Minerva Ventures

*Charting a Resilient Path*

# Innovation in $H_2O$ Technology

Marianna Grossman

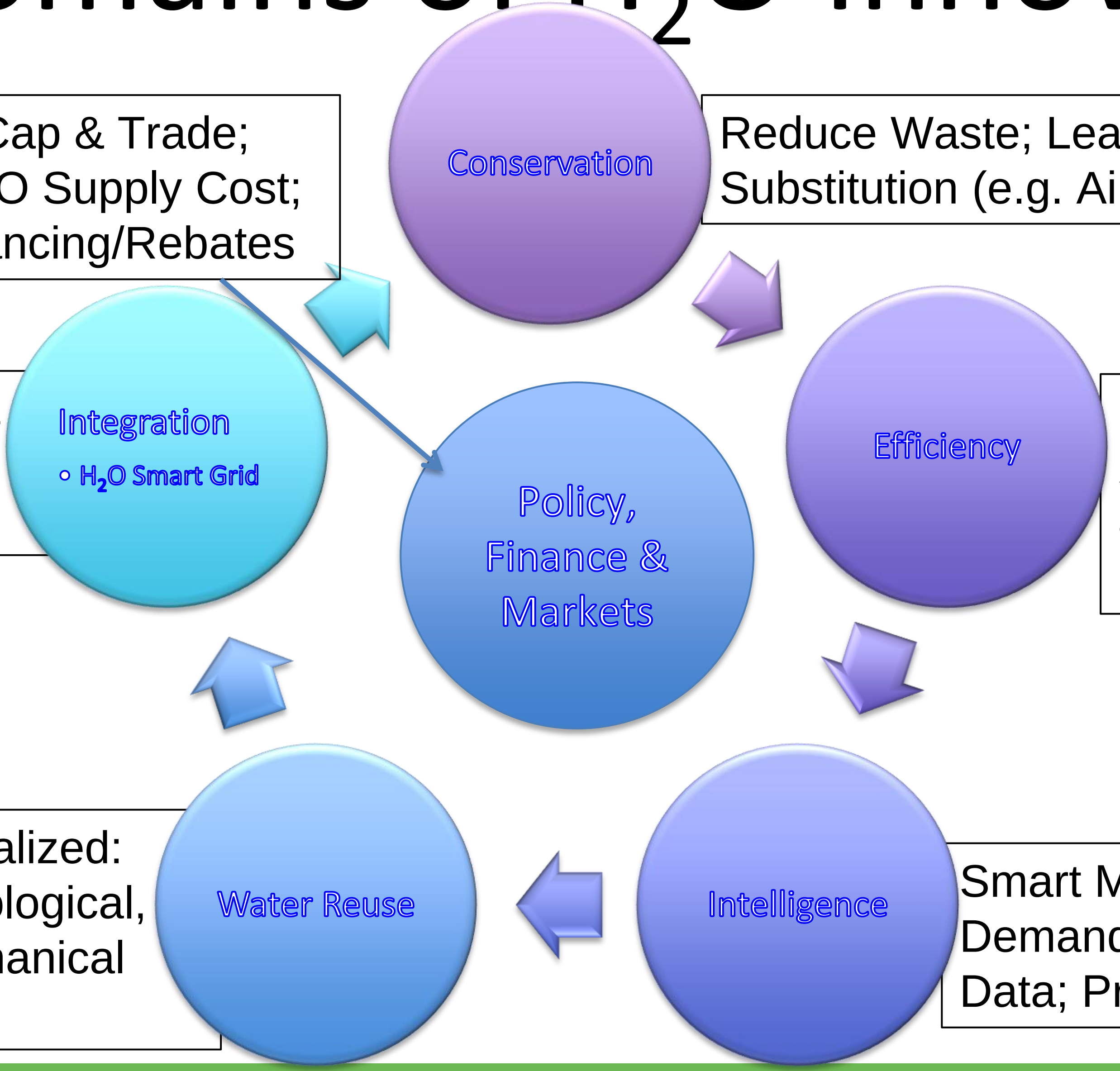
Sustainable Water Resources Roundtable

December 14-15, 2016

Florida Gulf Coast University

& Babcock Ranch

# Domains of $H_2O$ Innovation




Variable Pricing: Cap & Trade; Price at Future $H_2O$ Supply Cost; Infrastructure Financing/Rebates

Reduce Waste; Leak Detection; Low $H_2O$ Crops; Substitution (e.g. Air Cooling vs. $H_2O$ Cooling)

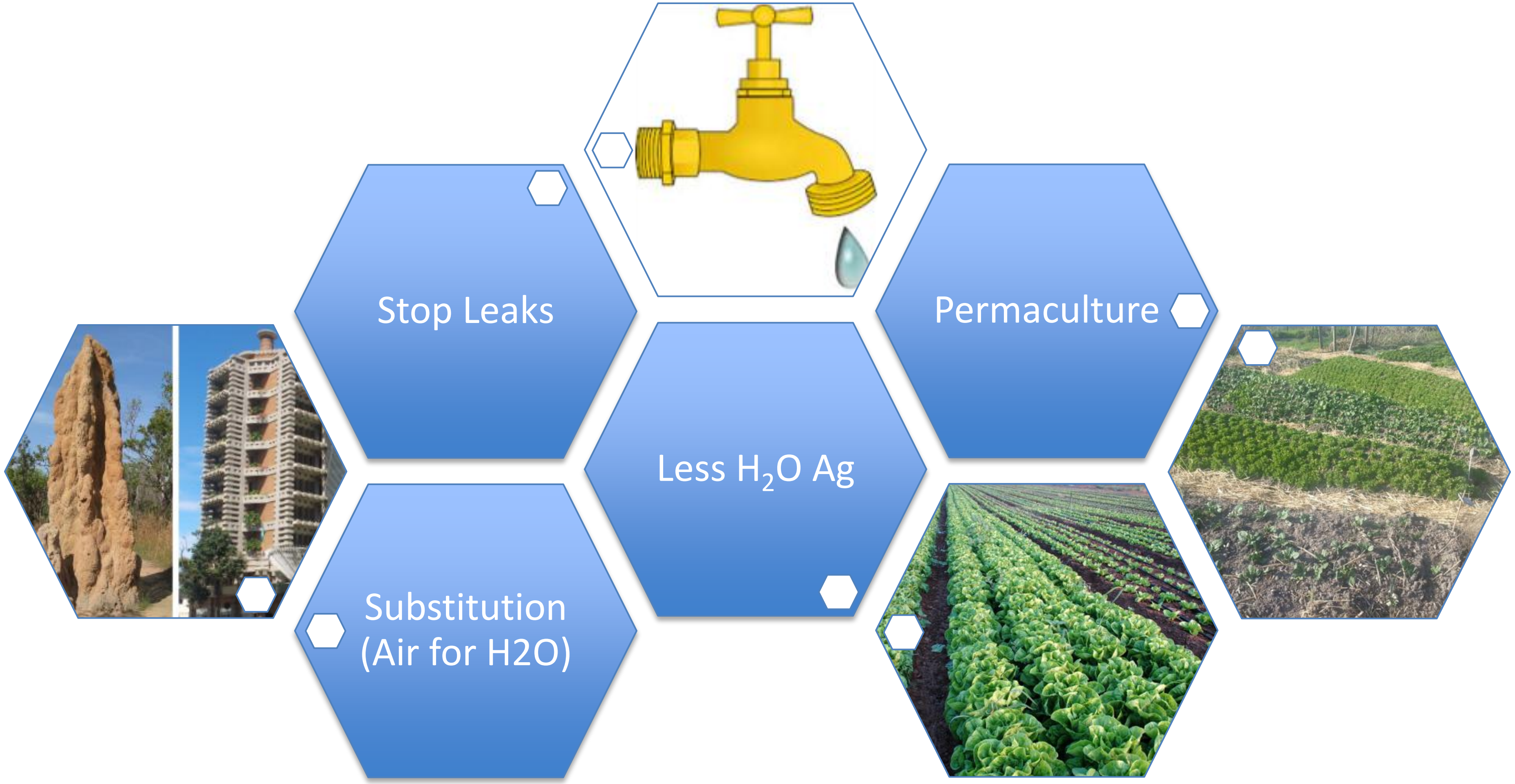
Dynamic Management of $H_2O$ Supply & Demand; Aquifer Mgt.

Make $H_2O$ Go Further Xeriscaping; Low-flow Fixtures & Appliances; Process Improvement

Distributed or Centralized: $H_2O$ Catchment; Biological, Chemical &/or Mechanical Treatment; Reuse

Smart Meters; Sensors; Controllers; Demand Management; Satellite Data; Predictive Analytics

# Conservation (Use Less & Substitution)



# Efficiency (Energy & Water Productivity)

- Low-water fixtures and appliances
- Process improvement to save water & energy
- Better product design
- Landscaping & agriculture smart irrigation

# Intelligent Water Management

## Internet of Things (IoT)

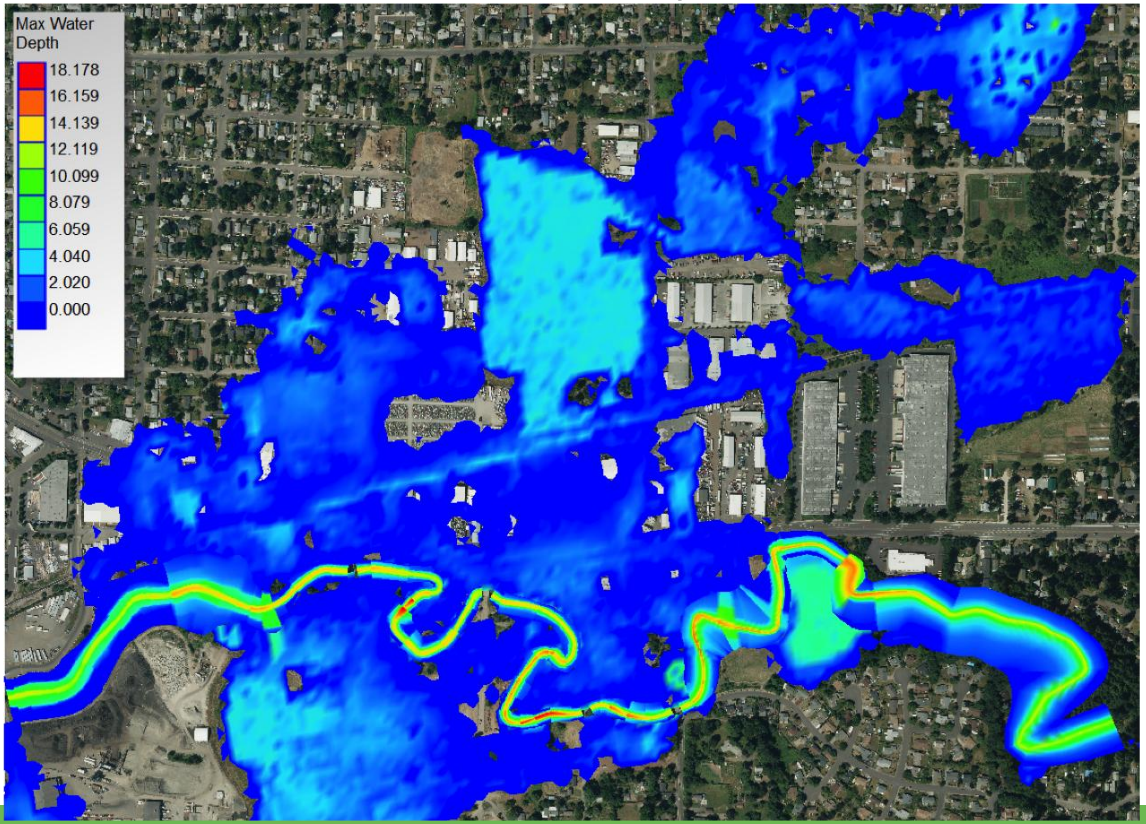
- Groundwater management: remote sensing, aquifer recharge, water rights management
- Advanced Metering Infrastructure (AMI)
  - Leak detection
  - Demand Management/Variable Pricing
- Sensors and controllers for quality & volume
- Predictive analytics; automation; visualization

# Intelligent Water Management

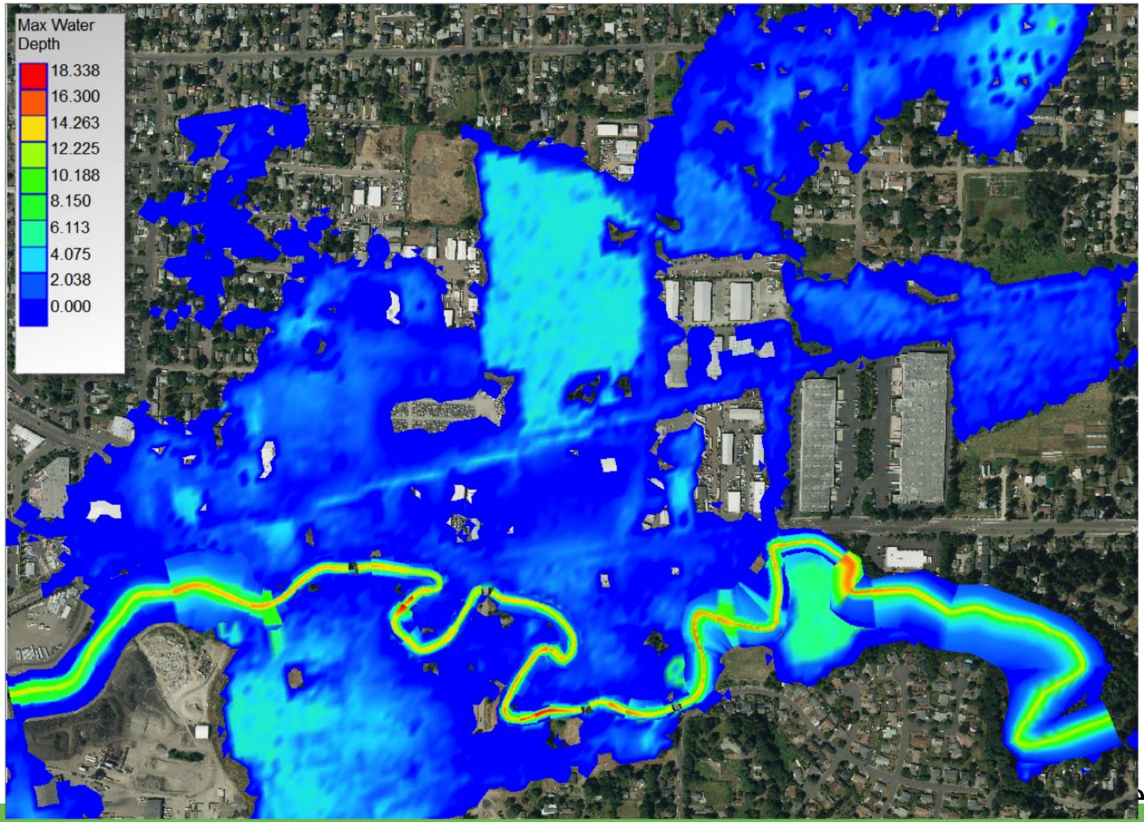
## Internet of Things (IoT)

## WeatherTrack™ Argos Analytics/Arup/IES

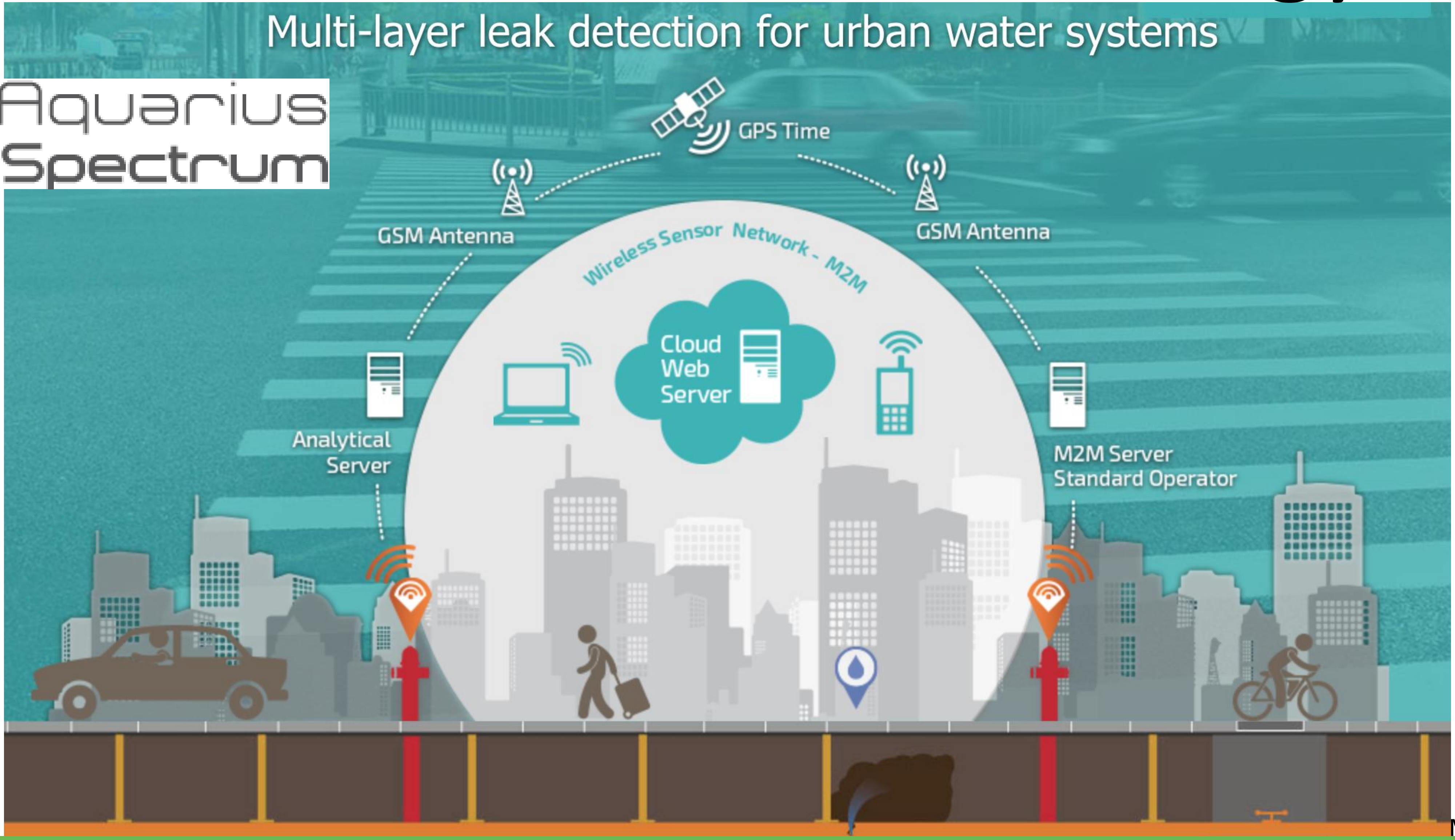
100 Year Flood – Existing Conditions



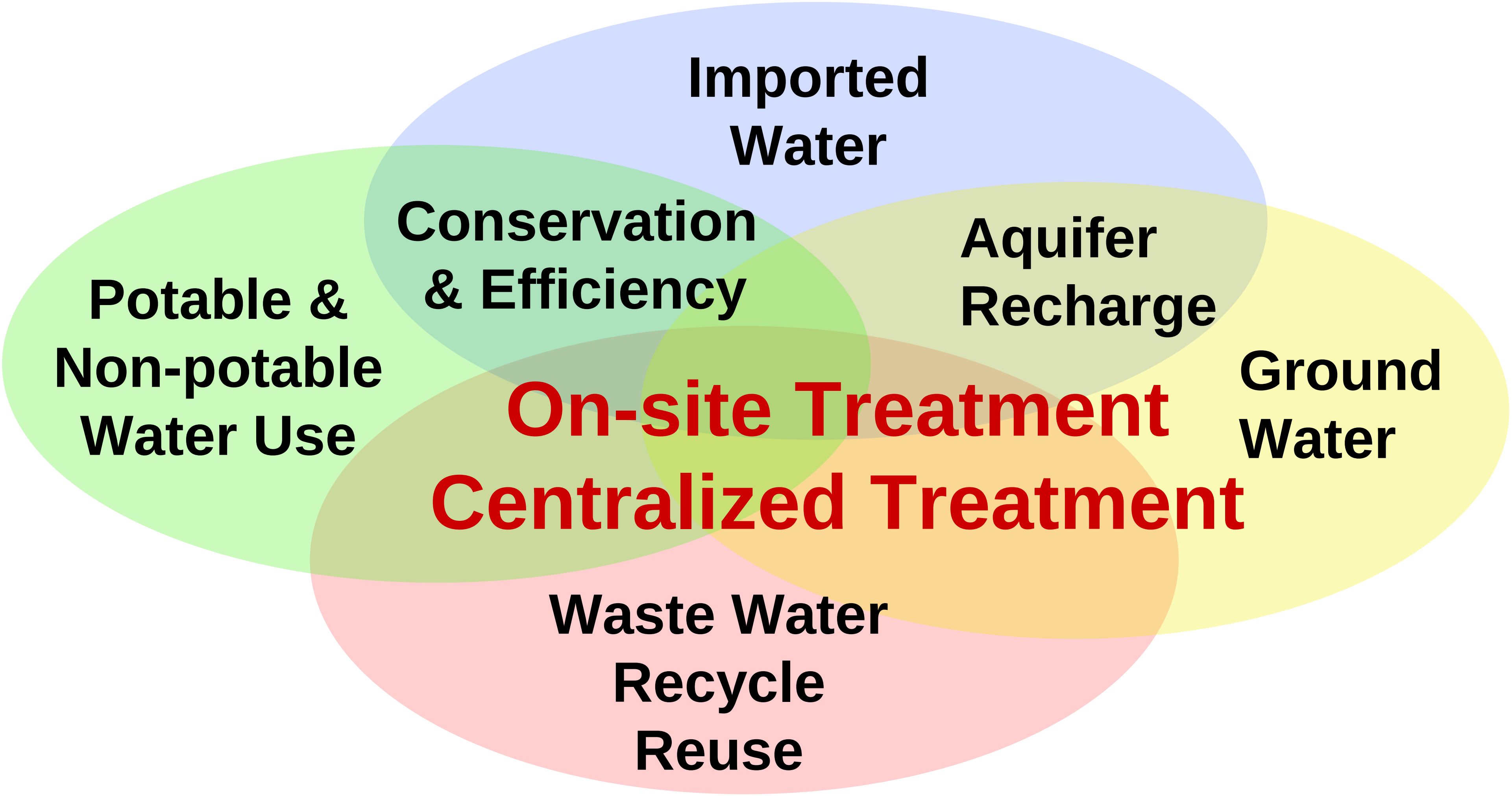

100 Year Flood – with 20% Higher Peak Flow



# Leak Detection Technology



# Integrated Water Management

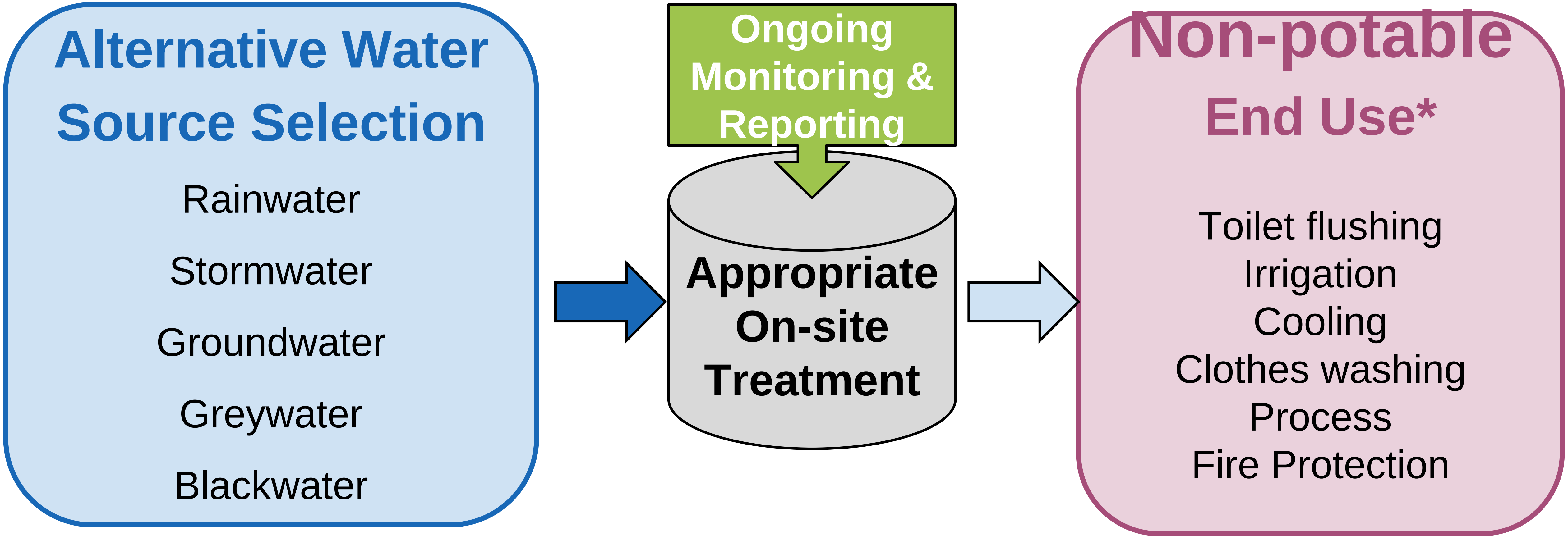


# Treatment, Reuse & Resource Recovery

- **Centralized**
  - Advanced Water Purification Treatment Plants
  - Treated wastewater for potable & non-potable uses
- **Decentralized**
  - $H_2O$ capture, treatment and reuse for buildings, sites, campuses or districts/sub-regional
  - Reuse technologies (bio., chemical & mechanical)




# SFPUC: Water Sources & End Uses

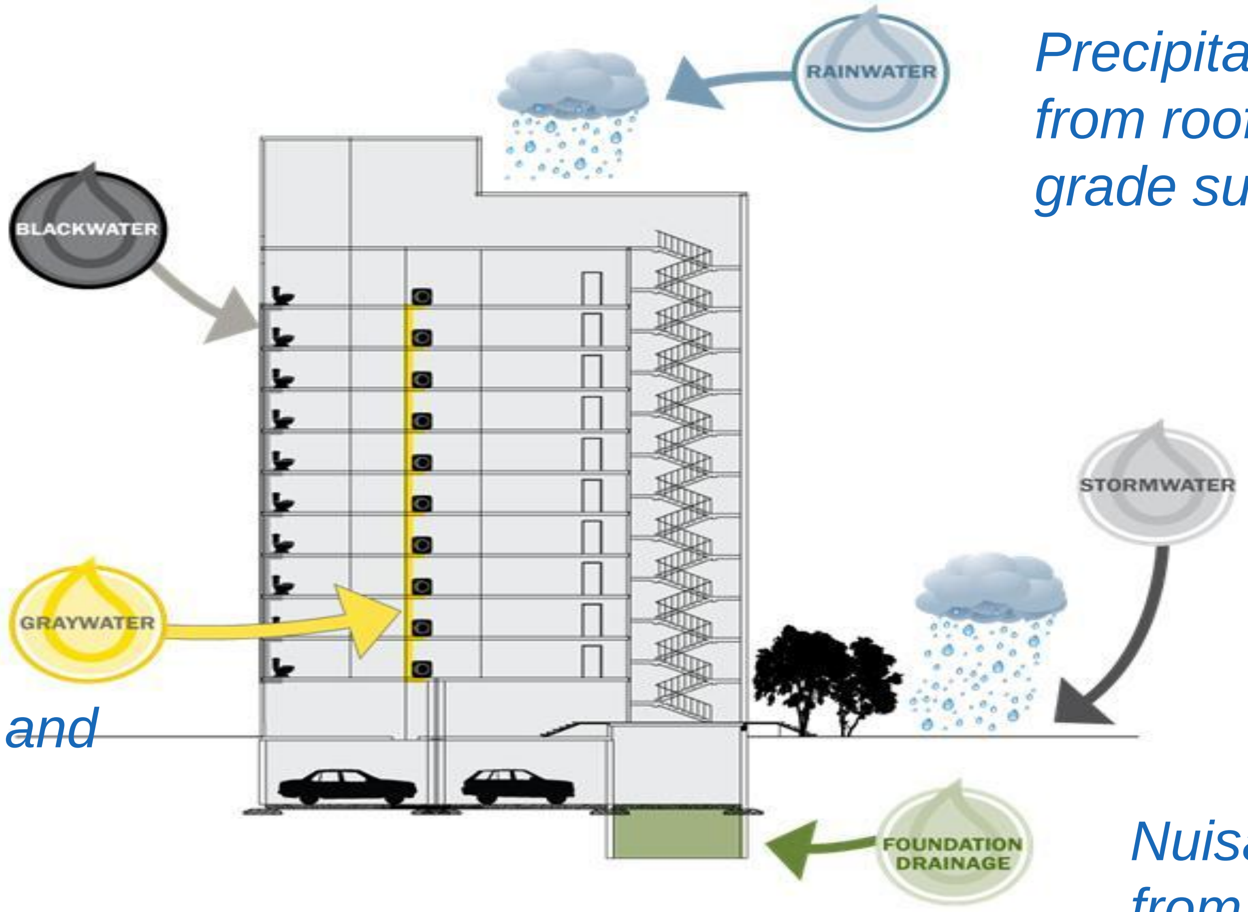



****over 75% of a commercial building's water demand can be met with non-potable water***

# Buildings Produce Water

Wastewater from toilets, dishwashers, kitchen sinks, and utility sinks

Wastewater from clothes washers, bathtubs, showers, and bathroom sinks




Precipitation collected from roofs and above-grade surfaces

Precipitation collected at or below grade

Nuisance groundwater from dewatering operations

# 181 Fremont, San Francisco: Mixed Use Development

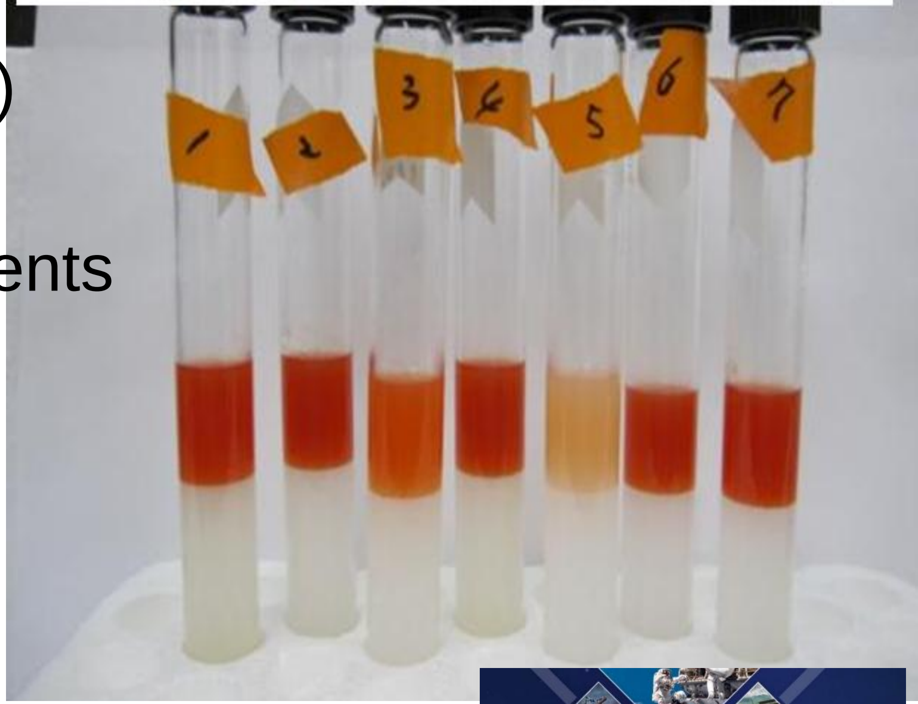
- Source: Graywater
- End Use: Toilets & Irrigation
- Status: Under Construction

# SFPUC 525 Golden Gate Ave. SF - Living Machine

# Bioremediation:
# Using Biological Systems to clean water

Intrinsyx uses collection of bacterial endophytes with specialized plant cultivars for remediating the most prolific environmental pollutants in surface/groundwater and soil.

- Heavy Metals/Metalloids (Chromium, Arsenic, Manganese, Nickel, Copper, Cadmium, and others)
- Nitrates and Phosphates
- Trichloroethylene (TCE) and other chlorinated solvents
- Oil & Gas (TPH, PAH)
- Radionuclides (Uranium)
- Pesticides
- Explosives (TNT, RDX, HMX)


Screening endophytes for pollution degradation capabilities

Intrinsyx
Space Age Biotechnologies for Earth and Beyond
www.intrinsyx.com

# Integrated Systems for Biologically Based Water Treatment

***Floating Treatment Wetlands***

- Floating Islands and Biofoams
  (Plant and Microbe Based)
- Large Volumes e.g., Waste Water Lagoons
- Sewage and Grey Water Effluent
- Surface and Storm Water Runoff
- Water Treatment and Recycling


**Landfill Leachate Results**

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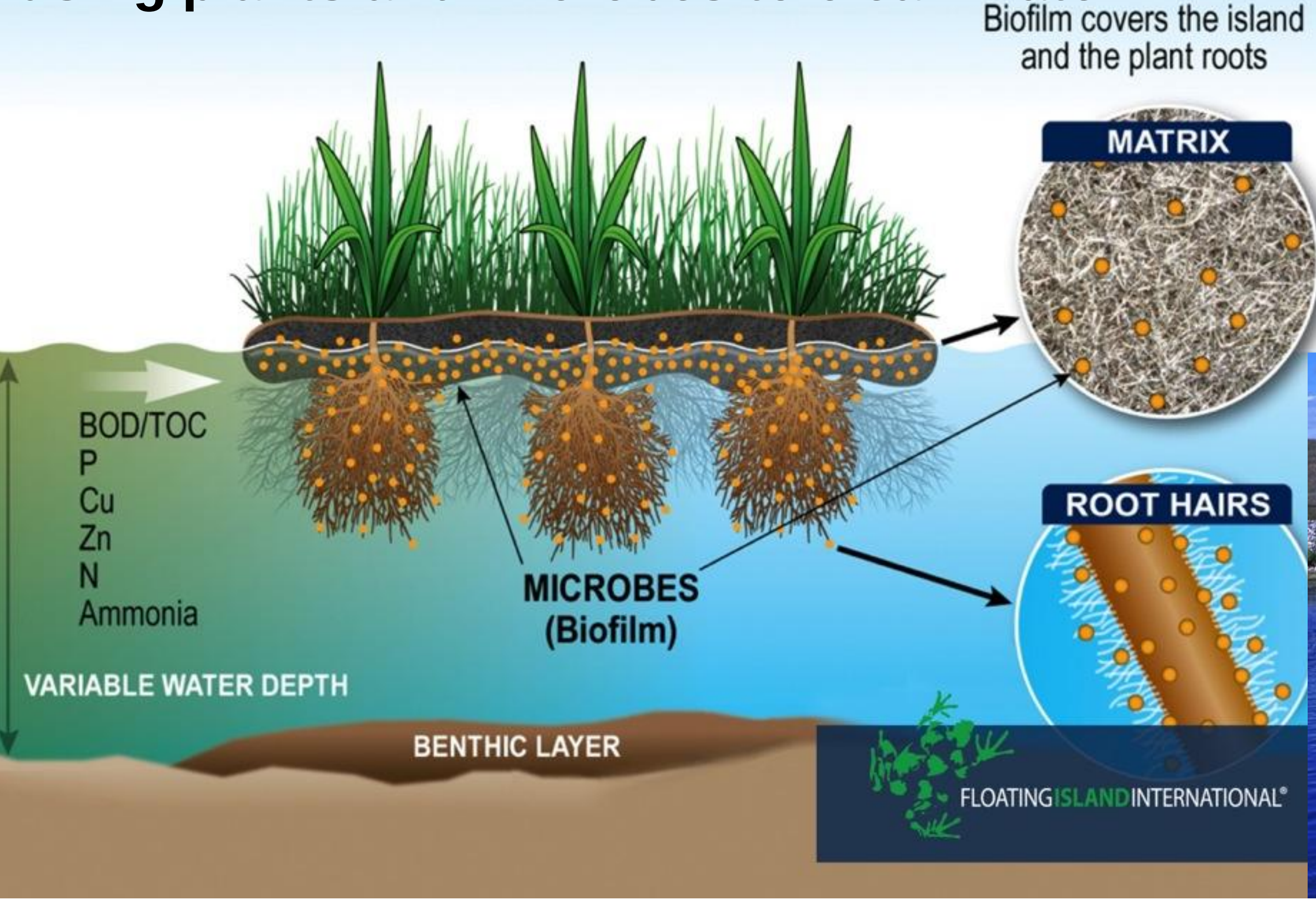
# Bioremediation:
# using plants and microbes to clean water





Wastewater lagoons

- Ongoing collaborations with the field’s leading scientists
- Novel collection of plant strains for removing heavy metals/metalloids & nutrients
- Endophytic bacterial strains for degrading pollutants (including TCE, PAHs, TPH)

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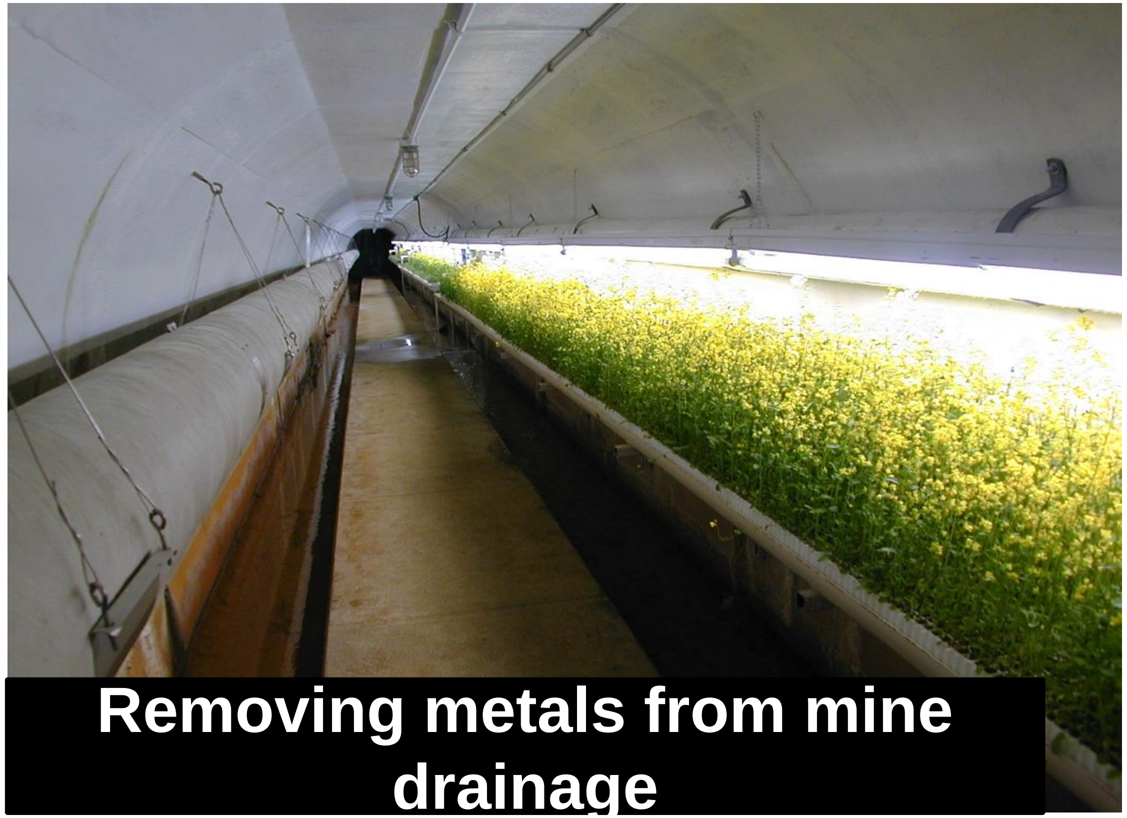
# Remediation of Wastewater Streams:

## Industrial, municipal, and agricultural wastewater

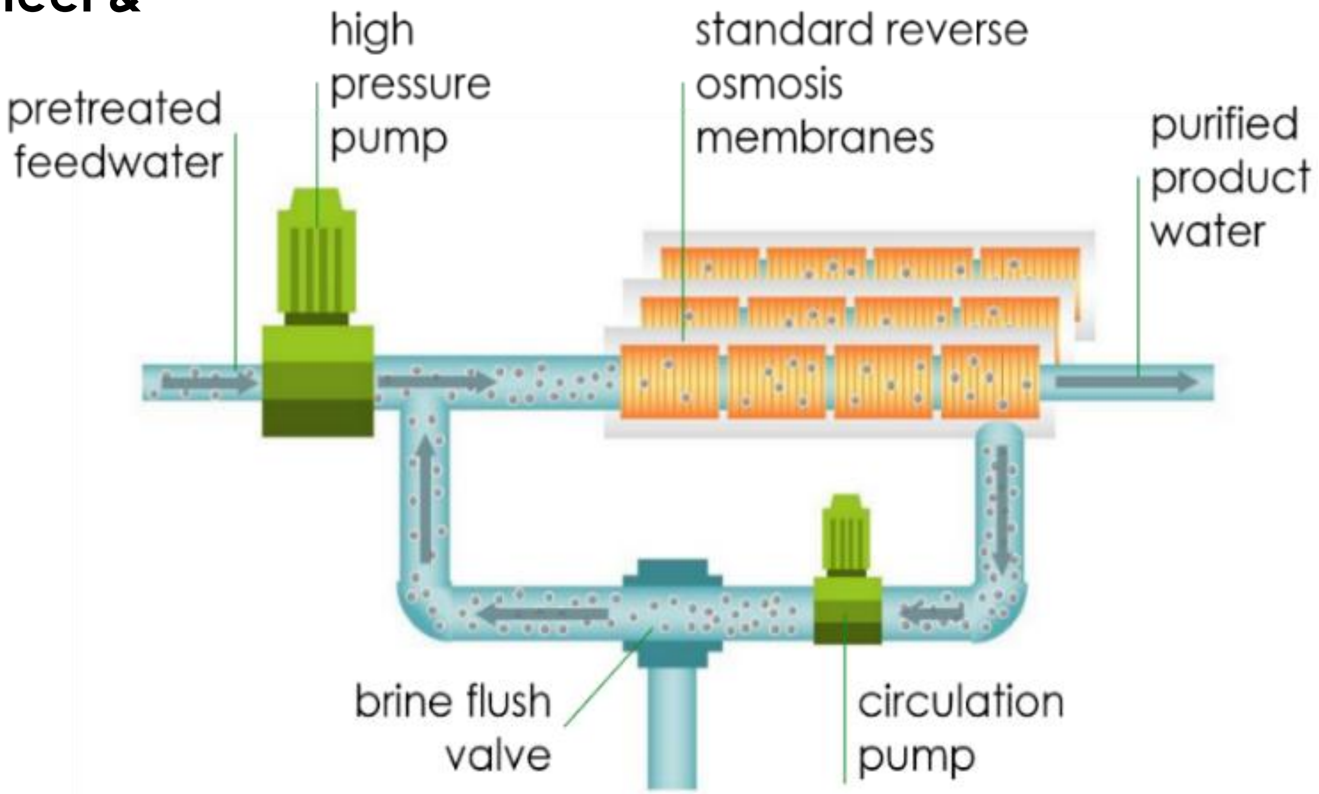


Removing metals from mine drainage

Sewage treatment

# CCD™ Reverse Osmosis – The New RO

*"The ReFlex RO is extremely easy to operate, it's user friendly, I would recommend it to anyone who needs high recovery, minimum man hours and low cost."*
**- Steven Doggit, Lead Operator, Mid-American Steel & Wire**



# Summary

**Maximum recovery** - Up to 98% = 50 – 80% reduction in water waste and disposal

**20 – 35% reduction in energy consumption**
Operates near thermodynamic minimum

Major Savings

**Increased reliability** and lowest OPEX through reduced scaling and fouling

**Unmatched flexibility** for changing water conditions and requirements

Stabilizing & Streamlining Production

**Standard components**, competitive CAPEX

**Patented**

**Fortune 500 companies** around the world rely on the consistent performance and ease of operation of their Desalitech RO solutions.

PALL Coca-Cola Cargill VEOLIA SAB MILLER Unilever P&G Procter&Gamble ADM L'ORÉAL MillerCoors SOUTHERN CALIFORNIA EDISON An EDISON INTERNATIONAL Company Kimberly-Clark Novelis HERSHEY'S

Desalitech

Stanford | Codiga Resource Recovery Center

# Resiliency through Resource Recovery From Wastewater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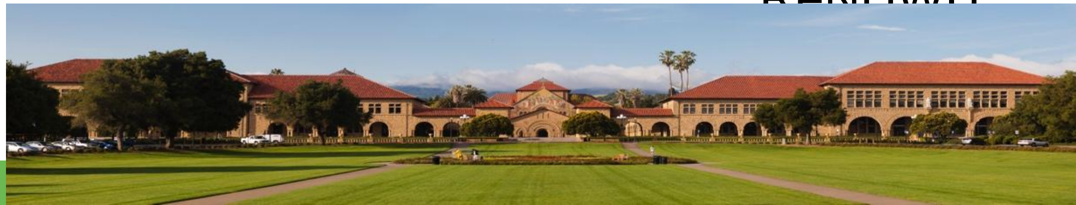
ReNUWIT

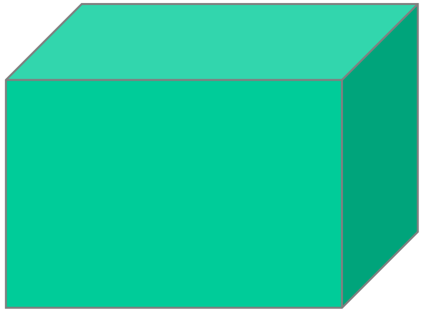

ReNUWIt
Re-inventing the Nation's
URBAN WATER
INFRASTRUCTURE

Woods Institute
for the Environment
Stanford University

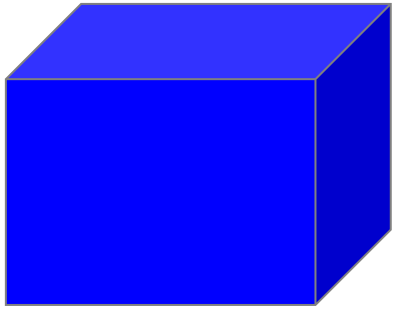


# The value of the water

| Resource | Product Recovered | Value-added Product Recovered | US \$ per m³ | US \$ Per MG |
|---|---|---|---|---|
| 1 m³ wastewater | 1 m³ clean water | 1 m³ for agriculture (CA 2015 drought conditions) | 0.90 | 3,400 |
| | | 1 m³ potable (US average 2014) | 1.50 | 5,700 |



***One m³ of wastewater***



***One m³ of clean water***

$0.90

$1.50

**In California, 43 wastewater treatment plants discharge 1,350 MGD of treated effluent to the Pacific Ocean.**

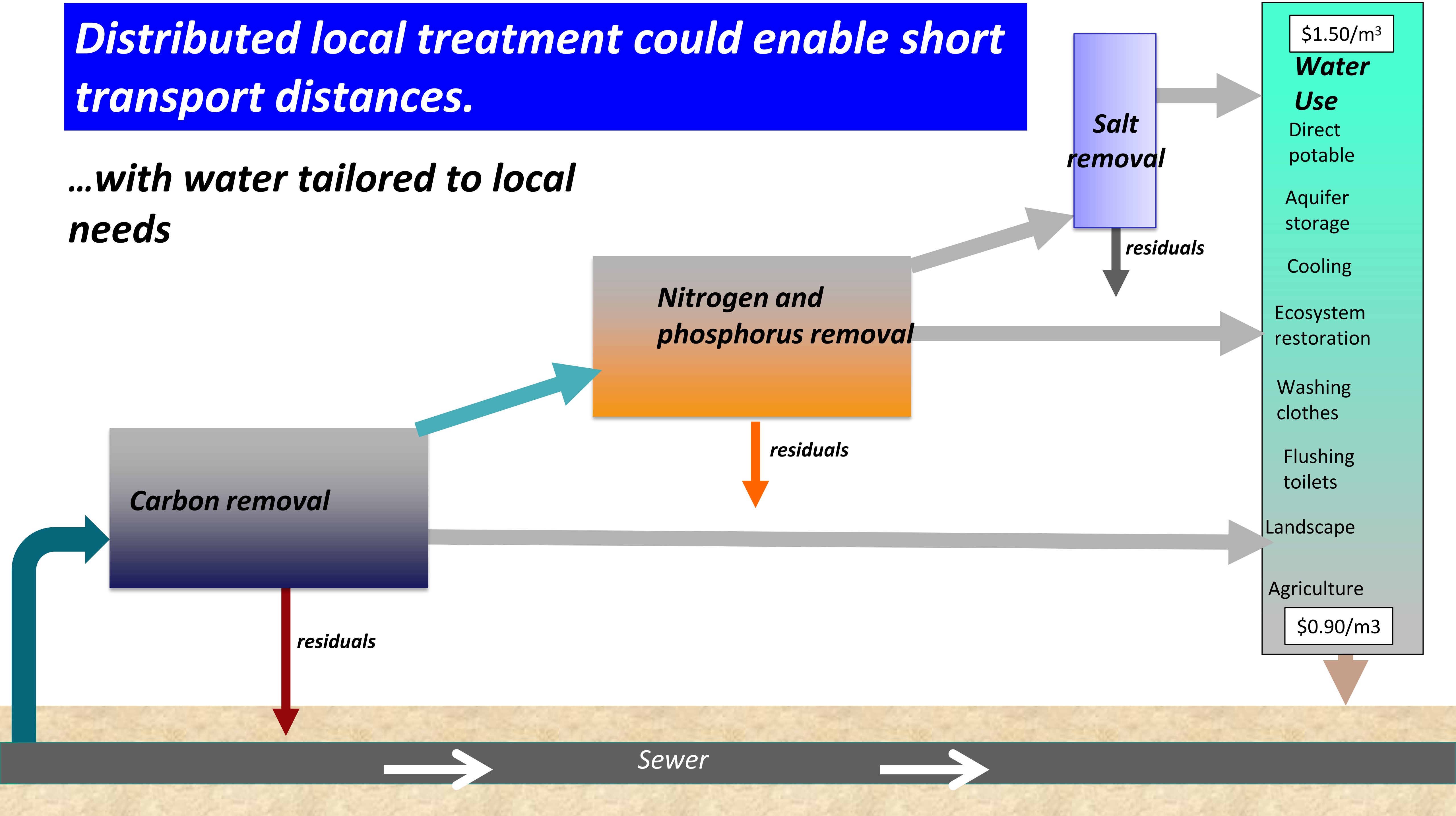
**If used for drinking water, that water would be worth $7.7 million/day.**

# The William and Cloy Codiga Resource Recovery Center, Stanford University

***Established in 2014, the Codiga Resource Recovery Center is a multidisciplinary learning center, dedicated to the development of innovative technologies for recovery of valuable resources from our waste streams.***

# Distributed local treatment could enable short transport distances.

*…with water tailored to local needs*



## *Currently, we only recover energy from suspended organics. How about recovering <u>more</u> energy?*

***Net energy <u>consumed</u> = 0.4-0.6 kWh/m$^3$***

*Energy used here*

*Primary treatment*

*Dissolved organics*

*Wastewater*

*Suspended organics*

*Currently*

*Aerobic bioreactor*

*1 kWh of electrical energy delivers 1 kg of oxygen*

*Settled Biosolids*

*Biogas*

*Energy produced here*

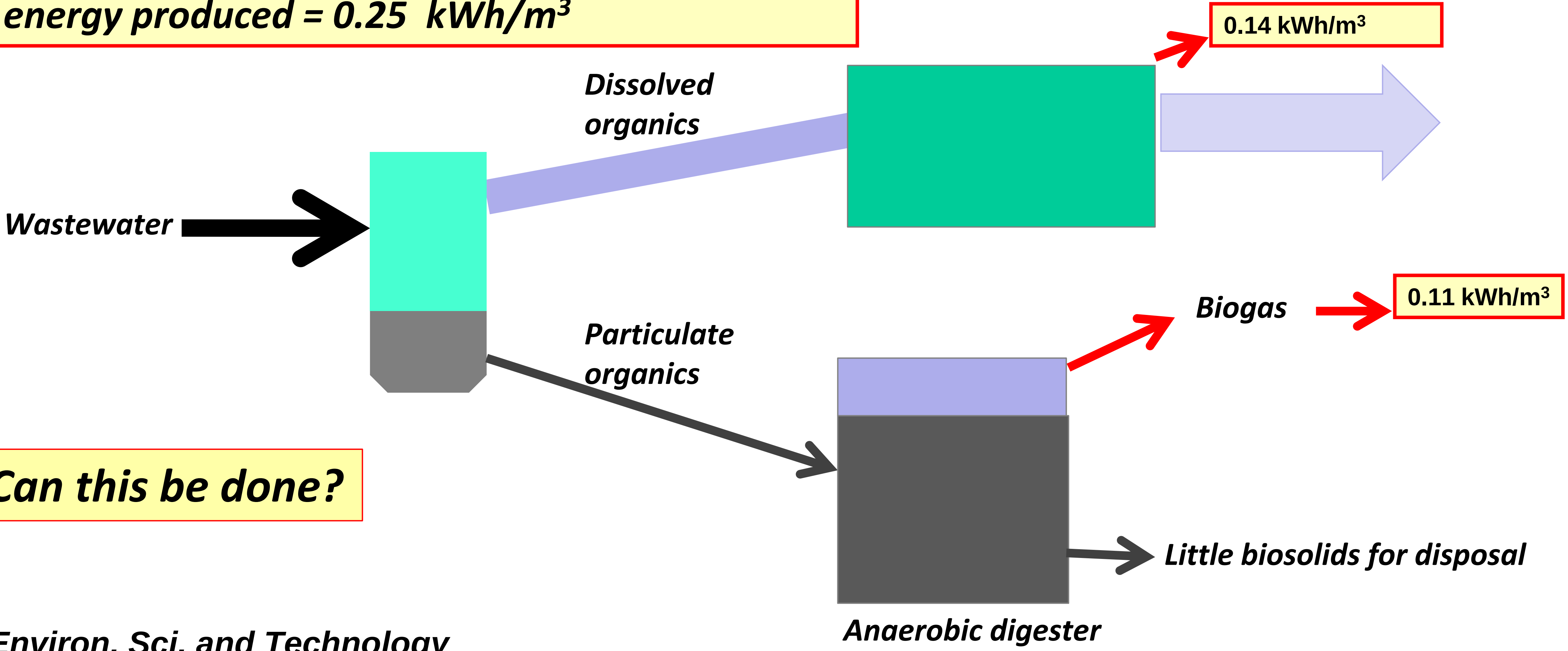
*Anaerobic digester*

*Stabilized solids*

~0.1 kg/m$^3$

## *If energy is recovered from dissolved organics, the energy balance flips.*

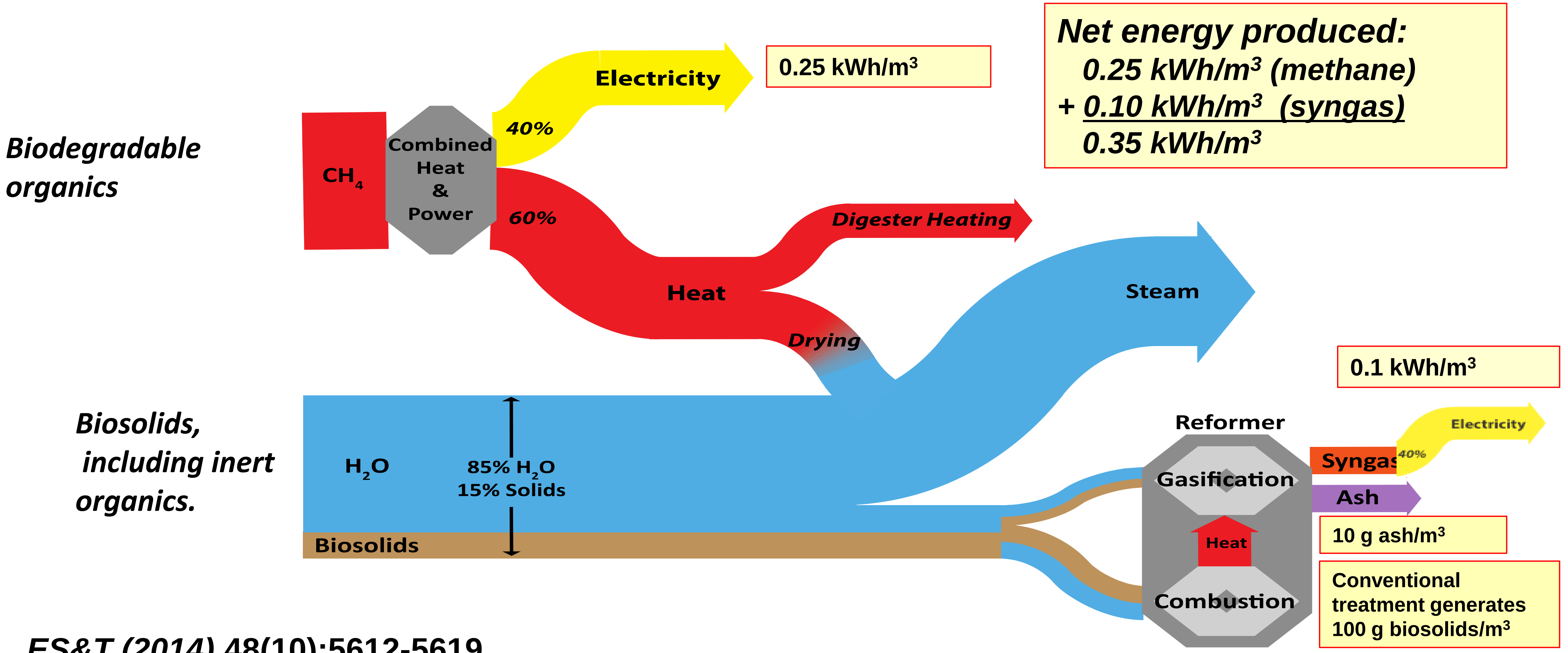
***Net energy produced = 0.25 kWh/m³***




***Can this be done?***

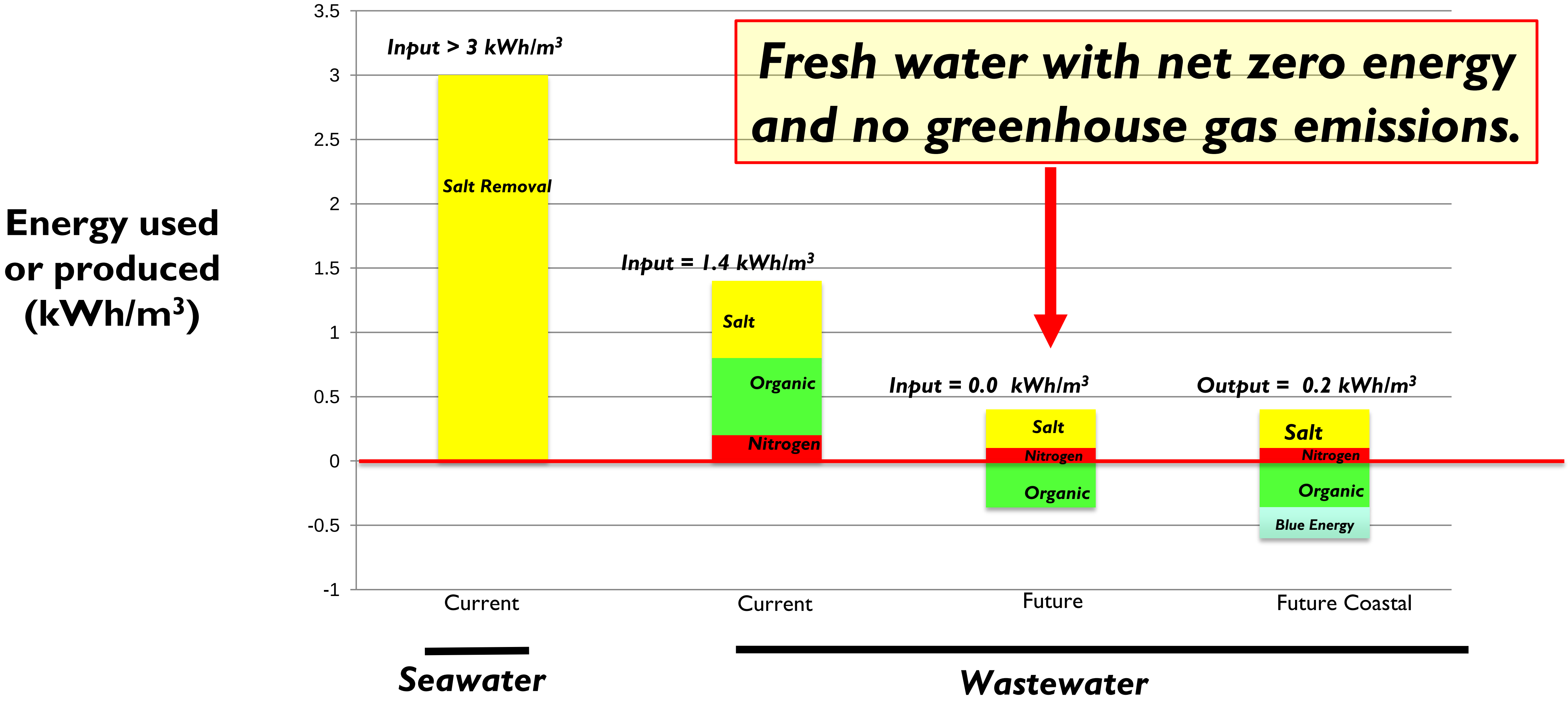
*Environ. Sci. and Technology (2014) 48(10):5612-5619.*

**The additional heat and the small quantity of biosolids produced enables complete drying. The dried biosolids can be gasified to syngas for more energy, leaving ash alone for disposal.**




*ES&T* (2014) 48(10):5612-5619.

# If these technologies can be field proofed, the results could look like this:



# Integration: Distributed Smart Grid for $H_2O$

- Integrating sources of water into a human-managed water cycle
- Managing both water supply and demand
- Water sharing within districts/buildings
- Connect with distributed micro-grid energy sources (renewable + storage)

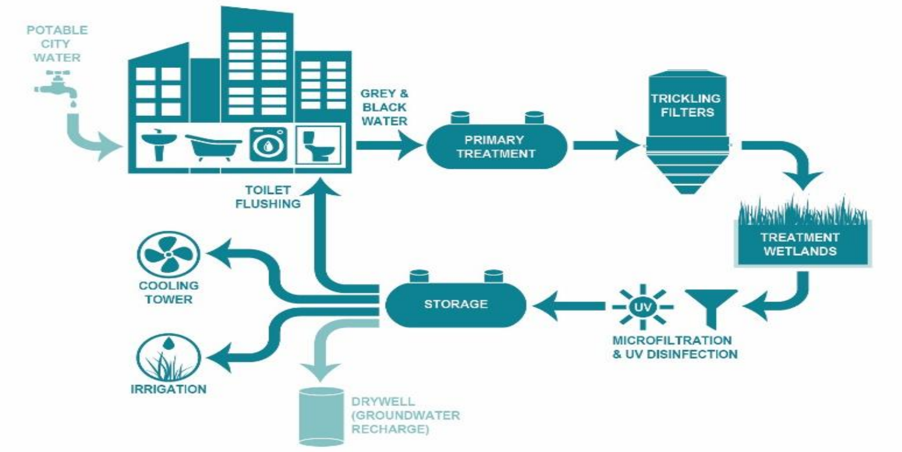
# Hassalo on 8th – Lloyd Ecodistrict Super Block: Portland, OR

## Project Background

- Four block "super block" development in the Lloyd District
- 637 new apartment units and
- 47,000 square feet of retail/commercial space
- Projected completion in Summer 2015

## Wastewater System

- 45,000 gallon wastewater per day
- Treatment steps:
  - primary treatment,
  - trickling filters,
  - tidal flow constructed wetlands,
  - anoxic constructed wetlands,
  - denitrification unit,
  - filtration,
  - disinfection with ozone and ultraviolet light.
- Closed loop system recycles water for toilet flushing, irrigation, and cooling tower make-up.




Project Rendering – Trickling Filters

Image Credit: GBD Architects

# Sidwell Friends Middle School: Washington, DC

## Stormwater System/2006

- Captures runoff from a green roof
- Directs it through a series of artistic flow forms. The flow form sculpture aerates the water to support a healthy ecosystem for pond.
- A recirculation pump sends water back to the flow form for continual treatment and appeal.
- As rain water enters the system, the pond overflows  to floodplain that infiltrates water into the natural environment.

## Wastewater System

- 3,000 gallons-per-day.
- Captures all wastewater (~3,000 gallons per day and cleans it through an onsite system including:
  - series of terraced constructed wetlands,
  - a trickling filter,
  - a recirculating sand filter, and
  - ultra violet (UV) disinfection.
- Closed loop system recycles water for toilet flushing and use in cooling towers.

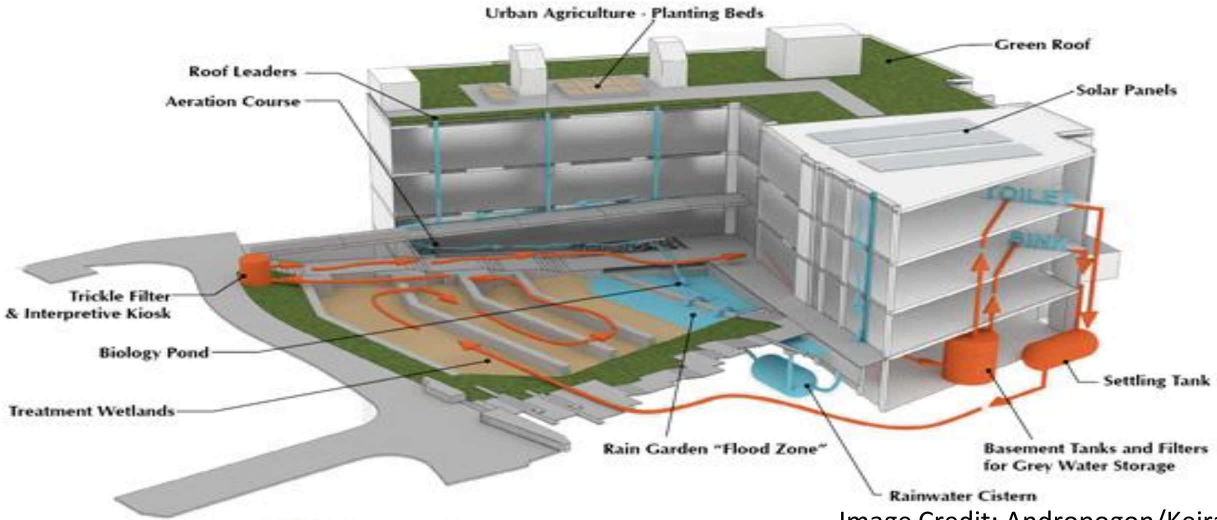
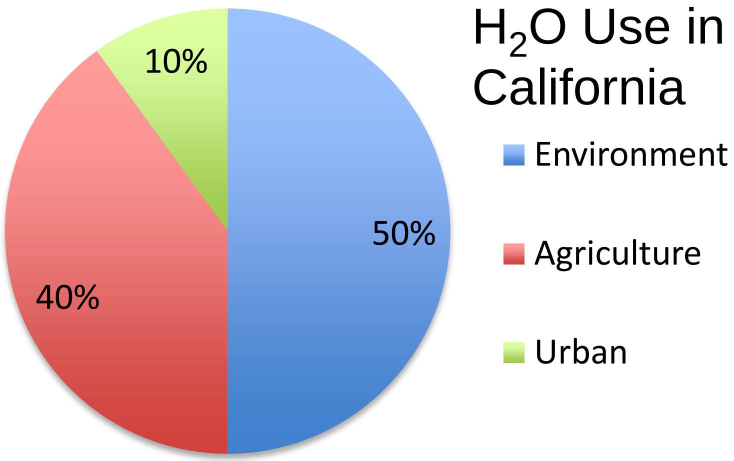



Image Credit: Andropogon/Keiran Timberlake

Wastewater Treatment Wetlands in Front of Middle School

# Policy, Financial and Market Innovation

- Cap and Trade for water rights
  - Rewards water saving practices
  - Makes water wasters pay more
  - Can provide water for the environment
- Finance: PACE, Rebates for Reuse, etc.
- Price water at accurate cost for replacement

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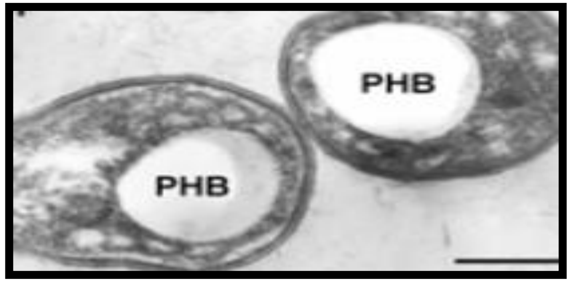
| Resource | Product Recovered | Value-added Product Recovered | US $ per $m^3$ | US $ per 1000 gallons |
|---|---|---|---|---|
| 1 $m^3$ wastewater | 1 $m^3$ clean water | 1 $m^3$ for agriculture (CA 2015 drought conditions) | 0.90 | 3.41 |
| | | 1 $m^3$ potable (US average 2014) | 1.50 | 5.67 |
| 0.3 kg organic | 0.1 kg compost | | 0.01 | 0.04 |
| | 0.1 $m^3$ methane | 0.35 kWh power | 0.04 | 0.16 |
| | 0.07 kg methane | compressed biomethane with 2015 state/fed credits* | 0.08 | 0.32 |
| | 0.07 kg methane | 0.03 kg PHB bioplastic | 0.12 | 0.46 |
| | 0.07 kg methane | 0.06 kg PHB prebiotic fish food supplement | 0.33 | 1.25 |

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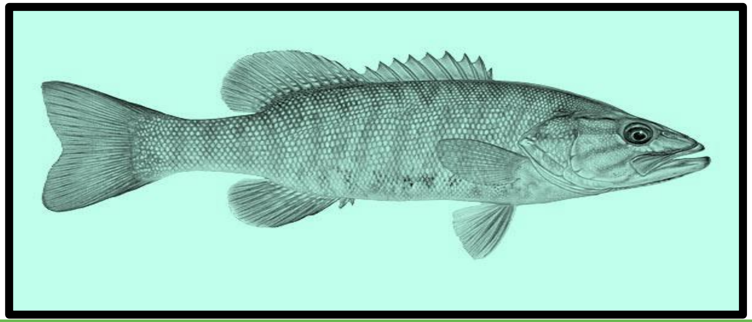
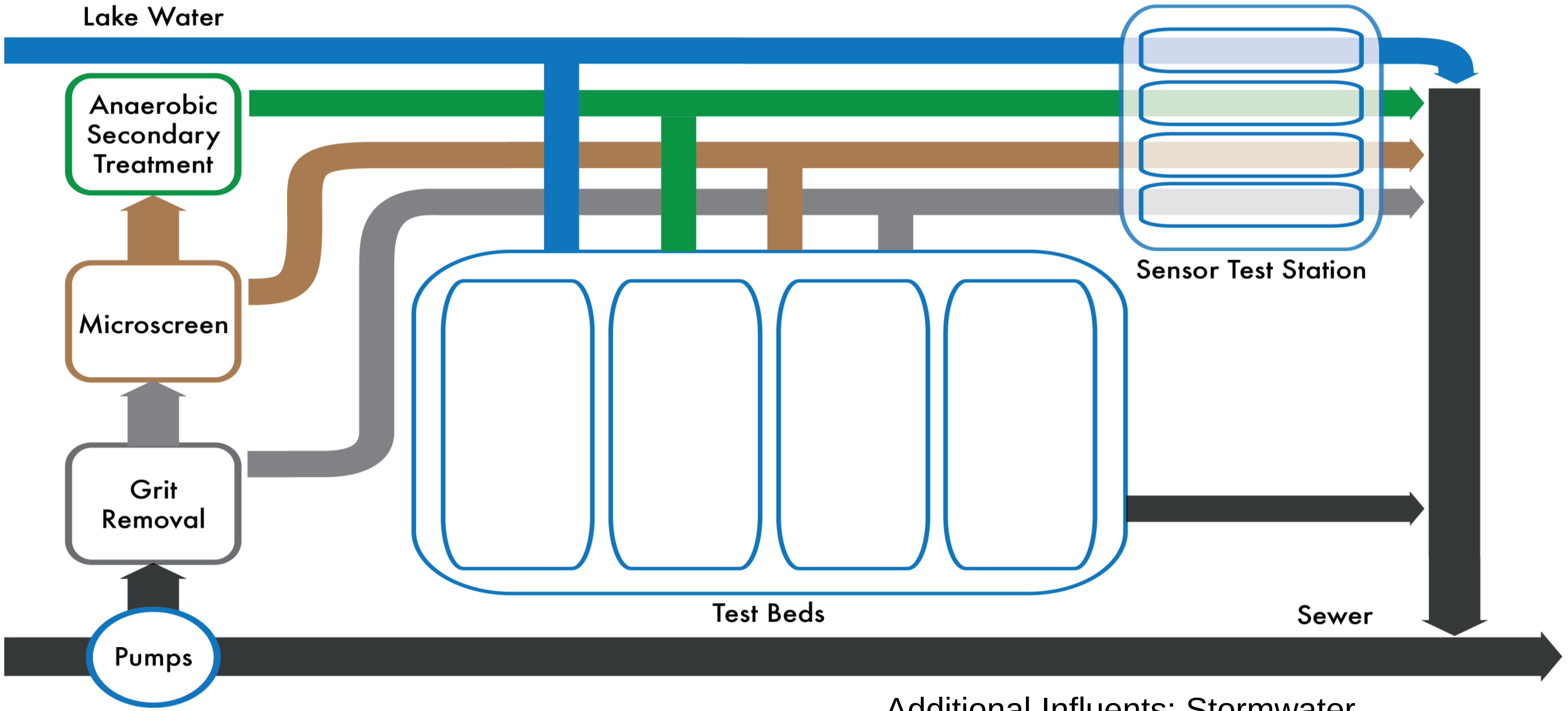


# Test Beds at CR2C




Additional Influents: Stormwater, Industrial Water (future)