Seoul National University
Department of Civil & Environmental Engineering

Waste to Energy Projects

Reuse-Wastewater & Sludge

Gabriel MUTTO
Samsung C&T-Water & Environment Engineering Team
December 2014

SAMSUNG
SAMSUNG C&T
Engineering & Construction Group

Career path

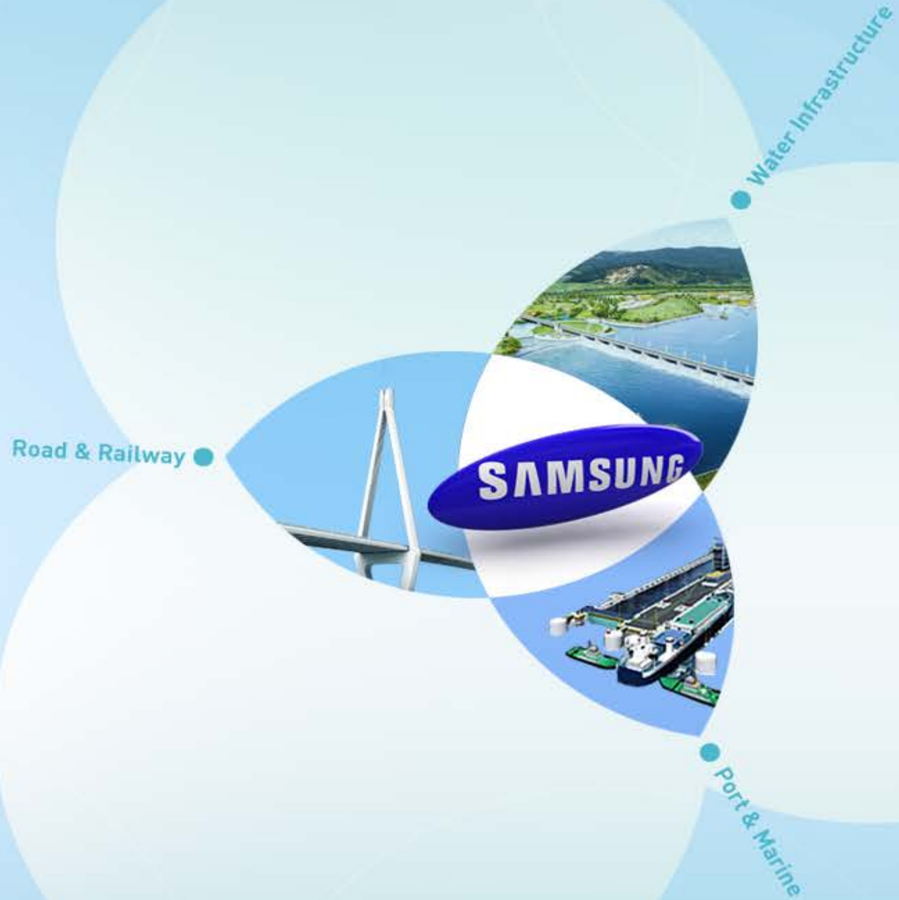
- Experience:

  3 years in water analysis laboratory and 17 years involved in different water treatment projects acting with several roles as Project Manager, Design Engineer and Process Engineer

- Positions Held:
  - April 2014– till date: Deputy General Manager, Samsung C&T, Water & Envorinment
  - January 2012– April 2014: Engineering Director Veolia Argentina
  - June 2007- September 2012: Applications Director Veolia Argentina
  - July 2005-June 2007: Process & Design Engineer Degrémont Argentina
  - May 2003-July 2005: Process Engineer and Engineering Manager Degrémont Korea
  - May 2002-May 2003: Design Engineer Degrémont Chili (off shore office Degrémont France)
  - May 1997-May 2002: Process Engineer, Project Manager, Star Up Engineer and Design Engineer Degrémont Argentina

Contents

1. Samsung Group



Affiliated Companies

30 Affiliates are commercially and legally independent,
but unified by sharing one Single Philosophy under Samsung Group

Electronics Industry (6)

Samsung Electronics
Samsung Electro-Mechanics
Samsung SDI
Samsung SDS
Samsung Display
Samsung Corning Advanced Glass

Financial Services (6)

Samsung Life Insurance
Samsung Fire & Marine Insurance
Samsung Card
Samsung Securities
Samsung Investment Trust Management
Samsung Venture Investment

Engineering & Constructions (3)

Samsung C&T Corporation
Samsung Engineering
Samsung Heavy Industries

Chemical Industry (5)

Samsung Total Petrochemicals
Samsung Petrochemicals
Samsung Fine Chemicals
Samsung BP Chemicals
Samsung Techwin

Others (10)

Cheil Industries
Samsung Everland
The Shilla Hotels & Resorts
Cheil Worldwide
S1 Corporation
Samsung Medical Center
Samsung Economics Research Institute
Samsung Bioepis
Samsung Biologics
Samsung Welstory

Co-work & Synergy Effect

2. Samsung C&T Corporation

Organization

Chief Executive Officer
Mr. Chi-Hun Choi

Corporate Support
- Strategy & Innovation
- Human Resources
- Finance & Accounting
- Risk Management

Global Marketing

Q-HSE

R&D Center

Procurement

Civil
- Road, Bridge & Tunnel
- Metro & Railway
- Port & Marine
- Water Resources
- Mining


Incheon Grand Bridge (2009)
21.27km

Building
- High-Rise, Mixed-Use
- Hi-Tech
- Healthcare, Aviation
- Sports Facilities


Burj-Khalifa (2010)
828m

Plant
- Power Generation
- Nuclear Power Plant
- Energy Storage
- Industrial Plant


Qurayyah IPP (2014)
4,000MW

Housing
- Residential Complex
- Urban Development


Housing Supply
217,000Units

M&E
- Civil Infra. M&E
- Building/Housing M&E
- Industrial Facility M&E


Delhi Subway (2013~)
15.5km

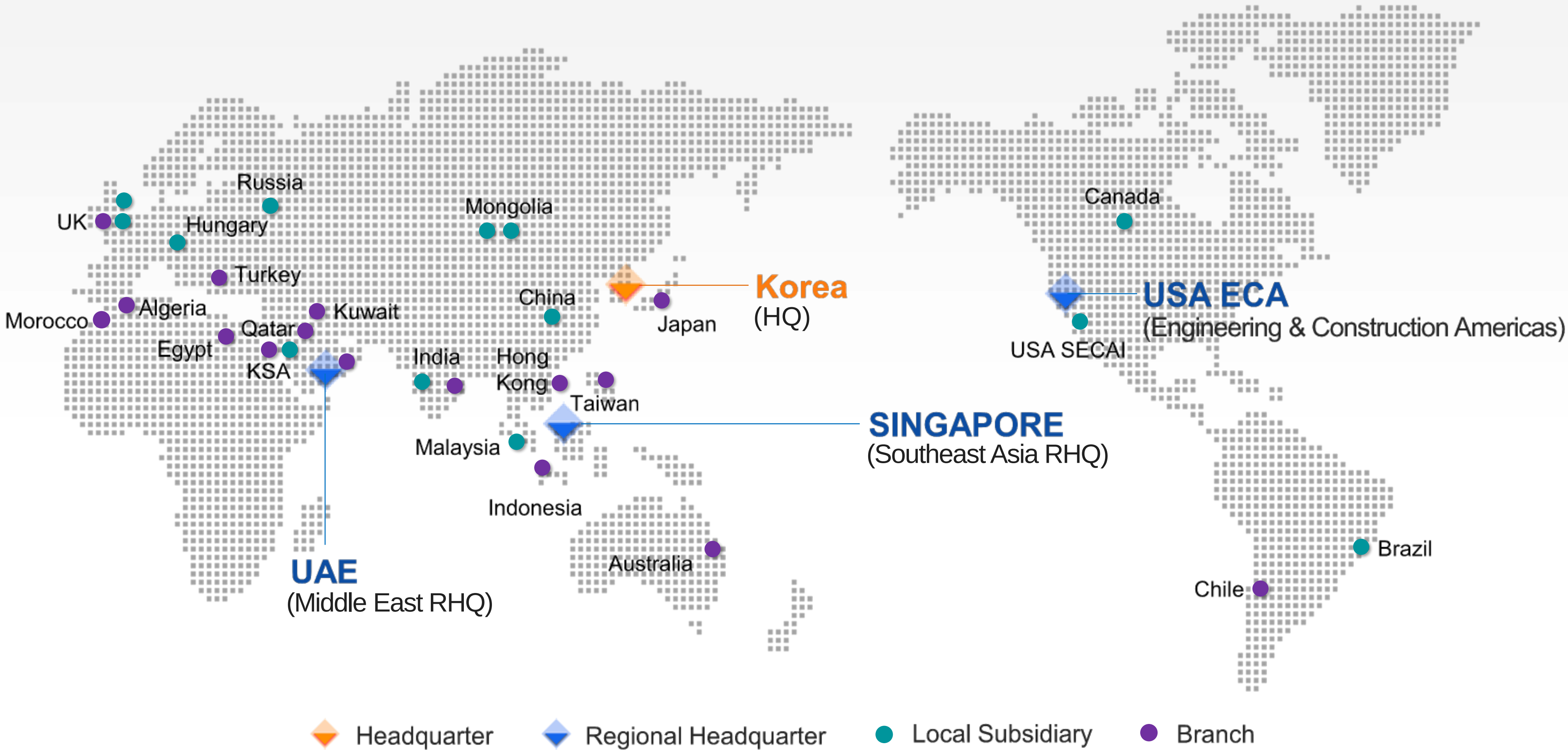
Global Operations

36 *Global Offices in* 26 *Countries*

Regional HQ: 3 / Local Subsidiary: 15 / Branch: 18

10,665 *Manpower*

HQ: 3,173 / Global Offices: 406 / Sites: 7,086



3. Civil Infrastructure Business Unit

Business Unit Overview

SAMSUNG C&T
Engineering & Construction Group

Road & Bridge
- Bridge & Tunnel
- Highway & Roadway
- Underground Expressway

Metro & Railway
- High Speed Railway
- LRT / MRT
- Freight
- Mining Infrastructure

Port & Marine
- Wharf / Breakwater / Jetty
- Dock / Dredging / Reclamation
- Offshore (Wind Farm, Pipeline)
- Mining Infrastructure

Water & Environment
- Dam / Hydropower Plant
- Water & Wastewater Treatment
- Sewer & Water Tunnel
- Soil Remediation

Total solution provider *in all areas of the construction business – financing, planning, design, procurement, construction, and O&M*




F/S — Financing — EPC — O&M

Project Competency – Bridge & Road

Mersey Gateway Bridge


Incheon Grand Bridge


Young-Jong Bridge


Al Salam St., UAE

Gun-Jang Bridge


Wando Bridge


MCE C486, Singapore


Busan-Ulsan Expressway

World Cup Bridge

Palm Jebel Ali, UAE


MCE C483, Singapore


Bukbu Arterial Road

Project Competency – Metro & Railway

Roy Hill, Australia

Riyadh Metro, KSA

Doha Metro, Qatar

UHG-GS Railroad, Mongolia

Relocation of Kalekoy Railway, Turkey

Delhi Metro, AMELC1 , India

Taiwan HSR, C280

Kyungbu HSR, 7-2/10-1

Seoul Metro 907

Busan Metro 311

Daejeon Metro 103

Kyungbu HSR, 14-3

Kyungbu HSE, 13-3

Project Competency – Port & Marine / Water

Son Duong Port, Vietnam

Jeju Naval Base(Caisson)

DTS T01, UAE

Dookdo Purification Facility


Busan New Port

Ulsan New Port (Caisson)


Ulsan North Breakwater


Incheon South Port

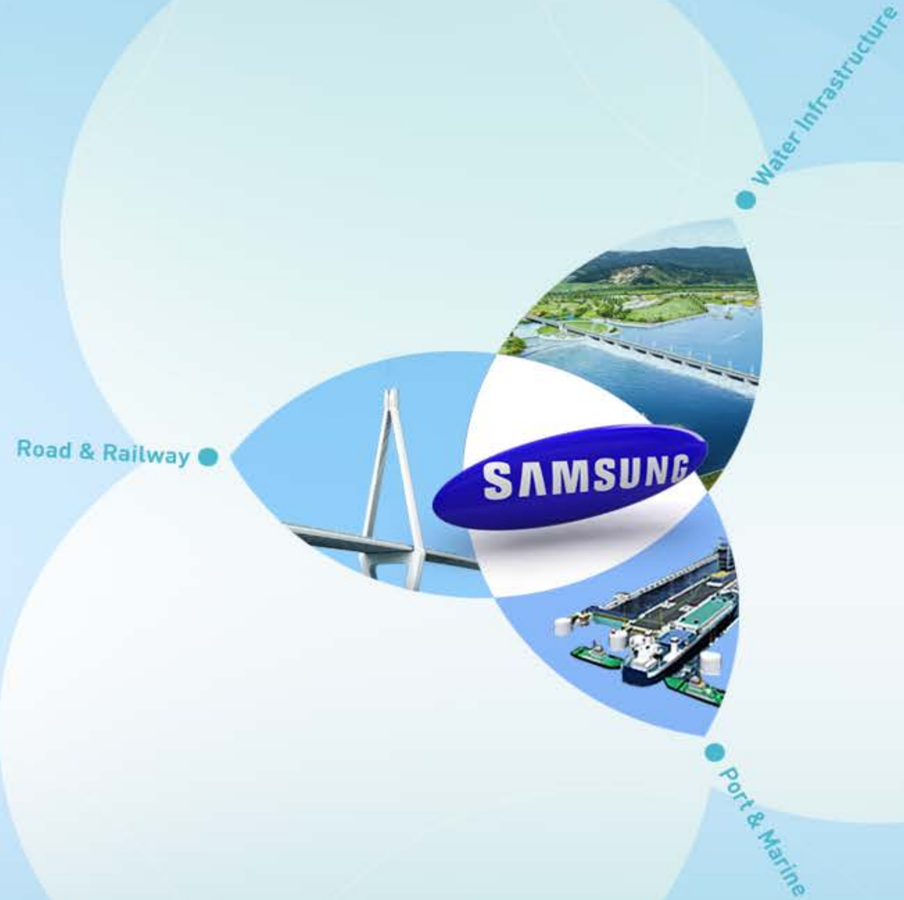

DTSS T-04, Singapore


Kyung-in Ara Canal

Wastewater Treat, Thailand


Yong-dam Multi Dam

4. Waste to Energy

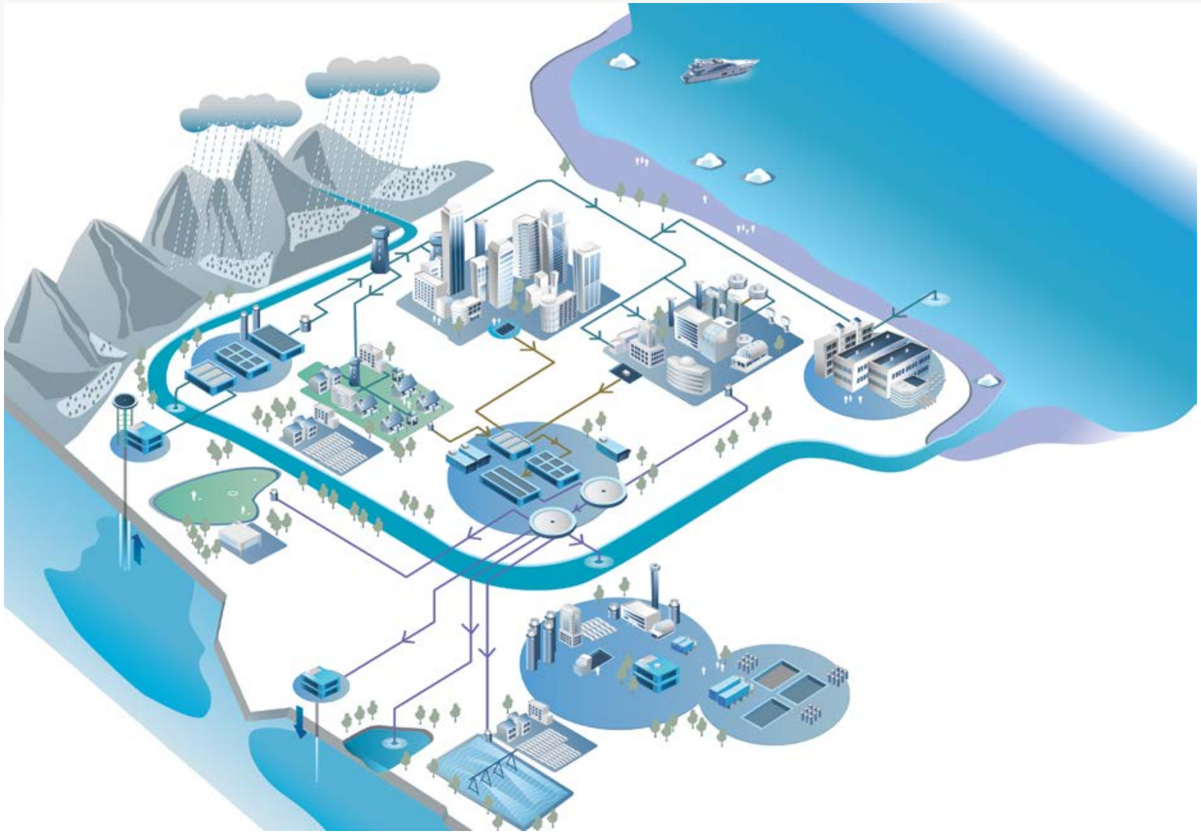


Water Infraestructure

A better urban life

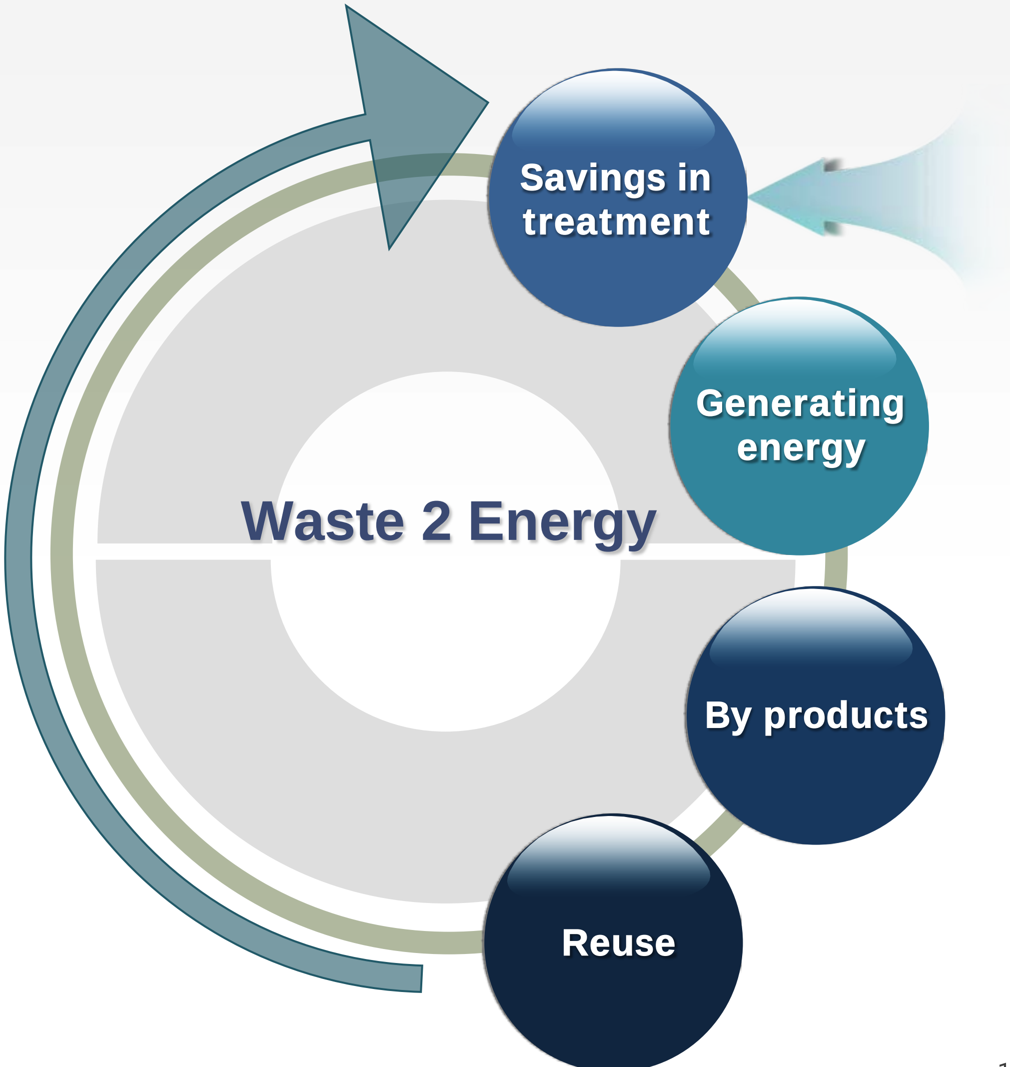
The world is facing climate change that threatens the supply and management of water resources. Hence, the most vital duty in the water sector is the securing of a clean water supply and promoting renewable energy generation.

• Infrastructure



- Dam / Hydropower
- Drainage tunnel system
- Industrial wastewater treatment plant
- River development
- Water supply network
- Soil remediation
- Water treatment plant
- Sewer network
- Reservoir
- Wastewater treatment plant / Re-use plant

Waste to Energy-Savings in treatment



Savings in treatment

1. Minimize process energy consumption
   - i. High efficiency equipment
   - ii. Diffusers
   - iii. Blowers
2. Process control
   - i. PLC and Scada
   - ii. Control optimization
3. Process improvement
   - i. Cutting edge technologies
   - ii. Optimal efficiency with lower energy consumption
   - iii. Optimal sludge generation and handling scheme

Savings in treatment-High efficiency equipments

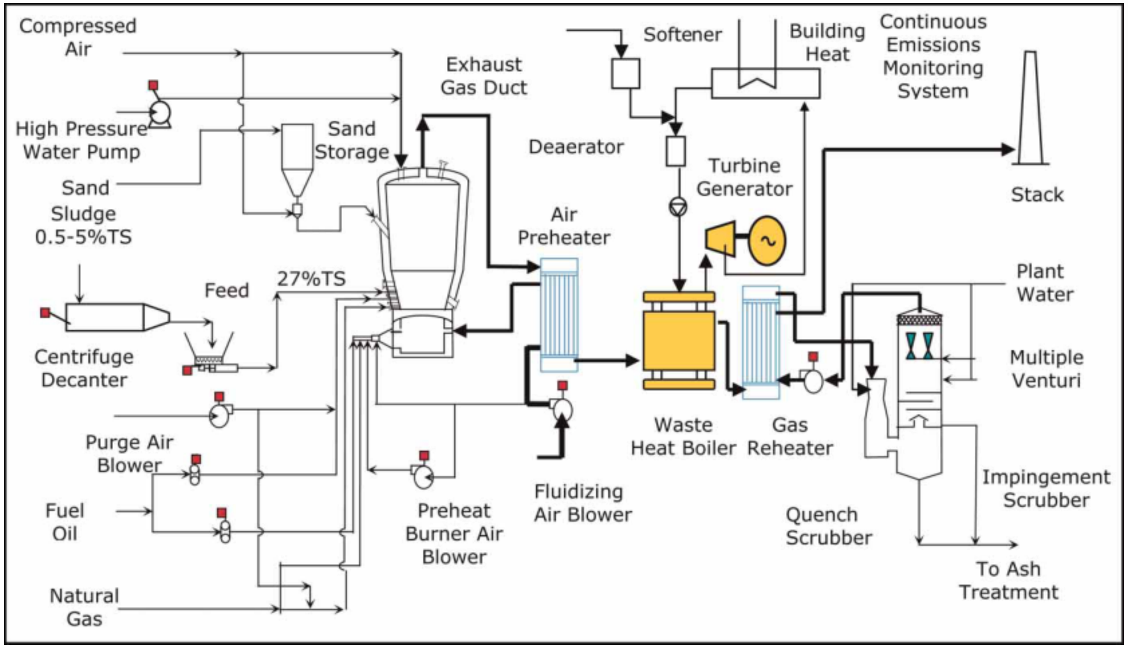
Fluid bed incineration

Thermal processes used in sludge disposal have become more attractive as process improvements have been introduced, such as power generation and efficient heat recovery.

Sustainable management is the main driver.

Fluid bed furnaces, especially the hot windbox (HWB) fluid bed, could operate without the use of any auxiliary fuel.

The reduction in fossil fuel consumption as well as the ability to produce electrical energy from a renewable source not only offsets the net carbon footprint of the treatment facility but can also qualify for carbon credits if and when such provisions are available for this treatment district.



Savings in treatment-High efficiency equipments

Fluid bed incineration-Case Studies-Degremont Technologies Infilco

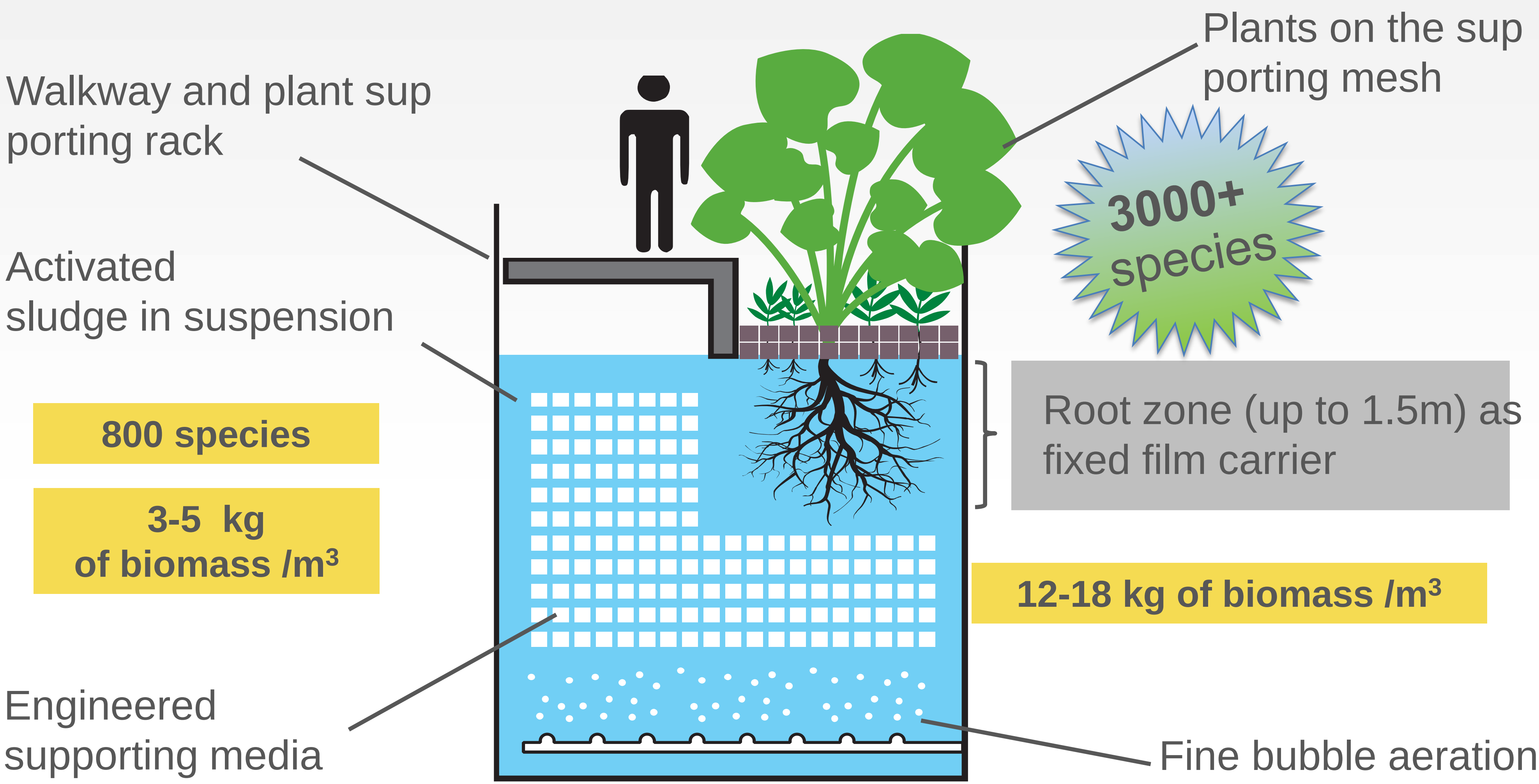
The electrical consumption per dry ton is less at Duffin Creek than at Lakeview, because at Duffin Creek the steam generated is used in a single stage turbine to drive the fluidizing air blower to eliminate energy demand from the 600 HP motor.

At Southerly, the steam produced is sent to a turbine generator to produce 1,225 kWh of electricity to satisfy Southerly's electrical needs for the incineration plant with a surplus of 20 kWh.

	Lakeview	Duffin Creek	Southerly
Sludge loading per line, Dry ton/h	4.17	4.37	3.79
Electrical kWh consumption per line	967	845	1205
Electrical consumption per dry ton, kW	232	215	289
Electricity production, kWh	0	0	1225
Net electricity production, kWh	0	0	20

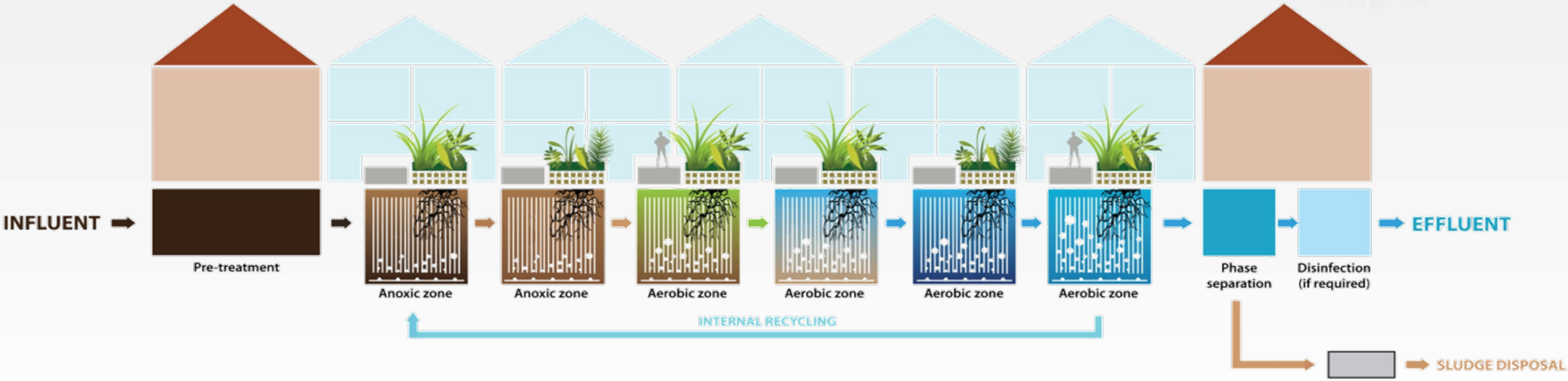
Savings in treatment-Process improvements

Organica FCR Reactor Is The “Heart of the Solution”



Savings in treatment-Process improvements

Series Of Food Chain Reactor Zones

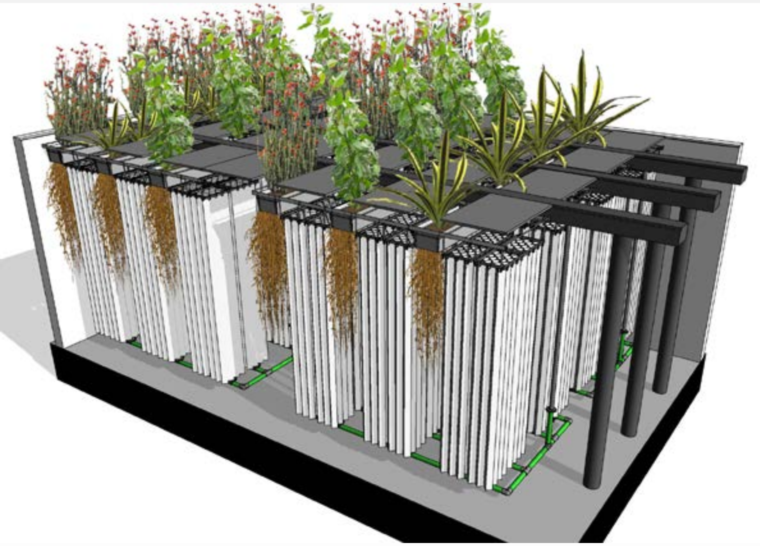


- The biological process takes place in a series of cascade reactors, with standard pretreatment at the beginning, and phase separation (via Organica Disc Filters or Secondary Clarifiers) and final polishing at the end.

- As water flows through from one reactor zone to the next, different ecologies will grow and adapt to the conditions in each stage. This configuration allows the "food chain effect" to develop, as higher level organisms become predators for the simpler organisms.

- The result is enhanced removal efficiency and resiliency, while utilizing less energy and producing less sludge.

Savings in treatment-Process improvements

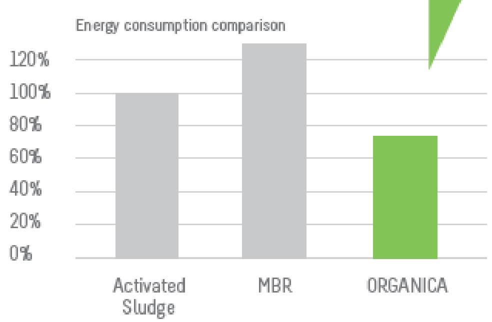


Microbial fuel cell

Organica’s Food-Chain-Reactor (FCR) is a complete wastewater treatment solution incorporated into a compact, single structure. Plants are selected for their root structure, root mass and their ability to withstand the conditions in various reactors. Only locally available species are used, plants are never transported across borders. Plant maintenance comprises of simple gardening practices that can be performed by ordinary wastewater plant operators, no special skills are required.

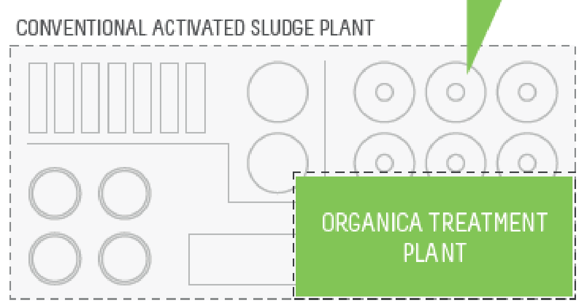
ENERGY SAVINGS

The cooperation of complex living systems, small footprint, proximity to wastewater source all contribute to siginificant energy savings.



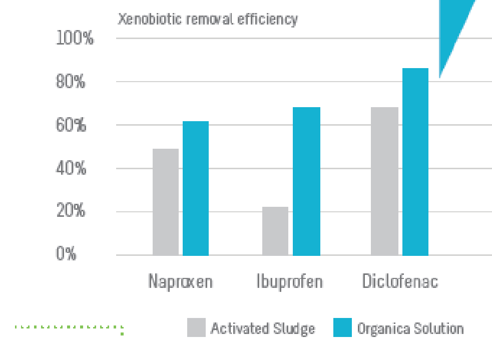
FOOTPRINT SAVINGS

Highly intensified biology and compact, architectural designs make the footprint of Organica facilities up to 40% smaller than any state-of-the-art technology and significantly smaller than conventional activated sludge plants.



CLEANER WATER

Research is showing that the broader and more complex ecology is able to break down a wider range of emerging pollutants of concern such as medicines and other xenobiotics with higher efficiency.



Generating Energy-Optimum biogas generation

- Needs : Sludge volume *Reduction & Producing energy* from sludge
- Solution: Anaerobic digestion enhanced by TH (Thermal Hydrolysis)
- High temperature (165°C), pressure (10 bar) and retention time (>30') allows to "crack" long chain molecules

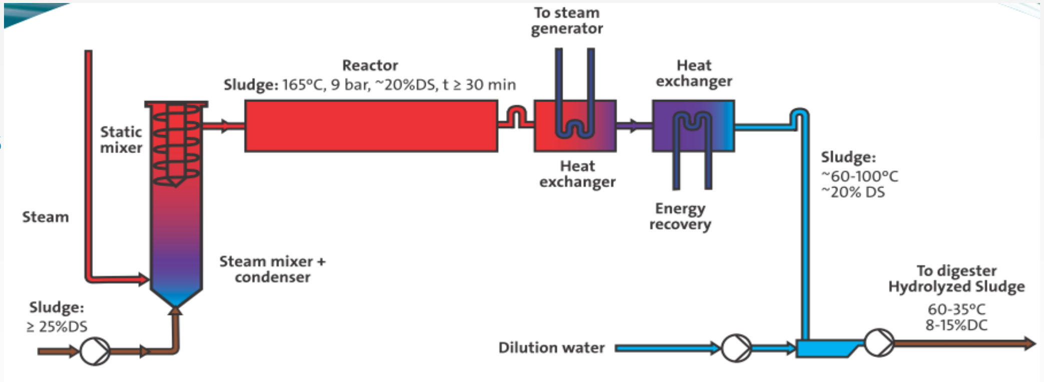
- Effects :
  - Solubilisation of organic matter previously not accessible for digestion
  - Pathogen destruction
  - Disintegrates cell structure/organic materials and dissolves naturally occurring cell polymers (exopolymeric substances- EPS), a form of protein, into an easily digestible feed for anaerobic digestion

Generating Energy-Optimum biogas generation

Principle THP + MAD (Mesophilic Anaerobic Digestion) Exelys Biothelys® Veolia

1) Improving sludge biodegradability by THP

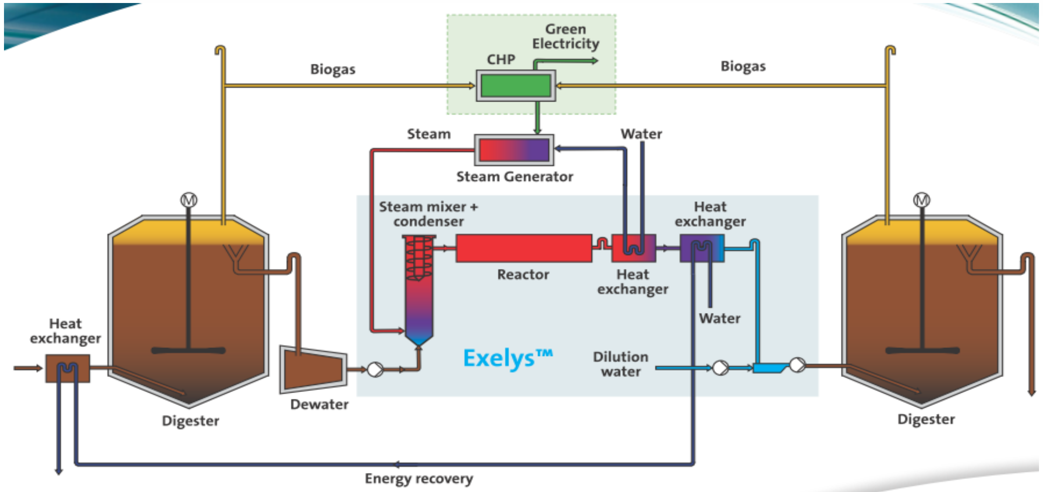
- 150-165˚C and 6-9 bar
- 20-30min
- on concentrated sludge > 16% dryness
- batch or continuous



2) Treating the hydrolyzed sludge by MAD,

- producing more biogas and reducing DS
- 15 days HRT
- 37-41˚C

Digestion – Lysis – Digestion



Generating Energy-Optimum biogas generation

Samsung C&T Engineering & Construction Group

Advantages of thermal hydrolysis

- Provide higher VM removal and higher biogas production
- Hygienisation (EPA class A)
- Dewatering (better dryness)
  - Biological sludge: from 21-22% to 28-35% by centrifuge
  - High final digested sludge volume reduction
- sludge viscosity Improvement (digester can operate at higher concentration)
- Volume of digester following TH reduced by 2-3
- High sludge quality: odorless, easy storage
- No foaming in digester observed

Biogas production increase (+30%)

Sludge to disposal decrease (-35%)

OR

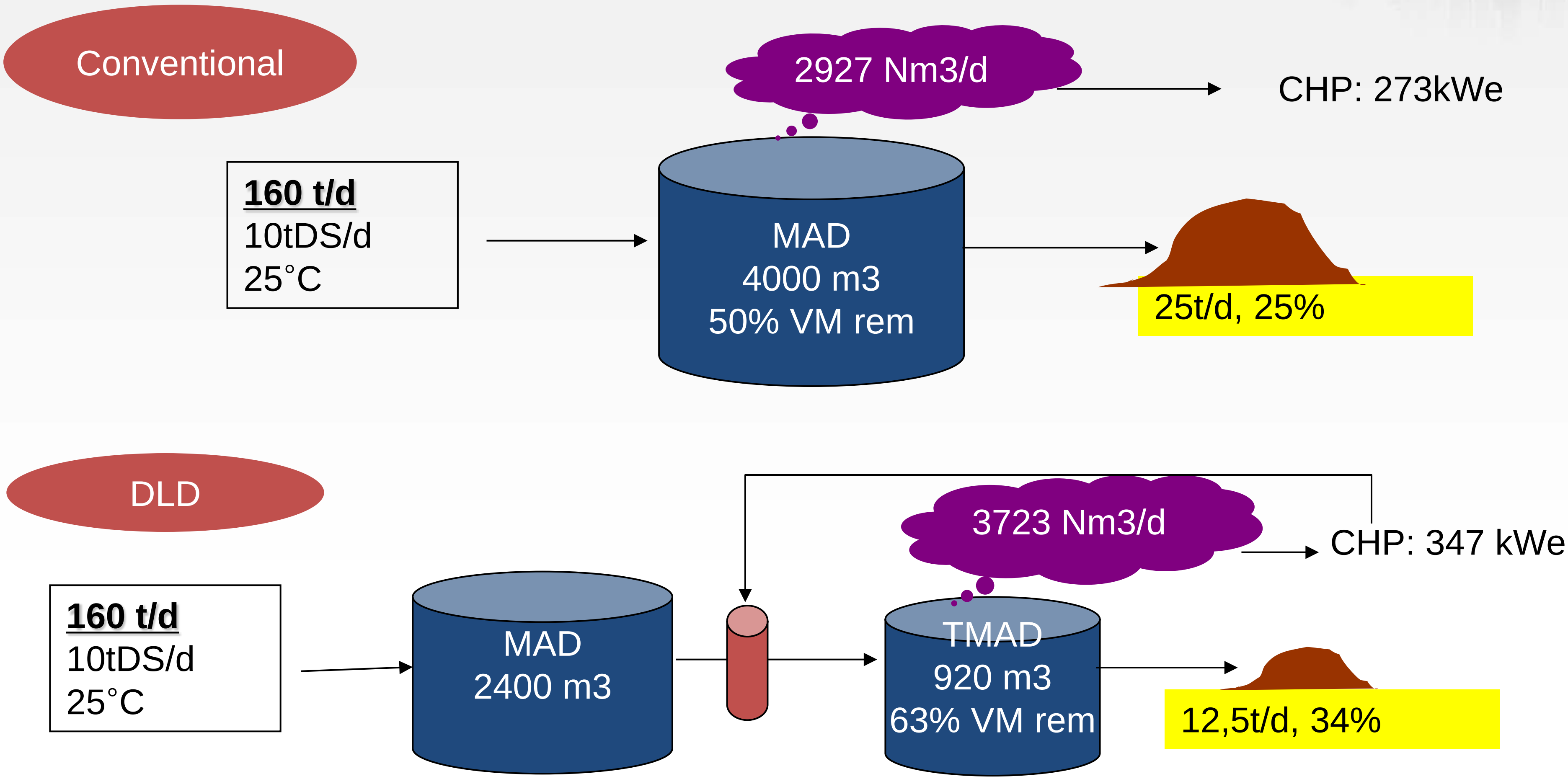
The capacity of the Digester increase (up to 50%)

AND

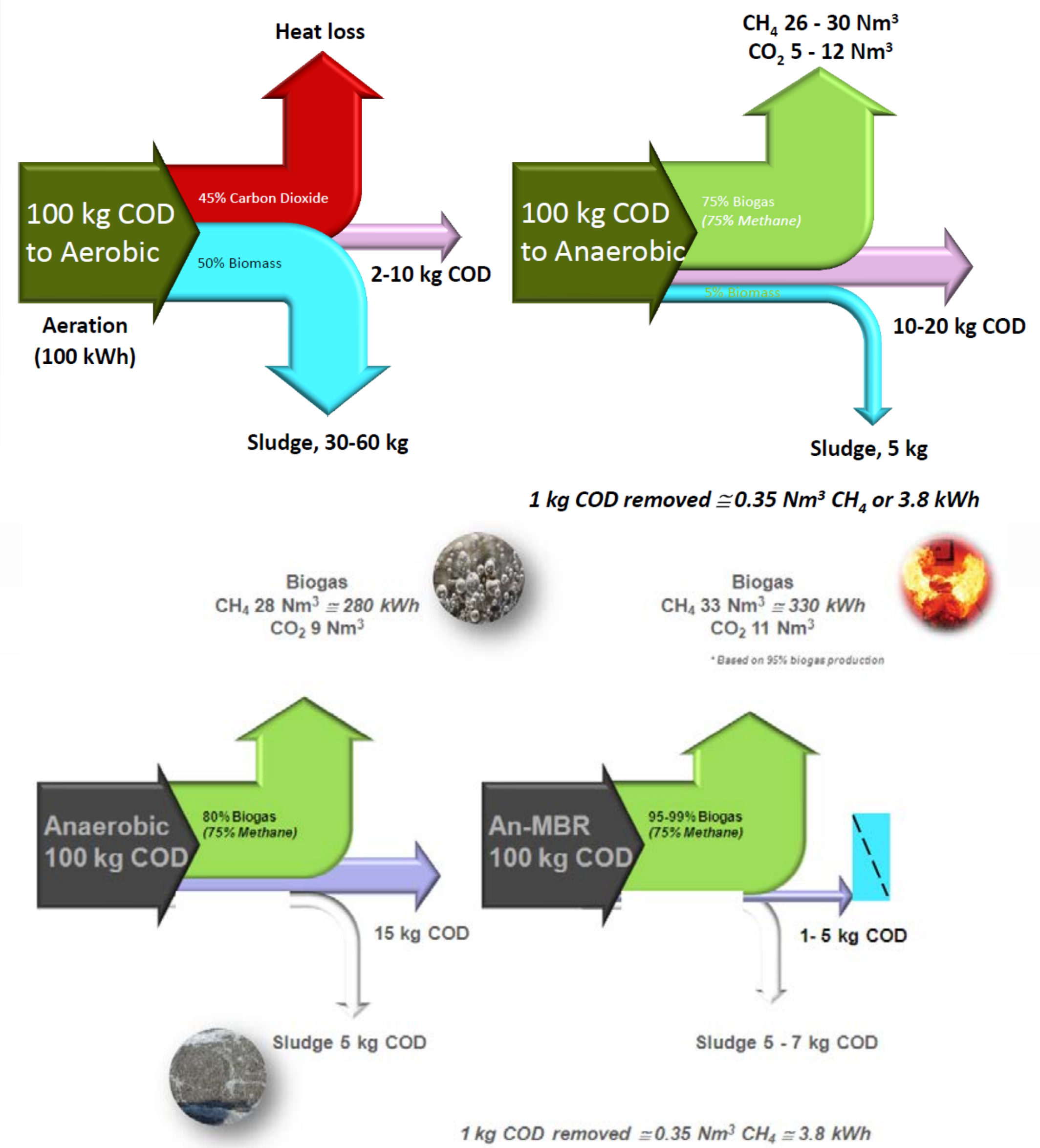
Complete hygiénisation of sludge

And efficient, reliable and robust solution

Generating Energy-Optimum biogas generation

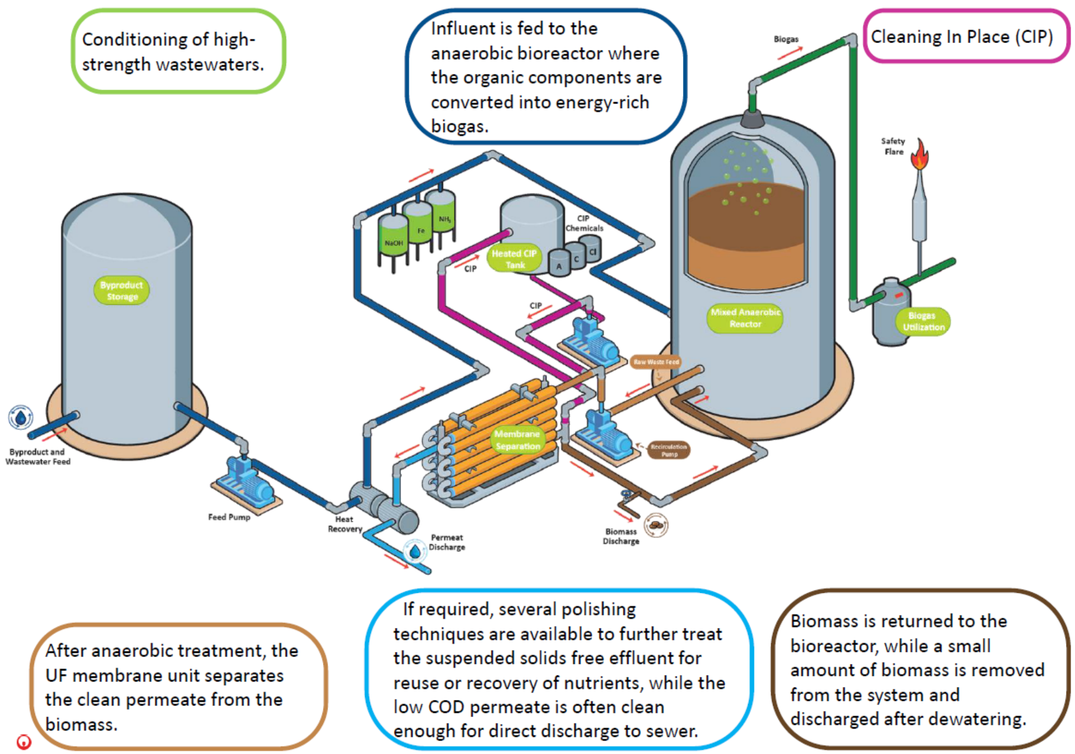


Generating Energy-Generating biogas



Generating Energy-Generating biogas

Memthane® step-by-step



Memthane®

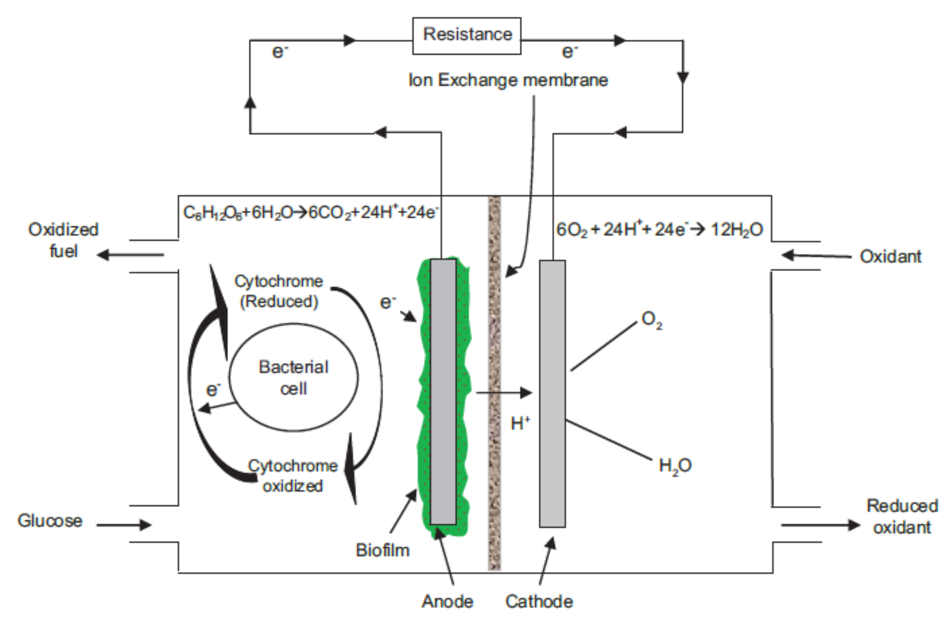
<u>High concentrated streams (COD 15,000 ~ 250,000) such as</u>

- **Dairies**
  - *Whey, Milk Processing*


- **Ethanol Facilities**
  - *Stillage type streams: Pot Ale, Spent Wash, Thin Stillage and Vinasse*

- **Food wastewaters containing Fat Oil and Grease (FOG)**
  - *Ice cream*
- **Wastewaters containing high COD**
  - *Biodiesel, Chemical Wastewaters*


Generating Energy-Biological fuel cell



Microbial fuel cell

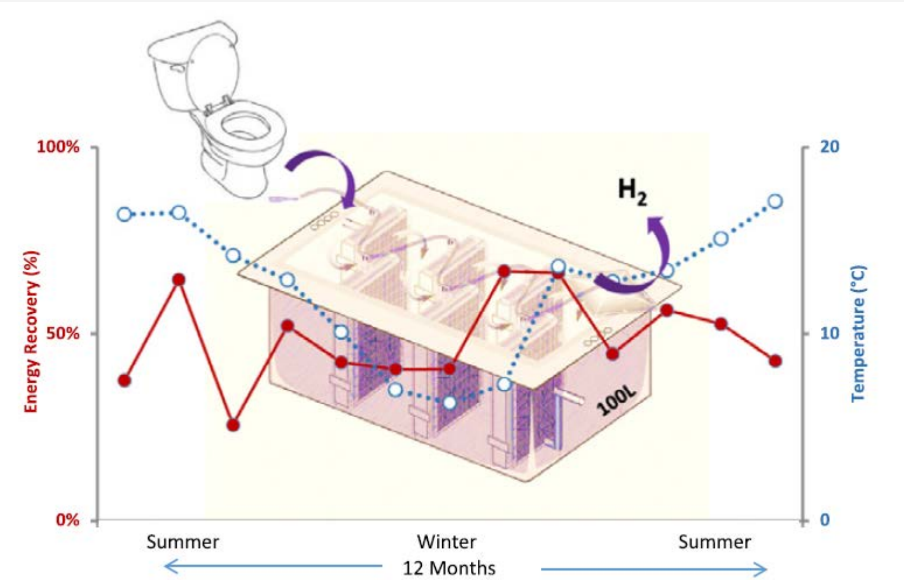
Are bioreactors that can convert the chemical energy present in organic compounds into chemical energy. Producing electricity using microrganism was first reported by Potter in 1911.

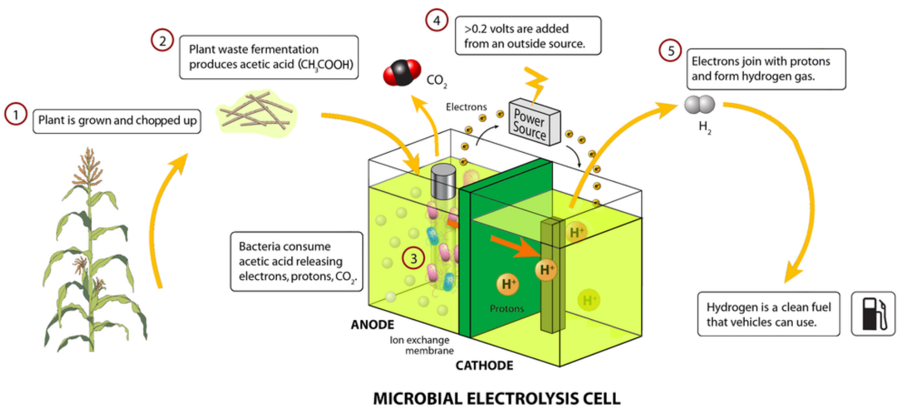
MFCs are devices that produce energy by the biodegreation of organic matter using bacteria as catalysts. Consist of anodic and cathodic chambers separated by a proton exchange membrane (PEM). The oxidation of organic matter occurs in the anodic chamber through bacteria thet generate electron and protons. The electrons are aborbed by anode and transported to the cathode through an external circuit.

Protons cross the PEM and enter the cathodic chamber where they combine with oxygen to form water.

There are several electrochemically active bacteria which have the capability to transfer electrons from inside the cell to the extracellular acceptors through c-type cytochromes and microbial nanowires (flagella) present on their outer membrane

Generating Energy-Biological fuel cell





Microbial fuel cell

MFCs play the dual duty of degrading effluents and genera
ting power by the treatment of industrial and municipal
wastewater. There is a linear relationship between
the organic content of wastewater and the power output
of MFCs. The biological oxygen demand (BOD) is an
indication of the strength of wastewater, and the power
output of an MFC reflects the BOD of the wastewater,
making MFC a possible BOD sensor.
Therefore, MFCs can be used to reduce the COD of waste
water and simultaneously generate power.
fed with primary sludge the MFC reduced both organic and
suspended solids, but the energy output was lower and the
formation of methane gas dominated the total energy
Production.This led to the opinion that although it may be
challenging to use MFCs consuming primary sludge for en
ergy production, it may find use in polishing the digested ef
fluent from anaerobic digesters.
Also MFCs can be turned into a microbial electrolysis cell (
MEC) by adding a small suplement electricity at the cathod
e to produce products such as hydrogen gas.

Generating Energy-Biological fuel cell

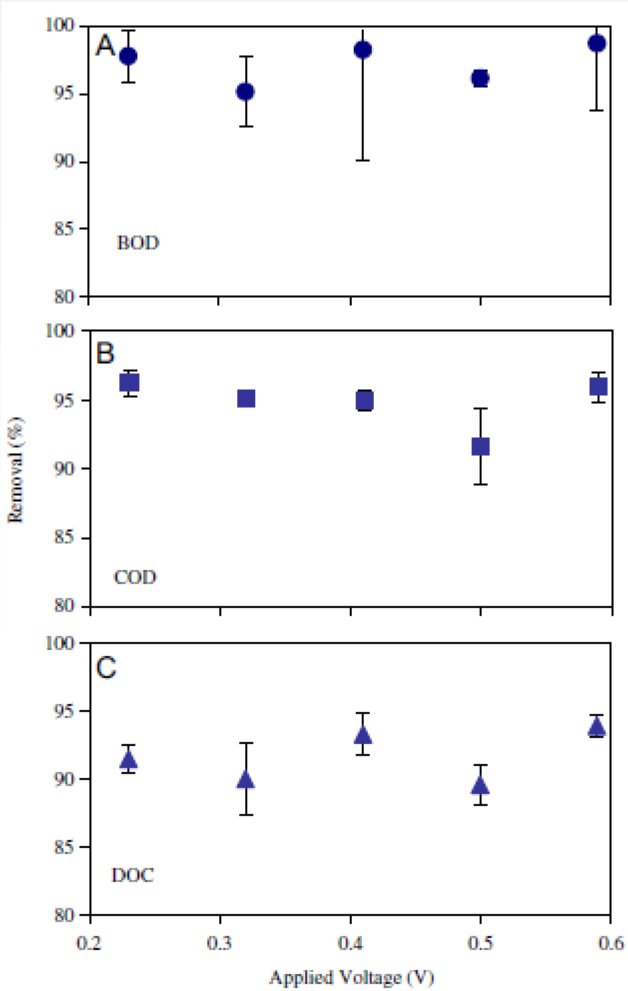
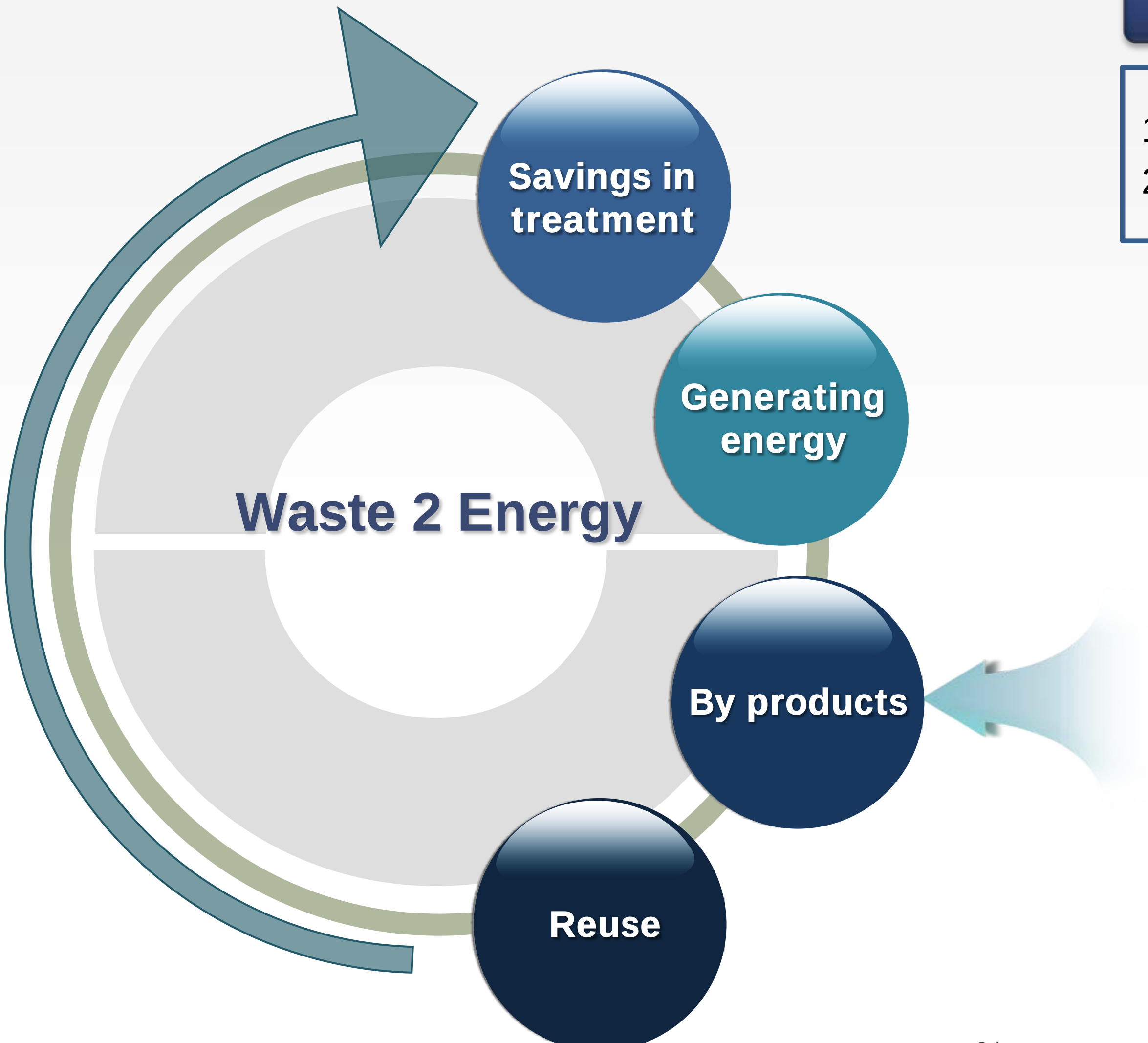


Fig. 7. Batch removal efficiencies of biochemical oxygen demand (A), chemical oxygen demand (B) and dissolved organic carbon (C) in domestic wastewater using graphite granules in anode chamber (and 36 mL headspace).

Bio-electrochemically assisted microbial reactor

The BEAMR and MFC systems share many similar characteristics, and therefore many findings for improving electricity generation in MFCs should be applicable for increasing hydrogen production in the BEAMR system. Hydrogen production was examined using domestic wastewater as the fuel in the BEAMR process, and Evaluated system performance in terms of hydrogen recovery, CE, and the effectiveness of treatment (BOD, COD, and DOC removal).
The initial condition ranges for the wastewater were:
BOD, 86 to 270 mg/*L; COD, 204 to 481 mg/L;*
DOC, 56.*8 to 90 mg/L. The average BOD*
concentration *(BOD5) at the end of a batch cycle was*
4.*5 mg/L with a maximum of 7.0 mg/L*
and was not a function of the initial wastewater strength. O verall removals (graphite granule tests) were: BOD,
97 *%; COD, 95;*and DOC, 92.
It is reasonable to expect that domestic wastewater could be used to make hydrogen in the BEAMR process as either acetate or wastewater can be used to generate elect ricity in an MFC.

Waste to energy-By products

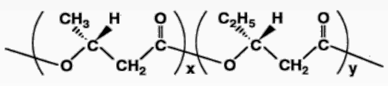


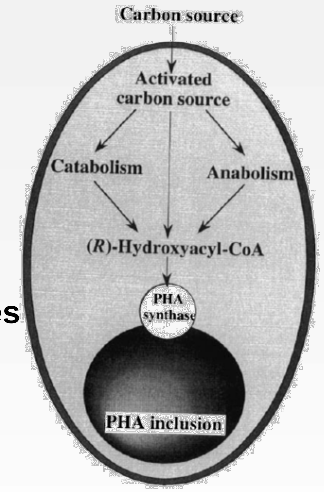
By products

1. Sludge: Struvite, Fertilizer
2. Biopolymer

By products-Biopolymer

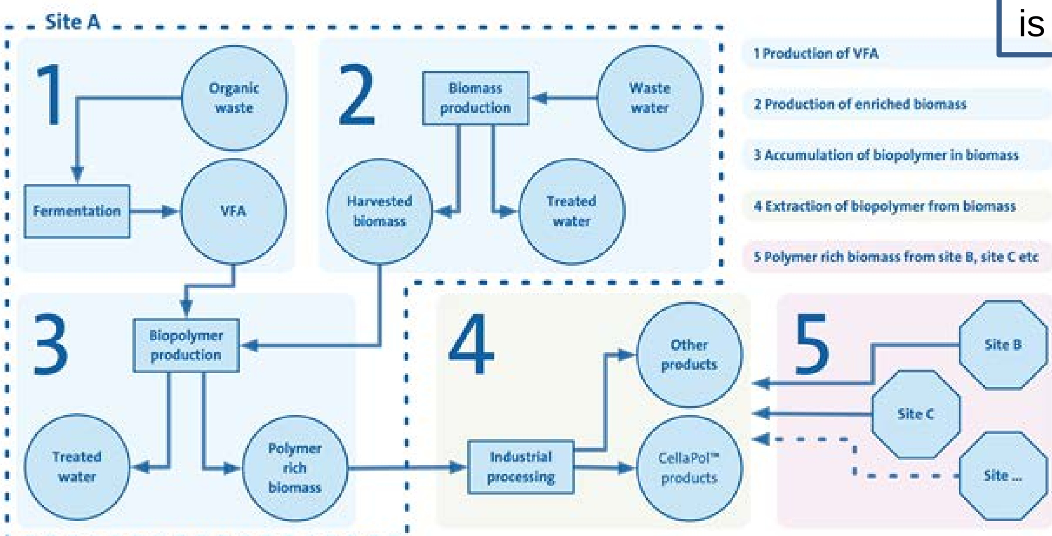
***Alcaligenes latus* loaded with PHA granules**

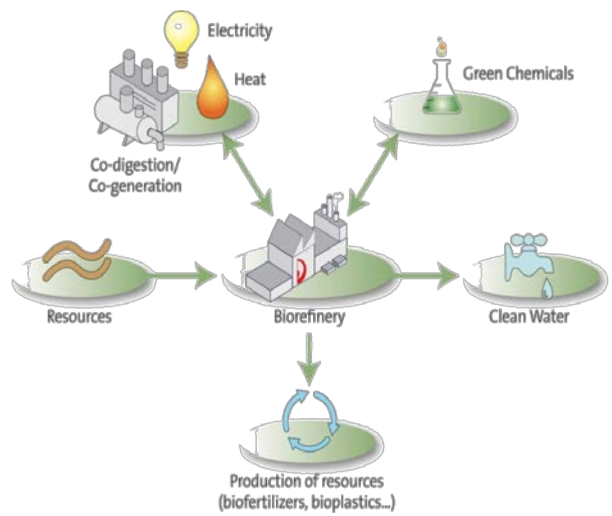




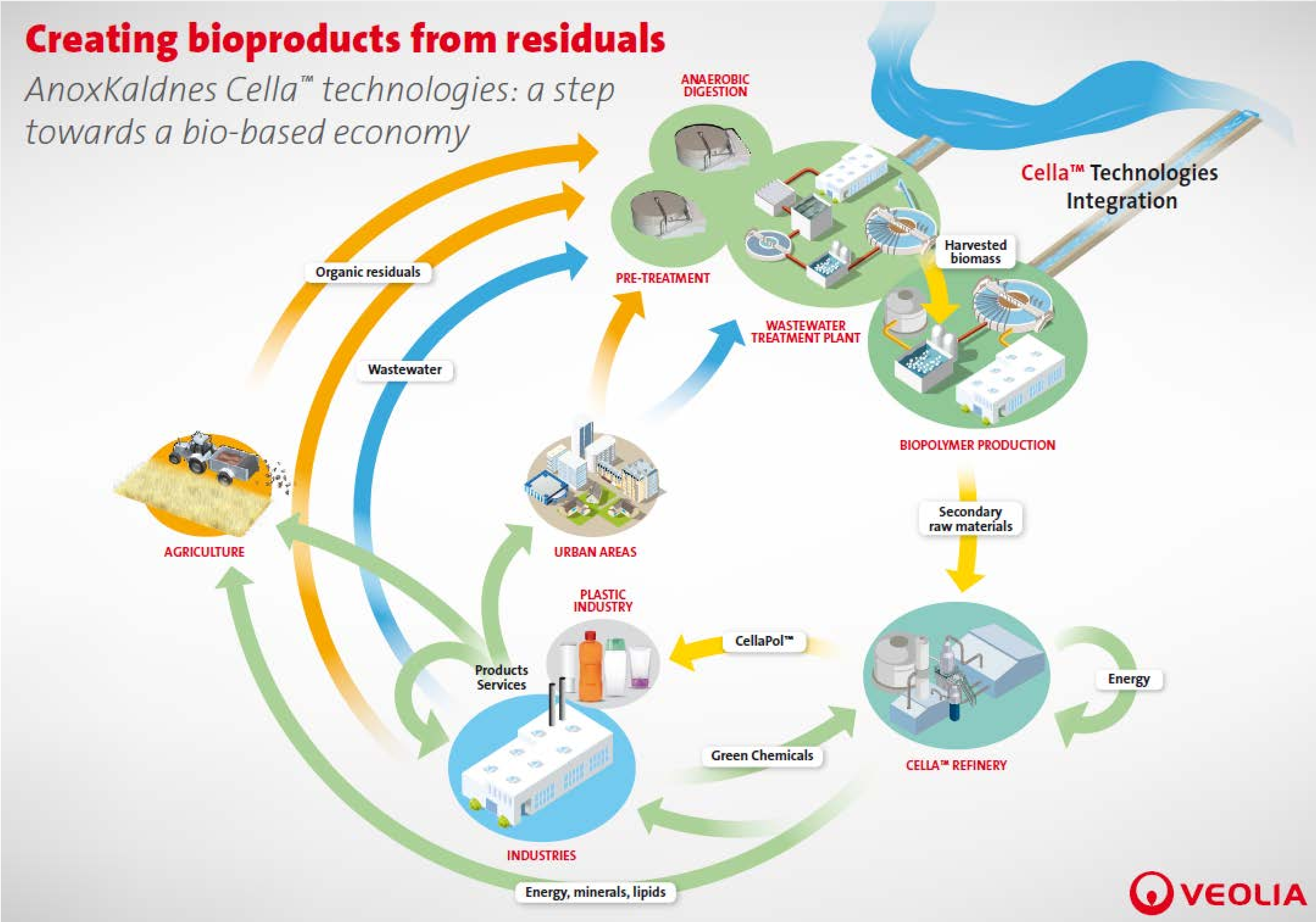
PHA

Polyhydroxyalkanoates (PHAs) are thermoplastic polymers that are biodegradable and can be produced from renewable resources.
The main subtrates used for the selective growth of PHA storing organism and PHA production have been volatile fatty acids (VFAs) since VFAs are efficiently converted into PHAs, whereas carbohydrates are preferably stored as polysaccharides.
For every ten tonnes of COD removed in a biological wastewater treatment system one to four tonnes of biomass is produced, in which contains bacteria that can store PHA

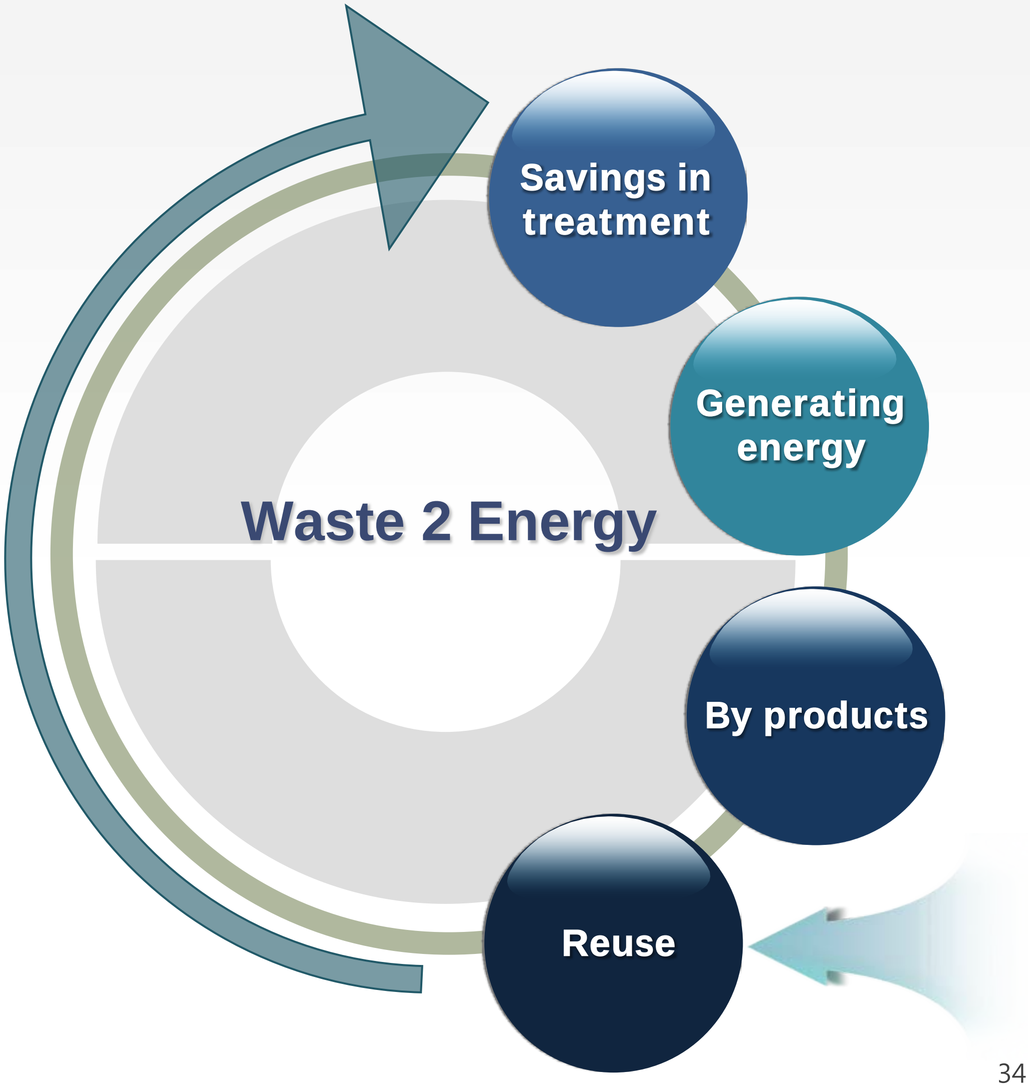




By products-Biopolymer



Waste to energy-Reuse



Reuse

1. Agricultural
2. Industrial
3. Groundwater recharge
4. Recreational uses
5. Urban use

Reuse- Description

Energy efficiency and sustainability are key drivers of water reuse, which is why water reuse is so integral to sustainable water management. The water-energy nexus recognizes that water and energy are mutually dependent, energy production requires large volumes of water, and water infrastructure requires large amounts of energy.

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs, therefore, sustainable water management can be defined as water resource management that meets the needs of present and future generations.

Water reuse is integral to sustainable water management because it allows water to remain in the environment and be preserved for future uses while meeting the water requirements of the present. Water and energy are interconnected, and sustainable management of either resource requires consideration of the other. Water reuse reduces energy use by eliminating additional potable water treatment and associated water conveyance because reclaimed water typically offsets potable water use and is used locally.

Reuse-Definitions

De facto reuse: *A situation where reuse of treated wastewater is, in fact, practiced but is not officially recognized (e.g., a drinking water supply intake located downstream from a wastewater treatment plant [WWTP] discharge point).*

Direct potable reuse (DPR): The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a drinking water treatment plant, either collocated or remote from the advanced wastewater treatment system.

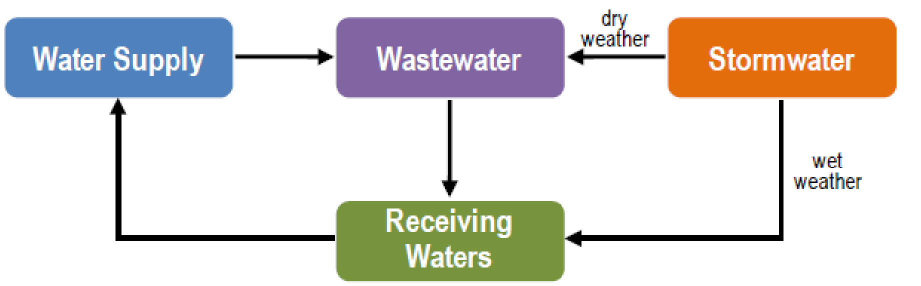
Indirect potable reuse (IPR): Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes drinking water treatment.

Nonpotable reuse: All water reuse applications that do not involve potable reuse.

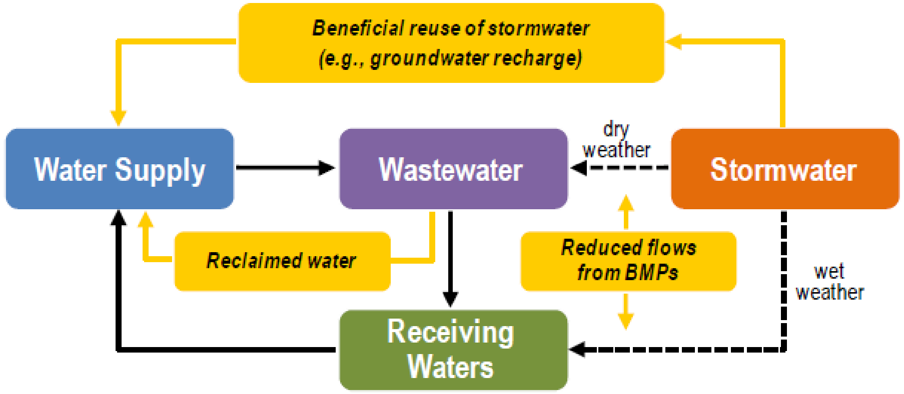
Potable reuse: Planned augmentation of a drinking water supply with reclaimed water.

Reuse & Management

Traditional Water Management (Non-integrated Water Resources)



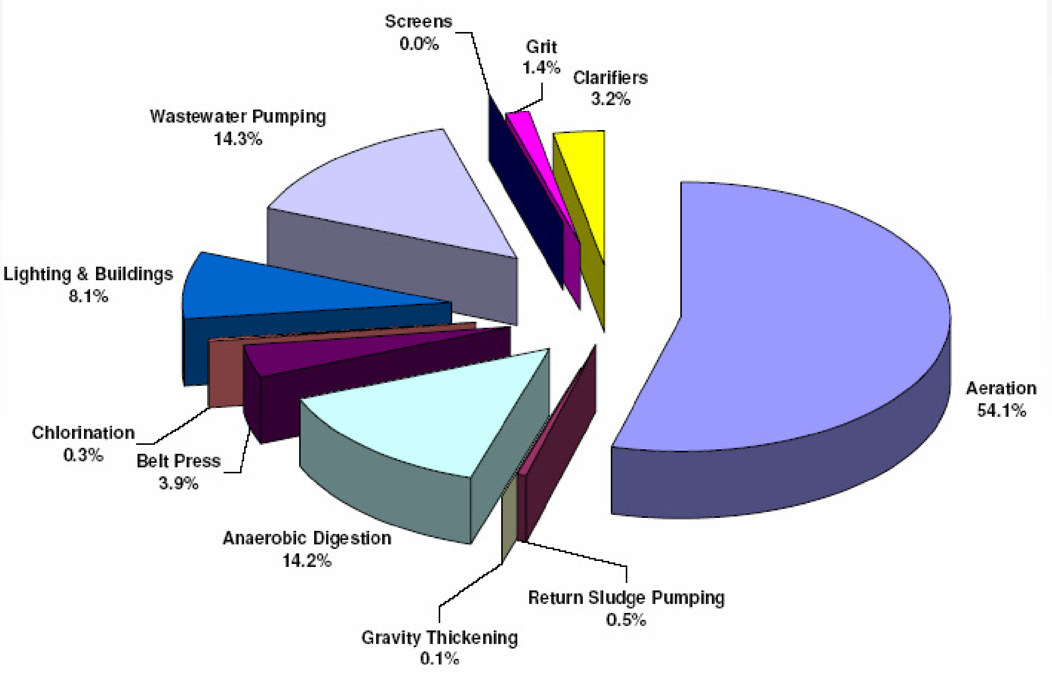
Total Water Management (Integrated Water Resources)



Water Management

The cities face weakness in the traditional practices of water management, which typically focus on individual resources or utilities.
Dry weather stormwater represents low flows that occur during non-peak events that may end up in the wastewater collection system, and wet weather stormwater represents higher flow periods that generally end up as discharge to receiving waters. Urban watersheds use more receiving waters for their water supplies and wastewater and stormwater into receiving waters.
Reduce the demand for freshwater are part of this comprehensive management Approach, like rather than viewing stormwater as a nuisance, it should be considered an asset that is allowed to recharge groundwater through best management practices, such as the use of swales, porous pavement, or cisterns.
Additionally, wastewater can be reused, providing both environmental and water supply benefits

Reuse



Electricity Requirements for Activated Sludge Wastewater

Derived from data from the Water Environment Energy Conservation Task Force *Energy Conservation in Wastewater Treatment*

Energy Management

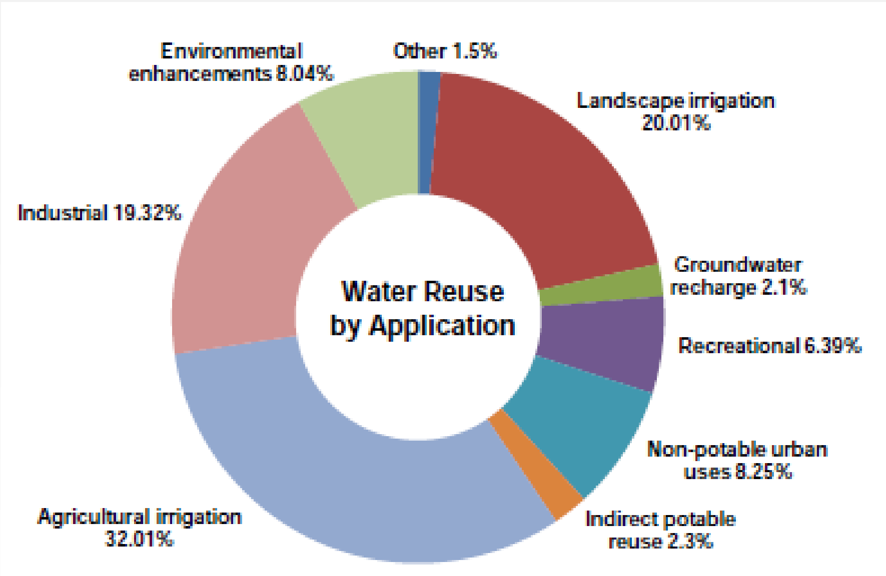
Knowing than cities use around up to 5% of its total energy consumption for drinking water and wastewater systems, implementing best management practices must be accompanied by optimal treatment facilities in which energy audits are highly important.

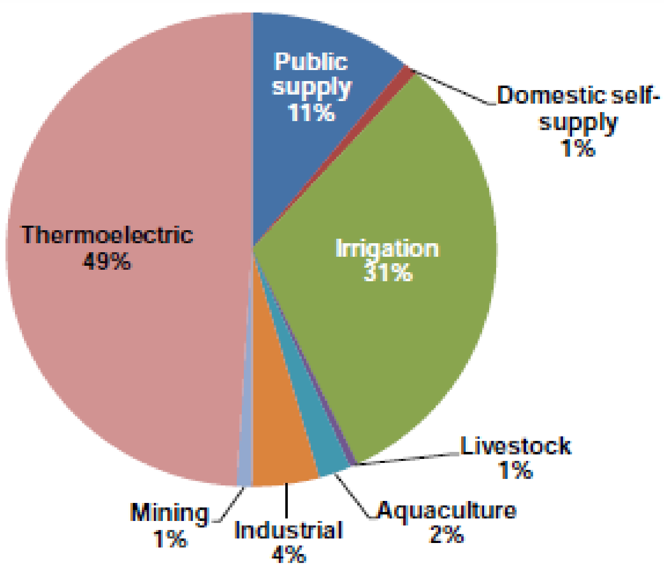
Wastewater Treatment BPs

Variable Frequency drive applications-0.5 to 5 years
Optimize flow with controls-Variable
Optimize aeration system-3 to 7 years
Fine bubble aeration-Variable
Variable Blower air flow rate-3 years
Dissolved oxygen control-2 to 3 years
Final effluent recycling-2 to 3 years

Reuse & Applications

Water & Energy Management





Category of reuse		Description
Urban Reuse	Unrestricted	The use of reclaimed water for nonpotable applications in municipal settings where public access is not restricted
	Restricted	The use of reclaimed water for nonpotable applications in municipal settings where public access is controlled or restricted by physical or institutional barriers, such as fencing, advisory signage, or temporal access restriction
Agricultural Reuse	Food Crops	The use of reclaimed water to irrigate food crops that are intended for human consumption
	Processed Food Crops and Non-food Crops	The use of reclaimed water to irrigate crops that are either processed before human consumption or not consumed by humans
Impoundments	Unrestricted	The use of reclaimed water in an impoundment in which no limitations are imposed on body-contact water recreation activities
	Restricted	The use of reclaimed water in an impoundment where body contact is restricted
Environmental Reuse		The use of reclaimed water to create, enhance, sustain, or augment water bodies including wetlands, aquatic habitats, or stream flow
Industrial Reuse		The use of reclaimed water in industrial applications and facilities, power production, and extraction of fossil fuels
Groundwater Recharge – Nonpotable Reuse		The use of reclaimed water to recharge aquifers that are not used as a potable water source
Potable Reuse	IPR	Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes normal drinking water treatment
	DPR	The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a water treatment plant, either collocated or remote from the advanced wastewater treatment system

Reuse & Applications and quality

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Treatment Level	Increasing Levels of Treatment →			
	Primary	Secondary	Filtration and Disinfection	Advanced
Processes	Sedimentation	Biological oxidation and disinfection	Chemical coagulation, biological or chemical nutrient removal, filtration, and disinfection	Activated carbon, reverse osmosis, advanced oxidation processes, soil aquifer treatment, etc.
End Use	No Uses Recommended	Surface irrigation of orchards and vineyards	Landscape and golf course irrigation	Indirect potable reuse including groundwater recharge of potable aquifer and surface water reservoir augmentation and potable reuse
		Non-food crop irrigation	Toilet flushing	
		Restricted landscape impoundments	Vehicle washing	
		Groundwater recharge of nonpotable aquifer	Food crop irrigation	
		Wetlands, wildlife habitat, stream augmentation	Unrestricted recreational impoundment	
		Industrial cooling processes	Industrial systems	
Human Exposure	Increasing Acceptable Levels of Human Exposure →			
Cost	Increasing Levels of Cost →			

Wastewater Reuse

Treated wastewater can achieved the values shown in this chart and with the a proper local wastewater management energy consumption and water footprint can be optimized.

	Primary	Secondary	Tertiary
BOD	19%	74%	5%
TSS	40%	55%	4%
TOC	21%	64%	8%
Ammonia-N	5%	52%	1%
Phosphate-P	16%	28%	54%
Iron	11%	59%	22%

Reuse-Water quality needed

Irrigation quality

Potential Irrigation Problem		Units	Degree of Restriction on Irrigation: None	Slight to Moderate	Severe
Salinity *(affects crop water availability)*[2]					
	EC_w	dS/m	< 0.7	0.7 – 3.0	> 3.0
	TDS	mg/L	< 450	450 – 2000	> 2000
Infiltration *(affects infiltration rate of water into the soil; evaluate using EC_w and SAR together)*[3]					
SAR	0 – 3	and EC_w =	> 0.7	0.7 – 0.2	< 0.2
	3 – 6		> 1.2	1.2 – 0.3	< 0.3
	6 – 12		> 1.9	1.9 – 0.5	< 0.5
	12 – 20		> 2.9	2.9 – 1.3	< 1.3
	20 – 40		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*					
	Sodium (Na)[4]				
	surface irrigation	SAR	< 3	3 – 9	> 9
	sprinkler irrigation	meq/l	< 3	> 3	
	Chloride (Cl)[4]				
	surface irrigation	meq/l	< 4	4 – 10	> 10
	sprinkler irrigation	meq/l	< 3	> 3	
	Boron (B)	mg/L	< 0.7	0.7 – 3.0	> 3.0
Miscellaneous Effects *(affects susceptible crops)*					
	Nitrate (NO_3-N)	mg/L	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)	meq/L	< 1.5	1.5 – 8.5	> 8.5
	pH		**Normal Range 6.5 – 8.4**		

Boilers

Drum Operating Pressure (psig)	0-300	301-450	451-600	601-750	751-900	901-1000	1001-1500	1501-2000	OTSG
Steam									
TDS max (ppm)	0.2-1.0	0.2-1.0	0.2-1.0	0.1-0.5	0.1-0.5	0.1-0.5	0.1	0.1	0.05
Boiler Water									
TDS max (ppm)	700-3500	600-3000	500-2500	200-1000	150-750	125-625	100	50	0.05
Alkalinity max (ppm)	350	300	250	200	150	100	n/a	n/a	n/a
TSS Max (ppm)	15	10	8	3	2	1	1	n/a	n/a
Conductivity max (μmho/cm)	1100-5400	900-4600	800-3800	300-1500	200-1200	200-1000	150	80	0.15-0.25
Silica max (ppm SiO2)	150	90	40	30	20	8	2	1	0.02
Feed Water (Condensate and Makeup, After Deaerator)									
Dissolved Oxygen (ppm O2)	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	n/a
Total Iron (ppm Fe)	0.1	0.05	0.03	0.025	0.02	0.02	0.01	0.01	0.01
Total Copper (ppm Cu)	0.05	0.025	0.02	0.02	0.015	0.01	0.01	0.01	0.002
Total Hardness (ppm CaCO3)	0.3	0.3	0.2	0.2	0.1	0.05	ND	ND	ND
pH @ 25° C	8.3-10.0	8.3-10.0	8.3-10.0	8.3-10.0	8.3-10.0	8.8-9.6	8.8-9.6	8.8-9.6	n/a
Nonvolatile TOC (ppm C)	1	1	0.5	0.5	0.5	0.2	0.2	0.2	ND
Oily Matter (ppm)	1	1	0.5	0.5	0.5	0.2	0.2	0.2	ND

Reuse & WTP

Microorganism removal

Type of Microorganism	Indicator microorganisms			Pathogenic microorganisms				
	Escherichia coli (indicator bacteria)	*Clostridium perfringens*	Phage (indicator virus)	Enteric bacteria (e.g., *Campylobacter*)	Enteric viruses	*Giardia lamblia*	*Cryptosporidium parvum*	Helminths
Bacteria	X	X		X				
Protozoa and helminths						X	X	X
Viruses			X		X			
Indicative Log Reductions in Various Stages of Wastewater Treatment[1]								
Secondary treatment	1 - 3	0.5 - 1	0.5 - 2.5	1 - 3	0.5 - 2	0.5 - 1.5	0.5 - 1	0 - 2
Dual media filtration[2]	0 - 1	0 - 1	1 - 4	0 - 1	0.5 - 3	1 - 3	1.5 - 2.5	2 - 3
Membrane filtration (UF, NF, and RO)[3]	4 - >6	>6	2 - >6	>6	2 - >6	>6	4 - >6	>6
Reservoir storage	1 - 5	N/A	1 - 4	1 - 5	1 - 4	3 - 4	1 - 3.5	1.5 - >3
Ozonation	2 - 6	0 - 0.5	2 - 6	2 - 6	3 - 6	2 - 4	1 - 2	N/A
UV disinfection	2 - >6	N/A	3 - >6	2 - >6	1 ->6	3 - >6	3 - >6	N/A
Advanced oxidation	>6	N/A	>6	>6	>6	>6	>6	N/A
Chlorination	2 - >6	1 - 2	0 - 2.5	2 - >6	1 - 3	0.5 - 1.5	0 - 0.5	0 – 1

Filtration size-contaminants

Filter Type	Filtration Driving Force	Nominal Pore Size, *um*	Contaminants targeted for removal
Depth			
Non-Compressible Media	Gravity or pressure differential	60-300	TSS, turbidity, some protozoan oocysts and cysts
Compressible Media			
Surface Filtration			
Surface Filtration	Gravity	5-20	TSS, turbidity, some protozoan oocysts and cysts
Membrane[2]			
Microfiltration	Pressure differential	0.05	TSS, turbidity, some protozoan oocysts and cysts, some bacteria and viruses
Ultrafiltration	Pressure differential	0.002-0.050	Macromolecules, colloids, most bacteria, some viruses, proteins
Nanofiltration	Pressure differential	<0.002	Small molecules, some hardness, viruses
Reverse Osmosis	Pressure differential	<0.002	Very small molecules, color, hardness, sulfates, nitrate, sodium, other ions

Processes for WTP

California Model IPR: WWTP → MF → RO → UV-A → Buffer → WTP →

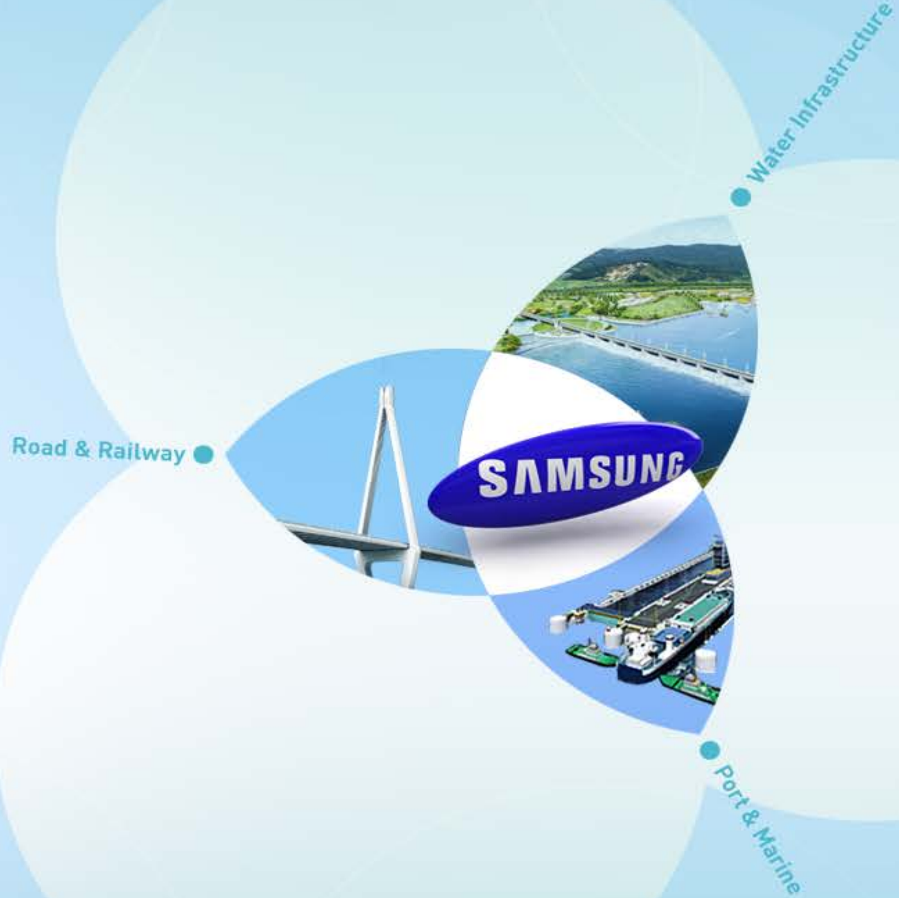
Surface Water (nutrients): WWTP → MF → RO → IX → UV-A → Buffer Blend → WTP →

Namibia Model (No RO): WWTP → DAF → Media Filtration → Ozone → BAC/GAC → UF → Buffer Blend → WTP →

Gwinnett County IPR: WWTP → MF → GAC → Ozone → Buffer Blend → WTP →

Cloudcraft Model (MBR): MBR → RO → UV-A → Buffer Blend → WTP →

4. Reuse case studies



Reuse-Case study-Aquapolo-Industry

Description

The State of São Paulo is the world's seventh most populous urban area.

The region contains nearly one-fourth of the country's population but less than 2% of Brazil's water.

The state government, recognizing the importance of safeguarding drinking water for the region's inhabitant, issued regulations to restrict the industrial use of potable water, forcing factories to look for ways to reuse their wastewater, or obtain recycled water from a nother source.

Upon completion, this groundbreaking facility will free up enough drinking water to continuously supply a population of 350,000 inhabitants, with the potential capacity to reach 600,000.

Solution

Koch Membrane Systems (KMS) concluded that membrane bioreactor (MBR) technology with a Tertiary Membrane Bioreactor (TMBR) system was the best solution for the new facility.

The Aquapolo facility employees KMS'PURON® MBR technology as well as MegaMagnum® reverse osmosis (RO) membranes.

The initial 2012/2014 phase will produce 56,160 m3/day (650 L/s) of reuse water, eventually reaching a capacity of 86,400 m3/day.

Reuse-Case study-Aquapolo-Industry

Reuse solution

Sixty-five percent of the plant output has already been sold under a 34-year contract to Quattor, a petrochemical company located within the Mauá petrochemical complex—Aquapolo's target market.

Other potential users are companies located along the 10-mile steel pipeline being built to carry water to the complex.

The recycled water used in industry for processes such as cooling, making steam, and cleaning requires removal of particular substances as well as a reduction of suspended solids and conductivity.

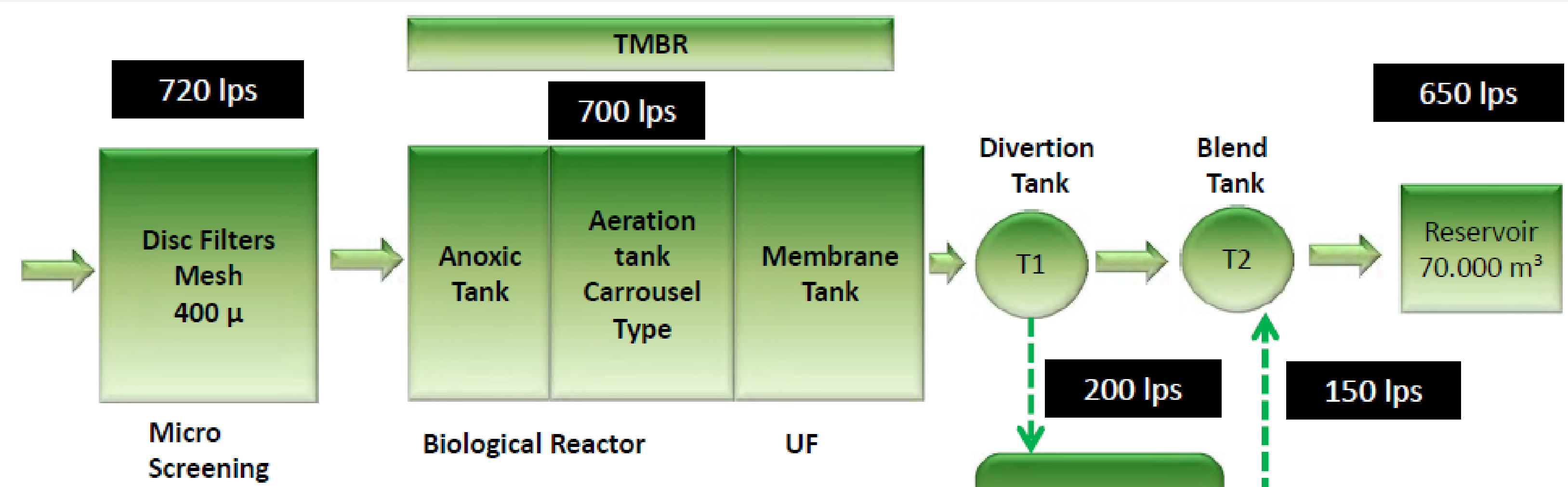
Challenges

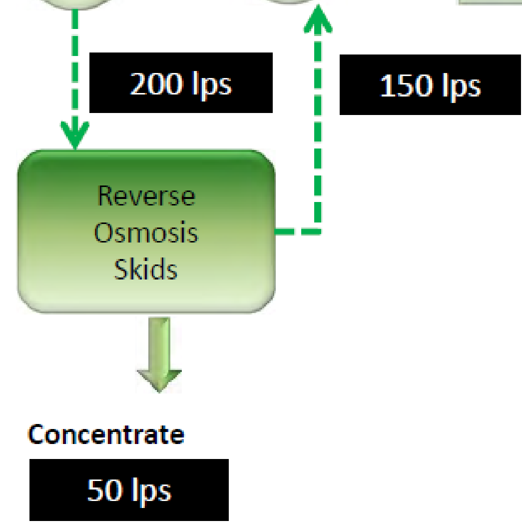
The poor performance of the secondary clarifiers, suffering regularly from bulking sludge, was a major potential threat for any RO solution. Even the installation of either sand filtration or direct ultrafiltration (UF) would only move the problem upstream, but never eradicate it.

Another point to address was the high ammonia level still present in the secondary effluent from the plant, varying between 10 and 25 mg/L NH4-N. As the current plant was only designed for carbonaceous removal, nitrification was impaired because the sludge retention time was too short, resulting in high ammonia effluent values. RO technology alone will not be able to meet strict reuse criteria of <1 mg/L NH4-N year average. While RO remained an essentialpart of the treatment process to reduce total dissolved solids and make the water clean enough for reuse, the RO system needed to be coupled with an effective pretreatment system.

Reuse-Case study-Aquapolo-Industry

Process-PFD





	Primary
Pre treatment	Disc Filter 400 micra
Bio recators	3500 m3
Membrane cassettes	63 units/1500 m2 each/94.500 m2
Flux	25 l/m2.h
MLSS (Membrane tanks)	5 to 8 g/l
MLSS (bio recators)	6.4 g/l

Reuse-Case study-Aquapolo-Industry

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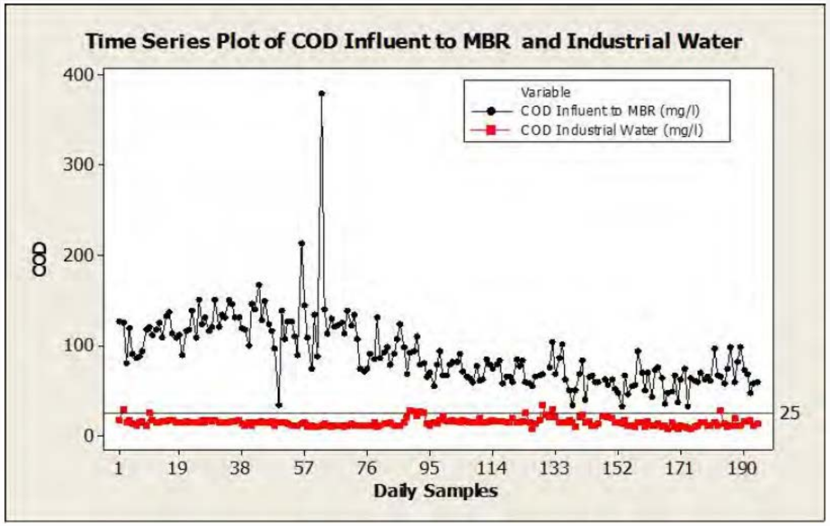
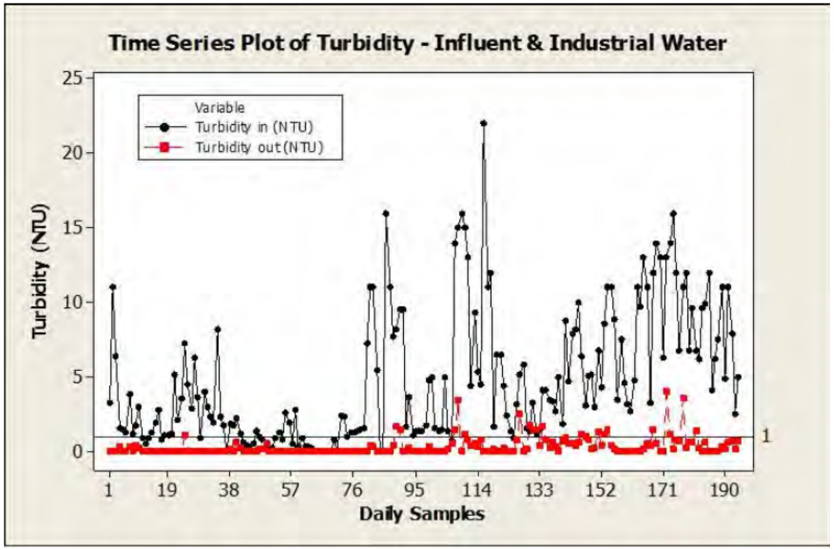
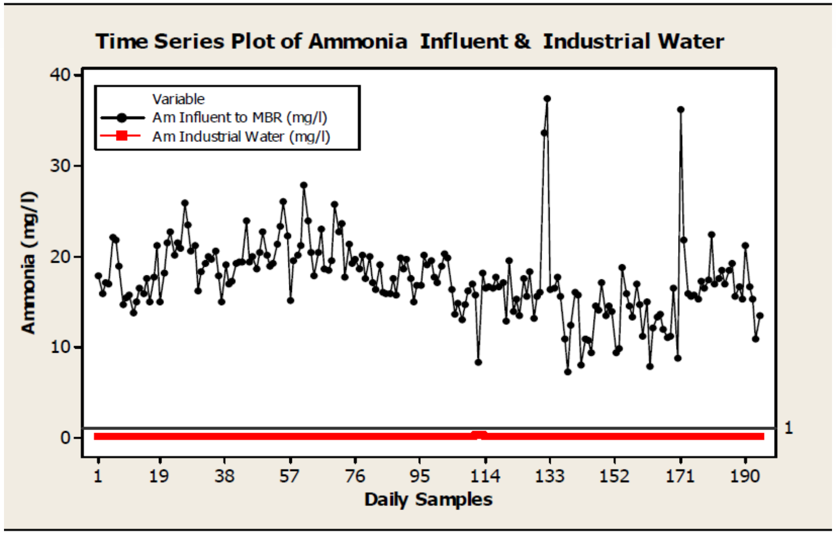
Results

PARAMETERS	Industrial Water Quality Required	AQUAPOLO Industrial Water Average Results
Temperature (°C)	15 to 30	18 to 25
BOD_5 (mg/l)	10	< 10
COD (mg/l)	25	< 25
Total Suspended Solids (mg/l)	2	< 1
Ammonia N_NH3 (mg/l)	1	< 0,40
pH	6,5 to 7,5	6,7 to 7,5
Turbidity (mg/l)	1	< 0,50



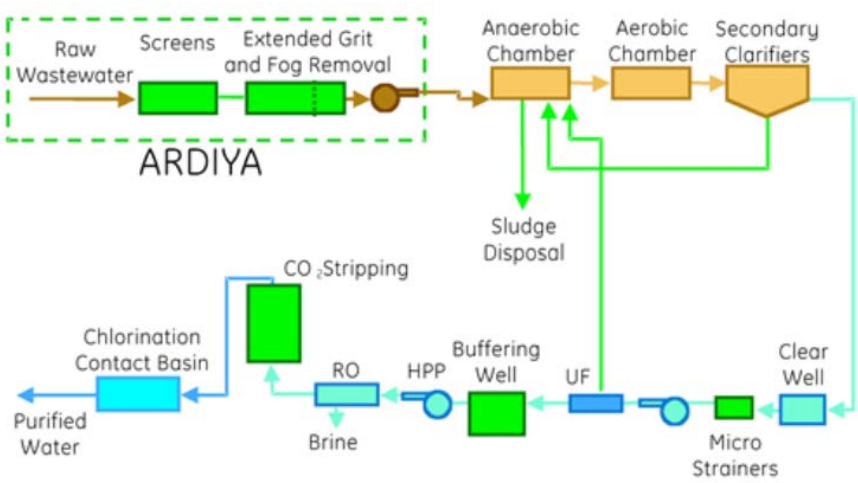




Reuse-Case study-Kuwait city-Agriculture

Description

Recover municipal wastewater from Kuwait City and the surrounding area. The consortium was established to design, build, own, operate and maintain a100 million gallon per day (mgd) (375,000 m3/day) wastewater treatment facility at Sulaibiya Near Kuwait City. The Sulaibiya facility is the world's largest membrane-based water reclamation facility. The reclaimed and desalinated water from the Sulaibiya facility is used for non-potable uses that impact the drinking water supply, by blending with brackish water to better exploit existing brackish water distribution facilities



Solution

A conventional biological wastewater treatment plant (WWTP) treats the effluent to better than secondary effluent quality.

*The secondary effluent then flows to the water reclamation plant, which uses ultrafiltration (UF) and reverse osmosis (RO) to further treat the water for reuse. Sludge from the wastewater treatment plant is treated to allow for disposal by landfill, incineration, or by compostin*g.

The water reclamation plant is designed to treat 100 mgd (375,000 m3/day) of secondary effluent, which is prefiltered with disk filters and then fed to the ultrafiltration system. UF product feeds a reverse osmosis plant, and UF waste is recycled to the WWTP. The UF system treats 100% ofthe flow after biological treatment since the UF waste is recycled. Hence, the feed to the RO system is also 100 mgd.

The RO plant is designed for 85% water recovery, so the expected production rate is 85 mgd.

Reuse-Case study-Kuwait city-Agriculture

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Results

The plant influent is typical domestic sewage.
The WWTP is designed to produce an effluent with an average monthly value of less than 20 mg/l BOD and 20 mg/l TSS.
The average total dissolved solids (TDS) in the feed Is 1,280 mg/l, and the plant product is less than 100 mg/l, significantly better than World Health Organization (WHO) potable water guidelines.

Table 1: Water Quality Data

	WWTP Effluent Average monthly value	Water Reclamation Plant Product Average monthly value	WHO Potable Water Guidelines
PH	7	6 – 9	6.5 – 8.5
TSS (mg/l)	12	< 1	
BOD (mg/l)	5	< 1	
Ammonia Nitrogen as N (mg/l)	< 2	< 1	
Nitrate (mg/l as N)	< 9	< 1	10
Phosphate (mg/l as PO4)	< 15	2	
Fat, Oil & Grease (mg/l)	< 0.5	< 0.5	
Conductivity (µS/cm)	2000		
TDS (mg/l)	< 1280	100	1000

Process

The effluent fed to the UF first passes through a disk filter, after which a small amount of coagulant is adde d to coagulate fine particulates and possibly allow some TOC removal to facilitate the operation of the plant. The SDI of the UF product will be below 2, an important criterion for the RO plant performance.
Previous experience treating secondary municipal effl uent with UF has shown that SDI values of less than 1 are possible.
The salinity of the municipal effluent has an average monthly value of 1,280 mg/l TDS, with a maximum value of 3,014 mg/l. RO is used to desalinate the water to 100 mg/l TDS, as well as provide a second barrier to bacteria and viruses.
RO technology is well proven for desalinating municipal effluent. The system consists of 42 identical skids in a 4:2:1 array. Approximately 21,000 membranes, provided by Toray of America, were required for this project. The RO system is limited to operating at 85% recovery by calcium phosphate precipitation, which can frequently be the limiting factor for water recovery in membrane systems desalinating municipal effluent.

Reuse-Case study-Australia-Industry

Description

The Wynnum Advanced Wastewater treatment plant is located south of the Brisbane River junction to the sea in Moreton Bay. Abundant wildlife live in and around Moreton Bay, which is like a lagoon because a series of off-shore barrier islands restrict the flow of oceanic water.

In 2008, as part of the area's sustainability efforts, an advanced wastewater treatment plant was built to produce Class A+ recycled water for industrial processes.

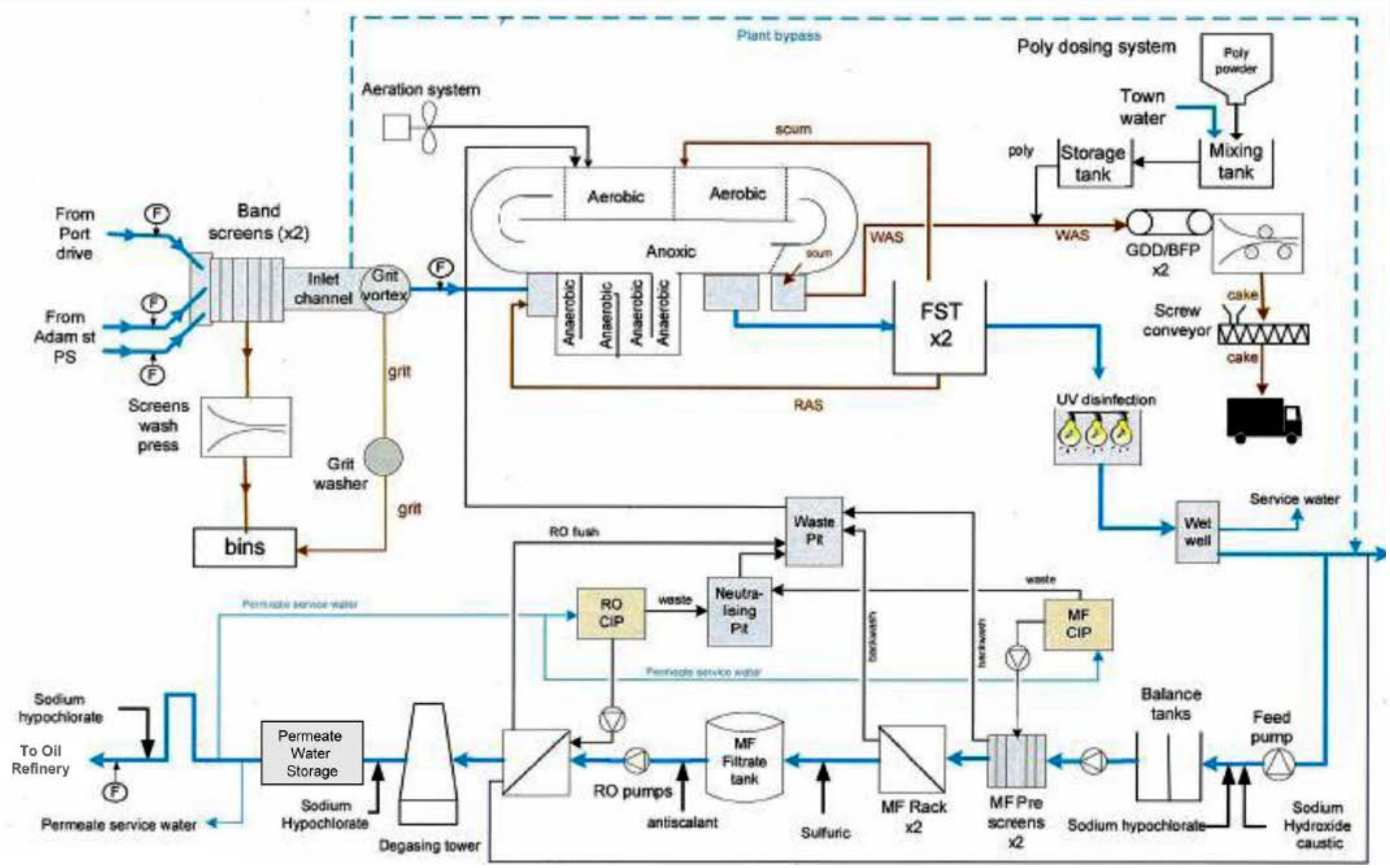
Solution

The water reclamation plant receives feed water from the upgraded wastewater treatment plant. Table 1 det ails the average feed water quality.The effluent water is chloraminated (2-3 mg/L) (Cl2) and then directed to the balance tank, where it goes through 0.5 μm Amiad screens and two microfiltration units—the SDI of the MF filtrate is less than three 100% of the time. The pH is corrected with H2SO4, and then the water moves through MF filtrate tanks, and an antiscalant dose before being fed to RO units. The RO system consists of two identical units of 16:8 configurations and each pressure vessel houses seven elements 336 pieces of BW30-400/34i-FR membranes are installed. The units recover 75% with a total design capacity of 5.3 ML/d. From there, the RO permeate is sent to the degassing tower, breakpoint chlorinated and then stored.

Produces 4,500 m3/d of high industrial grade Class A + recycled water daily from municipal sewage.

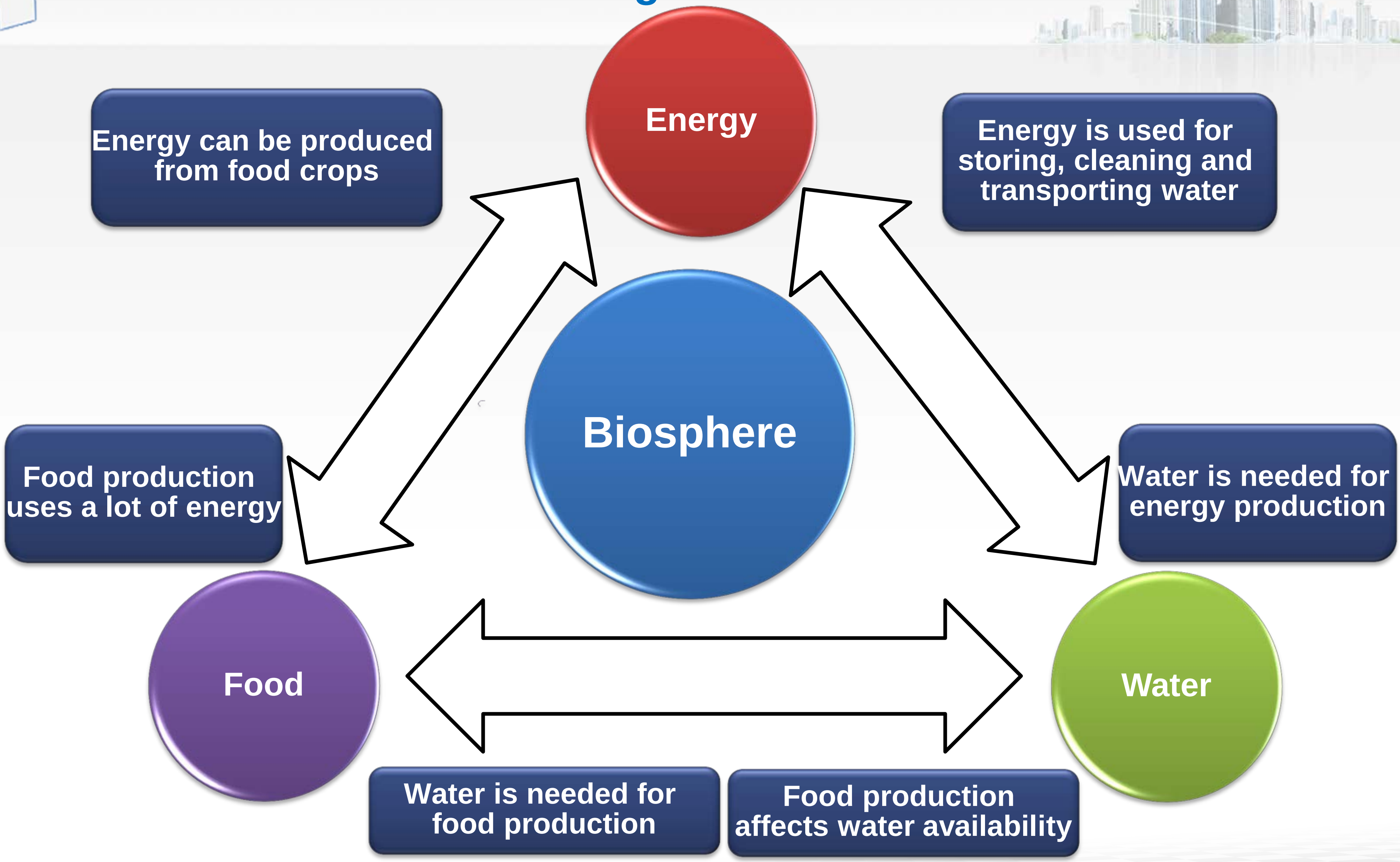
Challenges

Process-PFD-Results



Parameter	Unit	RO Feed
Temperature	°C	25 (19.5-30.8)
pH	—	7.2
Alkalinity	mg/L	135
Aluminium	mg/L	0.03
Ammonia N	mg/L	1.39
Calcium	mg/L	33.4
Chloride	mg/L	322
Fluoride	mg/L	0.15
Iron	mg/L	0.04
Magnesium	mg/L	24.4
Manganese	mg/L	0.05
Nitrite + Nitrate-N	mg/L	1.14
Ortho Phosphorus	mg/L	1.58
Potassium	mg/L	18.6
Silica	mg/L	16.6
Sodium	mg/L	241
Sulfate	mg/L	120
Feed Conductivity	(μS/Cm)	833 (378-1421)

"Water is the driving force of all nature"



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Thank you