BUILDING A WORLD OF DIFFERENCE

OPPORTUNITIES IN WASTEWATER TREATMENT

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17 November 11

BLACK & VEATCH
Building a world of difference.

CORE TECHNOLOGIES FOR UPGRADING (TREATING) A DOMESTIC LIQUID WASTE STREAM

PRELIMINARY TREATMENT

SCREENING
DEGRITTING
SEPTAGE PUMPOUTS ACCEPTANCE

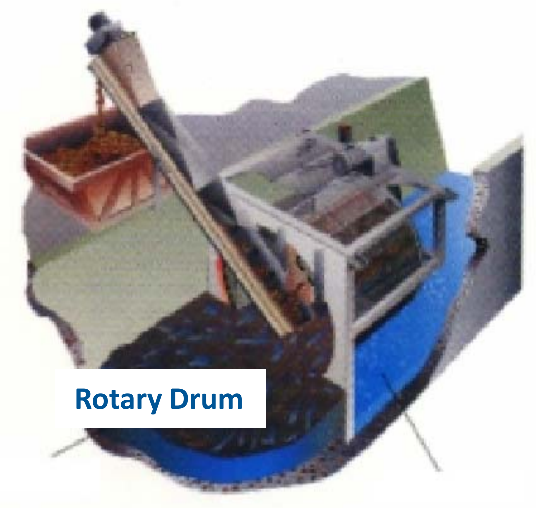
SCREENING

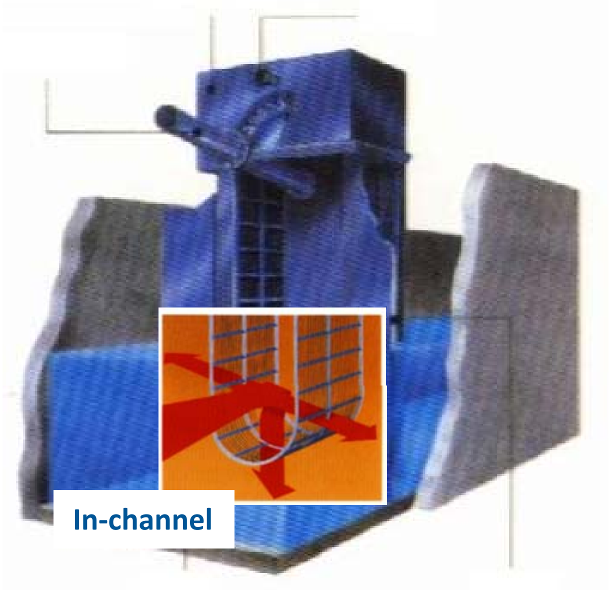
- **Purpose:**

Removal of solids, typical 6 – 9 mm but can be 2 mm, depending on processes downstream

- **Options:**

Selection depends on need and hydraulics; often coarse followed by fine screening (other deigns not shown)





PRELIMINARY TREATMENT

SCREENING

Step Screen

Advantages

- ✓ Large flow capacity
- ✓ Ease of installation & maintenance
- ✓ Low energy

Limitations

- ✓ Needs headroom
- ✓ Possible malodour

In-channel Screen

Advantages

- ✓ Large flow capacity
- ✓ Ease of installation and maintenance
- ✓ Low energy
- ✓ Low headroom

Limitations

- ✓ Possible malodour

Rotary Screen

Advantages

- ✓ Large flow capacity
- ✓ Low headloss
- ✓ No headroom

Limitations

- ✓ More power than others
- ✓ Requires large channel/pit
- ✓ Possible malodour

DEGRITTING

- **Purpose:**

(1) prevent excessive abrasion of mechanical equipment;

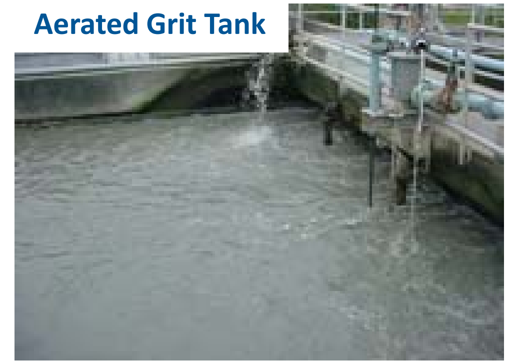
(2) prevent deposition of grit in pipes and channels;

(3) reduce accumulation of grit in downstream units such as settling basins and digesters.

Options:

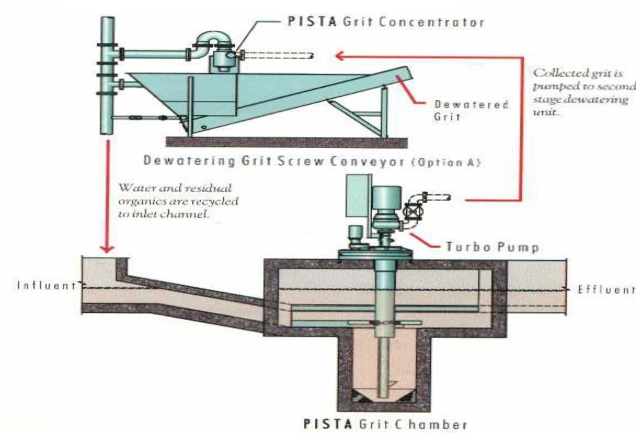
- Horizontal flow (square or rectangular configuration)
- Aerated (cylindrical or rectangular)
- Vortex-type (now becoming most popular)

Aerated Grit Tank



Aerated Grit Channel

Vortex Grit Removal



DEGRITTING

Aerated Grit Removal

Advantages

- ✓ Popularity
- ✓ Good at peak flows
- ✓ Good at 65 mesh and larger grit removal
- ✓ Adjustment of air determines grit size fraction for removal

Limitations

- ✓ Needs space
- ✓ Needs air supply
- ✓ BNR compatibility
- ✓ Possible malodour

Vortex Grit Removal

Advantages

- ✓ Low energy
- ✓ Compact design
- ✓ Grit removed to outside unit
- ✓ Compatible with BNR

Limitations

- 50 mesh (0.3 mm) 95+% removal
- 70 mesh (0.24 mm) 85+% removal
- 100 mesh (0.15 mm) 65+% removal

SEPTAGE PUMPOUT ACCEPTANCE

- **Purpose**

Most Asian cities have large numbers of septic tanks and few septage management centers. New WWTPs should incorporate septage receival facilities

- **Options**

1. **Dedicated septage treatment plants**
2. **Septage receiving areas at WWTPs**

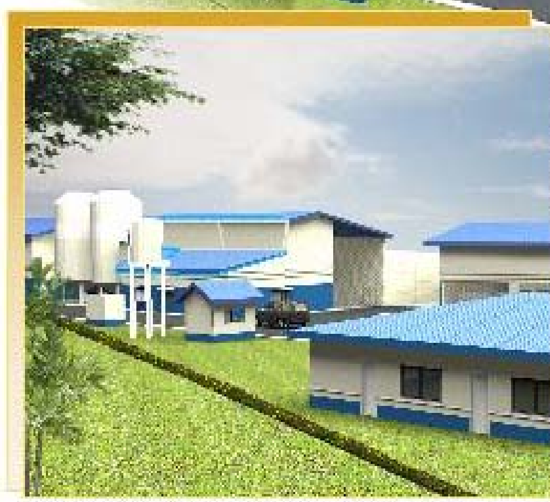
Dedicated Septage Treatment Plants

(example of design proposed for an Asian city)

SLUDGE STORAGE BUILDING

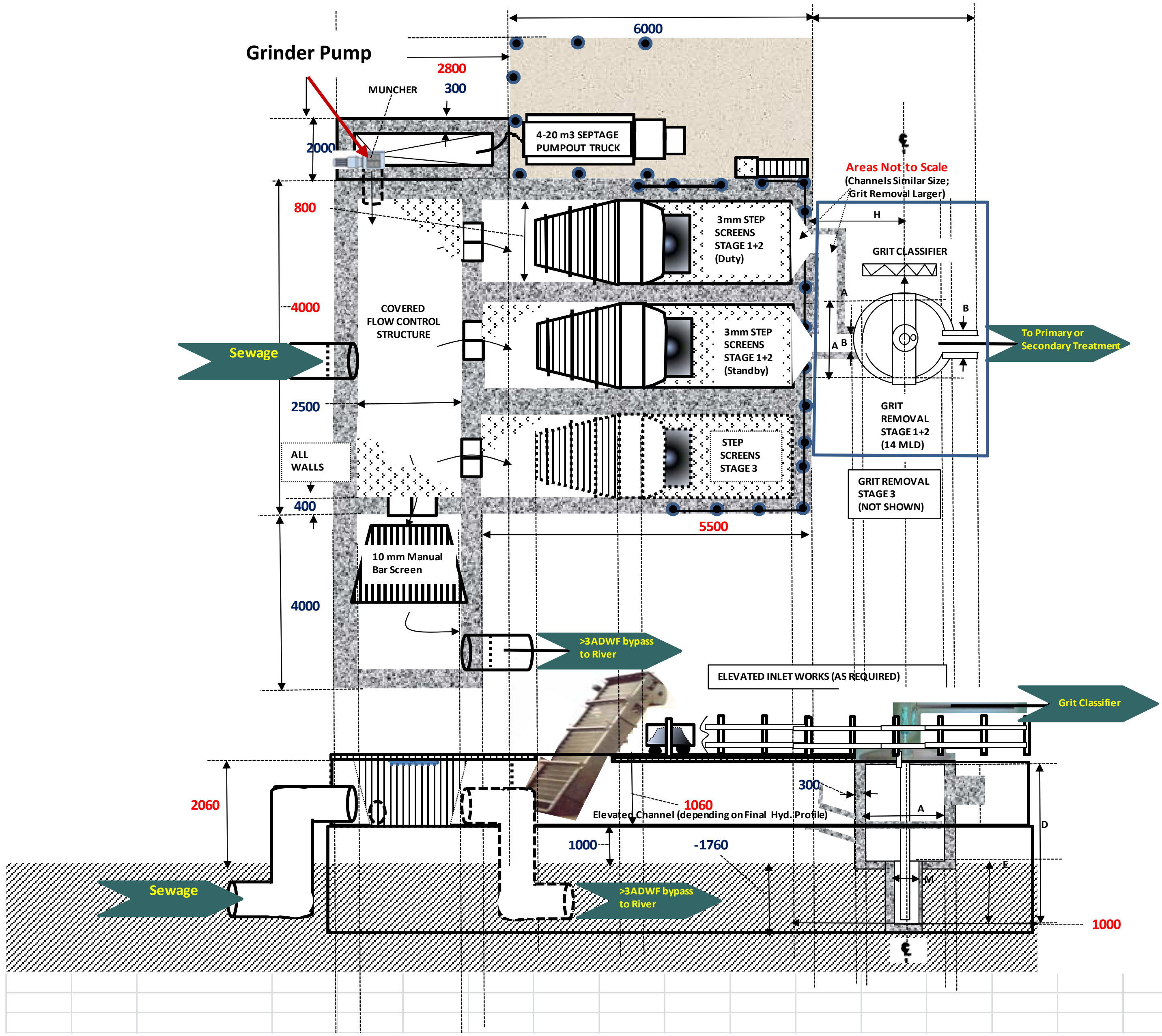
ENTRANCE

DEWATERING BUILDING



ADMINISTRATION BUILDING

Incorporate Septage Acceptance into Inlet Works



PRIMARY TREATMENT

PRIMARY TREATMENT

- **Purpose:**

Removal of solids to reduce downstream pollution and thus aeration requirements

- **Appropriate Influent Flows:**

For treatment plants <20 MLD it is often more economical to not have primary sedimentation.

Wastewater is screened and degritted and immediately subjected to biological treatment

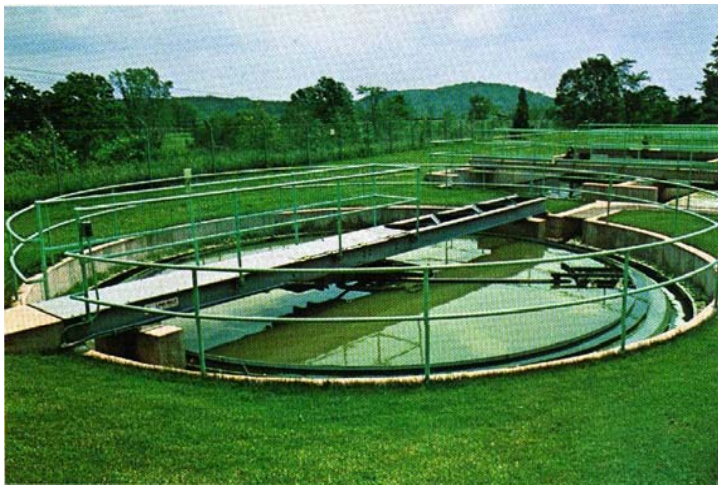
OPTIONS ALSO INCLUDE THE ADDITION OF CHEMICAL COAGULANTS

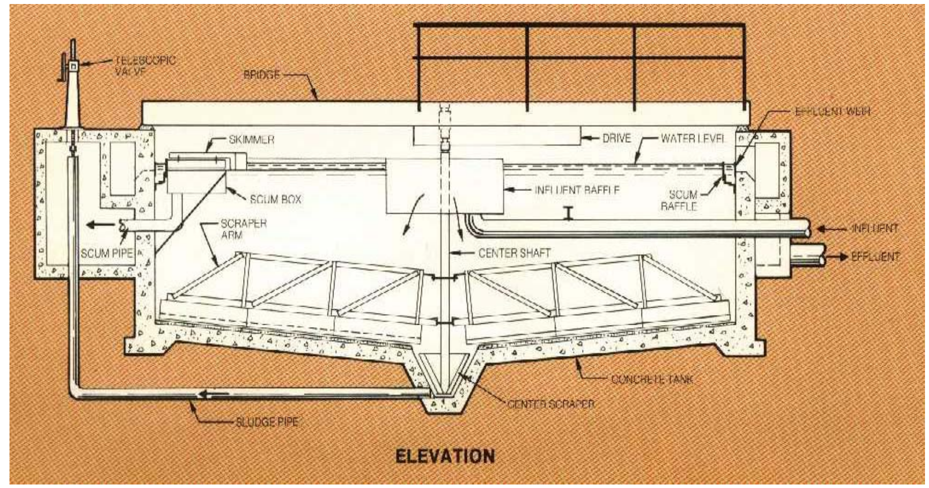
- Conventional primary clarifiers remove on average 50 to 70% of TSS and 25 to 40% of the COD or BOD demand in the incoming wastewater
- Use of chemically enhanced primary treatment (CEPT) minimizes footprint by reducing size of primary clarifiers and aeration basins.

  It can efficiently remove 60 to 90% of TSS, 40 to 70% of COD or BOD, 70 to 90% of phosphorus, and 80 to 90% of bacteria loadings

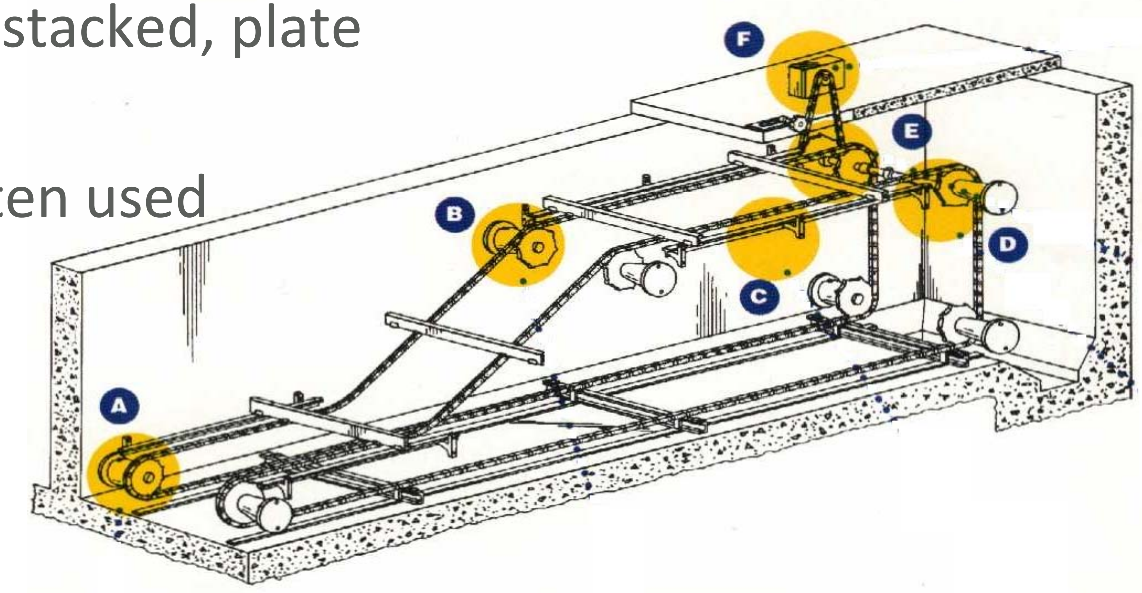
PRIMARY TREATMENT

OPTIONS INCLUDE VARIOUS CONFIGURATIONS AND/OR THE ADDITION OF COAGULANTS





- Circular, rectangular, stacked, plate & tube (saves space)
- Plastic chains now often used



ENHANCED PRIMARY SEDIMENTATION

		Advanced primary performance						Chemical addition		
		BOD			TSS					
Location	Flow, mgd	Influent, mg/L	Effluent, mg/L	Removed, %	Influent, mg/l	Effluent, mg/L	Removed, %	Type	Concen-tration, mg/L	Duration
Point Loma								$FeCl_3$	35	
City of San Diego	191	276	119	56.9	305	60	80.3	Anionic Polymer	0.26	Continuous
Orange County								$FeCl_3$	20	8 hours
Plant No. 1[b]	60	263	162	38.4	229	81	64.6	Anionic Polymer	0.25	peak flow
Orange County								$FeCl_3$	30	12 hours
Plant No. 2[b]	184	248	134	46.0	232	71	69.4	Anionic Polymer	0.14	peak flow
JWPCP										
Los Angeles County[a]	380	365	210	42.5	475	105	77.9	Anionic Polymer	0.15	Continuous
Hyperion								$FeCl_3$	20	
City of Los Angeles[a]	370	300	145	51.7	270	45	83.3	Anionic Polymer	.25	Continuous
Sarnia								$FeCl_3$	17	
Ontario, Canada	10	98	49	50.0	124	25	79.8	Anionic Polymer	.3	Continuous

* Advanced primary treatment has since been replaced by full secondary treatment.

** Full secondary treatment is scheduled to replace advanced primary treatment in 2012.

Note: TSS = total suspended solids; BOD = biochemical oxygen demand.

Fe addition at Malabar STP in Sydney (~450 MLD) was "moth balled" as it was too successful and Sydney Water could not manage all of the solids…

PRIMARY TREATMENT

Circular

Advantages

- ✓ Relatively trouble free as bearings are not under water
- ✓ Can use thinner walls
- ✓ More widely used
- ✓ Plate & tubes can be added to reduce size dia.

Limitations

- ✓ Requires more yard piping
- ✓ Requires more space

Rectangular

Advantages

- ✓ Larger tanks are more efficient than circular
- ✓ Good with space constrained sites
- ✓ Can be stacked

Limitations

- ✓ Cost
- ✓ Corrosion of internal elements if steel
- ✓ Performance

CEPT

Advantages

- ✓ Smaller tanks
- ✓ Further reduce downstream aeration reqmts

Limitations

- ✓ Cost / availability of chemical
- ✓ P is chemically bound and hard to access by plants
- ✓ Solids handling system may be undersized

SECONDARY TREATMENT

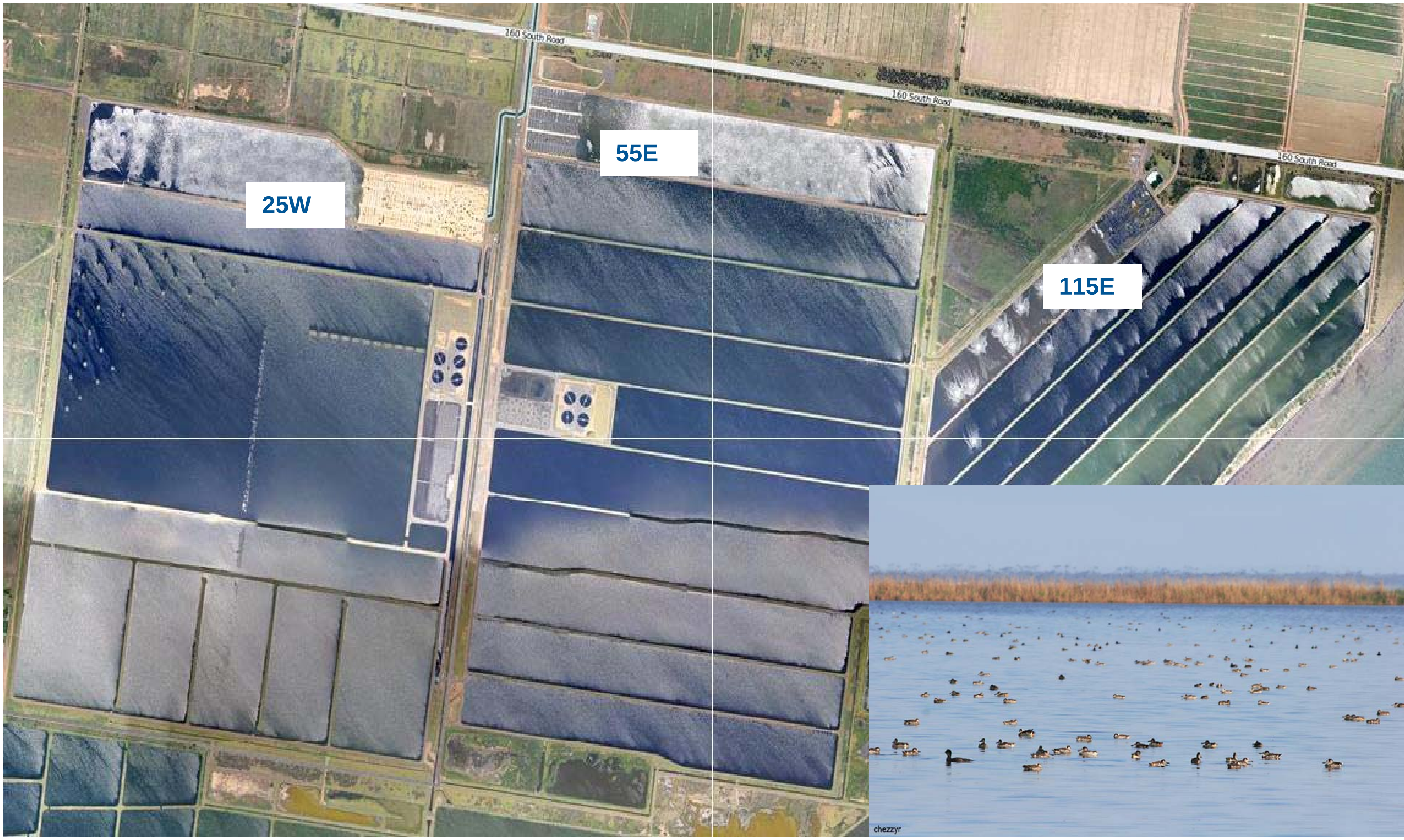
PURPOSE

SECONDARY TREATMENT

- Biological removal of carbon, nutrients, toxicity, some pathogens
- Configurations
  - Lagoons
  - Traditional activated sludge
  - Aerobic fixed film
  - Anaerobic

LAGOONS

Western Treatment Plant in Melbourne, Australia (ca. 3.8m people) treats 52% of Melbourne's sewage or 485 MLD on 11,000 ha. The WTP provides a haven for tens of thousands of birds and is recognised as one of the World's most significant wetlands.



LAGOONS

LAGOONS

Lagoons can offer some advantages for Asian cities just putting in wastewater treatment schemes (where land is available).

Advantages

- Low capital and operating expenses
- Low labor requirements
- Not complex
- Low maintenance
- Sludge management minimized
- Large land area preserved for future upgrades
- Anaerobic lagoons can be covered to collect biogas
- Potential water foul habitat

Disadvantages

- Effluent BOD < 50 mg/L difficult
- Supplemental disinfection required
- Large land requirement
- Odor can be an issue if anaerobic lagoons used and overloaded and/or uncovered

TRADITIONAL ACTIVATED SLUDGE

- **High Rate: SRT of 1 to 3 days**
  - Small footprint; no nutrient reduction; high sludge yield; additional solids stabilization.
- **Medium Rate: SRT of ca. 10 days**
  - Medium footprint; nitrification; reduced sludge yield; additional solids stabilization
- **Extended Aeration (SRT of ca. 20 days)**
  - Largest footprint; nitrification; lowest sludge yield; may produce stable sludge that can be directly dewatered and reused or disposed

Options: Continuous & Intermittent Systems

BIOLOGICAL NUTRIENT REMOVAL

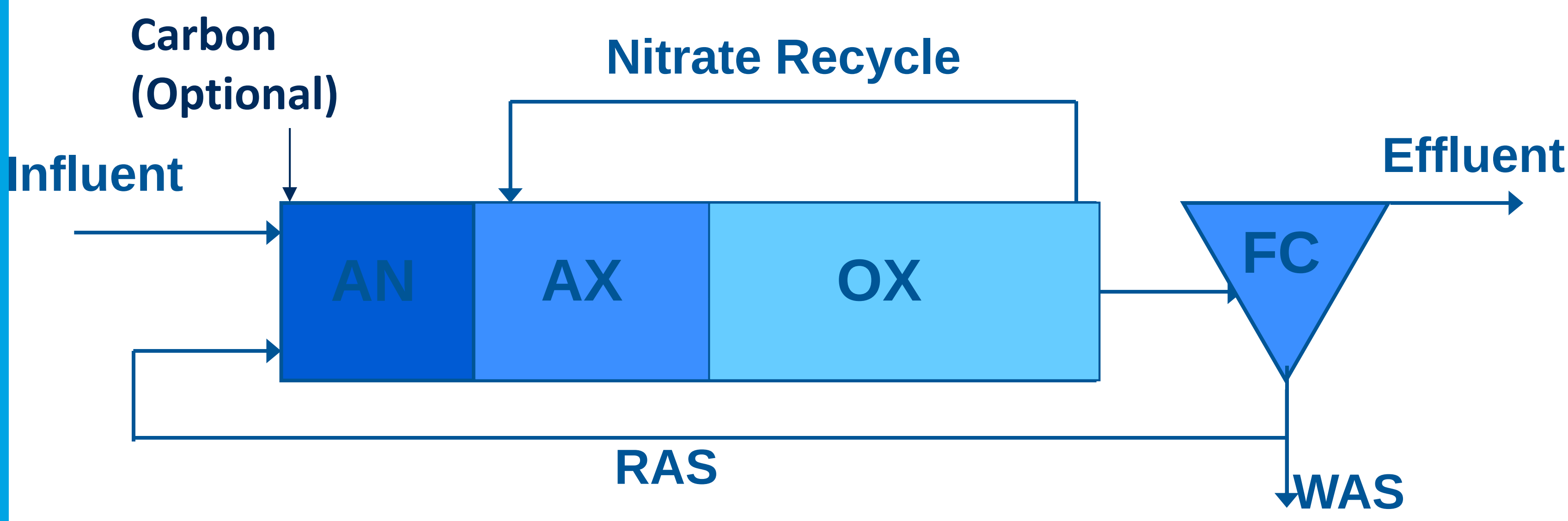
Termed BNR Processes

Carbon
- Mostly Biological
- Attached Growth or Suspended Growth
- Oxidative (e.g. O_3 but uncommon)
- Membrane

Nitrogen
- Mostly Biological
- Attached Growth or Suspended Growth
- Mostly using internal carbon sources
- External carbon sources for trimming
- Membrane

Phosphorus
- Biological and/or Chemical
- Suspended growth
- VFA for biological
- Membrane

BNR: CONFIGURATION BASIS IS ANAEROBIC/ANOXIC/OXIC ZONES



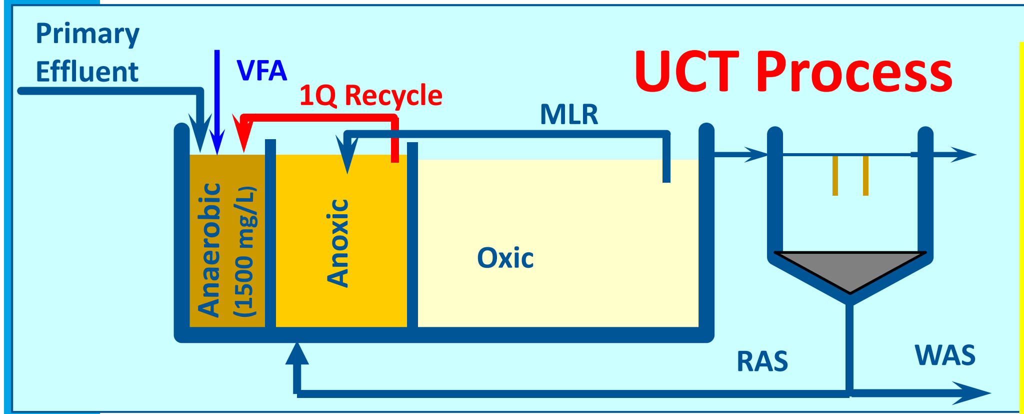
Biological Phosphorus Removal

- Anaerobic Environment – No DO or nitrates
- Carbon in VFA form is required
- External carbon may be required
- TN control is required
- Multiple BNR configurations available

Effluent Quality

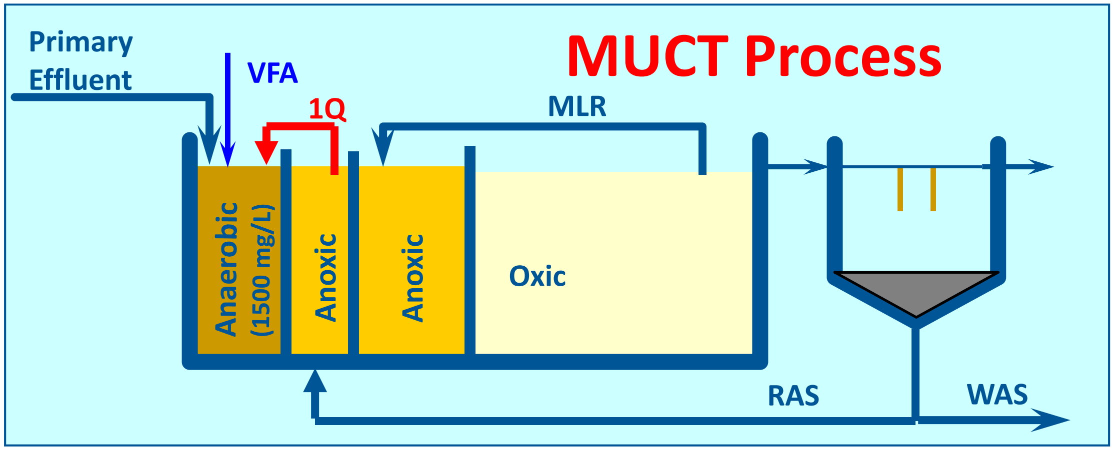
- NH_3-N < 1 mg/L
- TN = 6 - 10 mg/L
- TP $\leq$ 1 mg/L

BNR: UCT AND MODIFIED UCT PROCESS



Features

- Incorporate anoxic zone for RAS denite
- RAS Nitrate Conc. = 4 to 8 mg/L
- Influent VFA preserved for PAOs, but
- Low MLSS in Anaerobic zone – requires larger volume

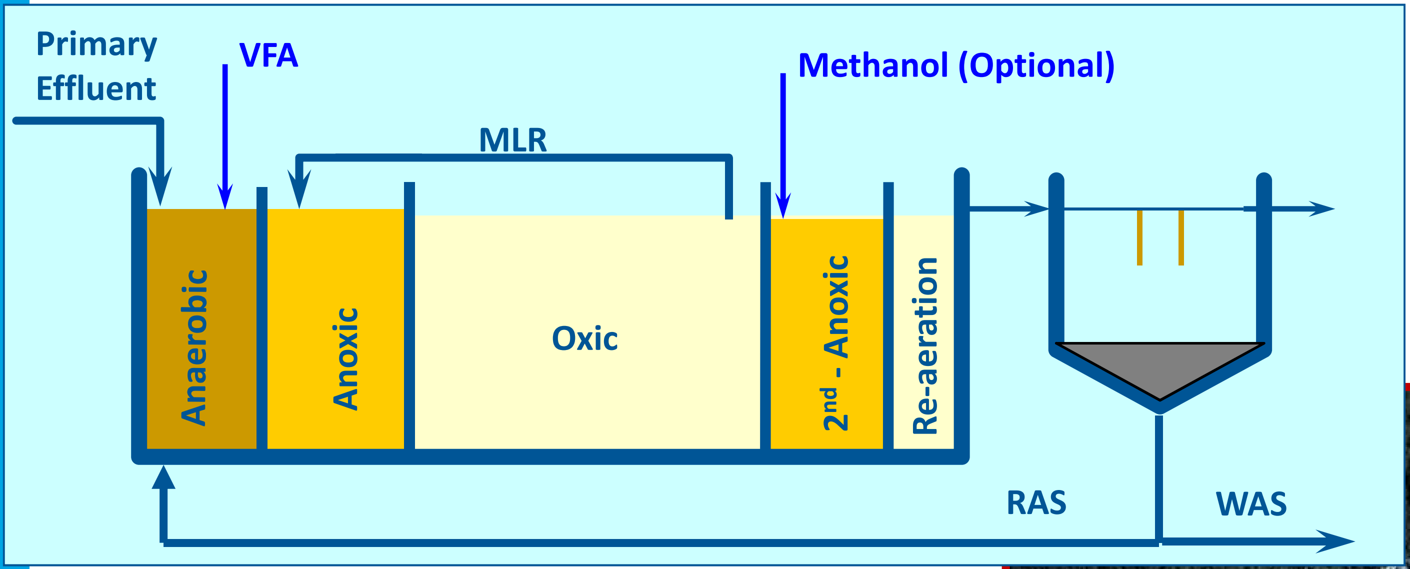


Effluent Quality

TP = 0.5 to 1 mg/L

TN = 6 to 10 mg/L

BNR: FIVE STAGE BARDENPHO – PROVIDES LOW N&P LEVELS



Effluent Quality

TP = 0.5 to 1 mg/L

TN = 2 to 3 mg/L

Features

- Low Effluent and RAS Nitrate = 1 to 1.5 mg/L
- Very little VFA lost to RAS Denitrification - no need for RAS denite

Bayou Marcus WRF
Pensacola, FL

TRADITIONAL ACTIVATED SLUDGE

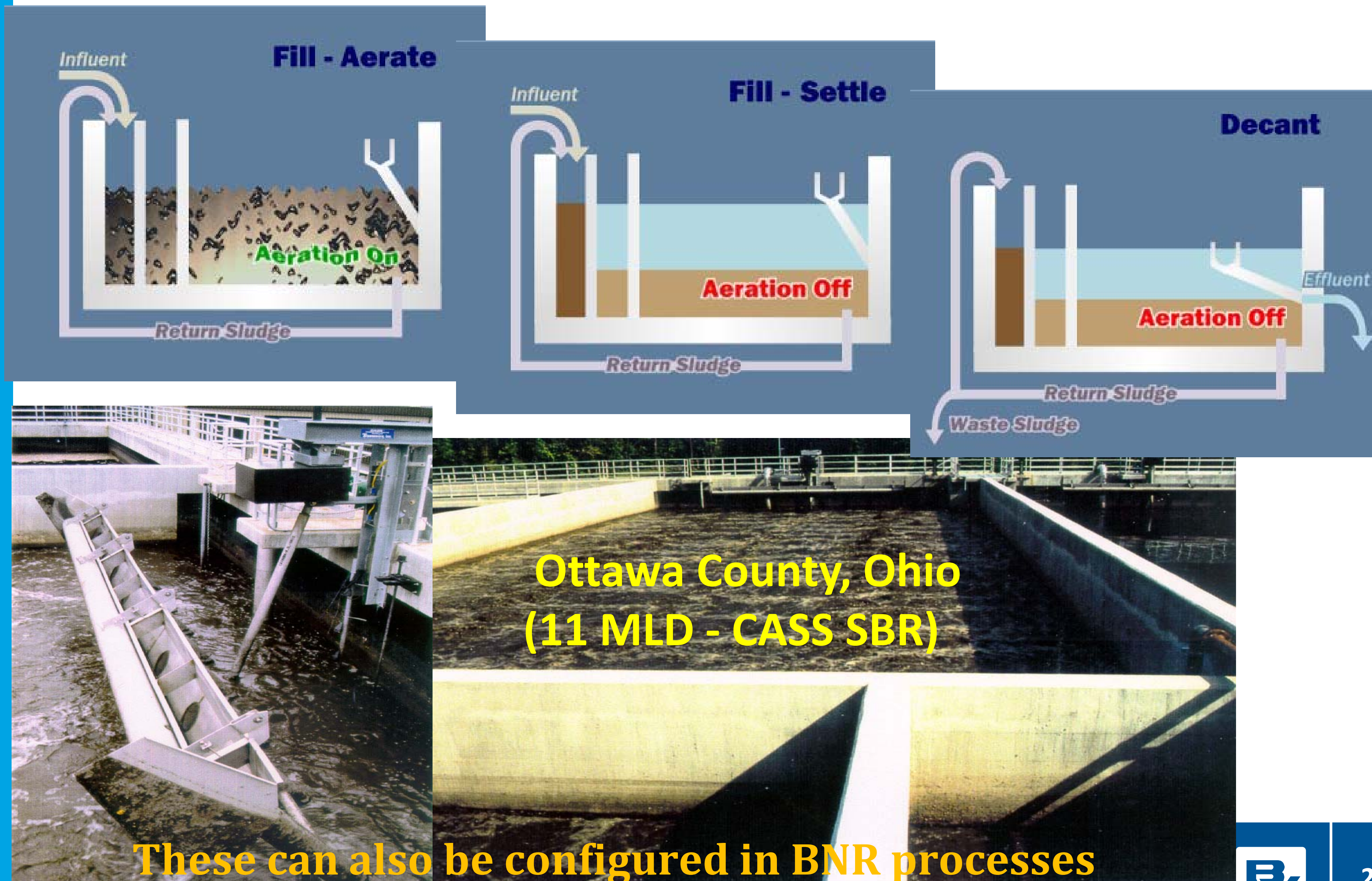
Advantages

- Operate w/ or w/o primary treatment
- Manage flow and load variation to some degree
- Continuous process relatively easy to operate
- Good nutrient reduction
- Simplified overall treatment train

Disadvantages

- Biological process
- Multiple tanks
- Required solids separation
- Requires solids stabilization
- Energy consumption large due to aerobic process
- Peak wet weather flows can be challenging

INTERMITTENTLY AERATED PROCESSES: SBR – CASS™ - IDAL PROCESSES



Ottawa County, Ohio
(11 MLD - CASS SBR)

These can also be configured in BNR processes

INTERMITTENTLY AERATED PROCESSES: SBR – CASS™ - IDAL PROCESSES

Advantages

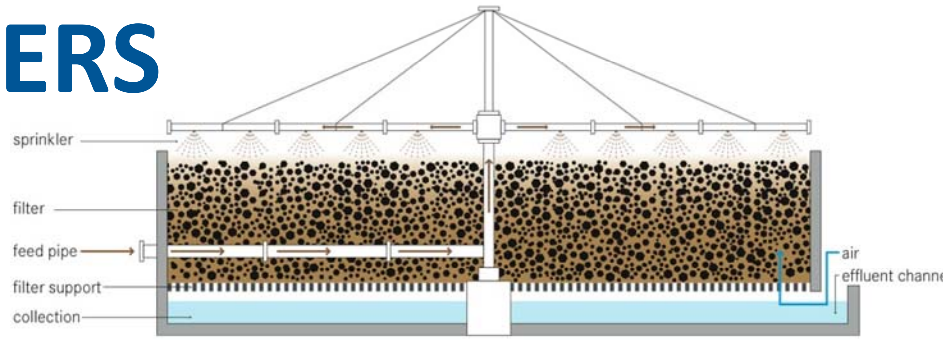
- No clarifier (smaller footprint)
- Nitrification / Denitrification automatic during settling/decanting
- Can be further configured for BNR optimization

Disadvantages

- Settling characteristics most important; a poor settling MLSS problematic
- High instrumentation
- Can impact downstream processes with slug discharge
- Larger blowers
- Good operator skills necessary

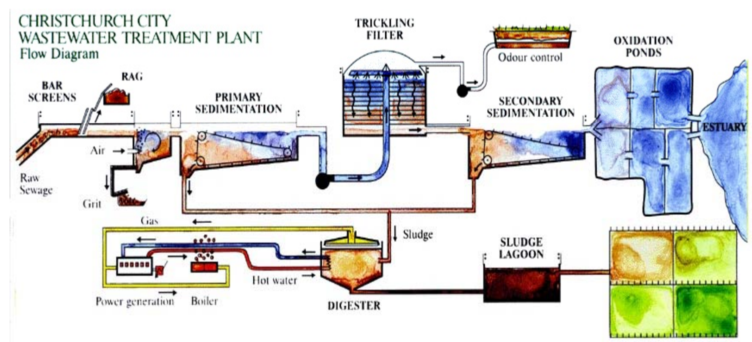
AEROBIC FIXED FILM

TRICKLING FILTERS



Advantages:

- Compact
- Ease of operation
- Low energy, low chemicals
- Can add filters for nitrogen removal as it becomes necessary
- Low to medium capex, depending on filter material



Disadvantages:

- Requires primary treatment
- Odour control may be required
- Further sludge treatment required
- 65 to 90% BOD removal, low N removal

ROTATING BIOLOGICAL FILTERS

Advantages:

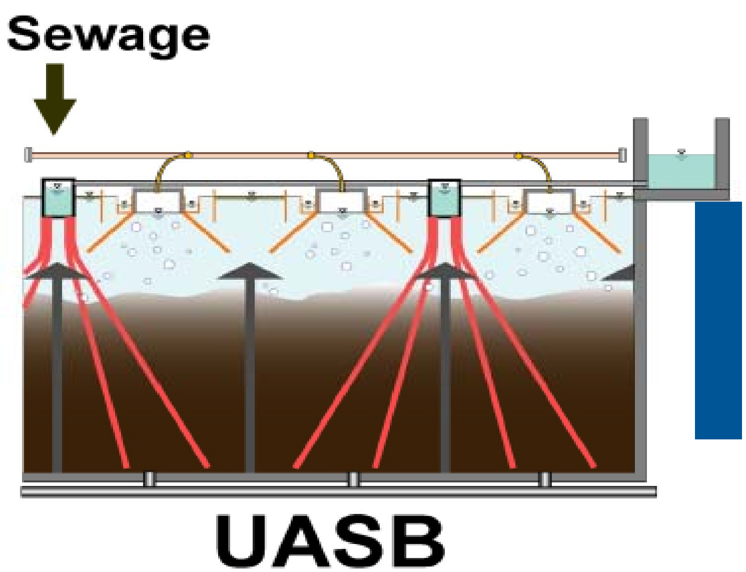
- Low operating costs
- Uses cylindrical structured media
- Supplemental air not required
- Ease of operation (automated)
- Small footprint
- Can add filters for N and dN removal as it becomes necessary
- Good effluent quality
- Medium to high Capex due to number of treatment trains

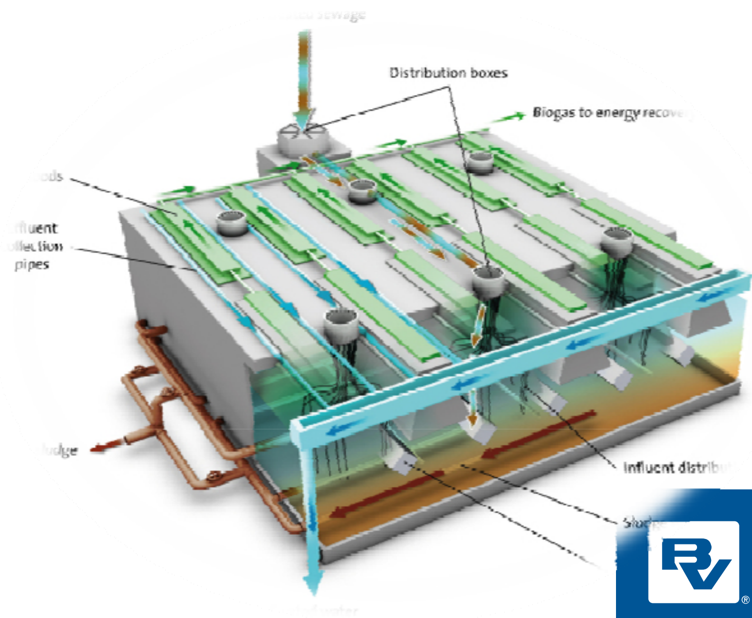
Disadvantages:

- Primary Treatment required
- Designs most for smaller plants (<15 MLD)
- Maintenance higher as equipment is rotating (lots of moving elements)
- Further sludge treatment required
- Multiple train designs are needed for larger flows

UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) REACTORS

UASBs are modular and less complicated to construct ("Upthane" from Biothane design shown in lower right); UASB reactor design typically capable of **60-80%** removal of organic load (at ca. 30 C) with biogas production.





UASB REACTORS

Advantages:

- No moving parts
- Net energy producer
- Small footprint
- No need for primary treatment or sludge digester
- Low capital cost
- Low solids production
- Removes 70 to 80% of influent BOD & TSS
- Technology for sewage has advanced since 1980s; now over 70 systems
- Smaller systems for SANIMAS available

The Onca UASB Treatment Plant, Belo Horizonte, Brazil, Designed to Serve a Population of 1 million

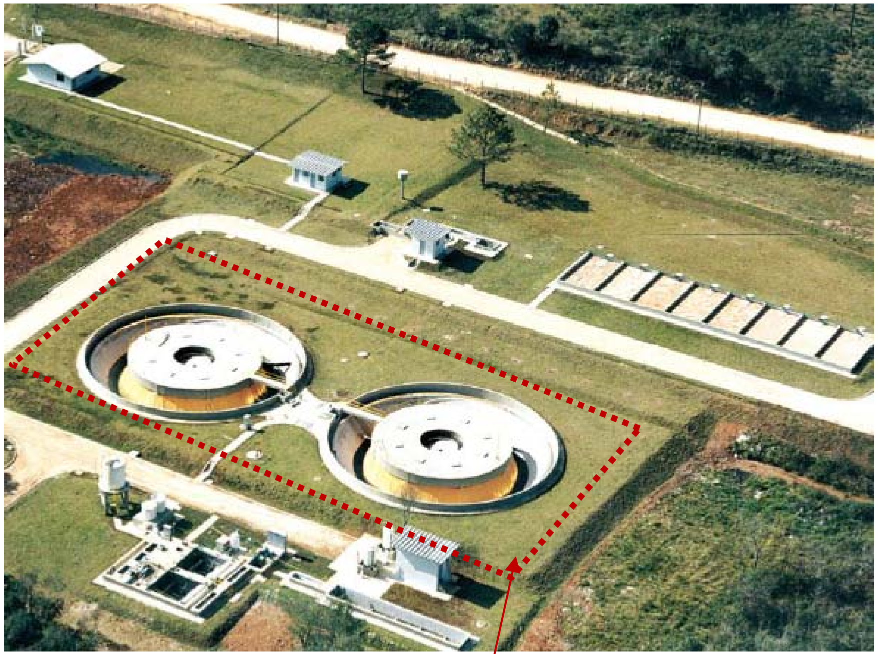
Disadvantages:

- Long startup times
- Eff BOD ~ 60 to 120 mg/L so additional treatment potentially
- Will not remove N & P
- Corrosion & toxicity can be problematic
- Skilled operators required
- Needs tropical climate
- Best for higher strength wastes
- Odor control imperative

OPERATING UASB EXAMPLES

Large Land Areas in many cities are not available...

The UASB reactor can reduce land requirements



Cambui WWTP

Campo Largo, 30,000 ep

Cylindrical UASB reactors

OPERATING UASB EXAMPLES (CONT.)

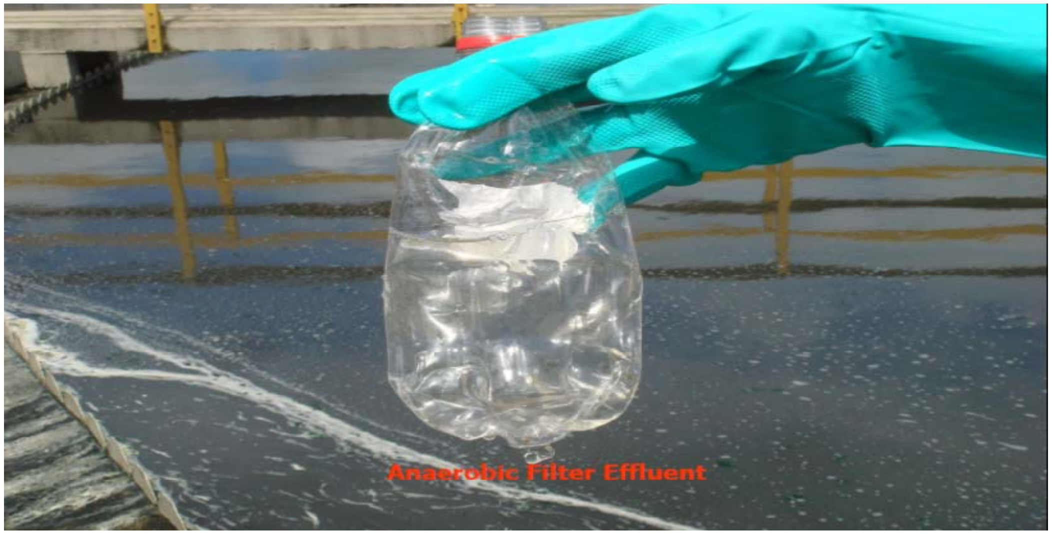
Bucaramanga, Colombia

ANAEROBIC SECONDARY TREATMENT

ANAEROBIC FILTERS

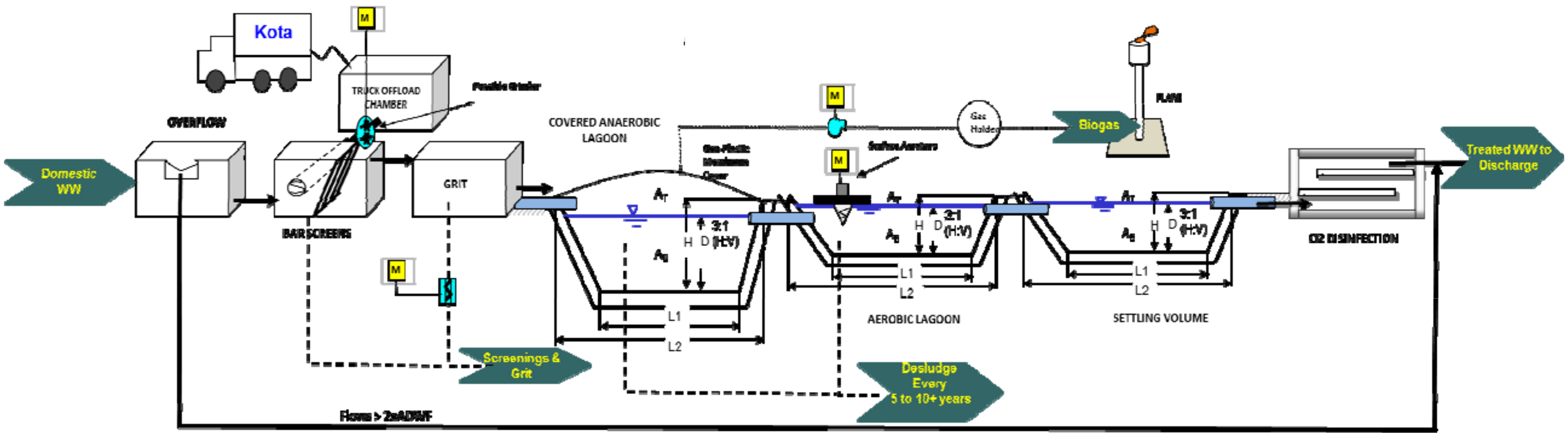
Effluent of Tibagi Plant, Parana, Brazil

BOD: 5 to 25 mg/L
COD: 40 to 100 mg/L
TSS: 4 to 10 mg/L



COVERED ANAEROBIC LAGOONS

- Use as pretreatment before aerobic lagoons or other aerobic treatment
- 60 to 80% carbon removal
- Biogas capture



COMPARISON OF PURE AEROBIC VERSES ANAEROBIC + AEROBIC TREATMENT

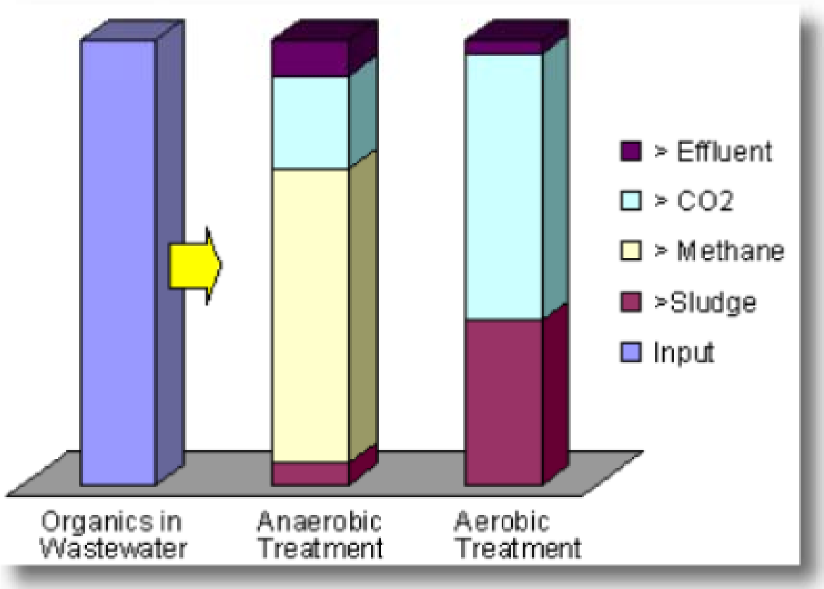
- Take a basis of 1000 kg BOD in tropical environment

Activated Sludge

- >40% ends up as waste biomass
- Primary sedimentation required
- 1,200 kg O_2 (@3 kWh/kgO2 = 3600 kWh)
- Sludge digester required
- Biogas produced
- Land take 100%

UASB+Activated Sludge

- ~25% ends up as waste sludge
- Primary sedimentation NOT required
- 450 kg O_2 (@3 kWh/kgO2 = 1350 kWh)
- Sludge digester NOT required
- Biogas produced
- Land tank <67%



TERTIARY TREATMENT

Removal and/or inactivation of pathogenic organisms

- **Filtration**
- **Disfinection**

DISINFECTION OPTIONS

- Gaseous chlorine still widely used in Asia
- Some Australian and US municipalities have replaced Cl_2 with NaOCl to reduce overall risk
- ClO_2 is a stronger disinfectant but not widely applied (chlorate issues one problem). It can be generated on site
- New UV systems have been developed, particularly for smaller systems
- Emerging strategies include peracetic acid $C_2H_4O_3$, made with H_2O_2 + CH_2COOH. Formerly used mostly in the food industry but is a power disinfectant, stronger than Cl_2 or ClO_2. Good for biofilms
- Ferrate (FeO_4^{2-}), iron (VI) is more powerful than O_3. It is the most powerful for water and wastewater. Ferrate is synthesized at the point of use using caustic, sodium or calcium hypochlorite, and ferric chloride. There are no DBPs produced.

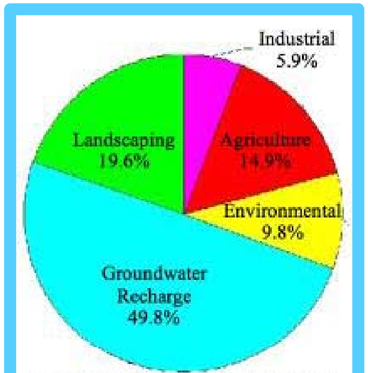
RECENT TECHNOLOGY ADVANCES FOR UPGRADING (TREATING) A DOMESTIC LIQUID WASTE STREAM

DRIVERS

- **Tightening Discharge Standards**
- **Land Restrictions**
- **Resource Recovery**
  - Reuse to offset potable usages: agriculture, industry, IPR
  - Energy: enhancements to increase energy
  - Solids: agricultural, fuel,
  - Nutrients: primarily phosphorus

REGULATIONS AROUND THE GLOBE REQUIRE HIGHER DEGREE OF TREATMENT

- Whole Effluent Toxicity
- Receiving Stream Water Quality
- Reuse Increasing



Distribution of Recycled Water Usage

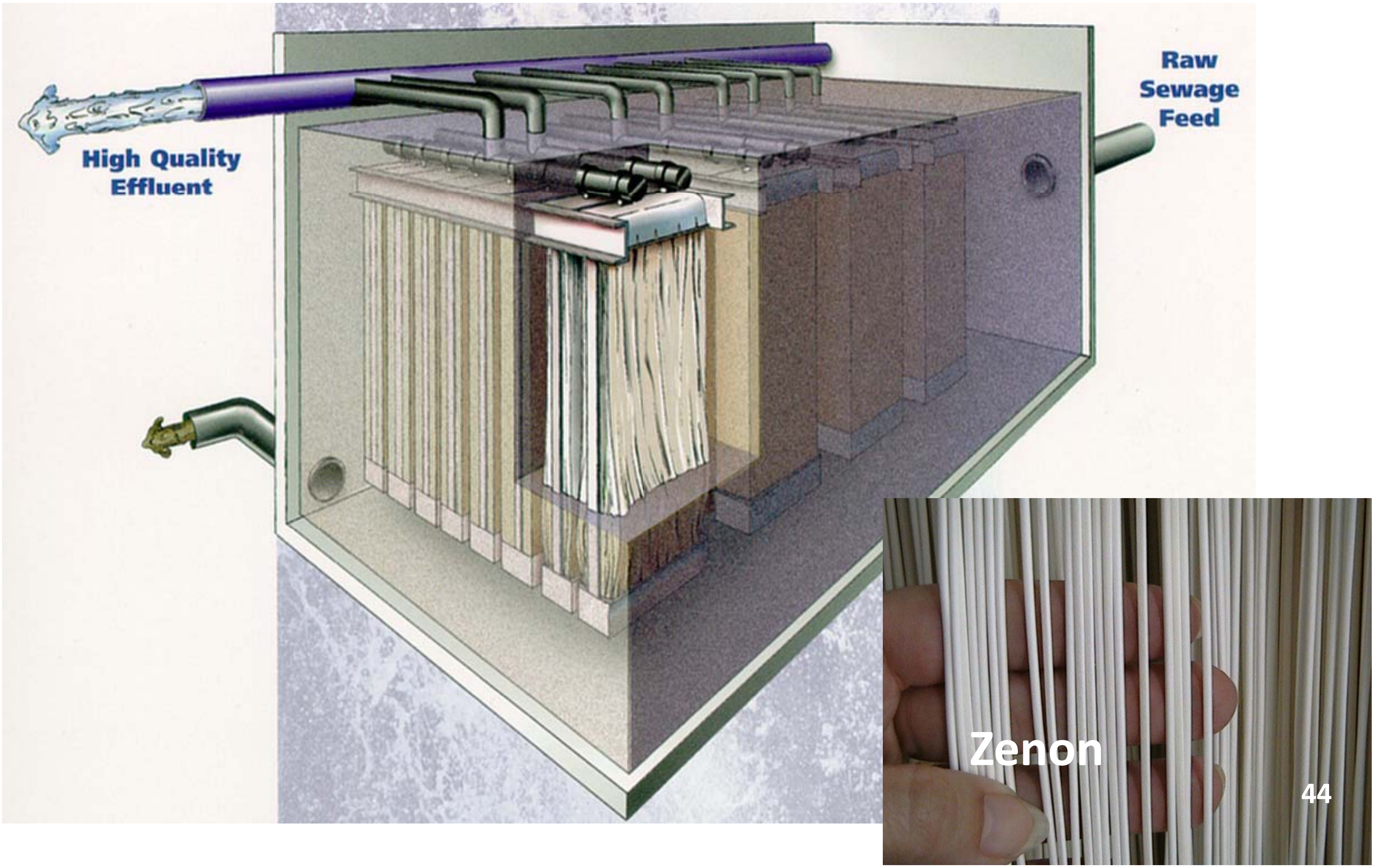
Ammonia
Nitrogen & Phosphorus

SMALL FOOTPRINT NUTRIENT REDUCTION SOLUTIONS

- Membrane Bioreactor (MBR)
- Biological Aerated Filters (BAF)
- Moving Bed Biofilm Reactor (MBBR)
- Integrated Fixed-Film Activated Sludge (IFAS)

SMALL FOOTPRINT

MEMBRANE BIOREACTOR (MBR) TECHNOLOGY



MBR

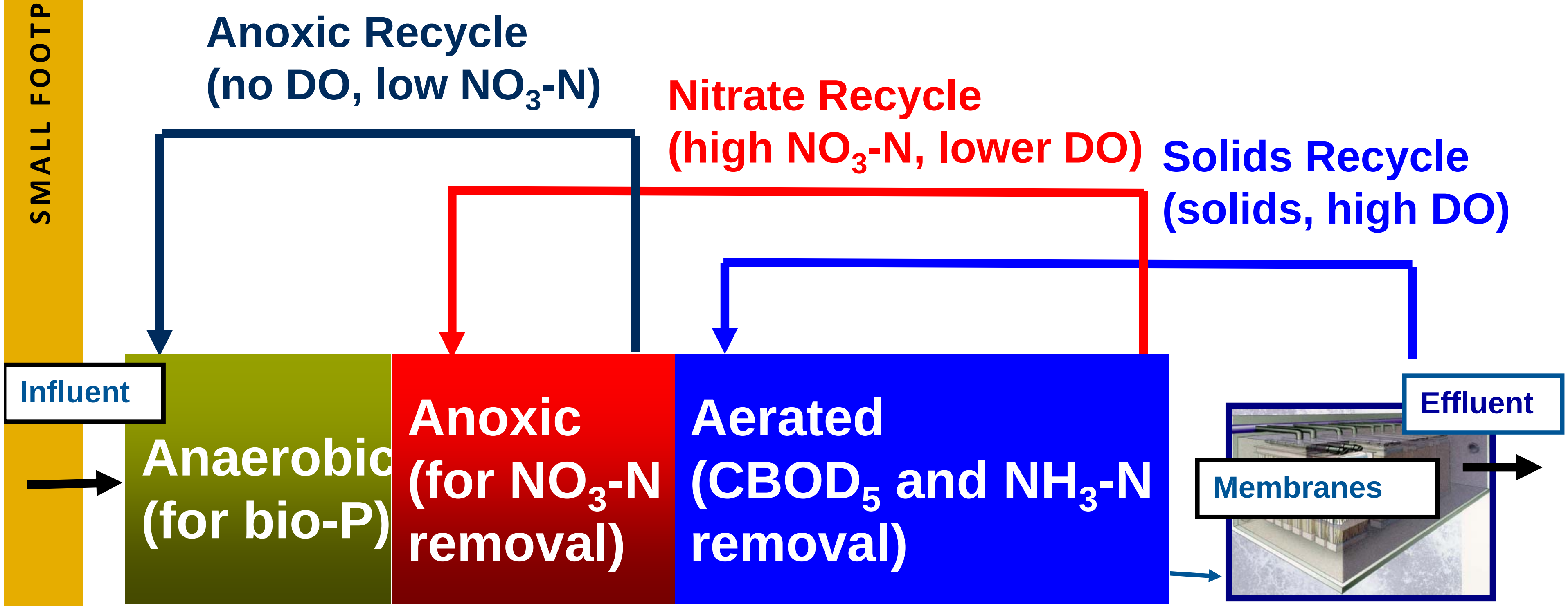
Advantages:

- High effluent quality
- Smallest aerobic footprint
- Stable process
- W/ or W/O PC
- Install membranes as needed
- Neighbor Friendly
- Retrofit options

Disadvantages:

- High operating cost: pumping and aeration
- Membrane cleaning and replacement

MBR AND BNR

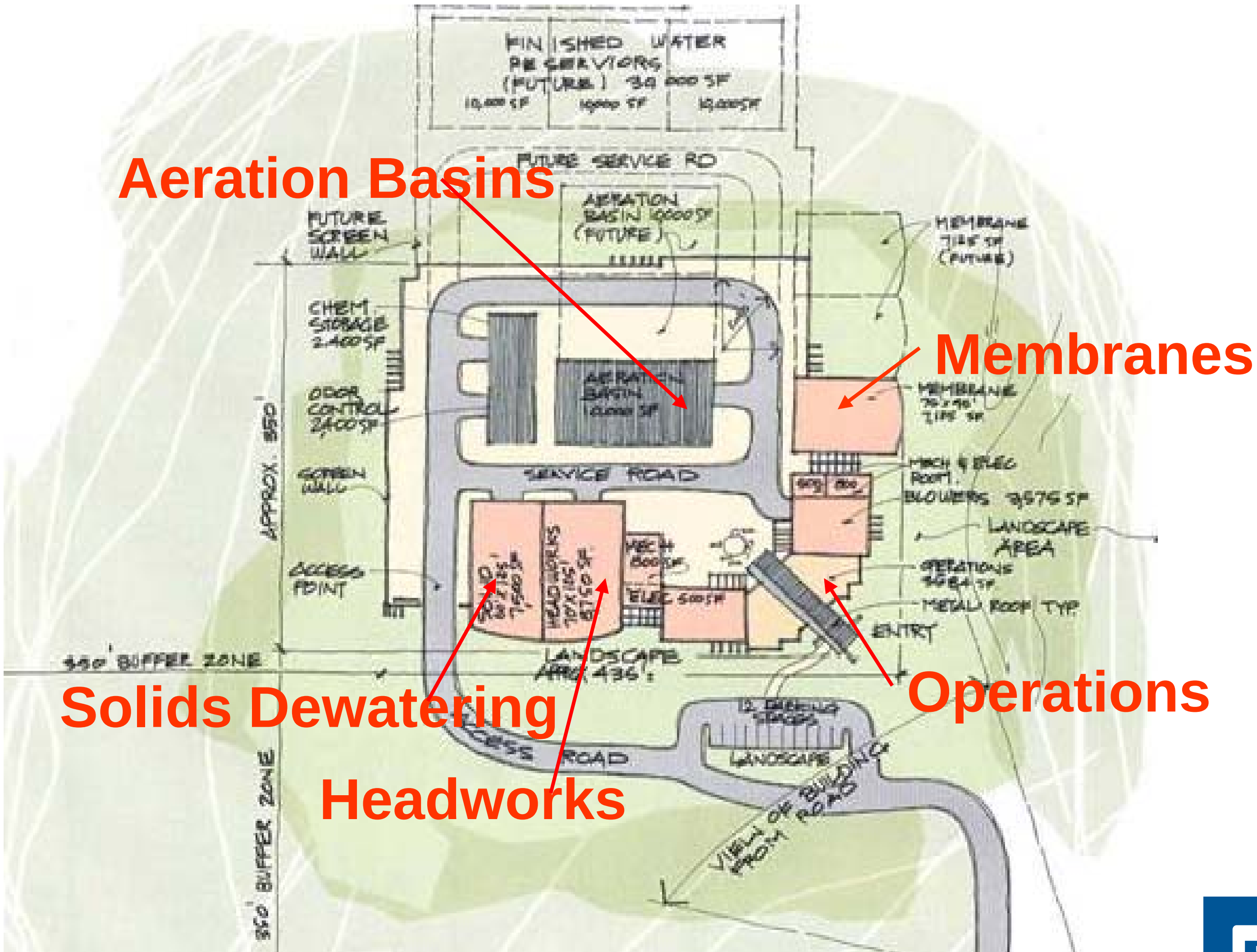

Anoxic Recycle
(no DO, low NO_3-N)
Nitrate Recycle
(high NO_3-N, lower DO)
Solids Recycle
(solids, high DO)
Influent
Anaerobic
(for bio-P)
Anoxic
(for NO_3-N
removal)
Aerated
($CBOD_5$ and NH_3-N
removal)
Membranes
Effluent

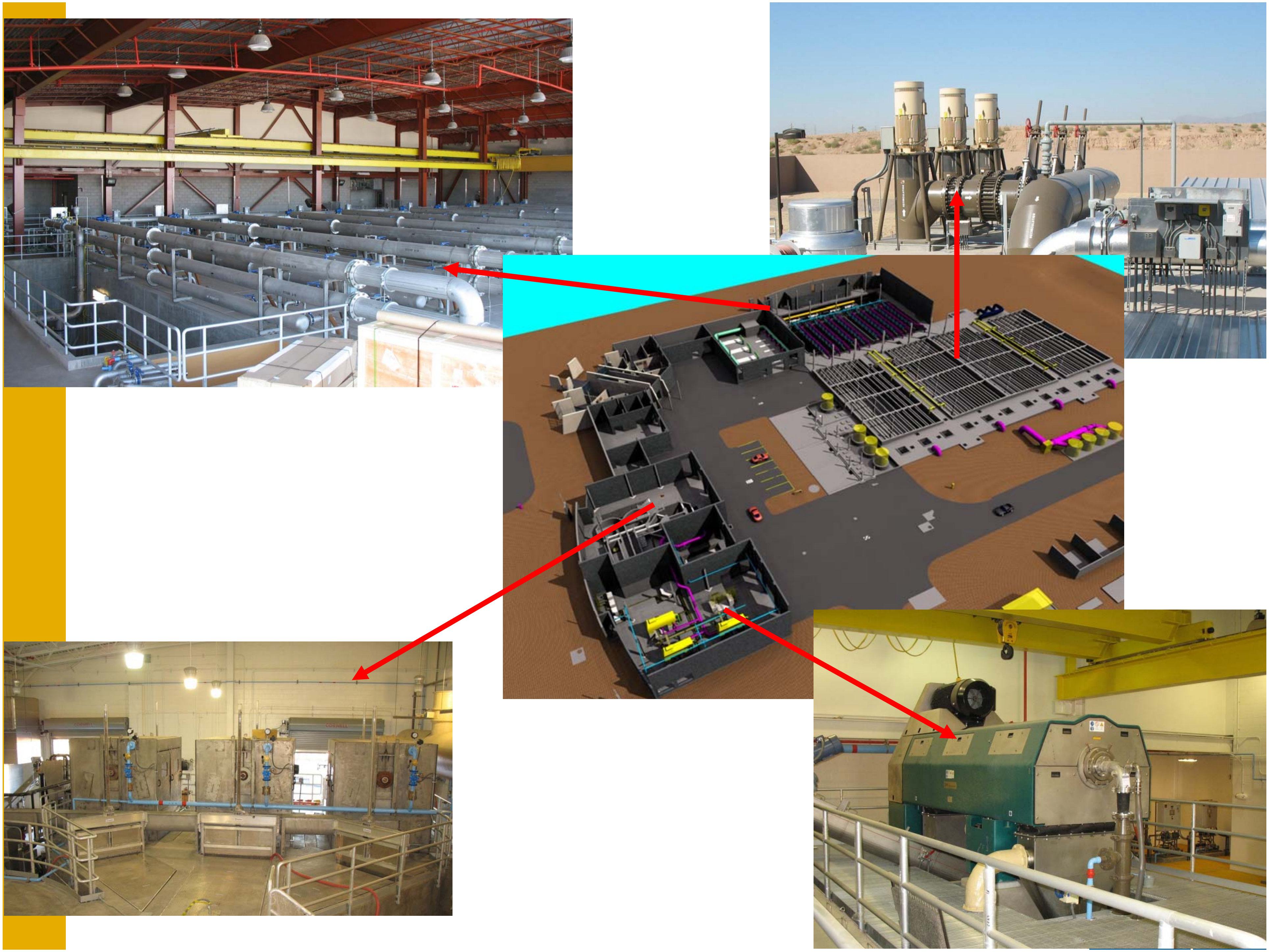
PEORIA, ARIZONA, USA: BUTLER DRIVE WRF 49,000 M^3/D AA, 96,000 M^3/D PEAK MEMBRANE BIOREACTOR

Butler 402

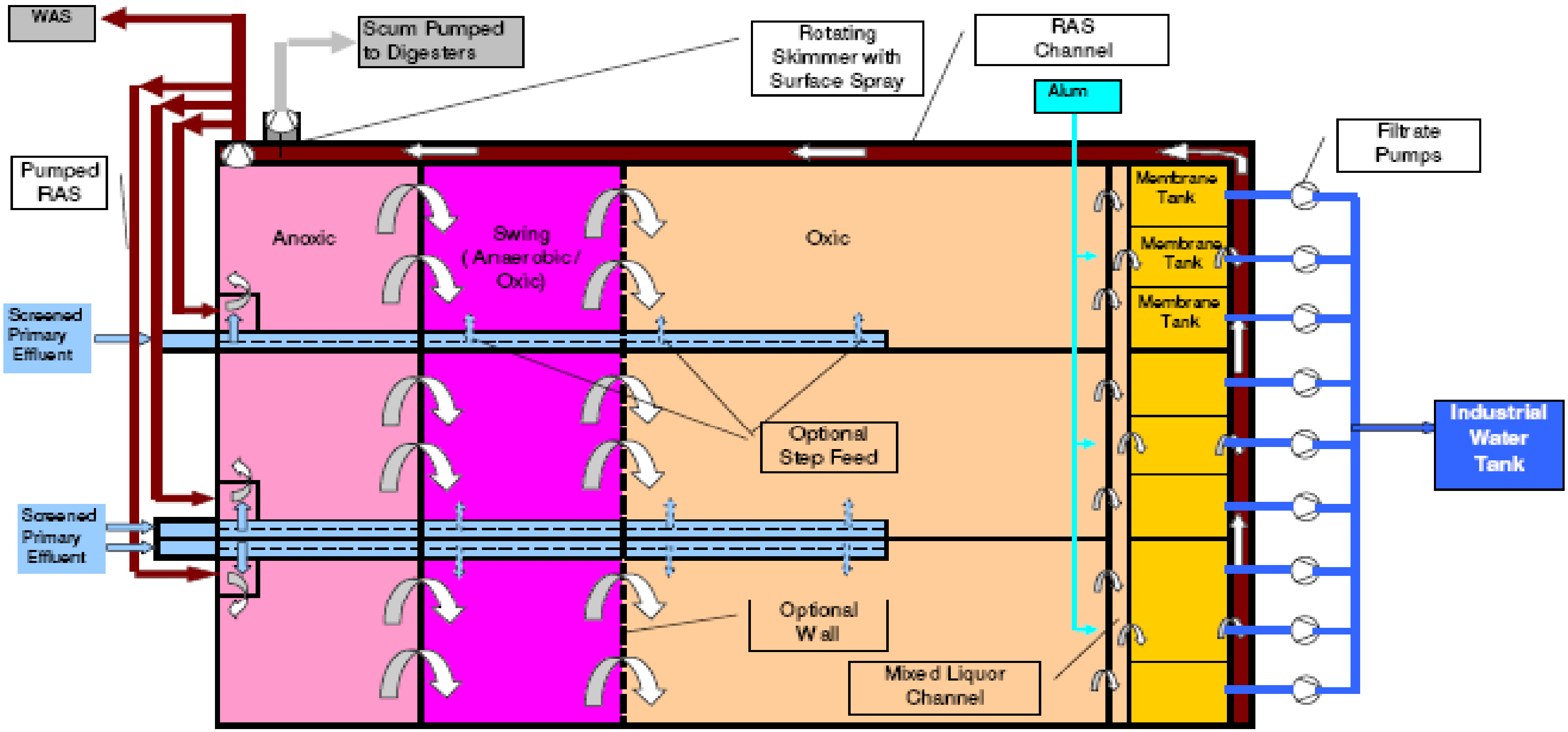
SMALL FOOTPRINT

PEORIA SITE PLAN
49,000 M^3/D ON 4.9 – 6 HA





JURONG WRP, SINGAPORE: 68,000 m^3/d RETROFIT MBR



Modifications to existing basins to MBR

Flexible nutrient removal operating strategy

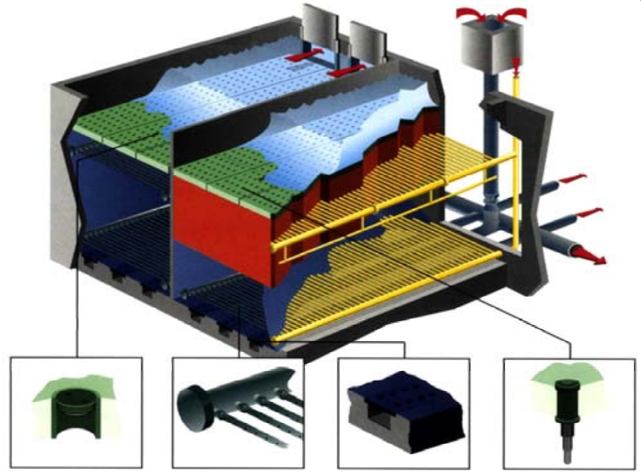
Complicated design due to industrial component

AEROBIC FIXED FILM

BIOLOGICAL AERATED FILTER (BAF)

Advantages:

- Modern TF
- Uses mineral or structured media with high O2 uptake
- Ease of operation (automated)
- Small footprint (30% of A/S)
- Neighbor friendly
- C, N or DN filters
- Good effluent quality
- Medium to high capex,

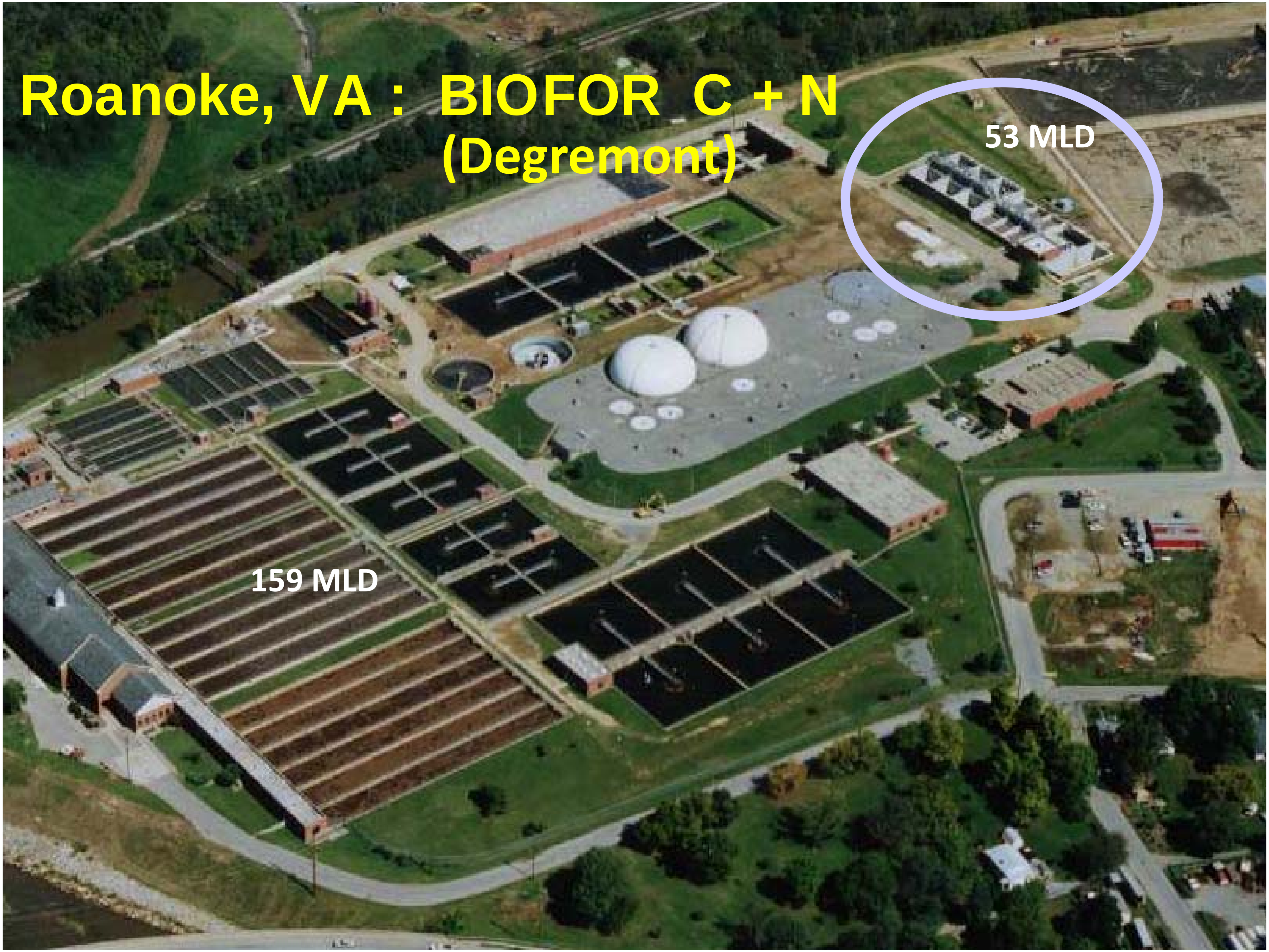


Disadvantages:

- Primary Treatment required
- Supplemental air required
- Backwashing required
- Thin sludge concentration
- Further sludge treatment required
- High level of instrumentation
- Designs are proprietary

SMALL FOOTPRINT

More BAF Details…


Roanoke, VA : BIOFOR C + N
(Degremont)
53 MLD
159 MLD

SUBMERGED AERATED FILTERS (SAF)

Advantages:

- Typically uses mineral or plastic structured media
- Ease of operation (automated)
- No backwashing required
- Can add filters for N and dN

Disadvantages:

- Primary Treatment required
- Supplemental air required
- Further sludge treatment required
- Media can block and with it deteriorated performance
- Requires solids separation step

STATIC MEDIA PROVIDERS

Others - SAF, SBC, FAST

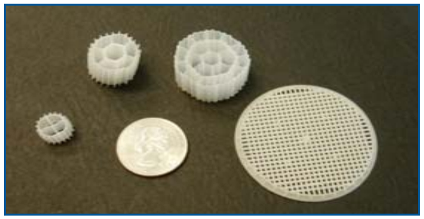
SMALL FOOTPRINT

IFAS / MBBR

Advantages:

- Can be used to upgrade existing tank
- Small footprint
- Uses plastic media
- C & N oxidation in same reactor
- Ease of operation
- Coarse bubble diffusers
- Anoxic & anaerobic configurations available
- Good effluent quality
- O&M similar to traditional AS
- Medium capex

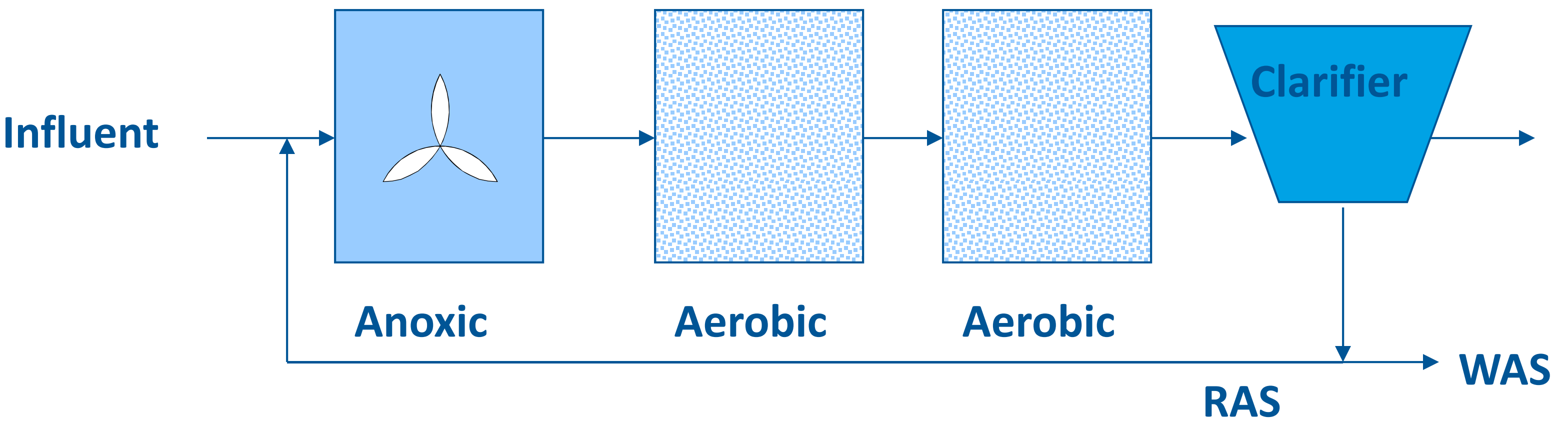
Sieves used to contain free-floating media



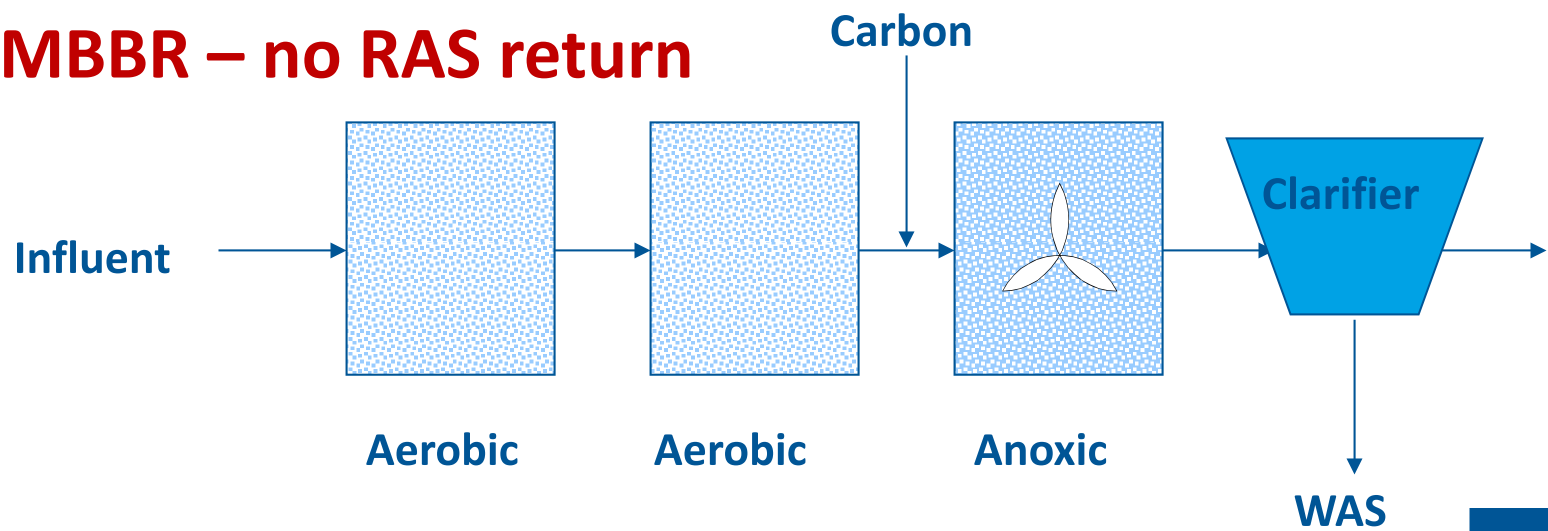
Disadvantages:

- Screening down to 6mm preferred
- Supplemental screens within AB required
- Further sludge treatment required
- Foaming potential

IFAS – RAS return

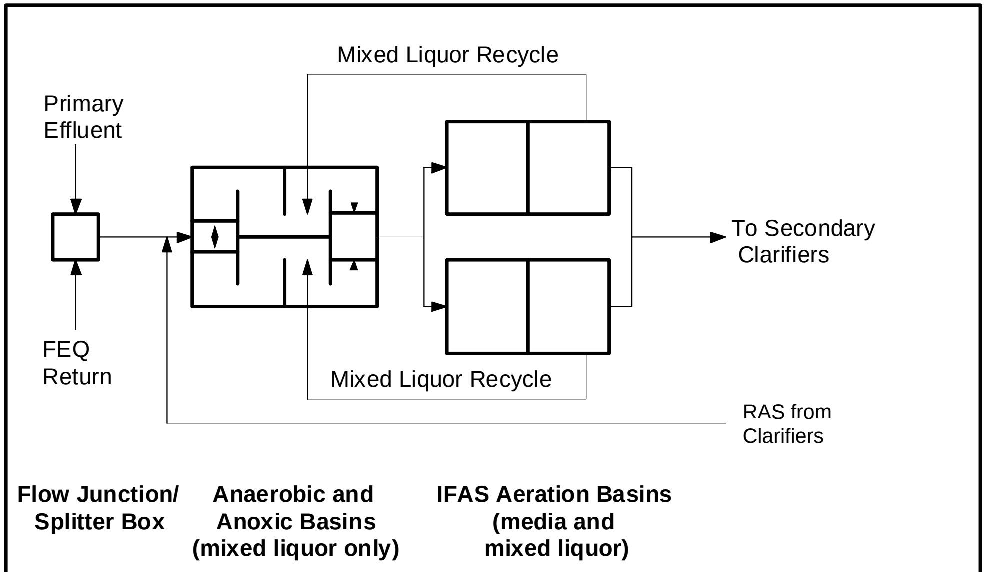


MBBR – no RAS return

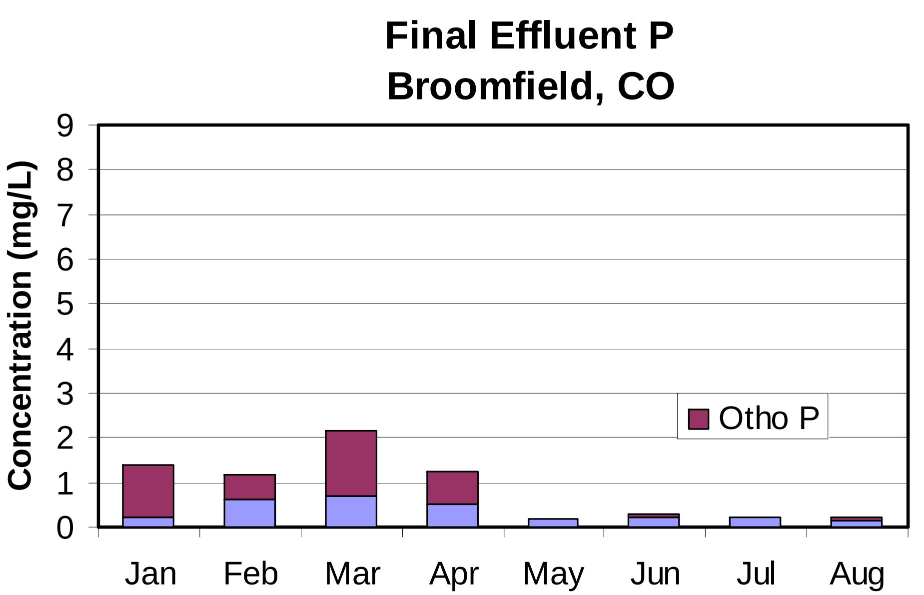


IFAS FOR BIOLOGICAL N&P REMOVAL – BROOMFIELD, CO

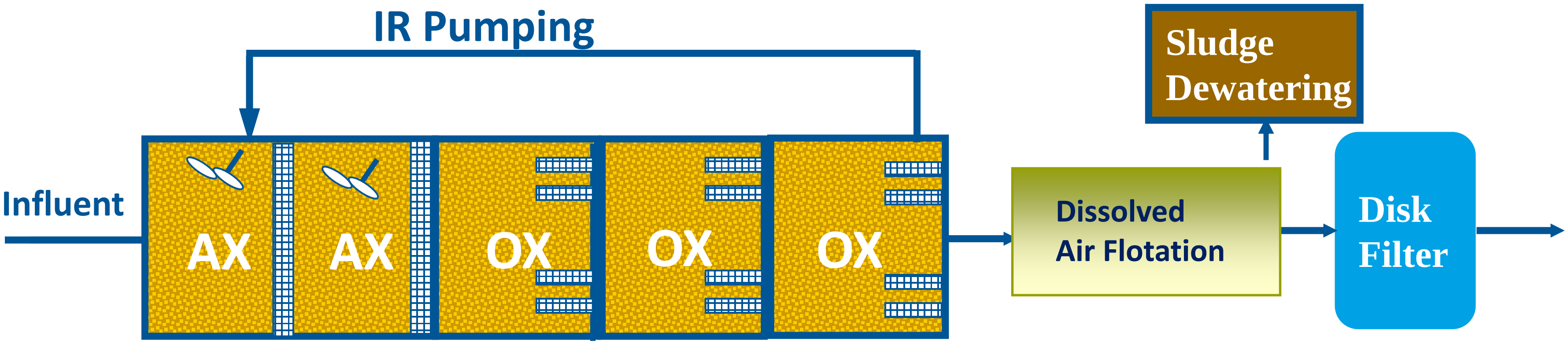
Broomfield, CO – IFAS Basins



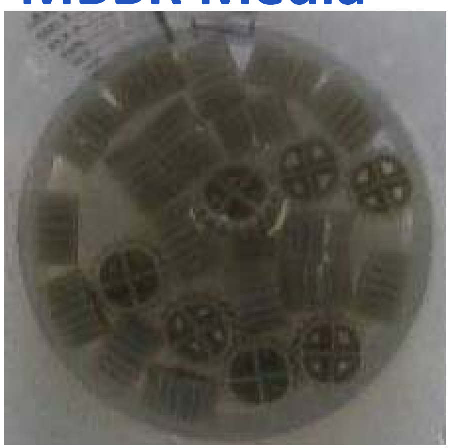
Process Schematic of Broomfield BNR/IFAS Facilities



MBBR/DAF PROCESS FOR NIT/DENIT (MOVE TO SMALL FOOTPRINT)



MBBR Media



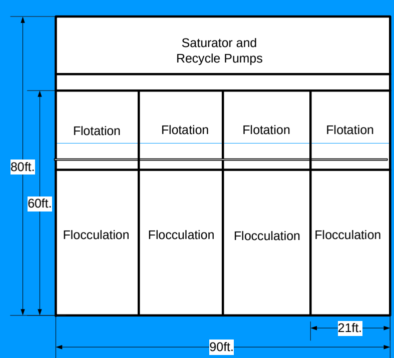
Media Retention Sieves

SMALL FOOTPRINT

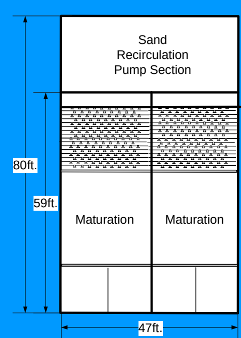
POST MBBR SOLIDS SEPARATION (75,000 m^3/D)

DAF – ACTIFLO VERSES CONVENITIONAL

2x **1x**



AquaDAF - 16 gpm/sq ft



Actiflo – 50 gpm/sq ft

AquaDAF **Actiflo**

FC
100 ft Dia.

FC
100 ft Dia

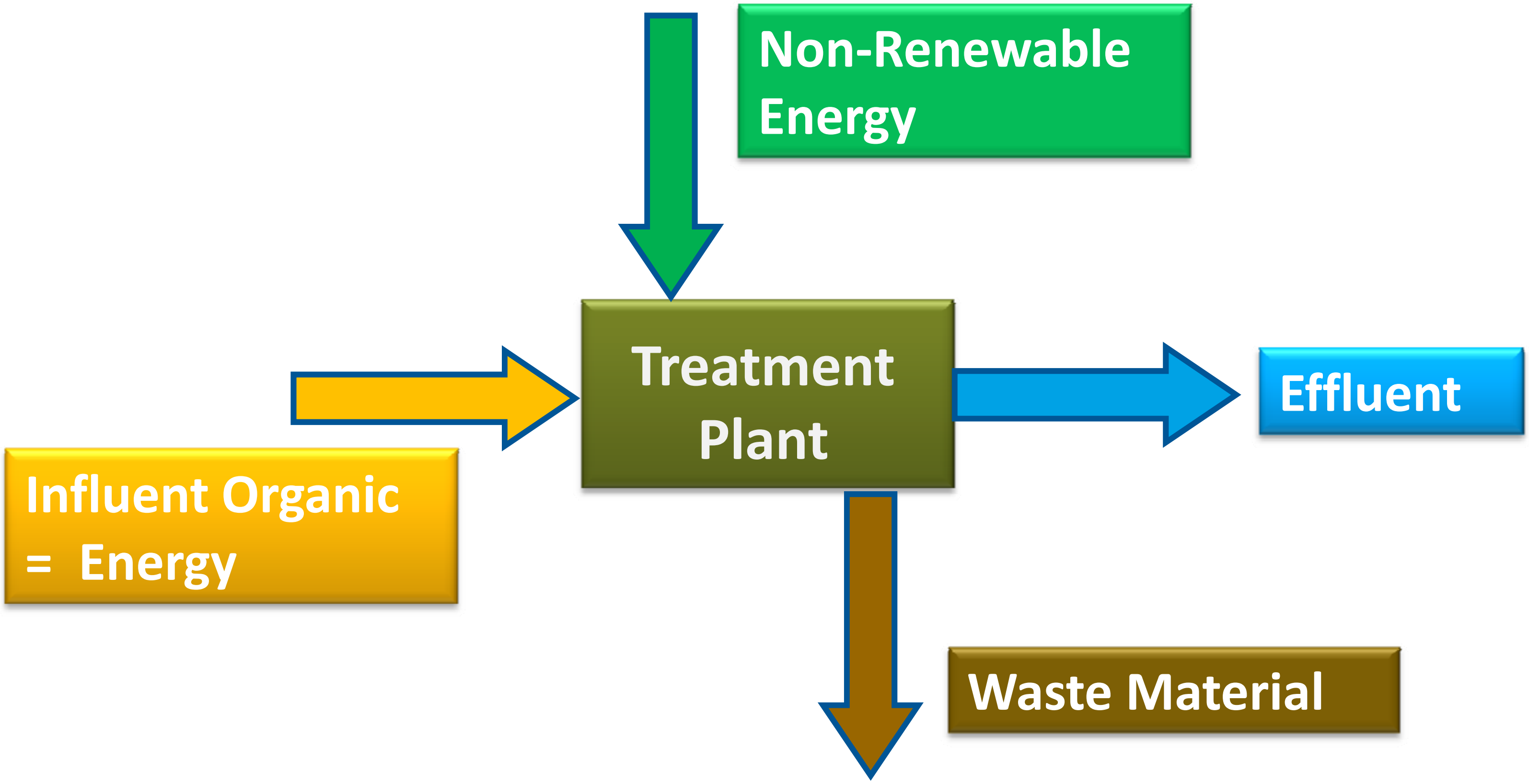
10x

FC
100 ft Dia

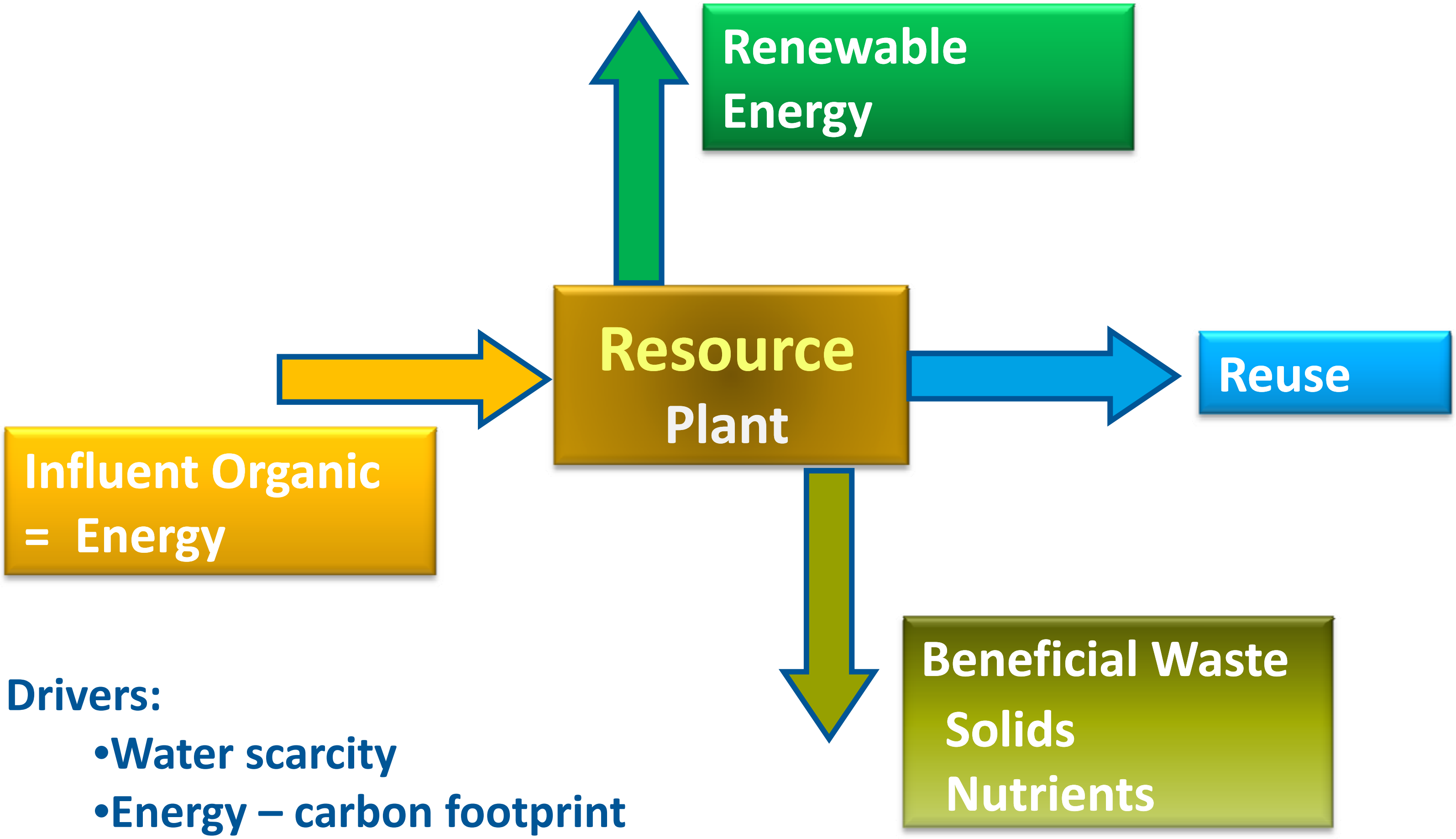
FC
100 ft Dia

Footprint of Conventional Clarification

PARADIGM CHANGE: RAW WASTEWATER IS A WASTE



PARADIGM CHANGE: RAW WASTEWATER IS A VALUABLE RESOURCE!



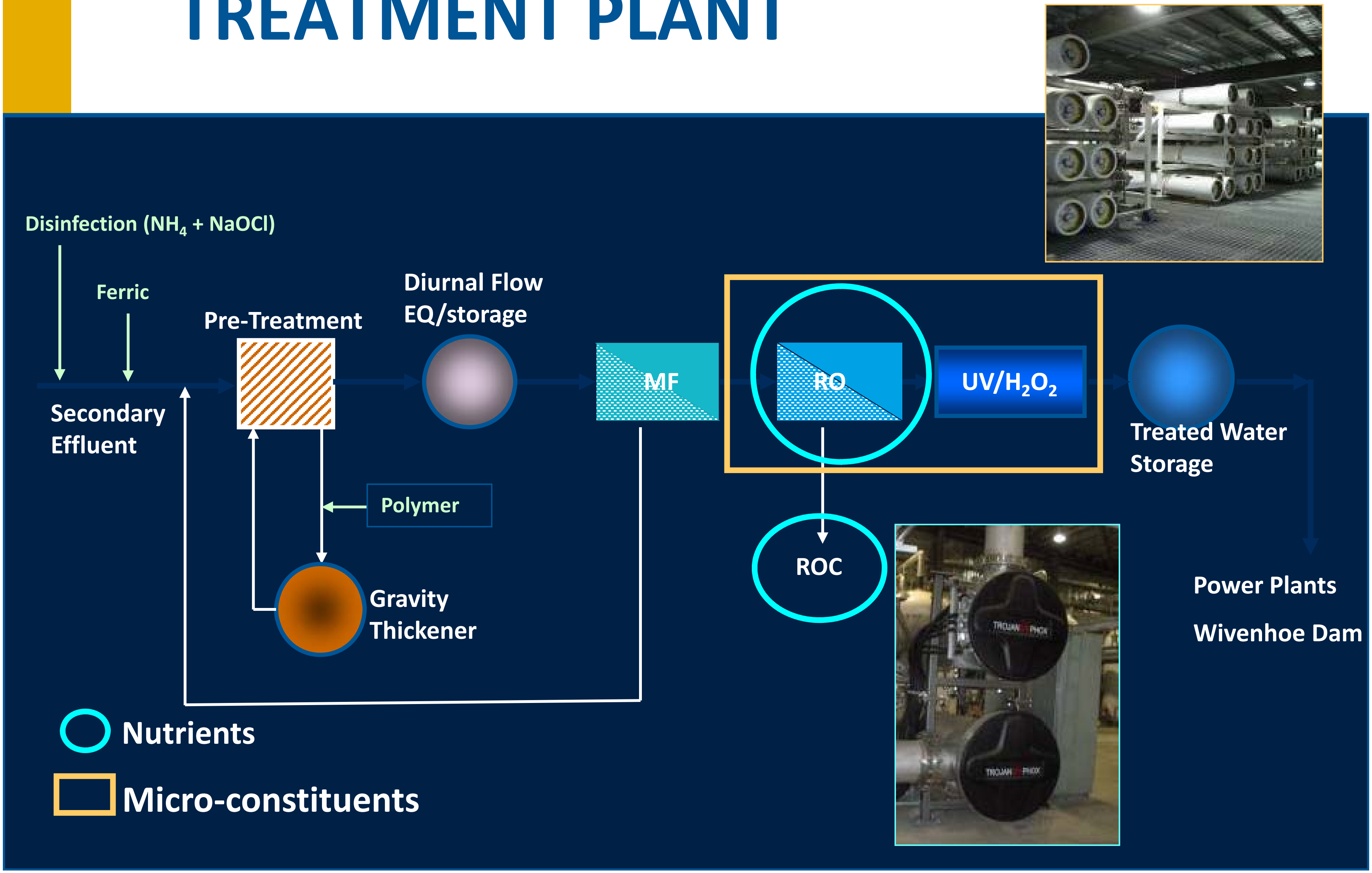
Drivers:

- Water scarcity
- Energy – carbon footprint
- Nutrient recovery
- Asset recovery

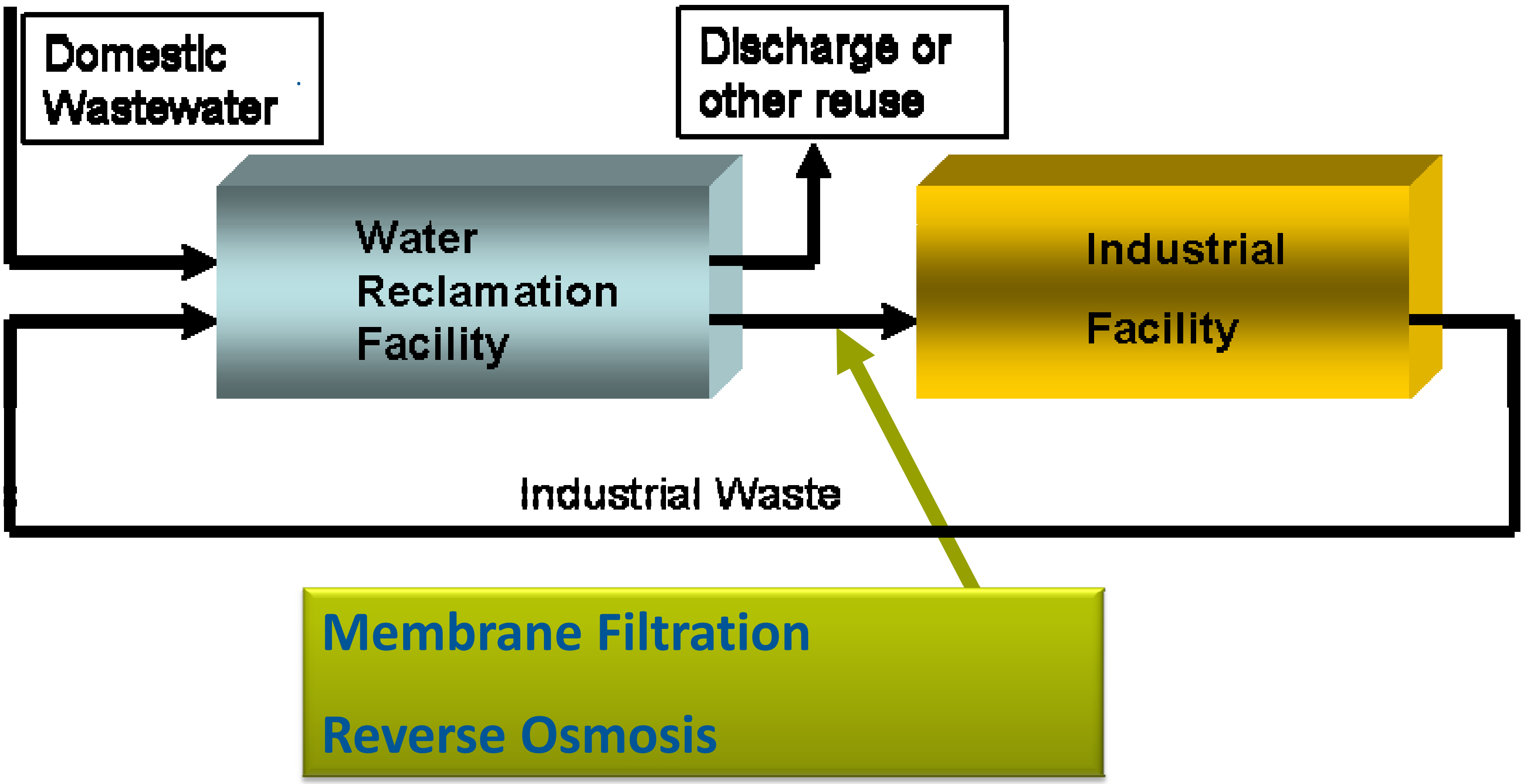
REUSE CAN DRIVE HIGHER LEVELS OF TREATMENT

- **Purpose:** **The use of treated wastewater to offset potable water usage. Becoming particularly important in these times of decreasing water supplies.**
- **Viral disinfection: Some reuse applications have standards that require removal of specific virsus. Victoria in Australia is one such state. Every new reuse scheme has to be individually assessed.**
- **Suspended solids: For reuse schemes, filtration is now becoming required because of the disinfection and delivery requirements.**
- **Additional nutrient removal: Driven by reuse**
- **TDS: Some reuse schemes implement RO to reduce TDS.**

BUNDAMBA ADVANCED WATER TREATMENT PLANT

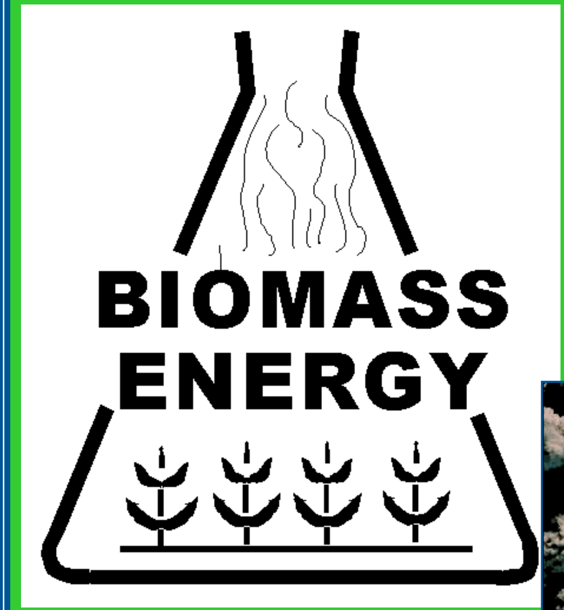


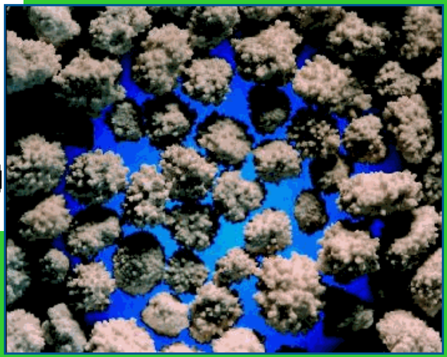
REUSE OPPORTUNITIES SHOULD MAXIMIZE SYNERGY WITH INDUSTRIAL FACILITIES



FOR SOLIDS THE GOAL IS TO…

Increase Recovery!





CONVERT PHOSPHORUS WASTE TO A PHOSPHORUS COMMODITY

Fertilizer Product Meets Goals

- Reduced chemical requirements
- Reduced energy requirements
- Reduced waste
- Sustainable method to reduce effluent phosphorus

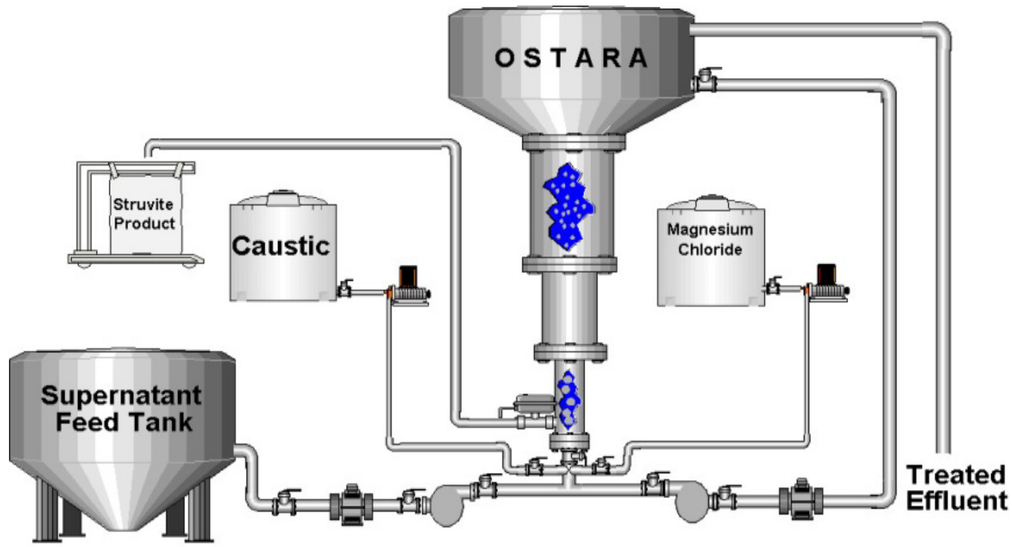
Operational benefits

- Struvite control
- Nutrient control of sidestreams

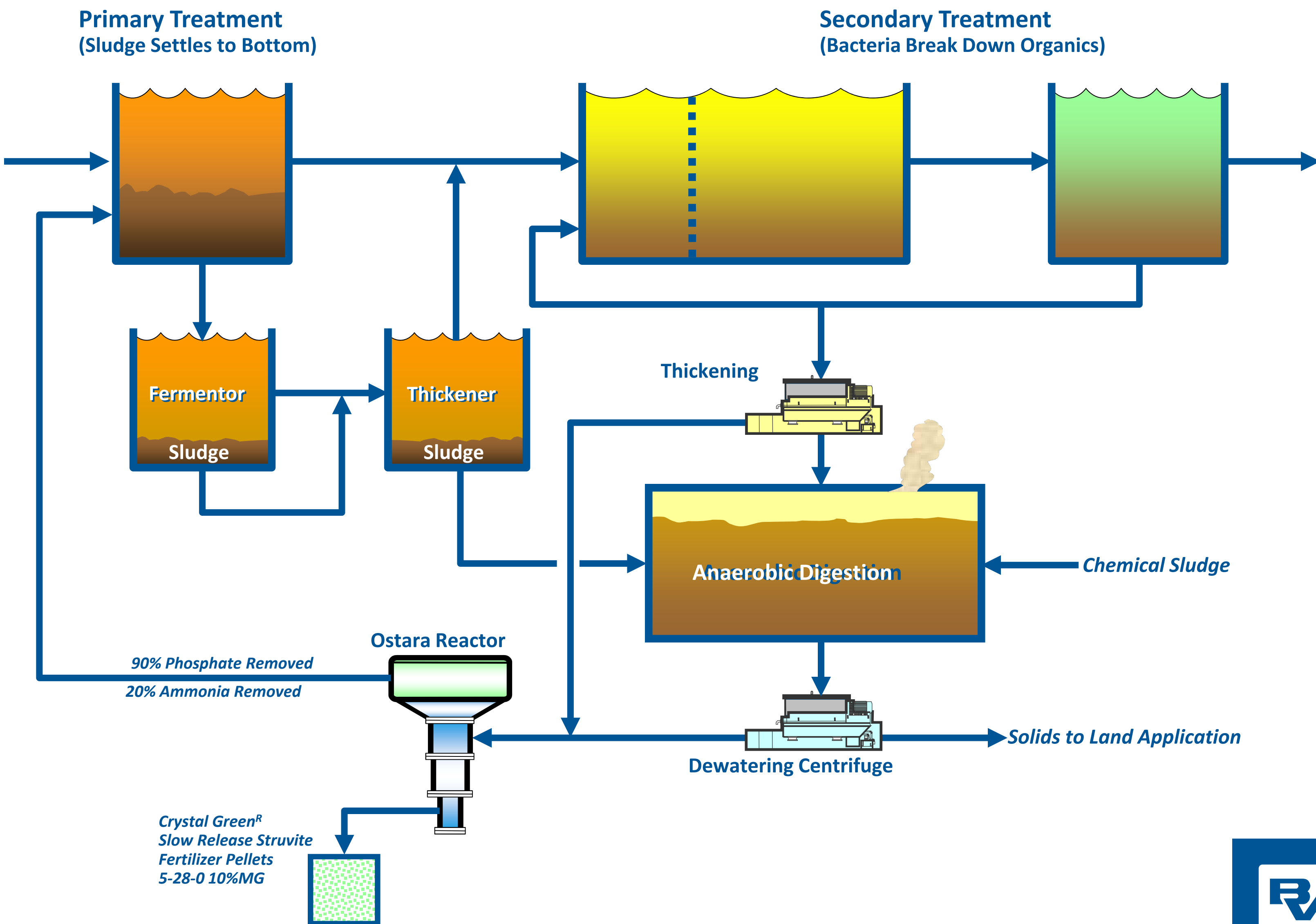
Courtesy of OSTARA

OSTARA PROCESS

- Creation of a struvite in a controlled manner to produce a sellable product.
- Struvite – Magnesium Ammonium Phosphate Hexahydrate
- Slow-release 5-28-0 (nitrogen, phosphorus, potassium by weight) 10% magnesium fertilizer



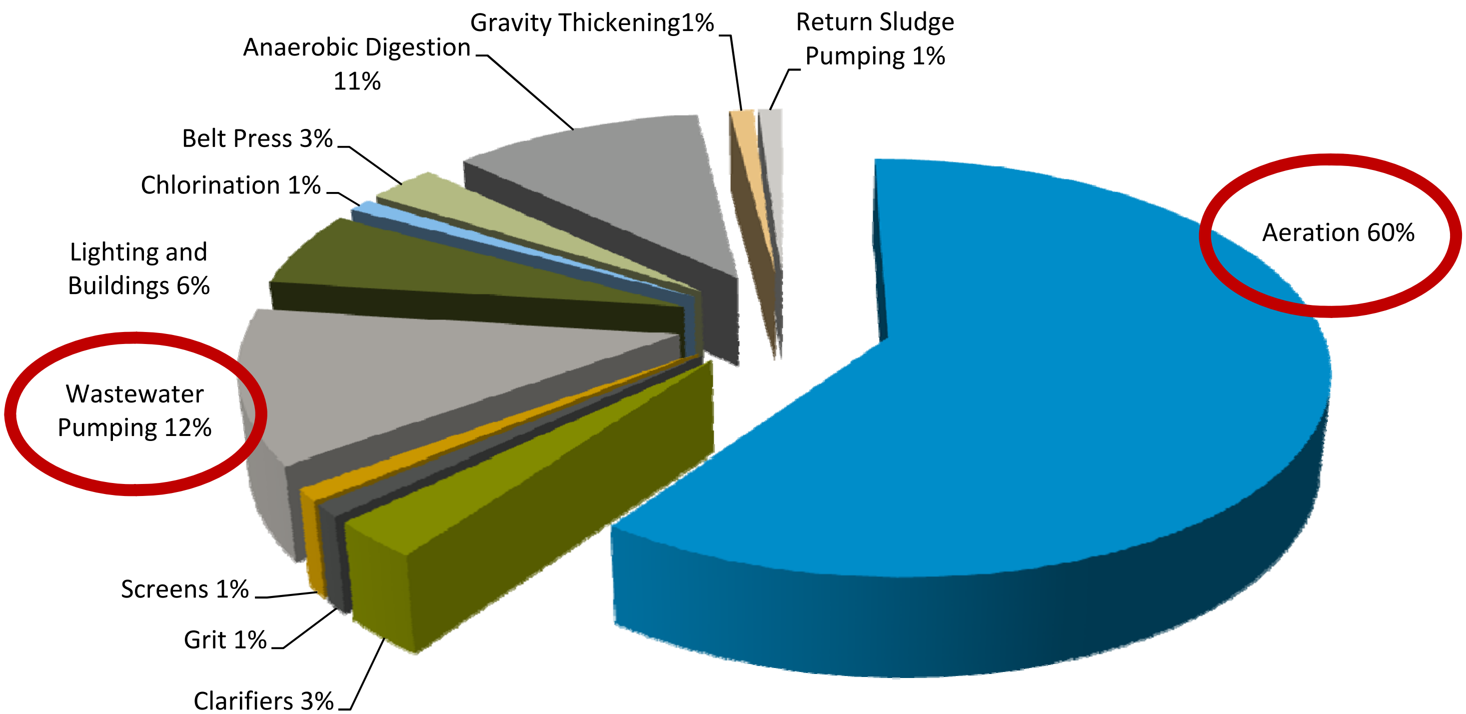
STRUVITE RECOVERY IN RETURN STREAMS USING OSTARA



RESOURCE REOVERY: NUTRIENTS

INSTALLATION AT DURHAM AWWTF

ENERGY SAVING OPPORTUNITIES – KNOW WHERE TO FOCUS



Typical Electrical Energy Requirements for Activated Sludge Treatment

DESIGN FOR ENERGY EFFICIENCY AND RELIABILITY

Process Selection

- Biggest opportunity for energy efficiency

Equipment Selection

- Oversized = inefficient

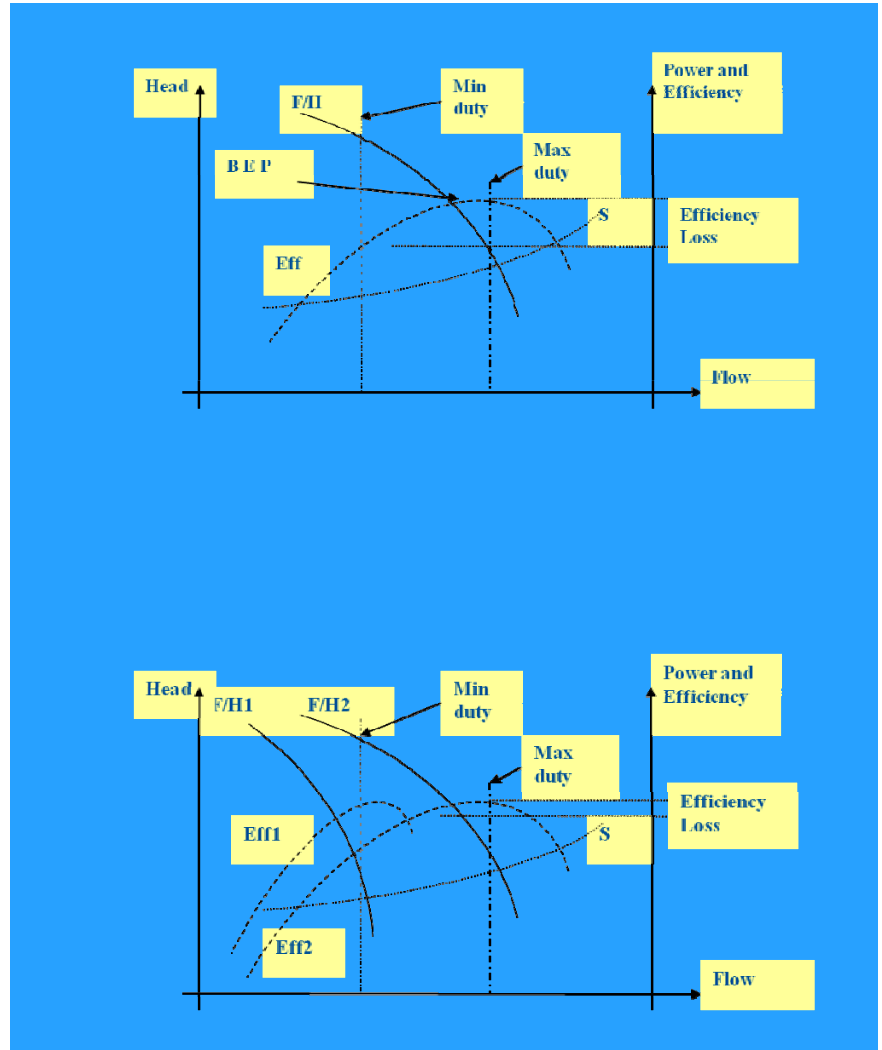
Peak Flow/Load Management

- Reduce peak demands & start/stops

PUMP EFFICIENCY

PROVIDE (DESIGN) & USE (OPERATE):

- Duty for Efficiency
- Two Smaller vs One Oversized Pump
- Variable Speed Drives



AERATION SYSTEM ENERGY OPTIMIZATION

Blowers + Piping/Diffusers + Controls = ONE SYSTEM

Need all components to work together for overall system energy efficiency

- **High-efficiency diffusers**
  - Fine bubble; Ultra-fine bubble
  - Understand effects of fouling
- **High-efficiency blowers**
  - Single-stage, integrally-geared centrifugal
  - High-speed turbo gearless centrifugal
- **Automatic DO/advanced control systems**
  - Most Open Valve; SRT/DO; BNR simulation
  - Instrument selection/maintenance

ENERGY EFFICIENT MIXERS

Hydro-disk Mixer for Digesters

Invent Mixer for Anoxic Zones

Table 4. Comparison of mixing energy requirements.

Type of Mixing Equipment	Unit Power Rating	
	kW/m^3	hp/1000cf
Hydro-disk	1,316	0.05
Impeller draft tubes	12,112	0.46
Other mechanical mixing*	5,226 to 26,330	0.2 to 1.0
Gas draft tubes*	5,266 to 7,899	0.2 to 0.3
*EPA Design Information Report.		

Massart et al 2008

LIFE CYCLE CONSIDERATIONS

PARTIAL LIST OF SUSTAINABILITY/LCM EVALUATION METHODS AND TOOLS

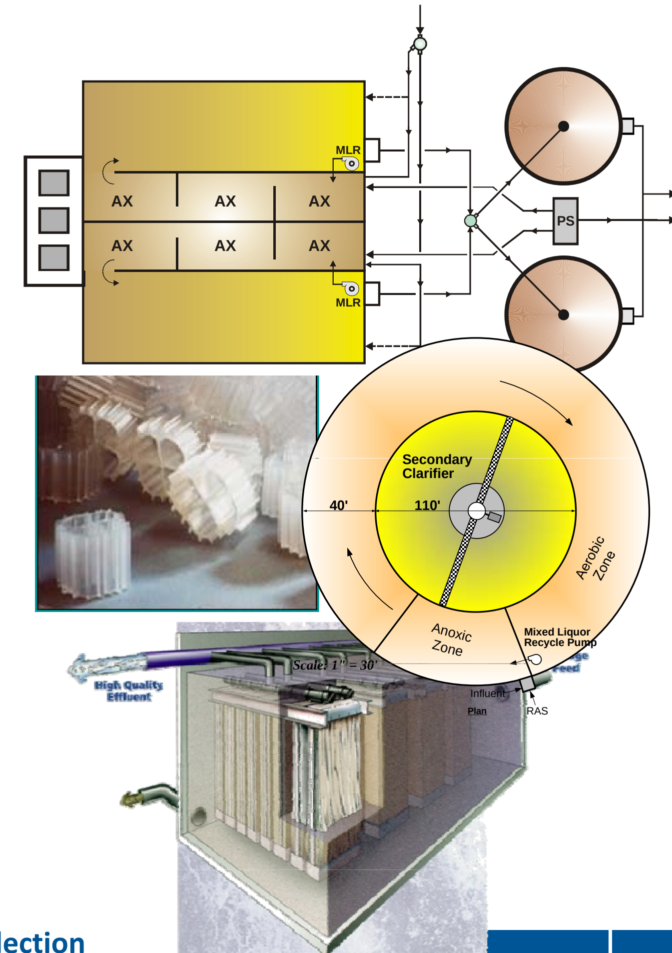
Risk Analysis/Management

Decision Support Tools/Systems

Environmental	Economic	Social
Material Flow Analysis	Cost-Benefit Analysis	Cost-Benefit Analysis
Embodied Energy Analysis	Total Cost Assessment	Total Cost Assessment
Design for Environment	Total Economic Value	**Life Cycle Cost Analysis**
Ecological Footprint	Full Cost Accounting	Multi-Criteria Decision Analysis
Life Cycle Assessment	**Life Cycle Cost Analysis**	Social LCA

CASE STUDY

- **30 MLD average design capacity**
- **Reclaimed water for irrigation - deep well injection during rainy season.**
- **Sustainability assessment with carbon footprinting carried out to support process selection:**
  - Alt. 1 - Membrane Bioreactor (MBR)
  - Alt. 2a - MLE circular basins
  - Alt. 2b - MLE rectangular basins
  - Alt. 3a – MBBR/DAF Nite/Denite
  - Alt. 3b – MBBR/DAF CBOD removal only



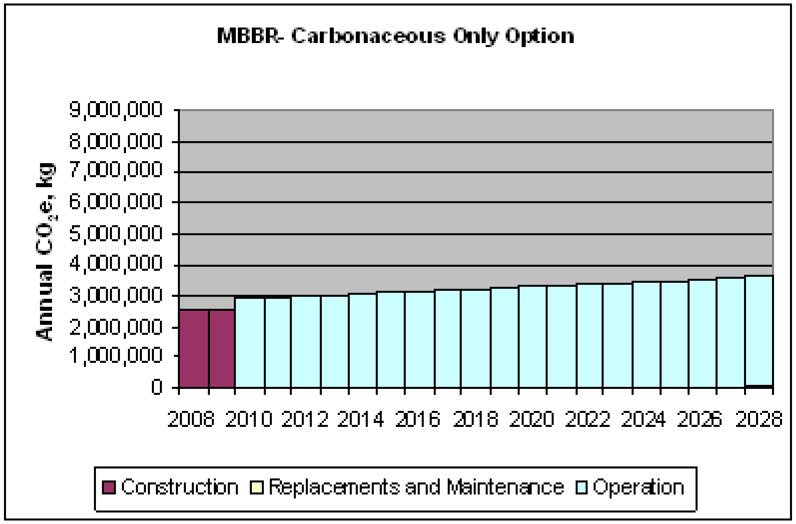
More details, Technical Session 82 WEFTEC 2010
A New Paradigm: Carbon Footprint and Sustainability Assessment for Process Selection
M. Steichen, A. Kadava, A. Shaw, T. Scanlan, M. Martin, S. Kazemi

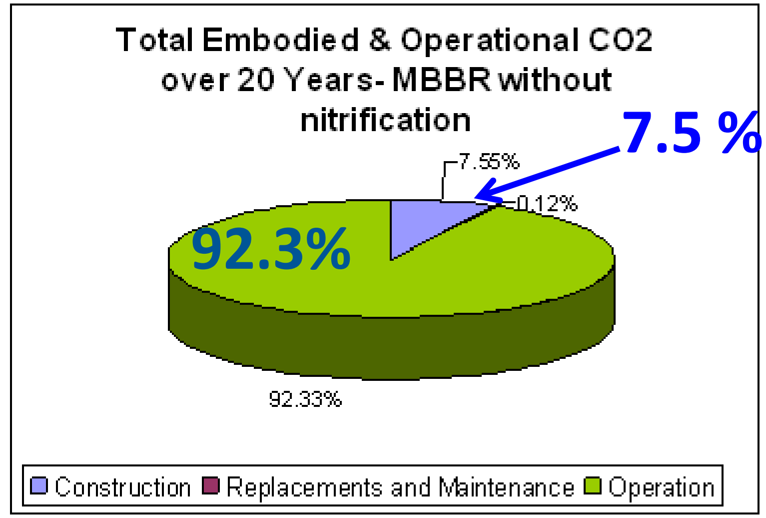
EMBODIED VS. OPERATIONAL CO_2 EMISSIONS

Annual CO2e, kg/yr

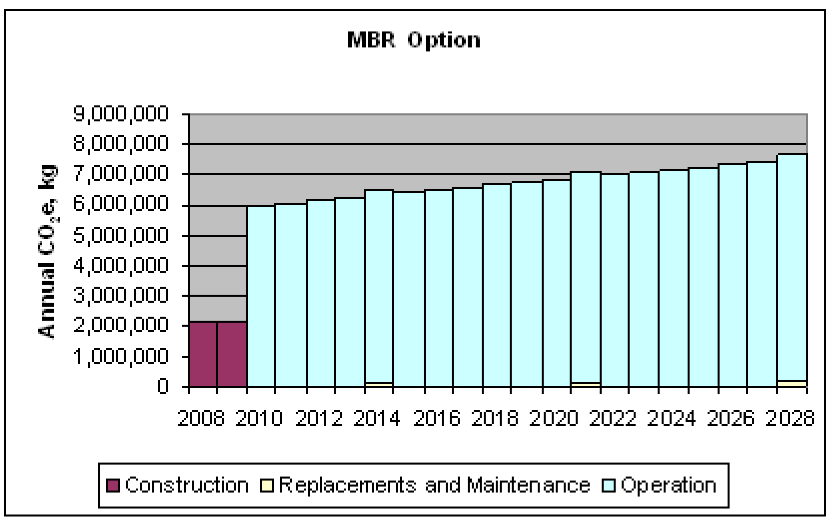
Relative Contribution

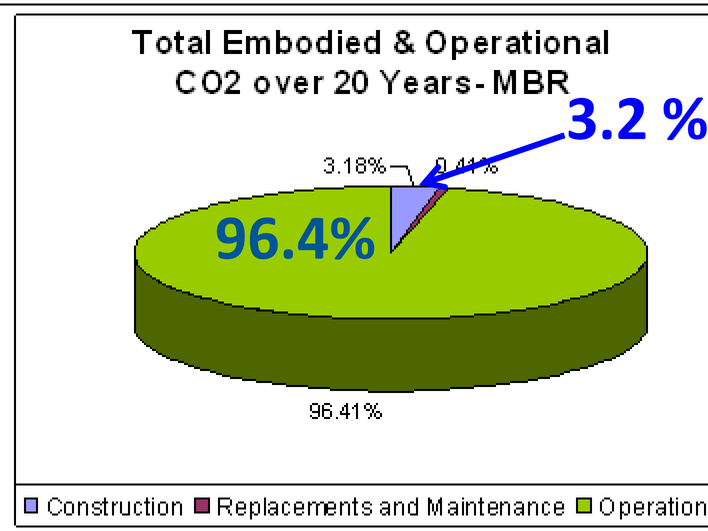
MBBR- Carb (No Nitrification)



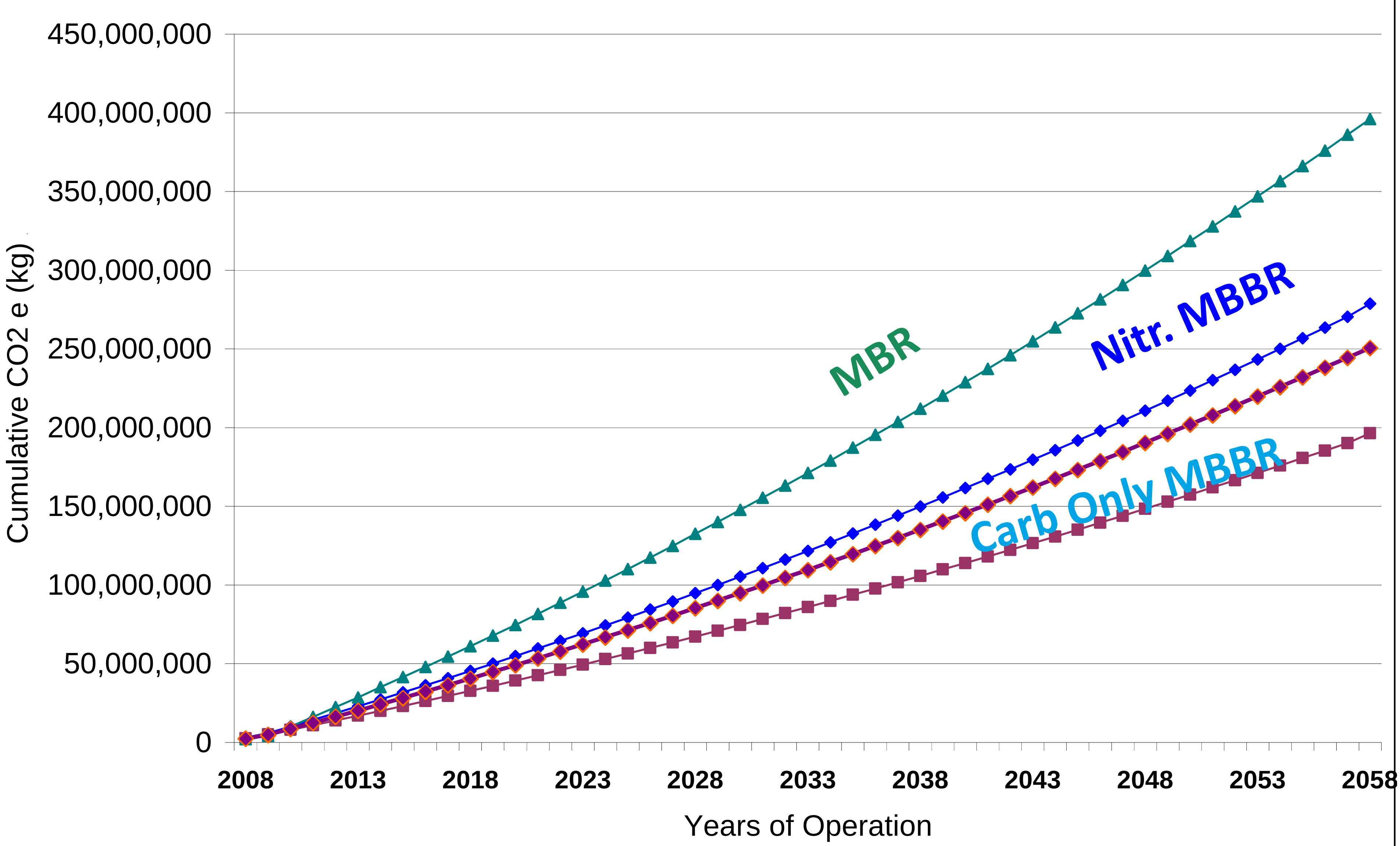


MBR

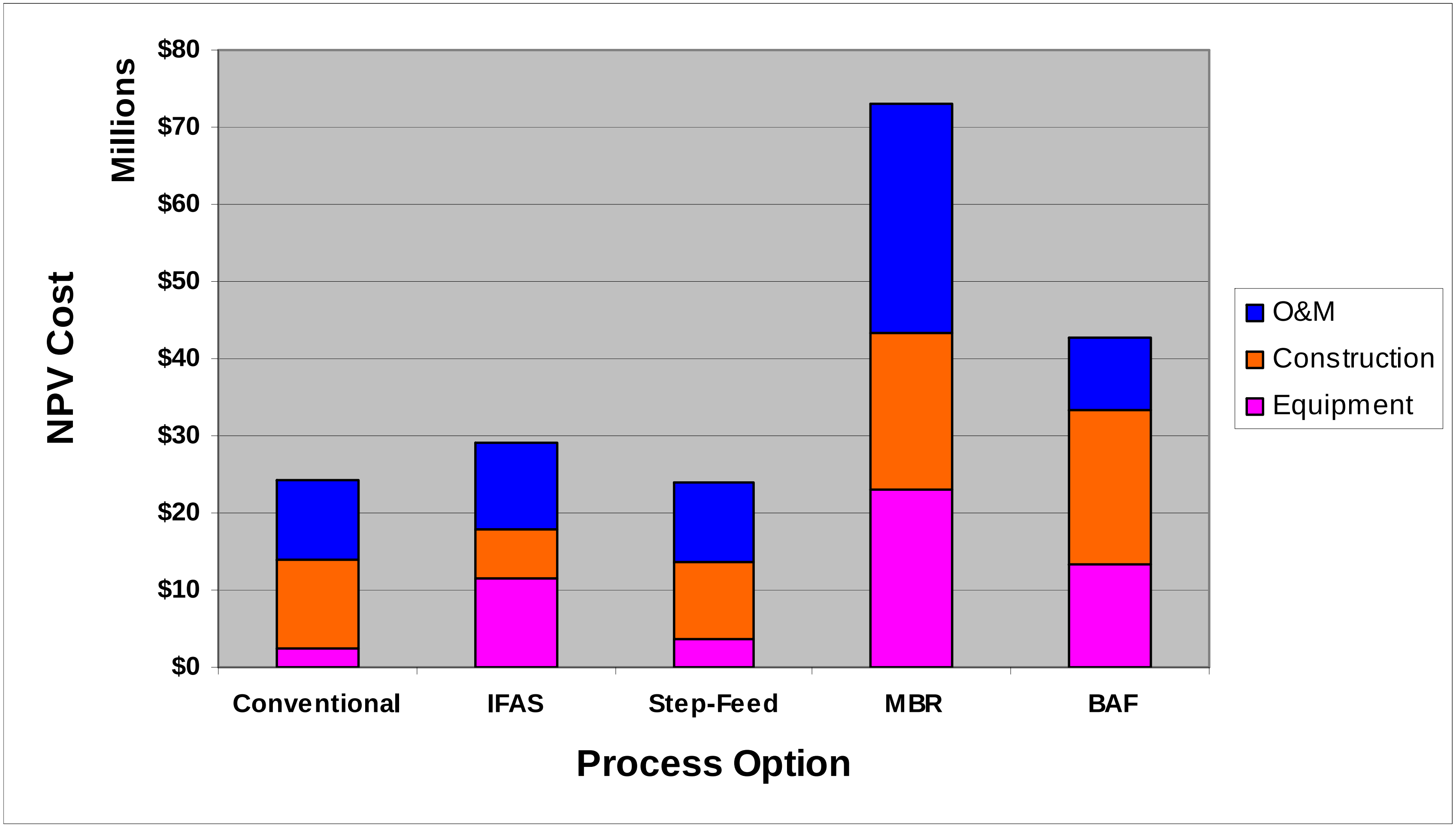




CUMULATIVE CARBON FOOTPRINT



LCA OF CONSTRUCTION + EQUIPMENT + O&M



Area, ha: +0.85 | +0 (added to existing) | +0.6 | +0.24 | +0.45

HOW TO REDUCE THE OVERALL CARBON FOOTPRINT

- **Reduce Power Use – Energy Efficiency (Save $$$)**
  - Use anaerobic processes
- **Biogas for Power Generation (Green Credits too?)**
- **Biosolids for Power → Incineration**
- **Avoid N_2O Production**
- **Sewer Emissions (not yet accounted for properly)?**

PROJECT & EQUIPMENT PROCUREMENT STRATEGIES TO ENCOURAGE INNOVATION

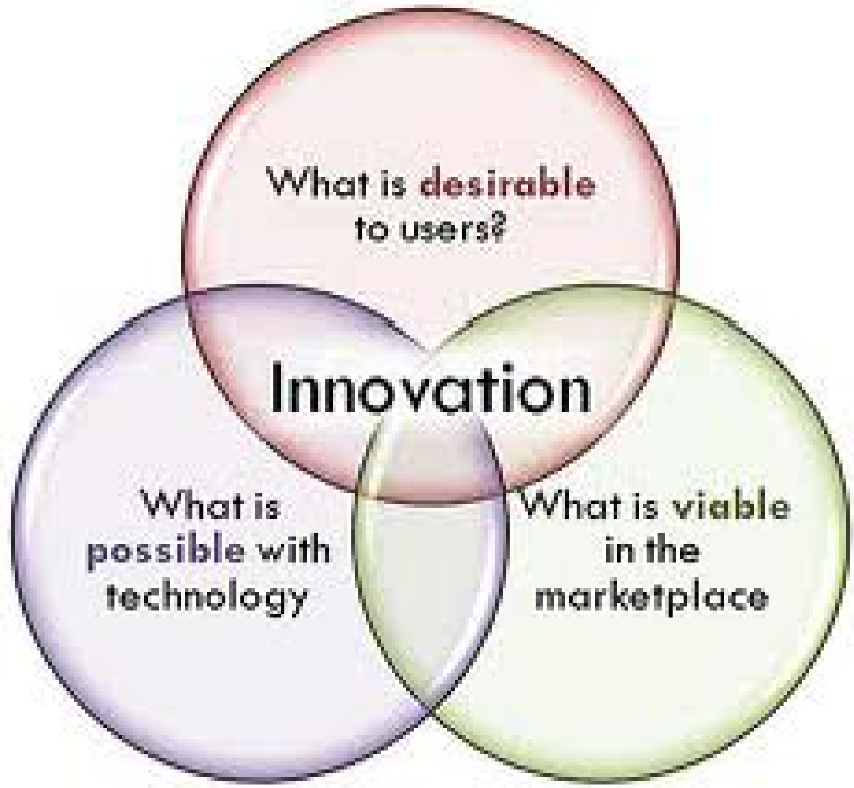
ENCOURAGING INNOVATION

To drive innovation -

- Performance based bidding vs prescriptive bidding
- Risk sharing

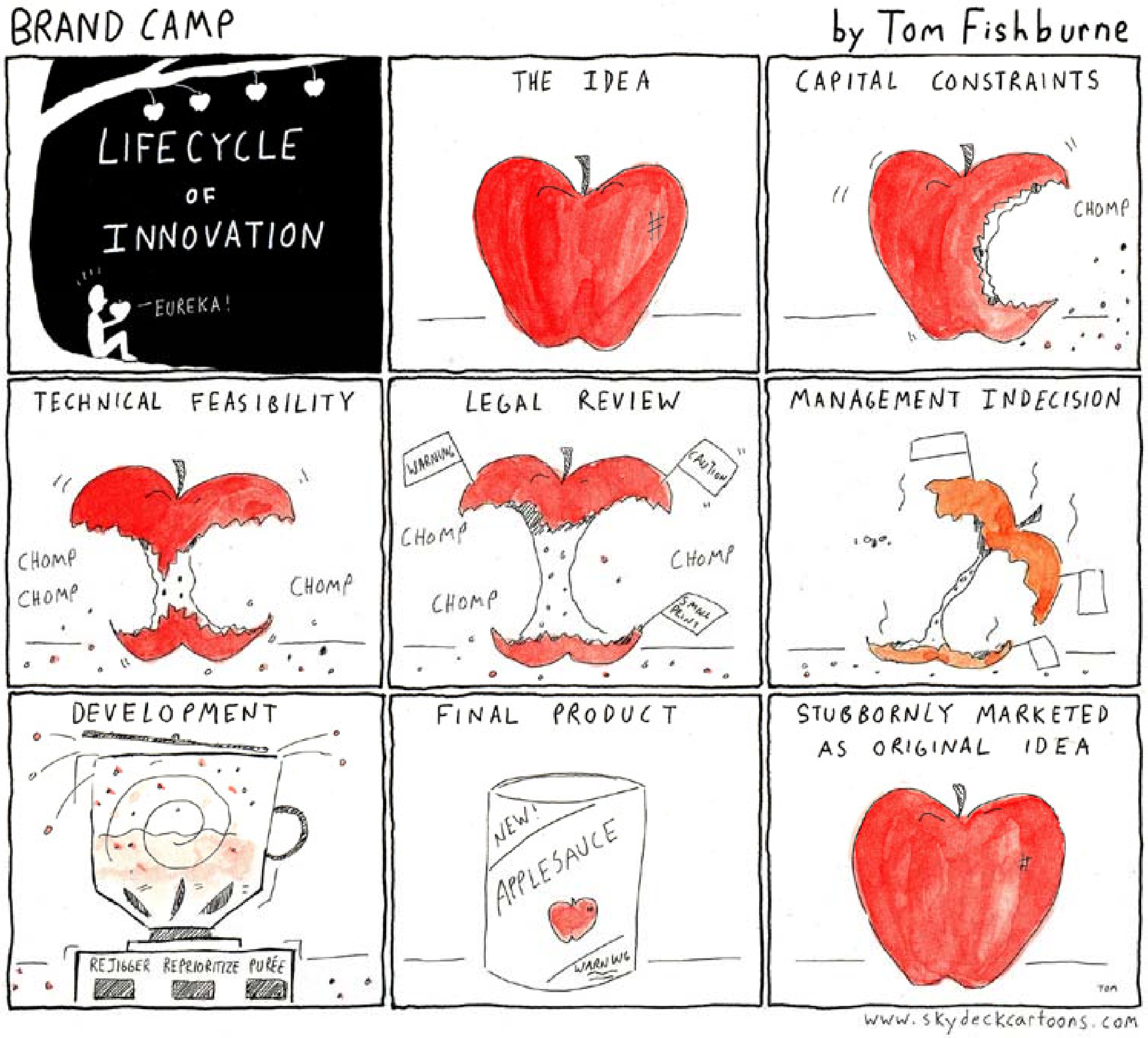
To deliver innovation -

- Traditional EPC
- EPCM
- Alliance
- DBO
- BOT
- BOOT
- Blend of any of the above



Preference? Client/project specific

WHAT INHIBITS IMPLEMENTATION?



- **RISK!**
- **Funding**
- **Regulatory requirements for "proven"**

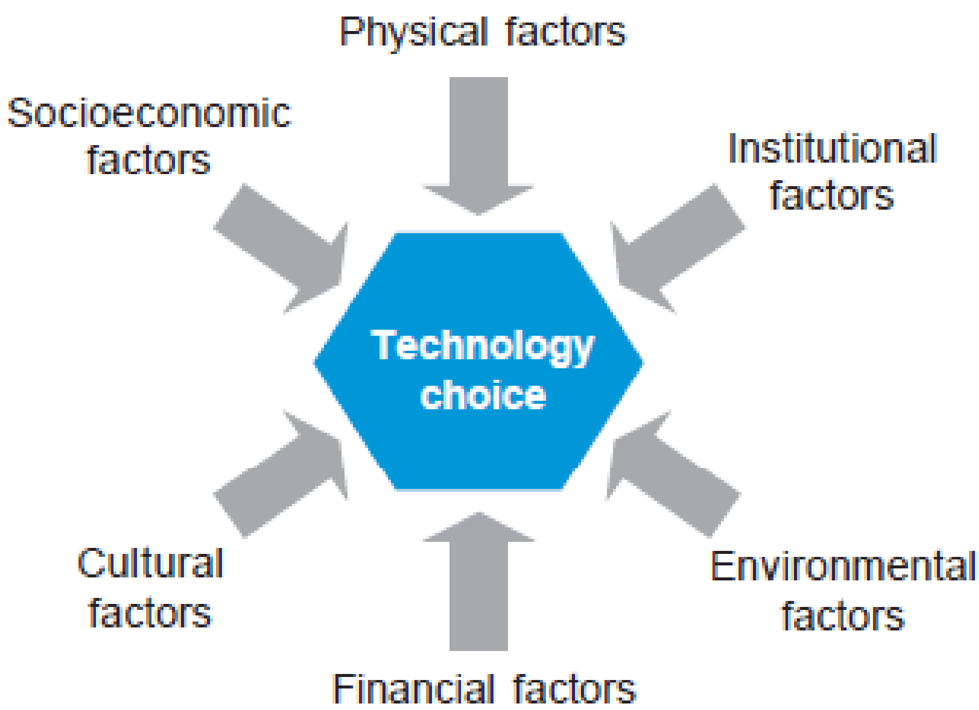
PROCUREMENT STRATEGIES

COMPARISON OF EPC & EPCM APPROACHES (BRIEFLY)

Task / Issue	EPC (Engineering, Procurement and Construction)	EPCM (Engineering, Procurement and Construction Management)
Scope of Supply	EPC Contract only as good as the original project specifications presented during bidding process. Changes to specifications / scope of supply after awarding of contract can be expensive, due to EPC contractor's sole contract with Owner and Owner's inability to "Shop Around" for multiple quotations from independent contractors / suppliers	Owners can modify project specifications with little or no trouble. Owner, with the assistance of the EPCM contractor can negotiate independent contracts with suppliers / vendors at any time due to the fact that project is under multiple (independent) contracts and not one (1) all encompassing contract
Project Budget Cost Overruns	The cost risks for a project are borne by the EPC contractor. Any cost overruns, for equipment and/or services within the EPC contractor's scope of supply, are for their own account and can not be passed onto Owner unless "change conditions" occur or contractual agreements to the contrary	The cost risks for a project are borne by the Owner. Any cost overruns, for equipment and/or services are for the Owner account (with the exception of fixed price supply contracts) i.e. Final equipment pricing bids / on site cost higher than originally budgeted.
Project Budget Cost Savings	The cost risks for a project are borne by the EPC contractor. Any cost savings, for equipment and/or services within the EPC contractor's scope of supply, are for their own account and are not passed onto Owner unless contractual agreements to the contrary	The cost risks for a project are borne by the Owner. Any cost savings, for equipment and/or services are for the Owner account ie. Equipment/Services bids are returned lower than budgeted.
Legal Cost	Legal Costs are low for Owner. Owner negotiates only one detailed supply contract with EPC contractor.	Legal Costs are higher for Owner. Owner negotiates multiple supply contracts directly with suppliers / contractor; with the assistance of EPCM contractor.
	EPC contractor must negotiate individual contracts with suppliers / vendors. EPC contractor's legal costs are high due to multiple contracts.	In the event of legal action is taken, Owner must bring legal action against individual suppliers / contractors. *(Usually a shorter process than EPC legal actions)*
	In the event of legal action is taken, Owner must sue EPC contractor, who in turn must bring legal action against appropriate suppliers / contractors. *(Usually a longer process than EPCM legal actions)*	
Administration	Owner's administration costs are low with EPC contract. Only minimal staff (management, QC, legal, etc.) needed to administer/monitor project. *May have negative effect on project "ownership" feeling within Owner's organization (Hands off).*	Owner's administration costs are higher with EPCM contracts. Substantial staffing levels needed to assist/compliment EPCM contractor in administering/monitoring project. *Promotes "ownership" feeling within Owner's organization. Project staff often transferred to operational staff after project completion.*

RURAL AND SMALL COMMUNITY SYSTEMS (DECENTRALISED SYSTEMS)

TECHNOLOGY SELECTION FOR SMALLER SYSTEMS



“A Guide to Decision Making: Technology Options for Urban Sanitation in India”, Water & Sanitation Program (WSP), Government of India (Sept. 2008).

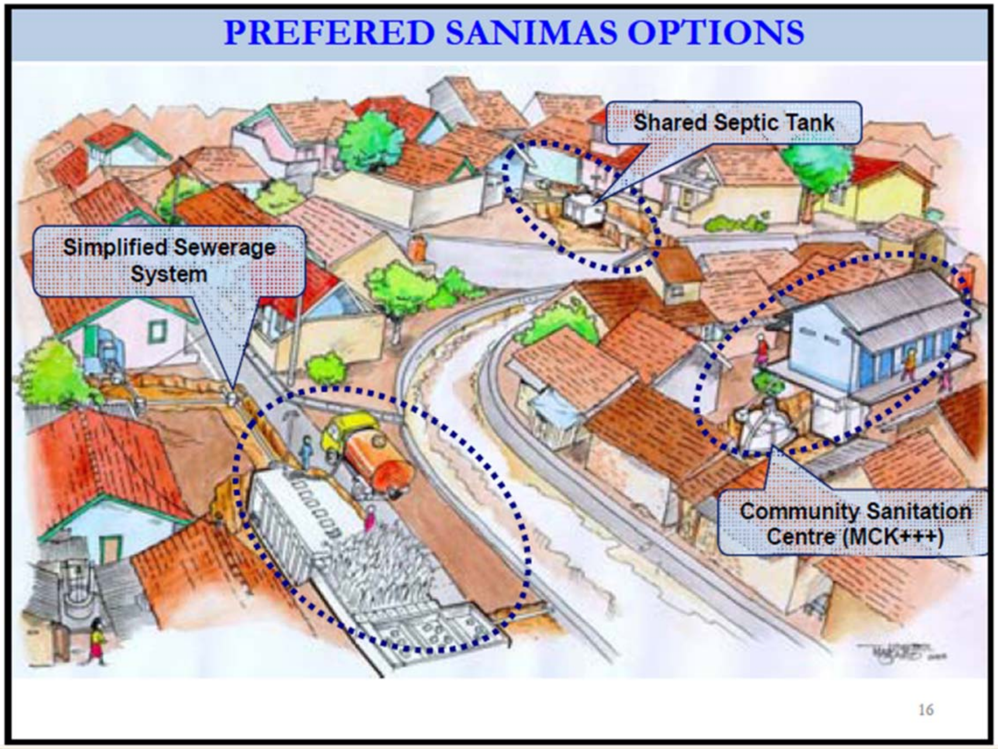
On-site facilities may provide more appropriate, cost effective technology and, in some cases, an inexpensive option…

DECENTRALISED SYSTEMS

- **Sanimas: "sanitation by communities" in Bahasa (Indonesian)**
- **Novel Communal Septic Designs**
- **Urine Separation**
- **Innovative Designs**
  - Use of plants
  - Anaerobic
  - Solar, co-gen, etc.

SANIMAS

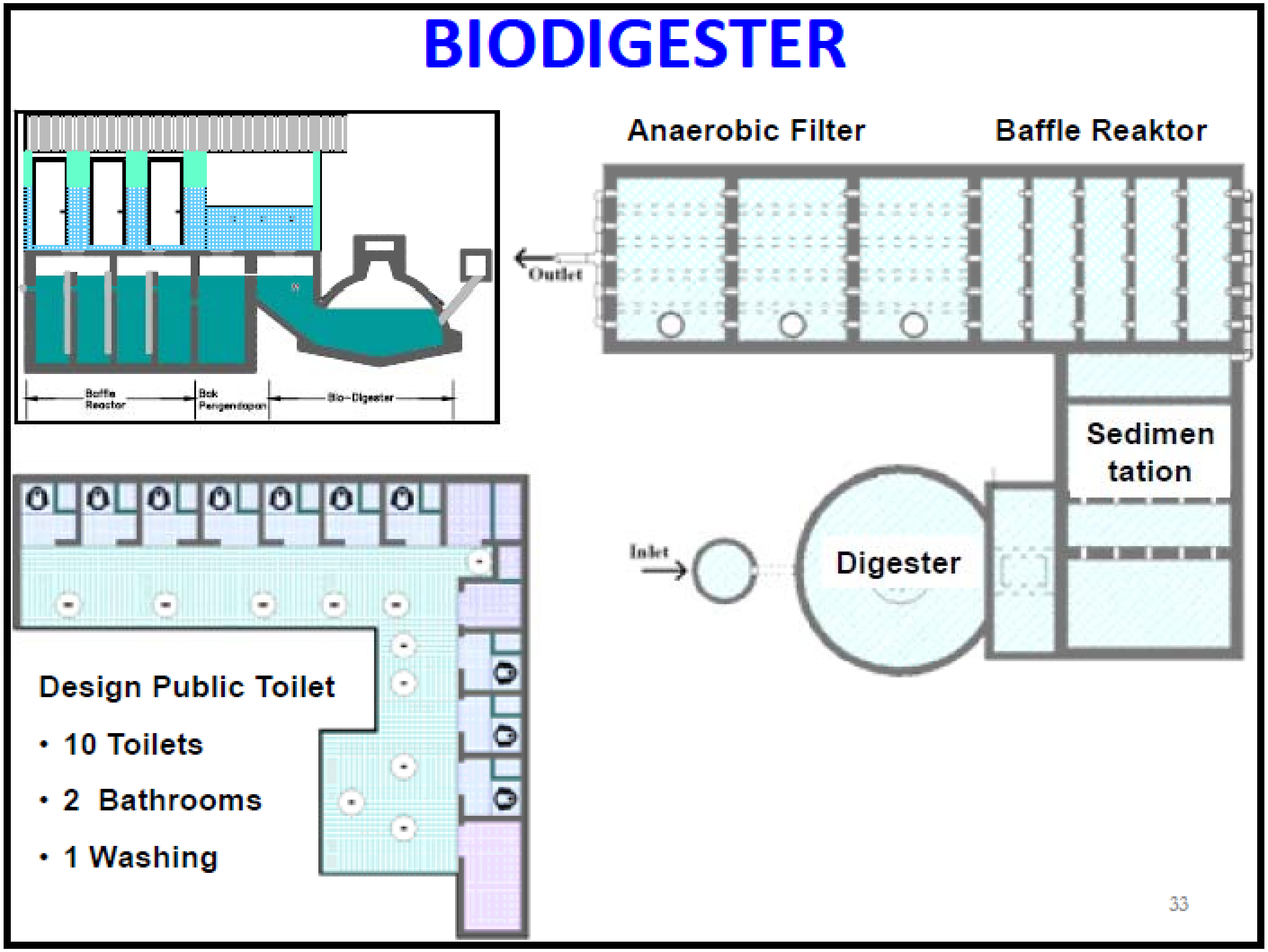
- **Definition**: facilitate and assist poor urban communities to plan implement and maintain sanitation systems of their choice
- **Source of funding**: multi-source
- **Components**: toilet, sewerage, treatment and disposal
- **Purpose**: Society engagement, improvement of health and improvement of environmental degradation, in an affordable manner, for those areas are poorly served by public infrastructure



Slide from H.B. Legowo from 5th Meeting of Kitakyushu Initiative Network, 10-11 Feb 2010, Kitakyushu, Japan

SANIMAS TREATMENTS

- Involve lower cost versions of the centralised systems

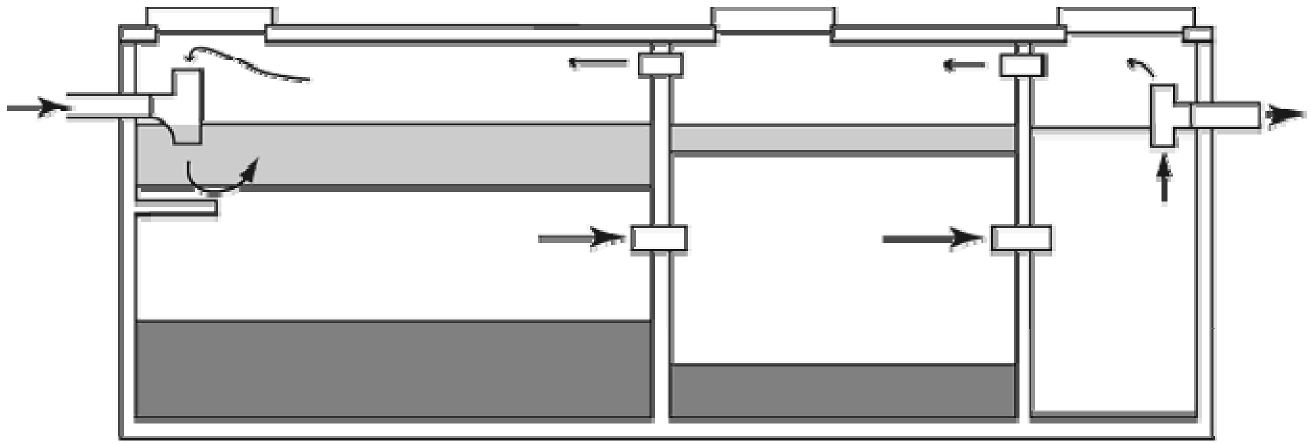


Slide from H.B. Legowo from 5th Meeting of Kitakyushu Initiative Network, 10-11 Feb 2010, Kitakyushu, Japan

DECENTRALIZED SYSTEMS

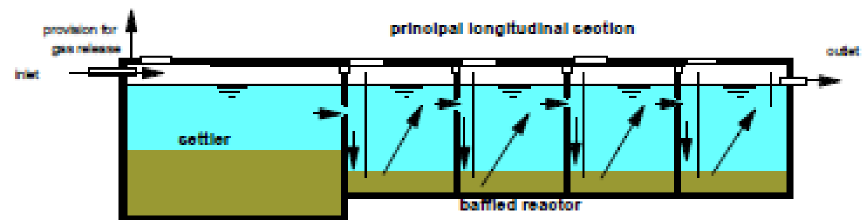
COMMUNAL SEPTIC TANKS

- Multi-chambers increase effectiveness

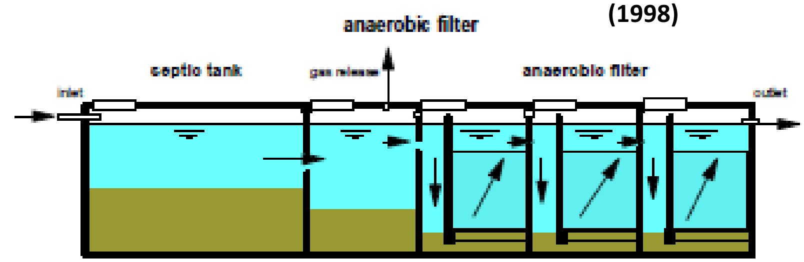


http://www.ferrocement.com/casa-ca8/ch8.en-ferroHouse-web.html

- DEWATS approach shown for Q < 500 m3/d



Dewats handbook (1998)



URINE SEPARATION

Urine separation devices
[Right photo from WHO with permission (2006); left from Kvarnstrom et al., 2006]

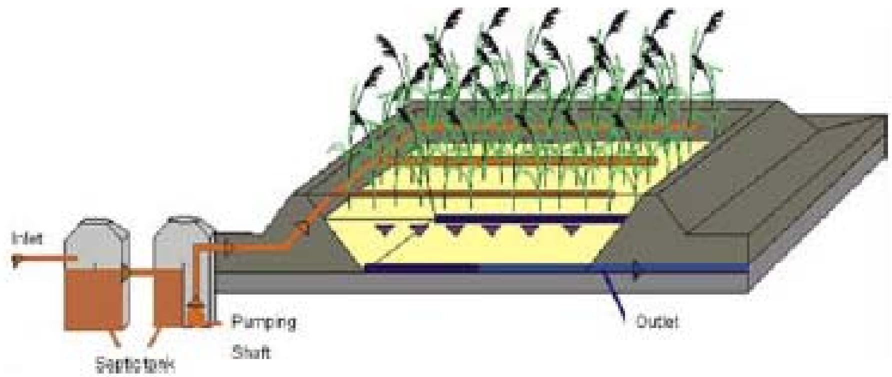
- **Vigorously promoted by the Stockholm Environmental Institute**
- **Urine contains 70 of nitrogen and 65% phosphorus from human and animal waste**
- **Urine is mostly sterile and when standing for a month or two kills all bacteria and viruses**
- **The price of fertilizer is out of the reach of more than half the world population**
- **In developing countries use of diluted urine can go a long way to solve hunger**

BACKYARD GARDEN – KAMPALA UGANDA

USE OF PLANTS

- "Low tech" solution
- Still require regular maintenance
- Dimensioning based on O_2 demand

Wetland in Dubai for WWT;
reeds reached 6m in height



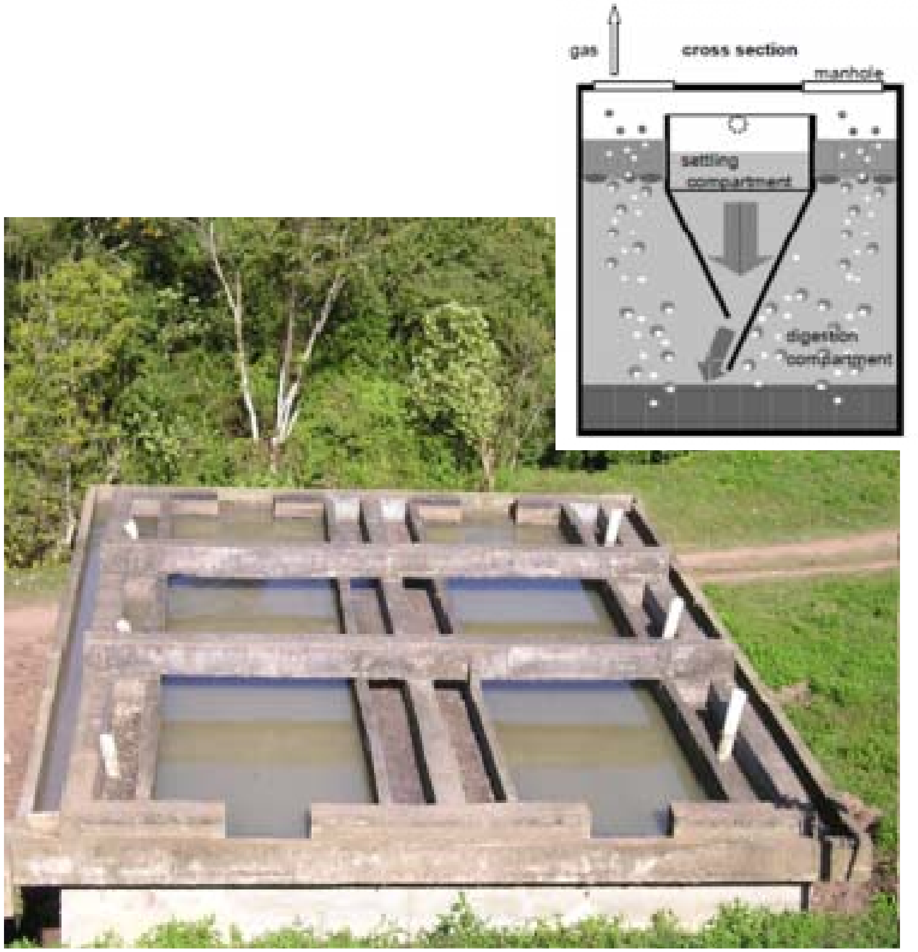
Example of Verticle Flow Bed (VFB) wetland – better for warmer climates..

Figure from Hoffman, H., C. Platzer, M. Winker and E. von Muench. "Technology Review of Constructed Wetland: Subsurface flow constructed wetlands for greywater and domestic wastewater treatment", Deutsche Gesellschaft für, Internationale Zusammenarbeit (GIZ) GmbH, publishers (Feb. 2011).

- TSS and organic matter removal is 90 to 99%
- Almost complete nitrification at 90%

ANAEROBIC SYSTEMS

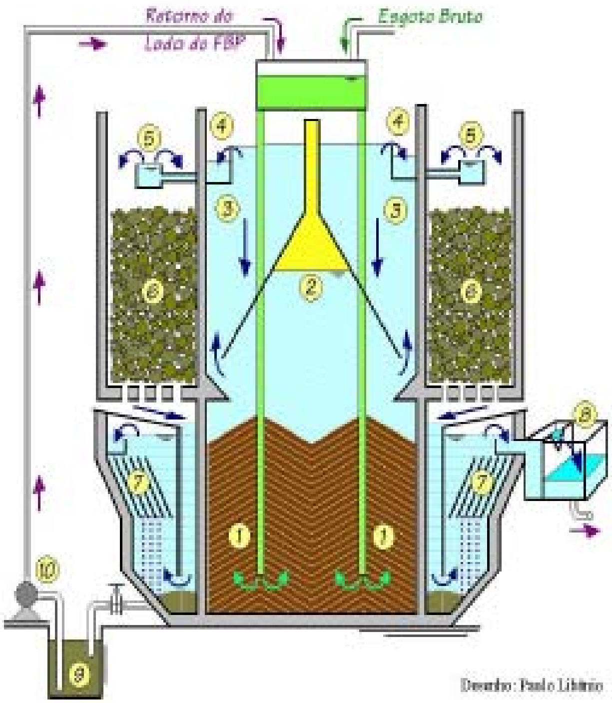
- **Imhoff tanks** – still used for smaller communities.
- **Construction costs - are slightly higher than the costs for a septic tank (SANIMAS 2005).**
- **Costs for desludging - motorised or manual must be considered.**
- **Imhoff is a pre-treatment facility and in many cases connected to further treatment installations such as leach field, soak pits, horizontal flow, vertical flow or free-surface constructed wetlands, lagoons or other.**



Open Imhoff tank in Las Vegas, Honduras. Source: MIKELONIS (2008

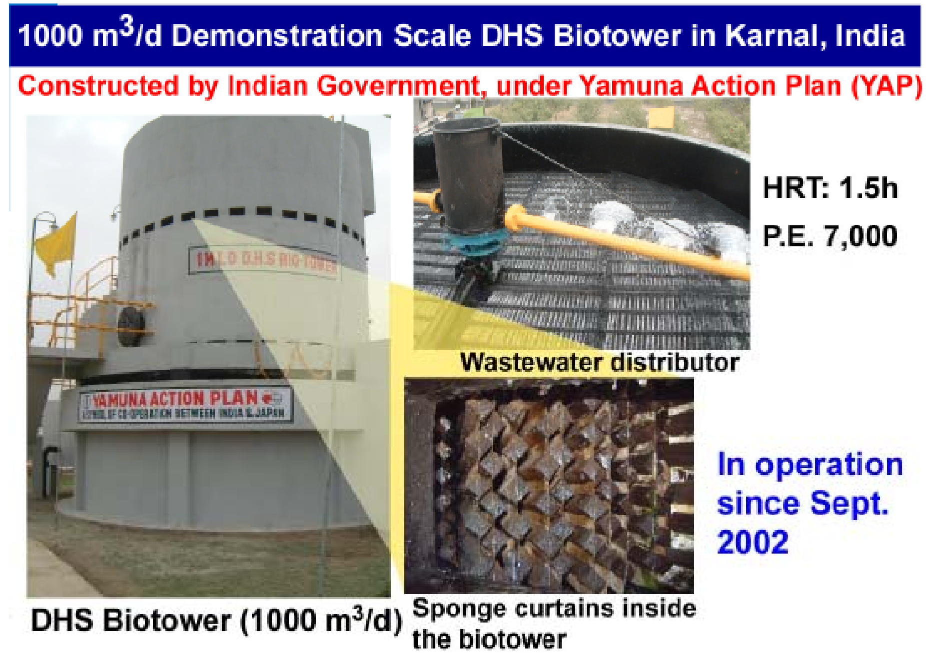
ANAEROBIC SYSTEMS

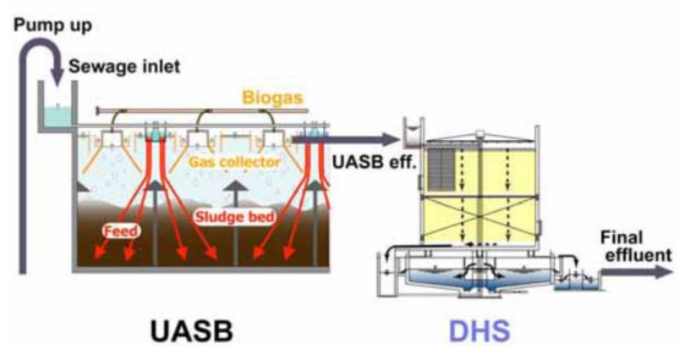
- **Integrated anaerobic – aerobic treatment** – still used for smaller communities.
- Model used in Brazil.



ANAEROBIC SYSTEMS

- **Integrated anaerobic – DHS (downflow hanging sponge cubes)**
  - Purported to be low cost and easy maintenance
  - Requires no external aeration and minimal withdrawal of excess sludge
  - HRT of ca. 8.3 hours (7 hrs in UASB), 81-84% COD removal, 73-78% nitrification, 94-97% unfiltered BOD removal in 550 d test*



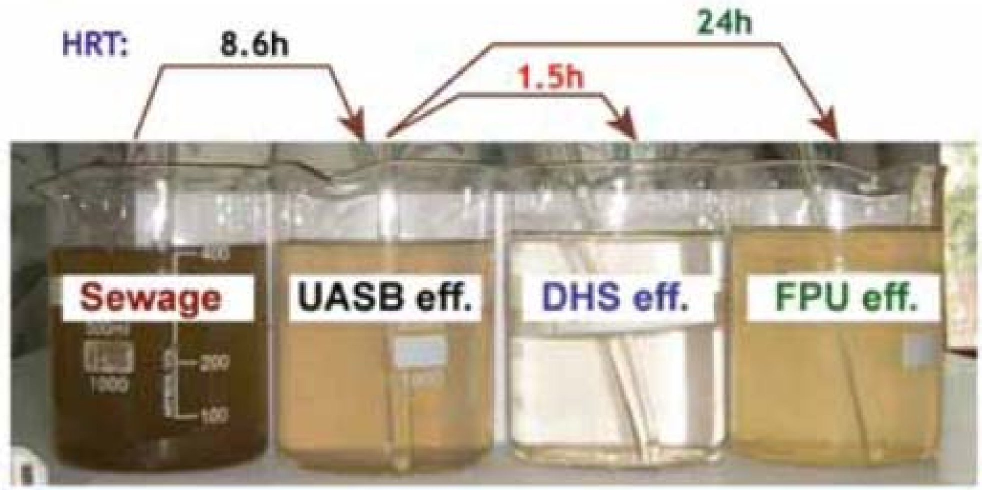


Kobayashi, T. (ed.). *Recent Progress of Biochemical and Biomedical Engineering in Japan, Vol 90 (2004)*

ANAEROBIC SYSTEMS

- Integrated anaerobic – DHS (downflow hanging sponge cubes)

Overall Summary Result of 5-ys non-stop operation

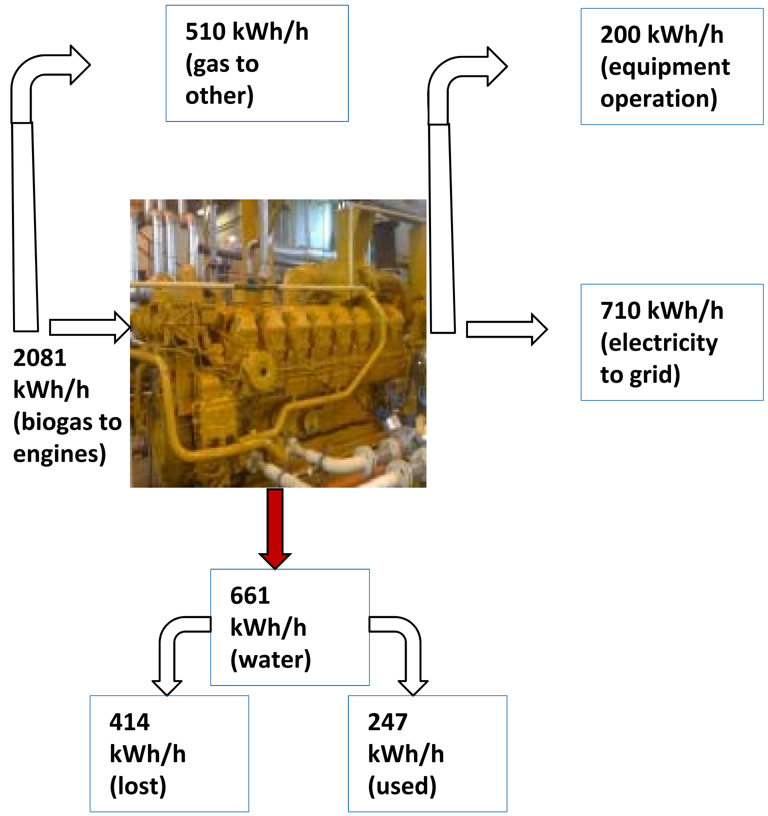


	Sewage	UASB	UASB+DHS	UASB+FPU
Total BOD (mg/L)	152	53	6 (96%)	41
Total COD (mg/L)	436	172	31 (92%)	137
SS (mg/L)	235	50	13 (94%)	47
F.coli (MPN/100ml)	8.9×10^6	5.6×10^6	1.6×10^5 (2log10)	1.8×10^6
NH4-N (mg/L)	24	25	5 (79%)	24
DO	0	0	5.4	-

Harada, H. "India-Japan International Collaboration for an Innovative Sewage Treatment Technology with Cost-effective and Minimum Energy Requirement" *Asian Science & Tech. Seminar, Thailand (9March2008).*

CO-GENERATION

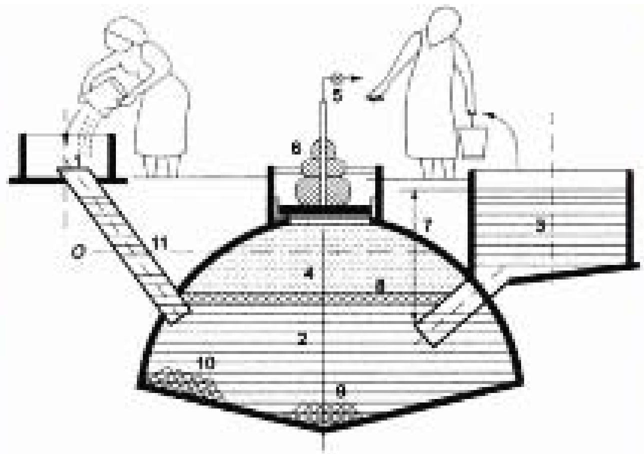
- **Larger scale:** municipalities are implementing co-gen in a big way in Australia to offset carbon



Jordão, E.P. "Cogeneration of electrical and thermal energy from biogas in wastewater treatment plants: the case for Brazil, Conference in Venice (2010).

CO-GENERATION

- **Smaller scale**



- ➢ Plants are for providing household gas
- ➢ Sometimes also used for lighting
- ➢ Tropical to subtropical temperatures better (otherwise too big)

It is estimated that there are 50,000 anaerobic digesters in Nepal and >8m in China

Bisschops, I, E. Schuman, K. Kujawa and H. Spanjers. "Technical background on small scale anaerobic digestion of food waste". http://www.slideshare.net/RembrandtK/technical-background-small-scale-biogas-production

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