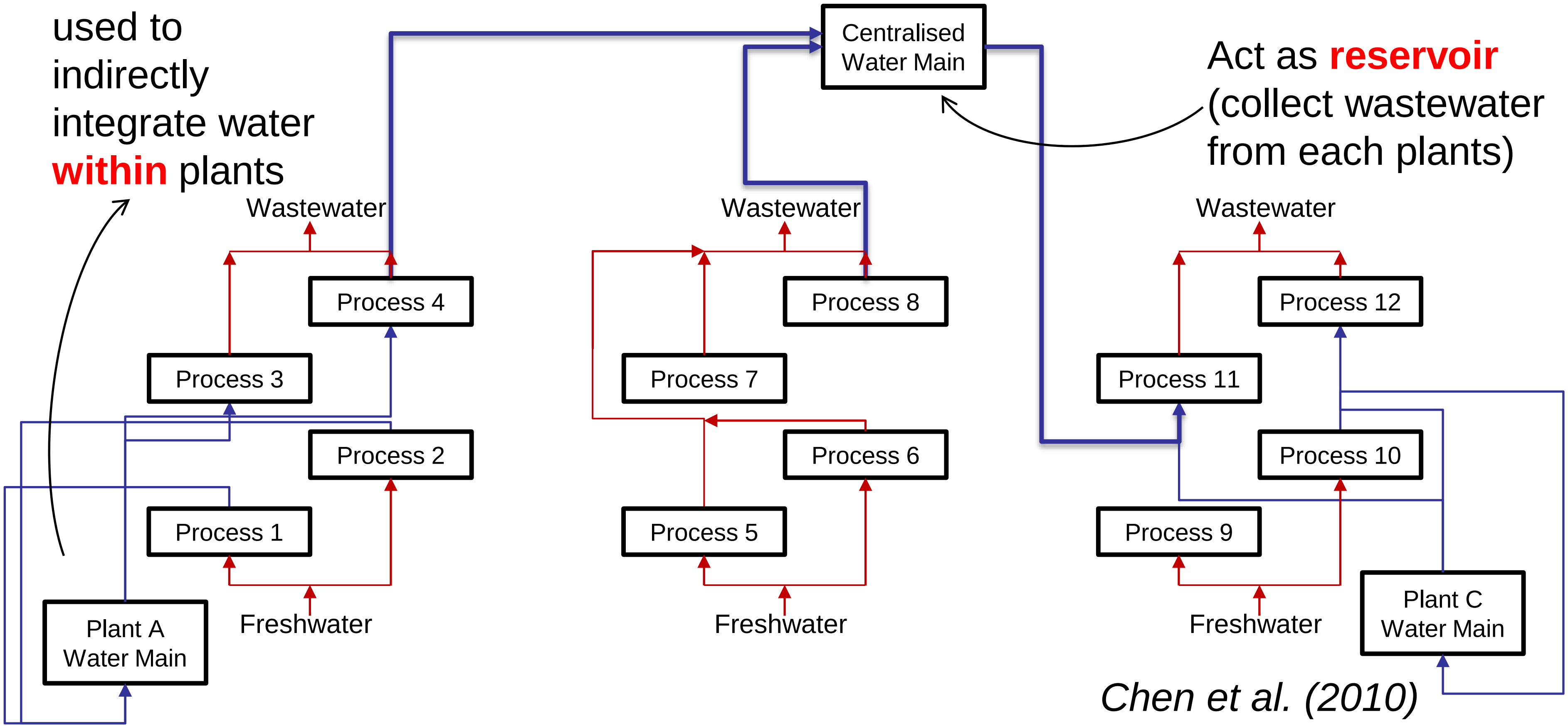
Interplant Water Exchange Concepts - Model 5

Maximise water exchange within plant + Remaining send to centralised water mains

Individual water main is used to indirectly integrate water **within** plants

Centralised water main is used to integrate water **between** plants

Act as **reservoir** (collect wastewater from each plants)



Chen et al. (2010)

Ref: *Chen C.L., Hung S.W., Lee J.Y., 2010, Design of interplant water network with central and decentralized water mains, Computers and Chemical Engineering, 34, 1522–31.*

Challenges

- Water tariff too cheap in certain countries like Malaysia
- Ensuring water quality and continuous supply(reliability)
- Safety and operability
- How to convince all the stakeholders?

Food for thoughts

Interplant Water Exchange -
Possible government support

Can we have similar concept to FiT but for water?

Possible research

1 Systems Engineering Modelling	2 Mechanism Study	3 Tools & Technology Development	4 Capacity Building
Total Site Centralised Water Integration	Mechanism & Policy Study	IT Systems	TSWI Guideline
Supply Side Planning	Business model	TSWI Technologies	Training Module
Demand Side Planning	Social Acceptance Study	Management Systems	Train the trainers
End-of-pipe Planning	Standards		Awareness programme
Logistic planning	Stakeholder Engagement		
Risk Assessment			
Economic Analysis			

Key Take Home Messages

- ❑ Water shortage – one of the world's biggest risk
- ❑ Engineer water sustainability via Holistic WM
- ❑ Water Minimisation - Maximise within facilities
- ❑ Consider Centralising: Interplant Water Exchange with Win-win Business Model

ACKNOWLEDGEMENTS

[1]Universiti Teknologi Malaysia (UTM)

[2]Process Systems Engineering Centre (PROSPECT)

Research Institute for Sustainable Environment (RISE)

Faculty of Chemical Engineering, UTM

[3]Sustainable Process Integration Laboratory (SPIL),

NETME Centre (Faculty of Mechanical Engineering, Brno University of Technology

[4]Ministry of Education (MoE) MALAYSIA

A Huge Thank You, and Congratulations to…

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'Engineering the Future'

Thank You

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