U.S. DEPARTMENT OF ENERGY

# WATER "PROCESSING": DYNAMICS, METRICS, SENSORS

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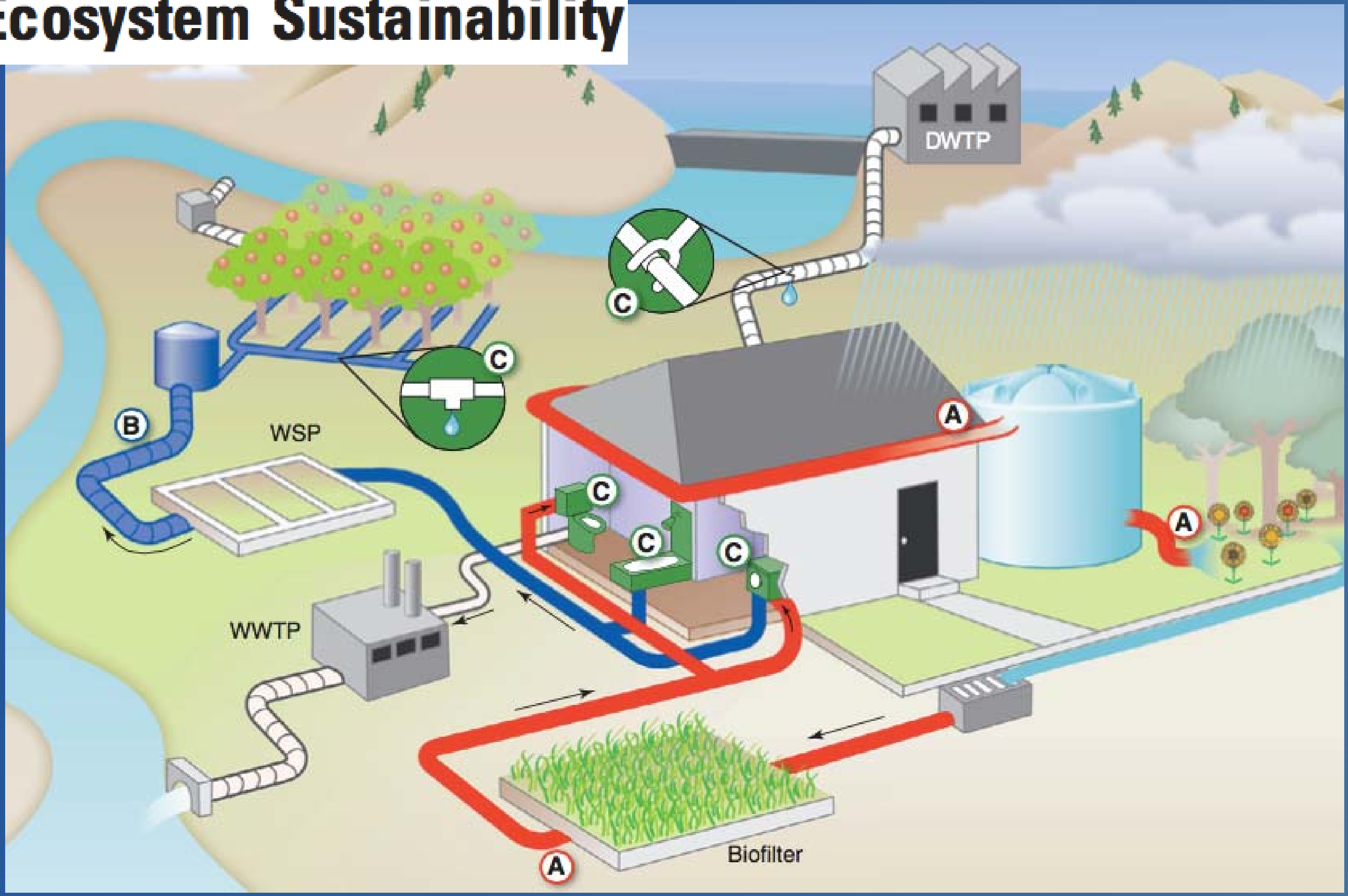
# ENERGY & WATER PROCESSES

REVIEW

# Taking the "Waste" out of "Wastewater" for Human Water Security and Ecosystem Sustainability

**A: SUBSTITUTION**
**B: REGENERATION**
**C: REDUCTION**

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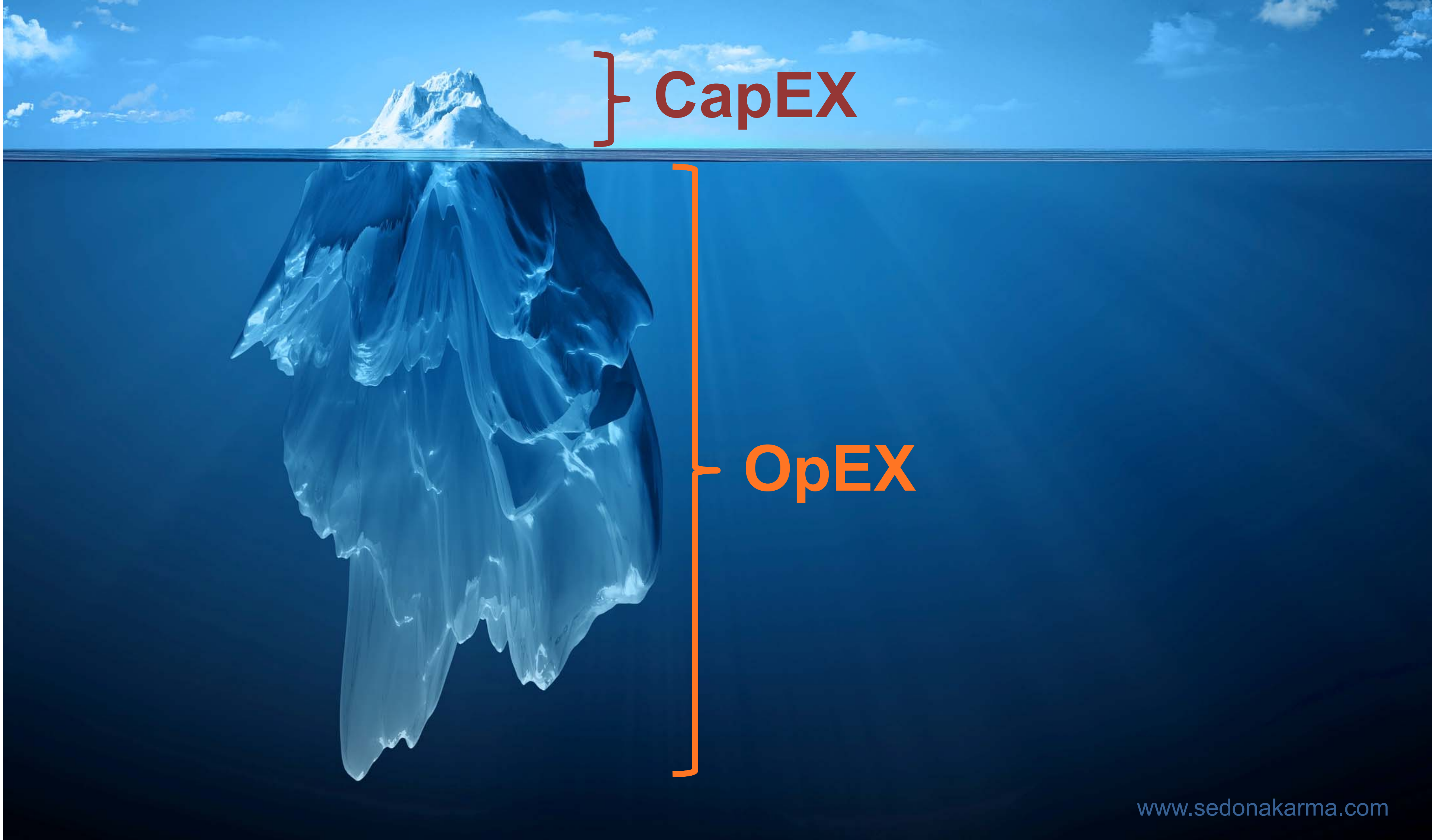
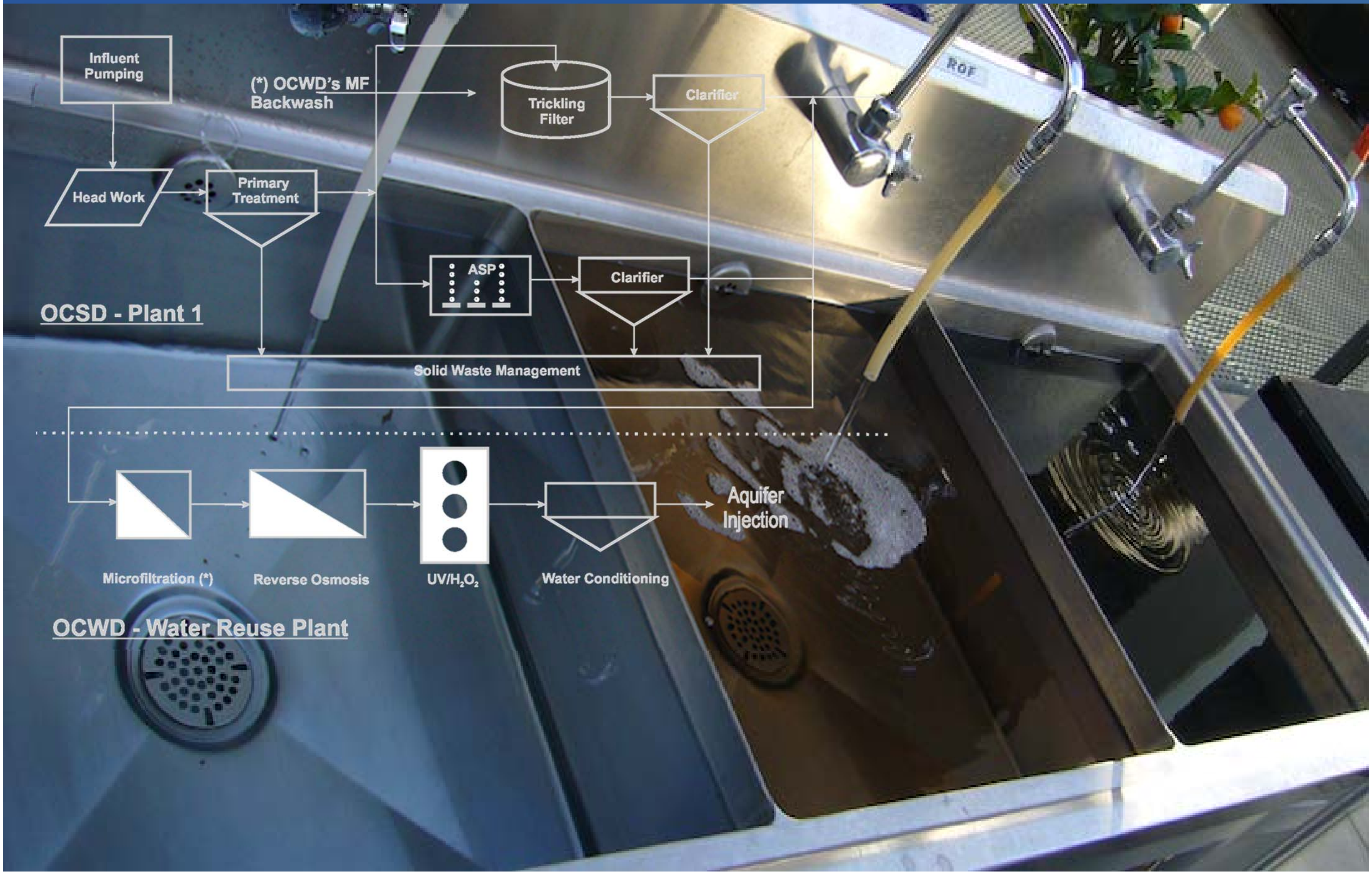
Grant et al (2012) *Science* 337(6095) 681-686

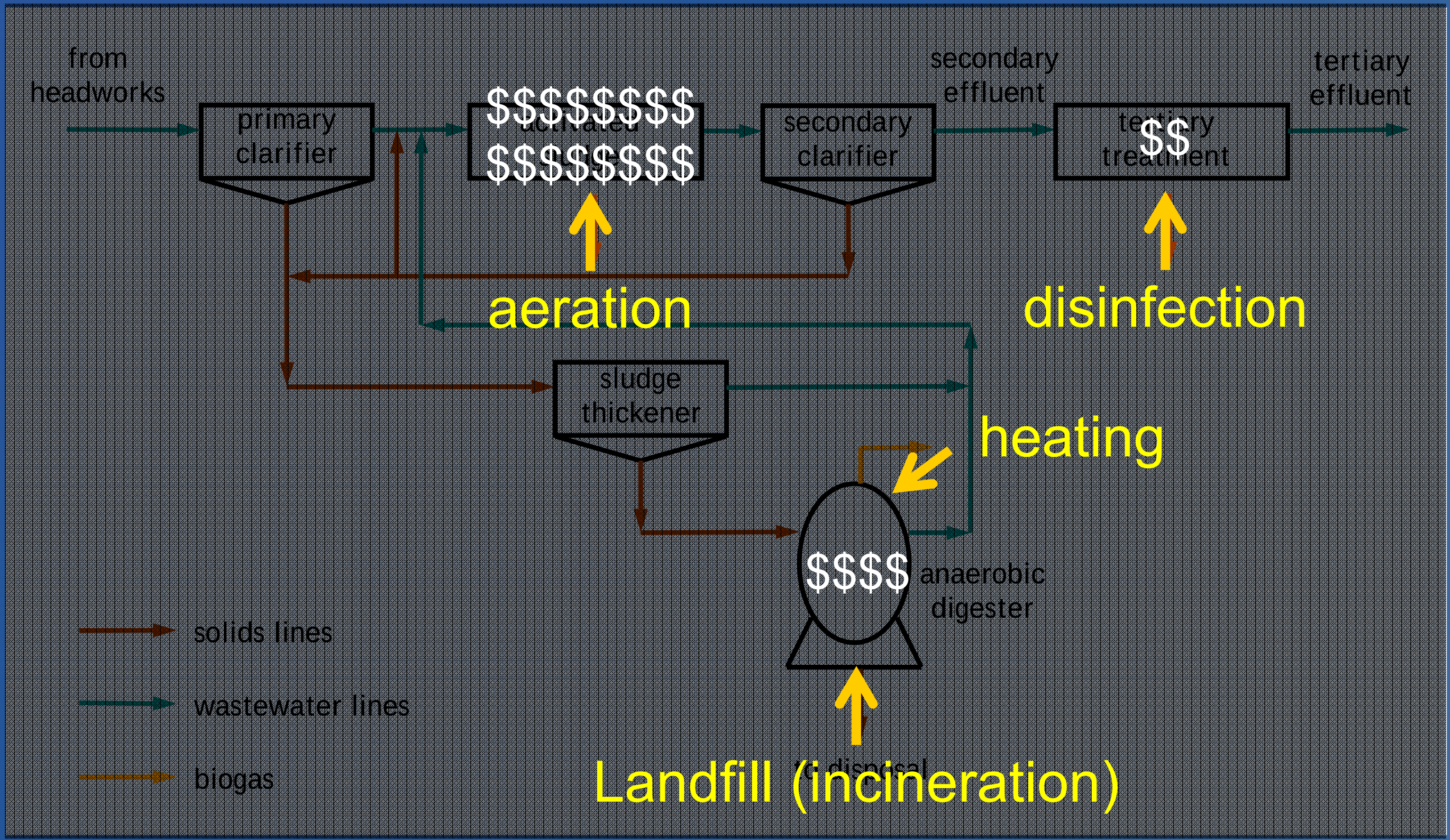
# The Iceberg Paradigm



# CLOSING THE WATER PROCESSING CYCLE



# ENERGY FOOTPRINT




Aeration cost = 45-75% of plant energy (w/o influent/effluent pumping)

Rosso and Stenstrom (2005) *Wat. Res.* 39: 3773-3780

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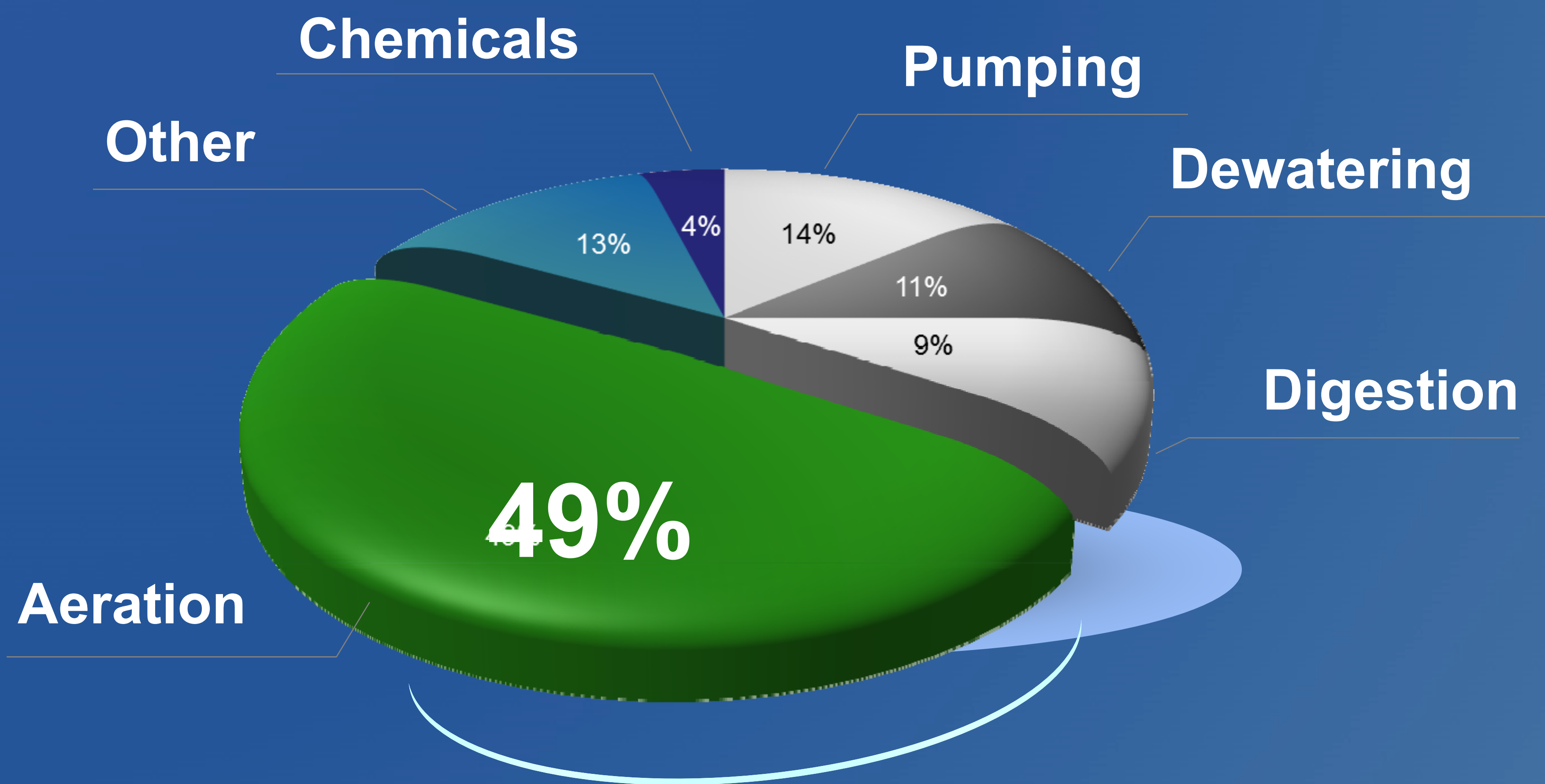
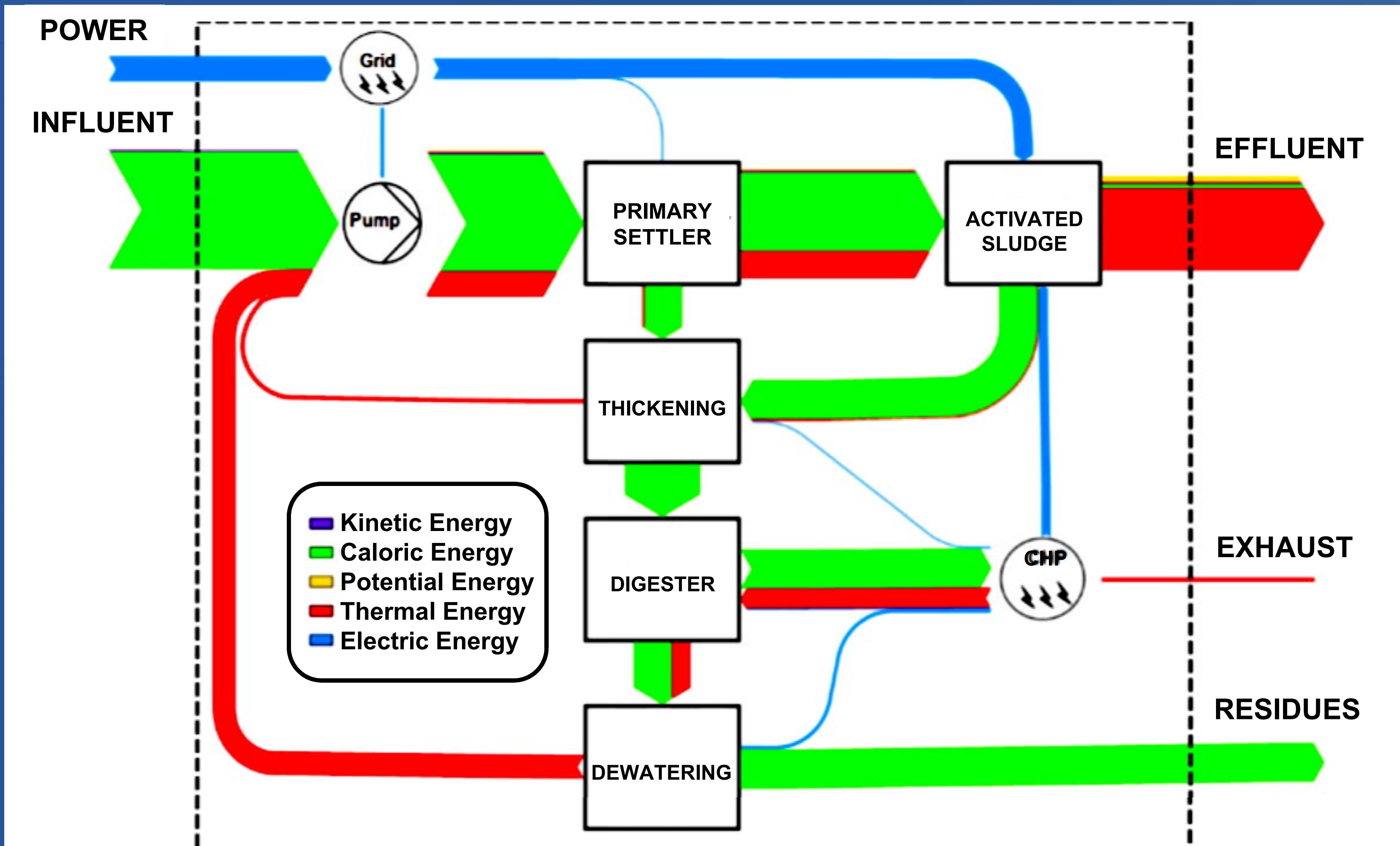
# ENERGY & WRRF




(WEF MOP32, 2009)

# Many forms of energy in WW

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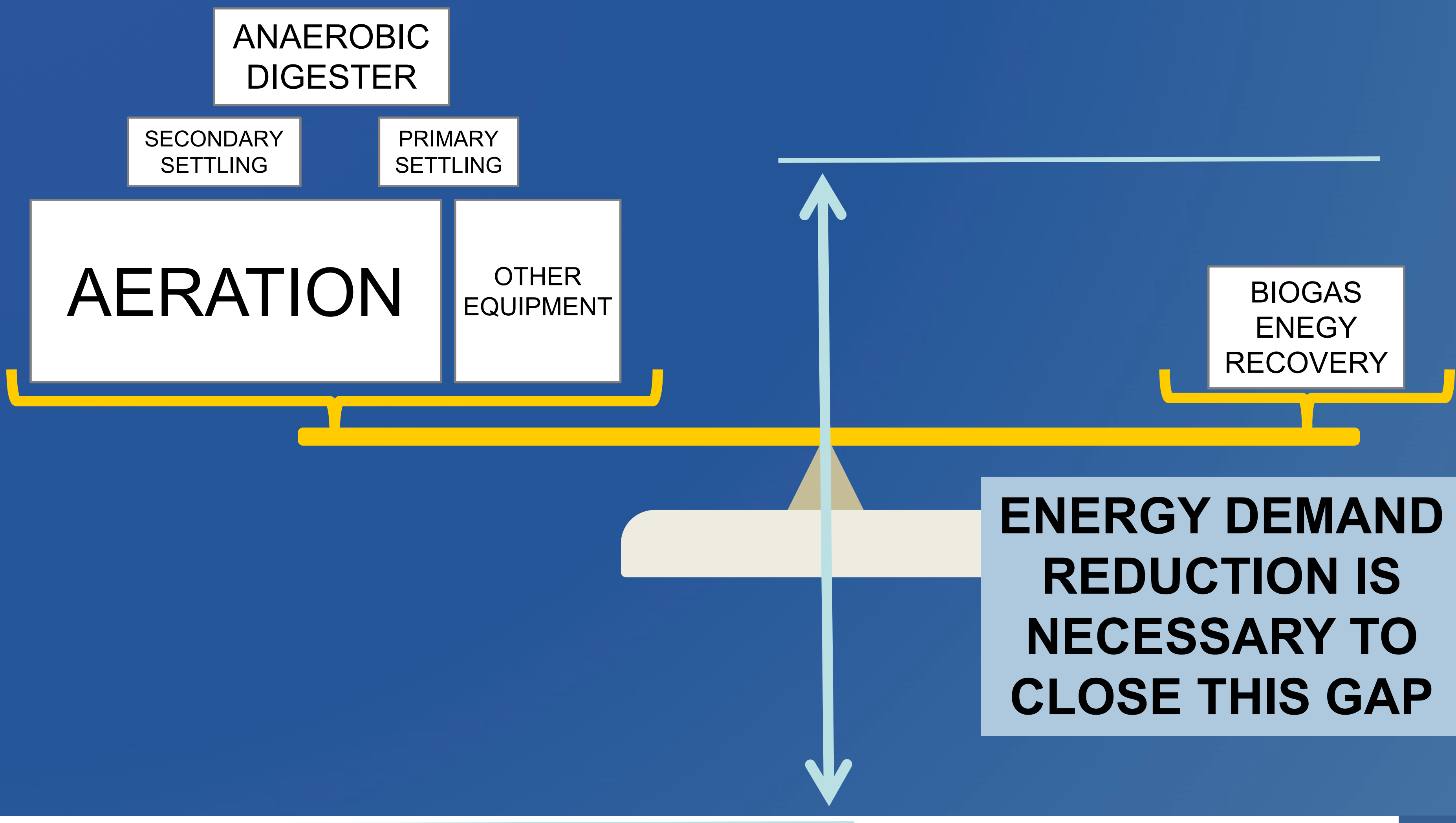
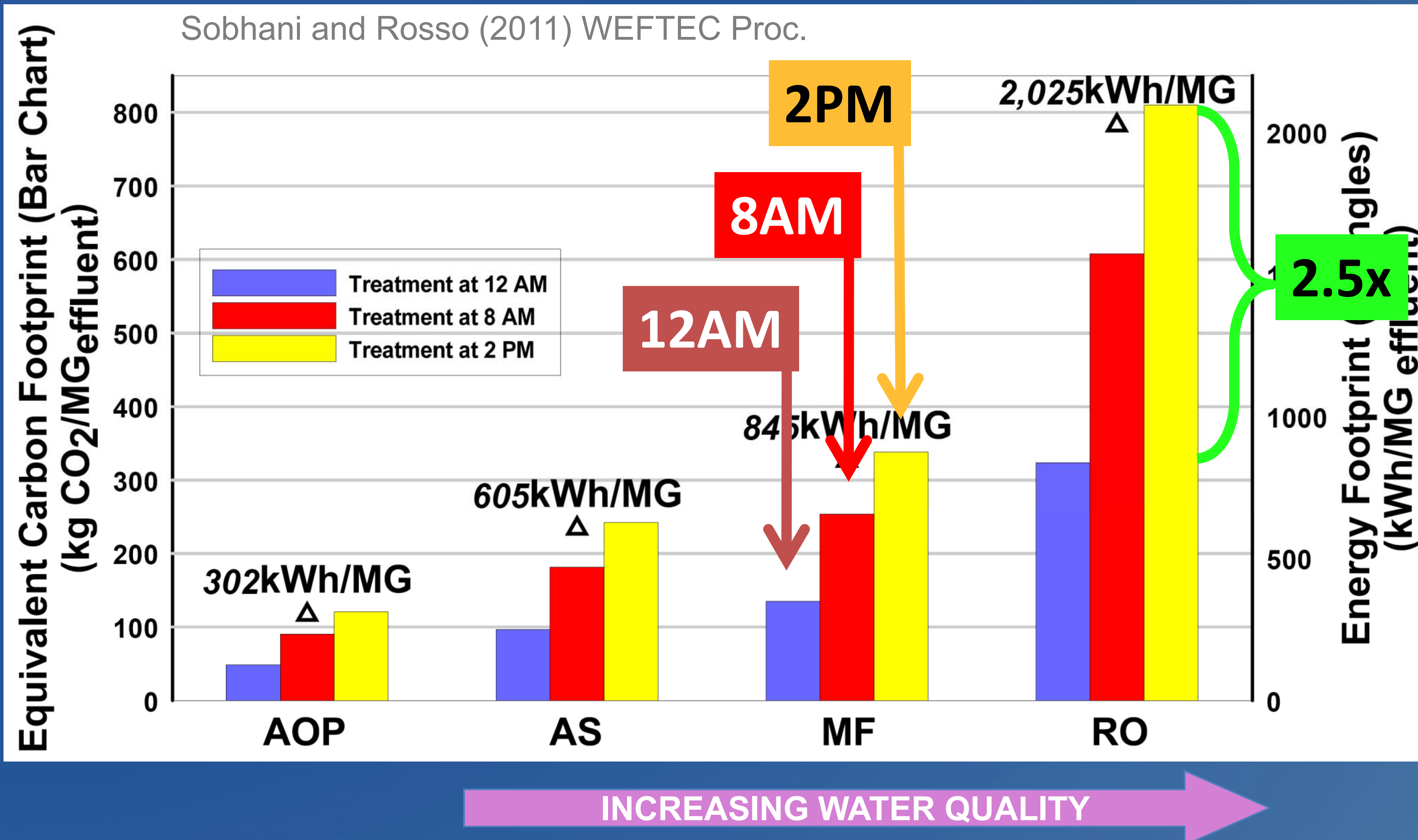
Adapted from Wett (2016) *IWA/WEF WWTmod*

# BALANCE


ANAEROBIC DIGESTER
SECONDARY SETTLING
PRIMARY SETTLING
AERATION
OTHER EQUIPMENT
BIOGAS ENEGY RECOVERY
ENERGY DEMAND REDUCTION IS NECESSARY TO CLOSE THIS GAP

# Energy Intensity in Water Reuse




NORMALIZED METRICS DO NOT NECESSARILY REFLECT ACTUAL IMPACT

# INFORMATION IS POWER

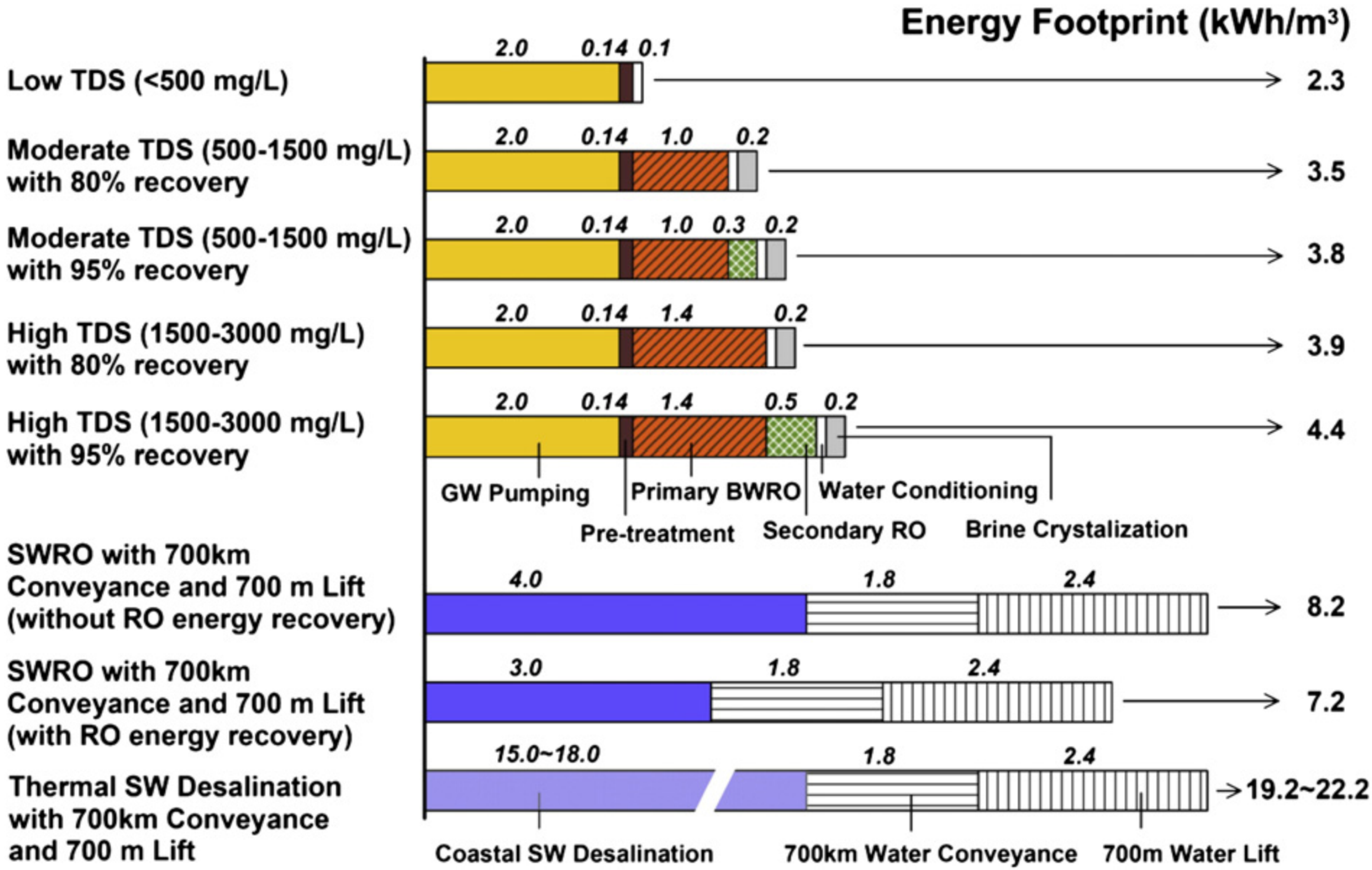
$$eFP_{TOT} = \sum_{i=1}^{n} eFP_i = \sum_{i=1}^{n}\sum_{j=1}^{m} n_j \cdot p_j \cdot \eta_j \cdot t_j$$

Rosso et al (2012) Wat. Practice Technol.

#units power efficiency time in operation

| Information Available | Modelling Nature | Difficulty to Gather | Margin for Improvement | Data Availability |
|---|---|---|---|---|
| Power bill | Cumulative | Easy | Small | Very common |
| Power by unit | Static | Moderate | Moderate | Rare |
| Power by Time-of-use (TOU) | Dynamic | Difficult | Large | Very rare |

# Water-Energy-Efficiency



# BIG CHALLENGES

WATER RESEARCH 81 (2015) 113–123

Available online at www.sciencedirect.com

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ELSEVIER

WATER RESEARCH

**The difference between energy consumption and energy cost: Modelling energy tariff structures for water resource recovery facilities**

CrossMark

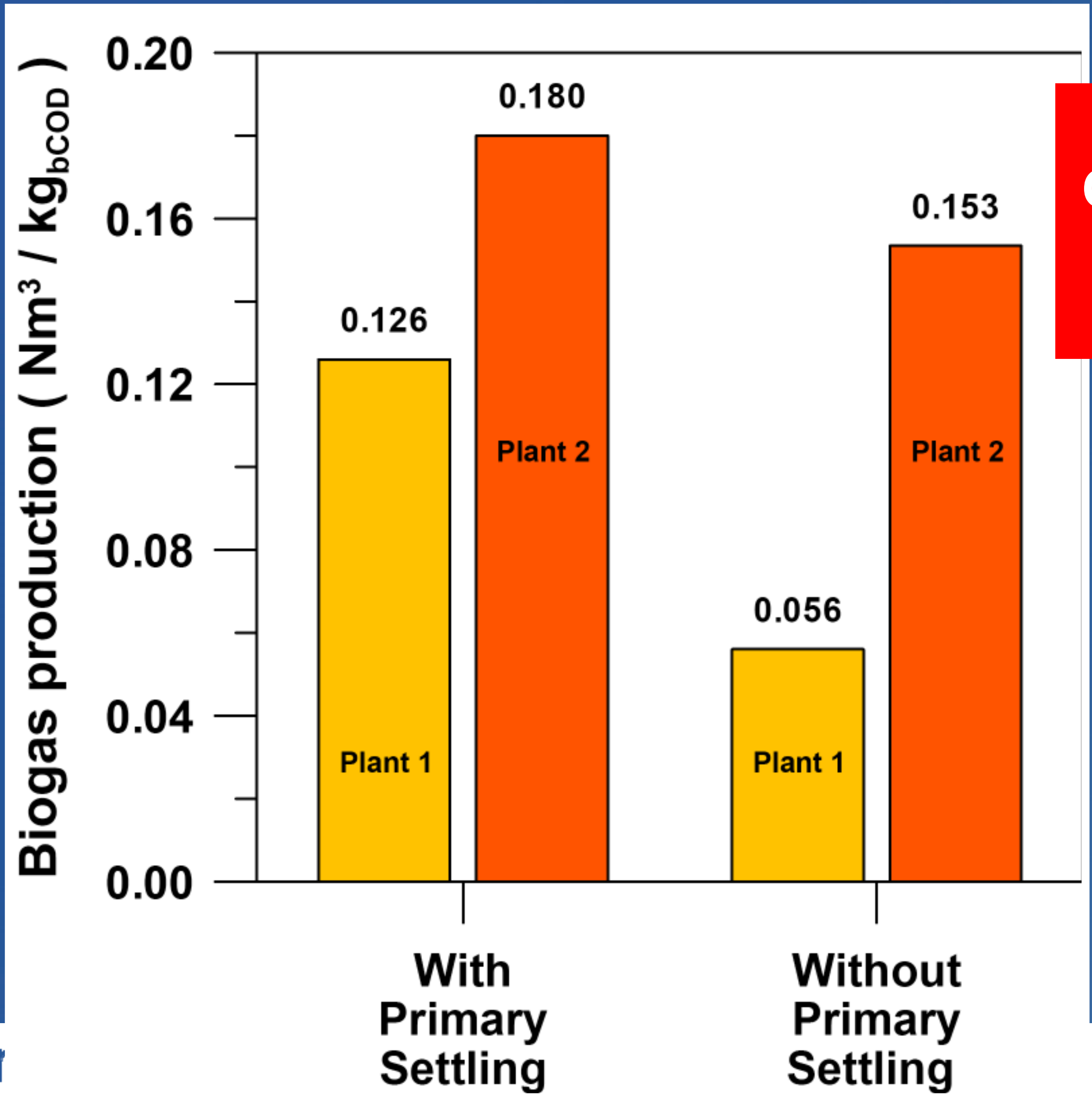
- IS ENERGY INTENSITY A GOOD INDICATOR?
- WHAT ABOUT POWER DENSITY?
- SHOULD THE OVERALL ENERGY COST BE THE METRIC?
- THE ADVENT OF RELIABLE AMMONIA SENSORS
- REAL-TIME AERATION EFFICIENCY MONITORING

# PROCESS ANALYSIS AND AUDITS

# The cost of inefficient primaries

Biogas production with and without primary settling

Gori et al (2013) Wat. Sci. Technol.




**REMEMBER: CHALLENGES IN FLOW METERING**

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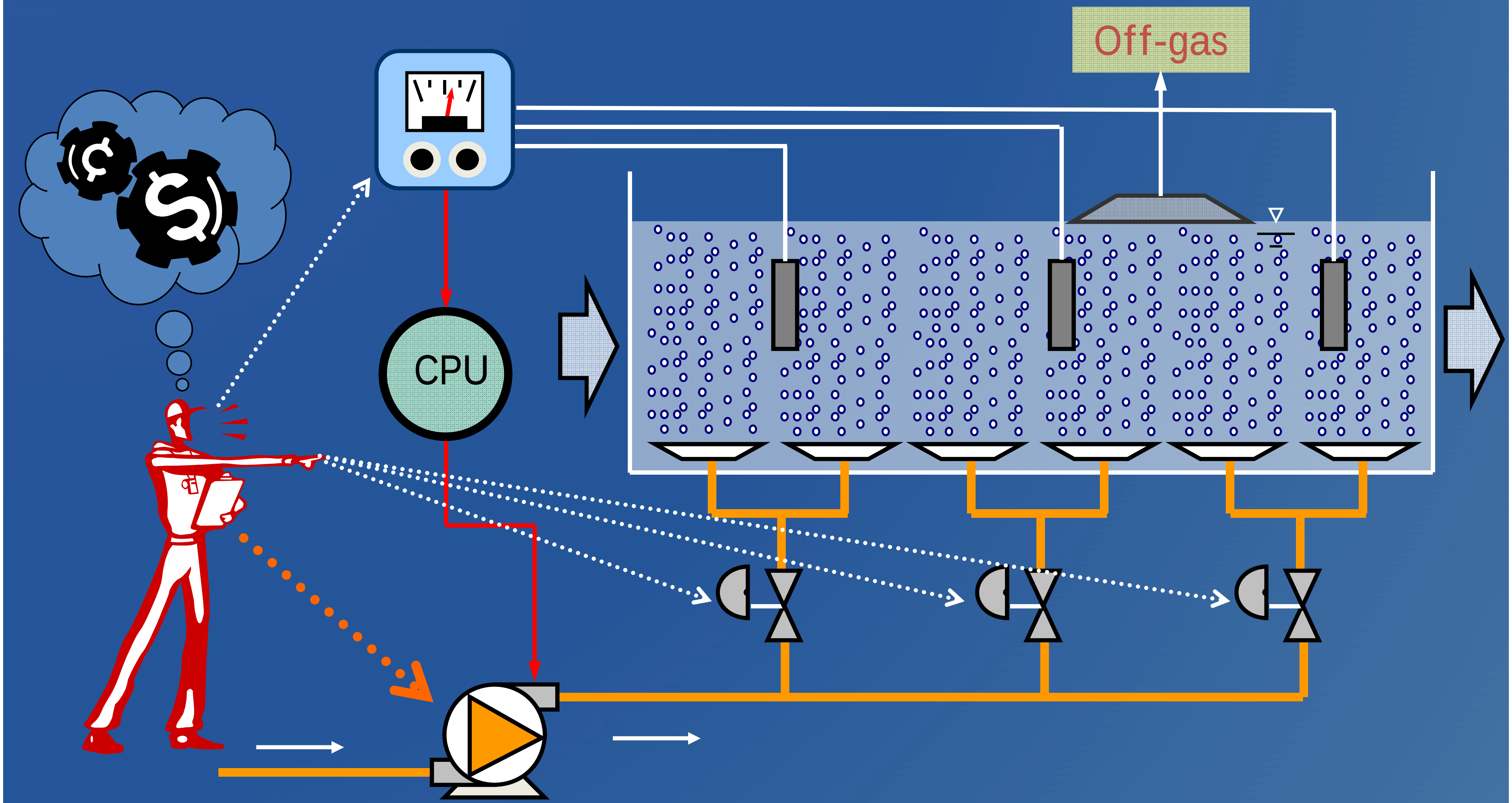
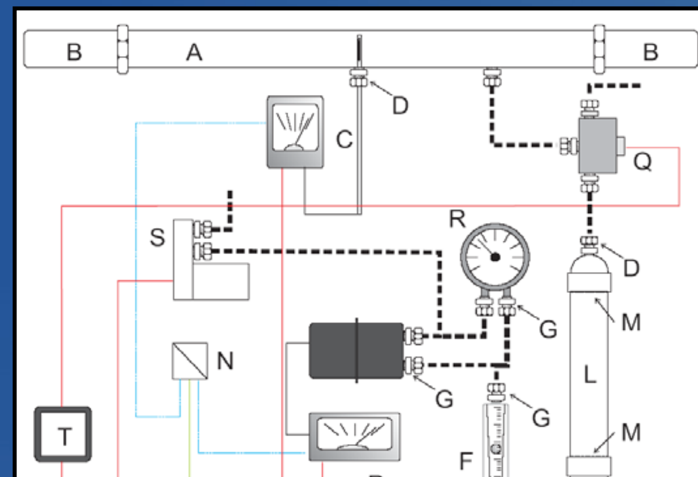
# GAS SENSORS ARE MORE THAN HOT AIR




$$OTR = (k_L a \cdot V)\,[C_{sat}-(DO_{exc}+DO_{needed})] = kg_{O_2}/d = \$\$\$/d$$

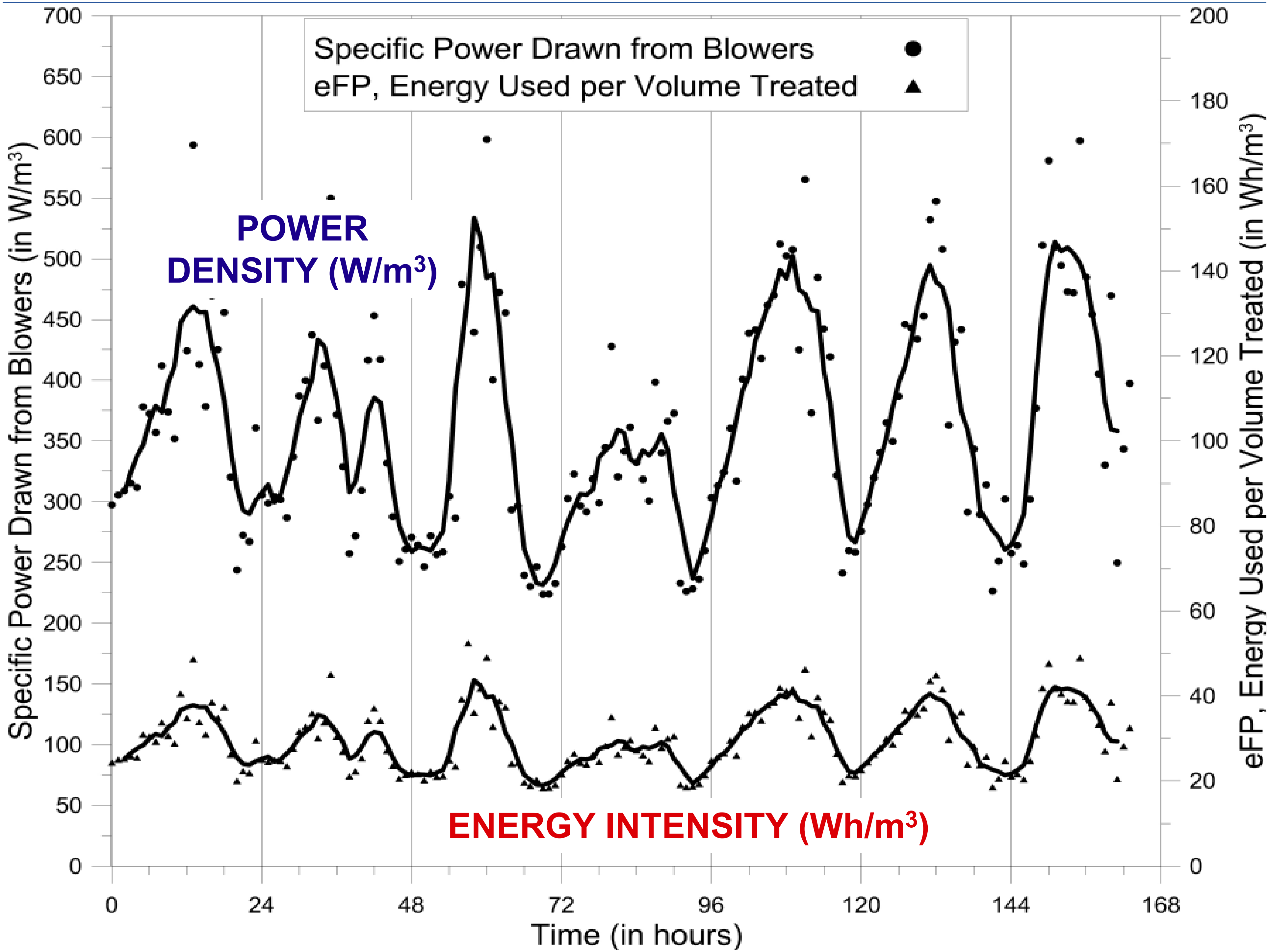
# Real-Time Off-Gas Analysis




- These analyzers provide measurements necessary for aeration efficiency improvement and aeration energy savings
- Gas analyzers can provide real-time measurement of aeration energy
- No fouling issues

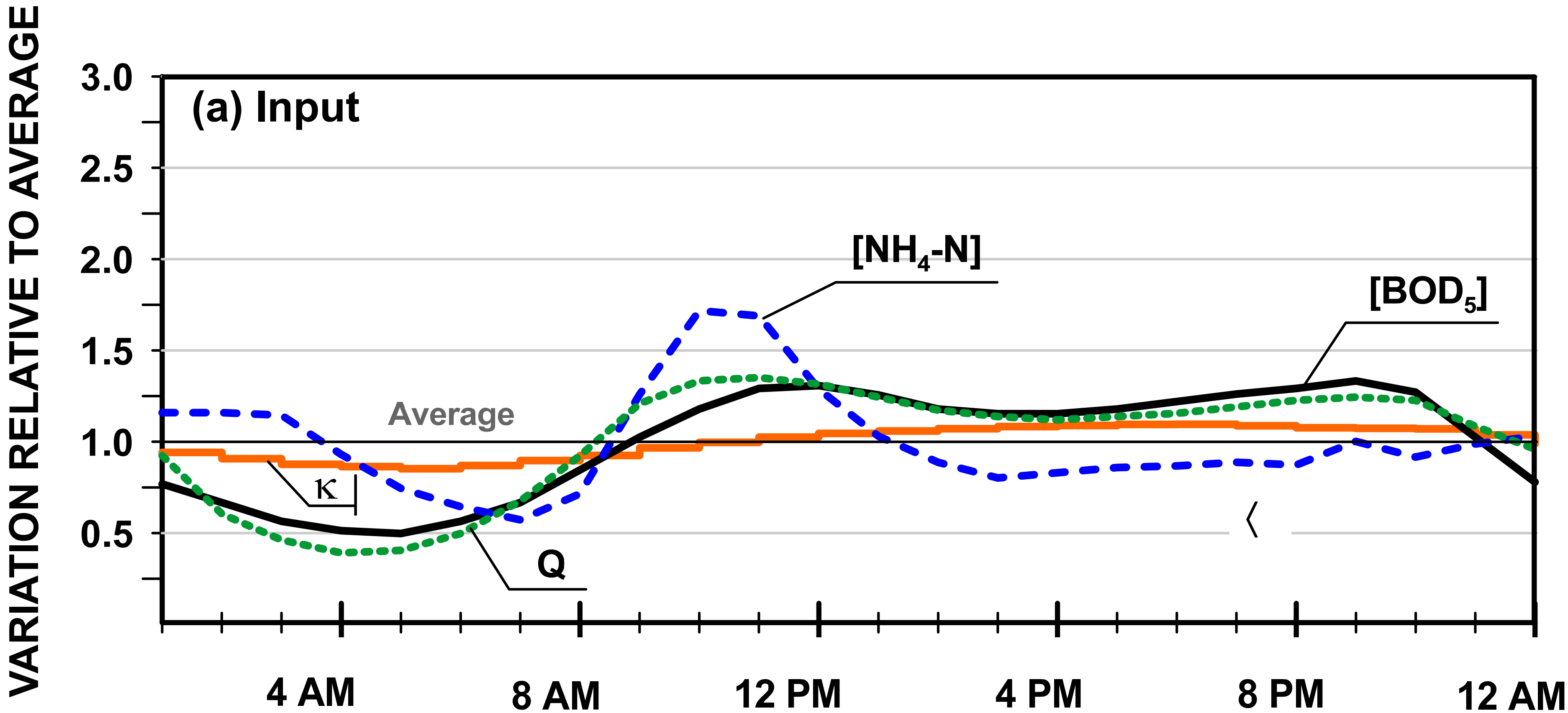


Leu et al (2009) *Wat. Environ. Res.*



Specific Power Drawn from Blowers
eFP, Energy Used per Volume Treated
POWER DENSITY (W/m³)
ENERGY INTENSITY (Wh/m³)
Specific Power Drawn from Blowers (in W/m³)
eFP, Energy Used per Volume Treated (in Wh/m³)
Time (in hours)
0
24
48
72
96
120
144
168
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
20
40
60
80
100
120
140
160
180
200

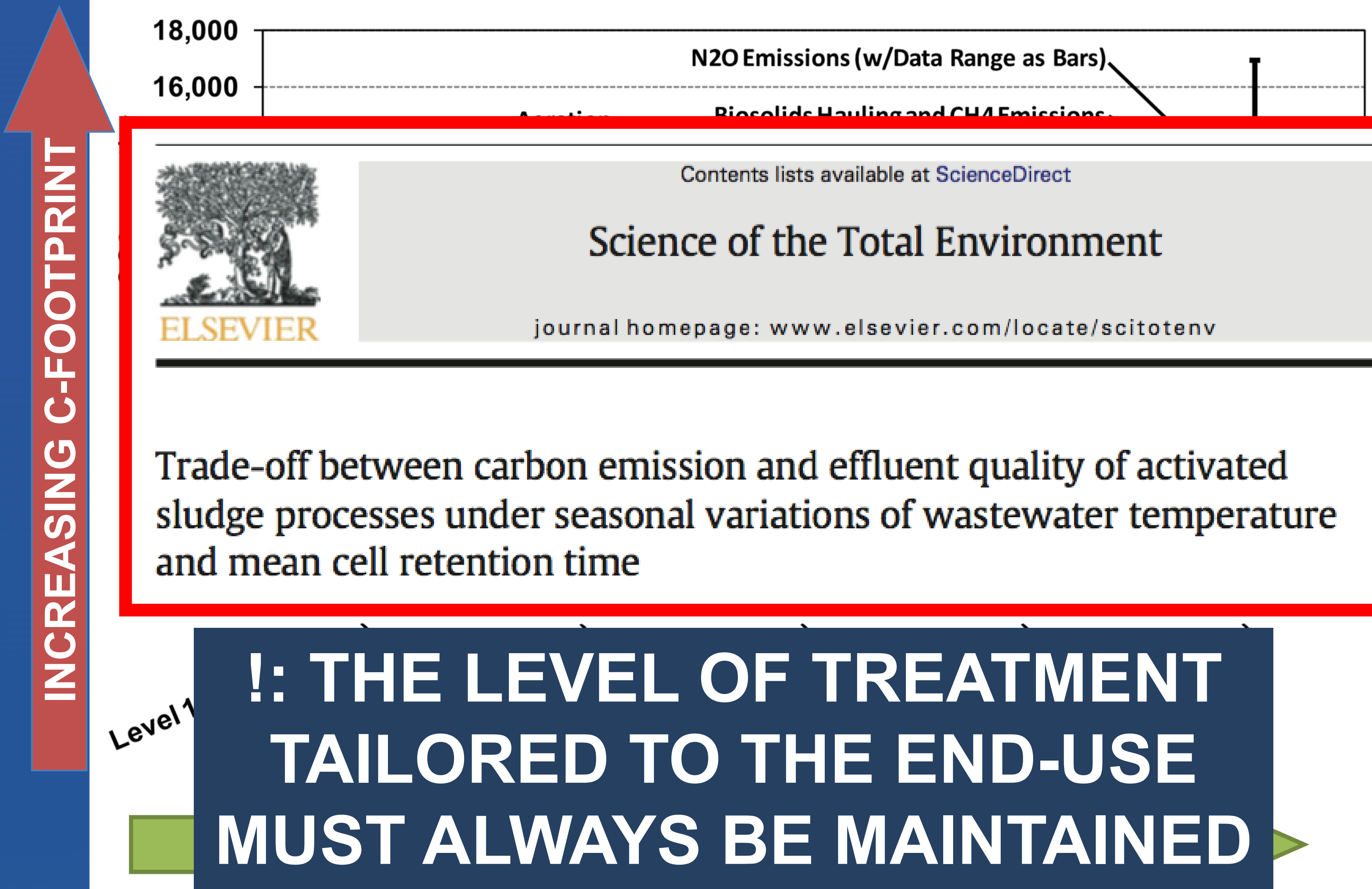
# Activated Sludge Process: Diurnal Dynamics




**IMPORTANCE OF PROCESS DYNAMICS: POWER vs. ENERGY**

**POWER DEMAND CHARGES: kW and kVAR**

# TREATMENT vs. CARBON FOOTPRINT




Contents lists available at ScienceDirect

Science of the Total Environment

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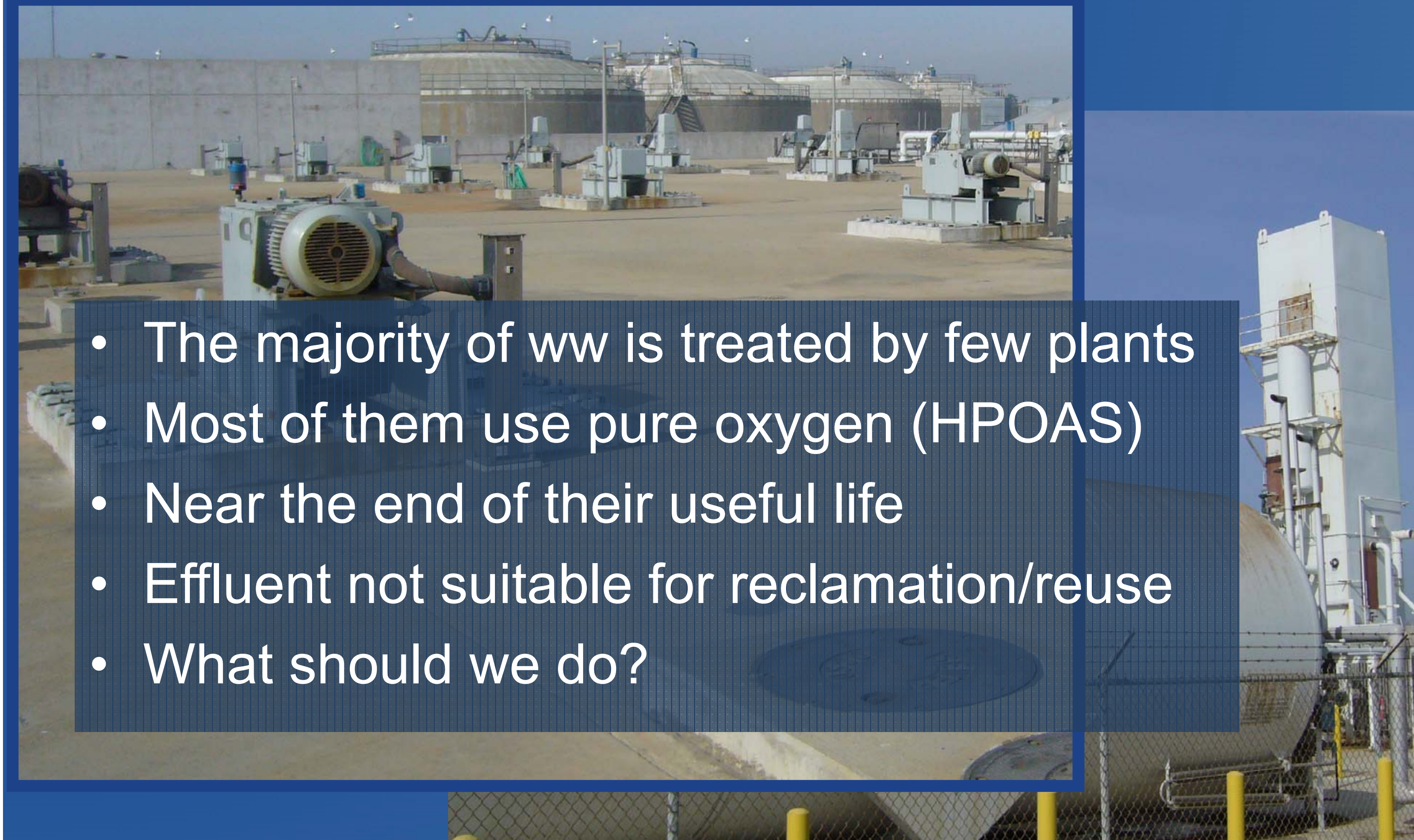
ELSEVIER

Trade-off between carbon emission and effluent quality of activated sludge processes under seasonal variations of wastewater temperature and mean cell retention time

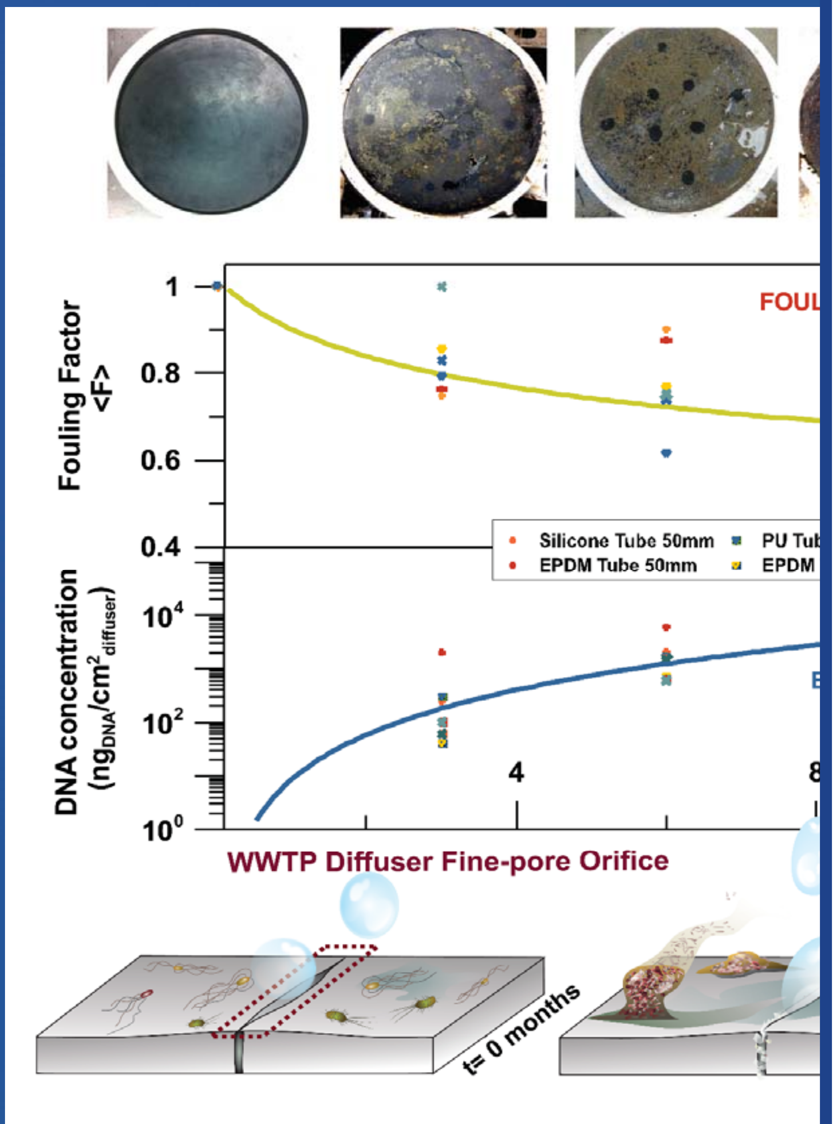
**!: THE LEVEL OF TREATMENT TAILORED TO THE END-USE MUST ALWAYS BE MAINTAINED**

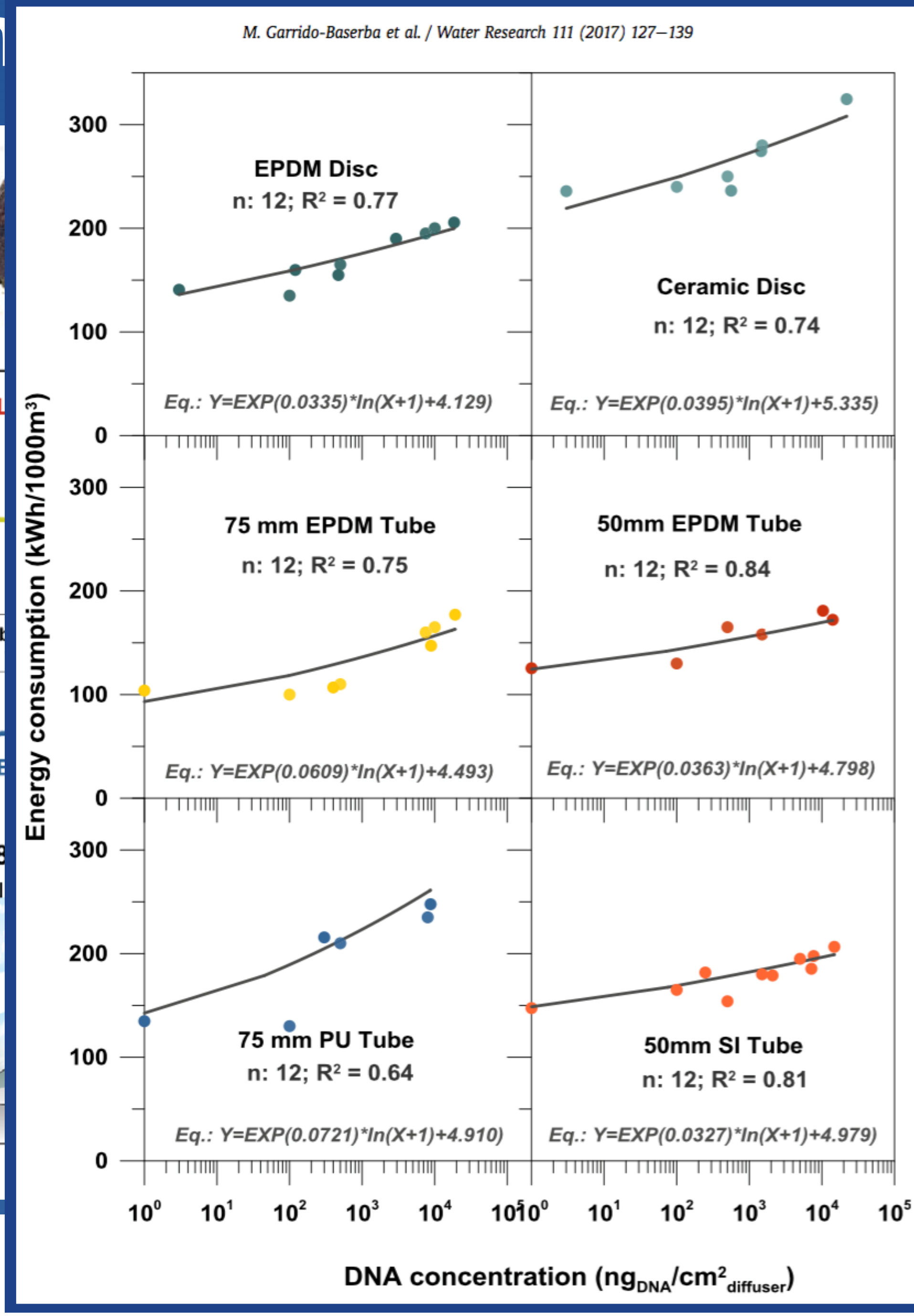
# THE ELEPHANT IN THE COUNTRY



- The majority of ww is treated by few plants
- Most of them use pure oxygen (HPOAS)
- Near the end of their useful life
- Effluent not suitable for reclamation/reuse
- What should we do?

# The Power of Foulin

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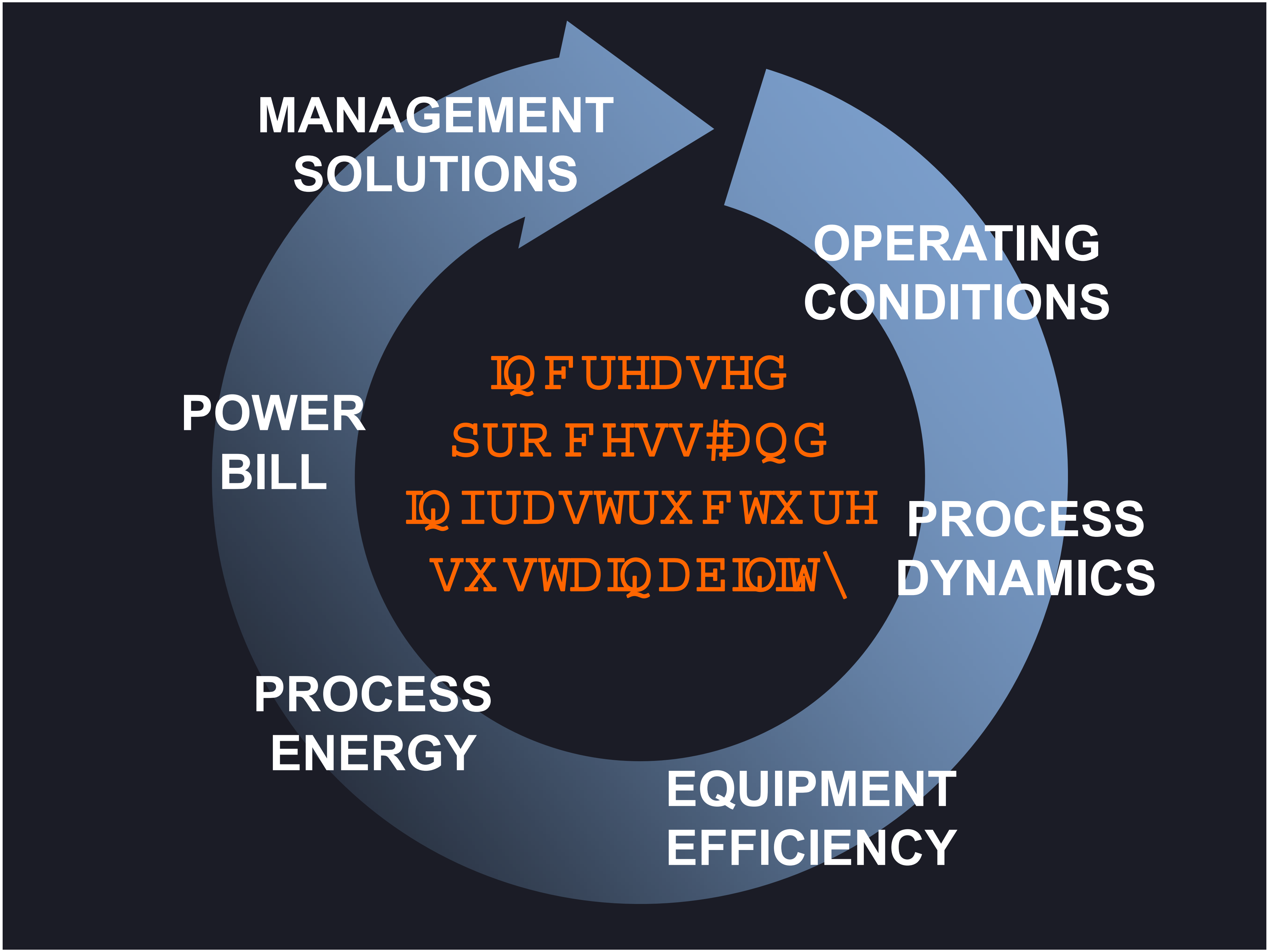
MANAGEMENT SOLUTIONS
OPERATING CONDITIONS
PROCESS DYNAMICS
EQUIPMENT EFFICIENCY
PROCESS ENERGY
POWER BILL
IQ FUHDVHG SUR FHVV#DQG IQ IUDVWUXFWXUH VXVWDLQDELOLW\


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EPL

ENVIRONMENTAL PROCESS LAB


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