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Chesapeake Water Environment Association

Water Resource Recovery Facility of the Future is Now!

Presented By

Daniel R. Dair

Clean Water and Energy from Wastewater

Agenda

Section I: INTRODUCTION

Section II: WRRF OF THE FUTURE

Section III: CASE STUDY – WWTP Strass

Section IV: DEMON TECHNOLOGY REVIEW

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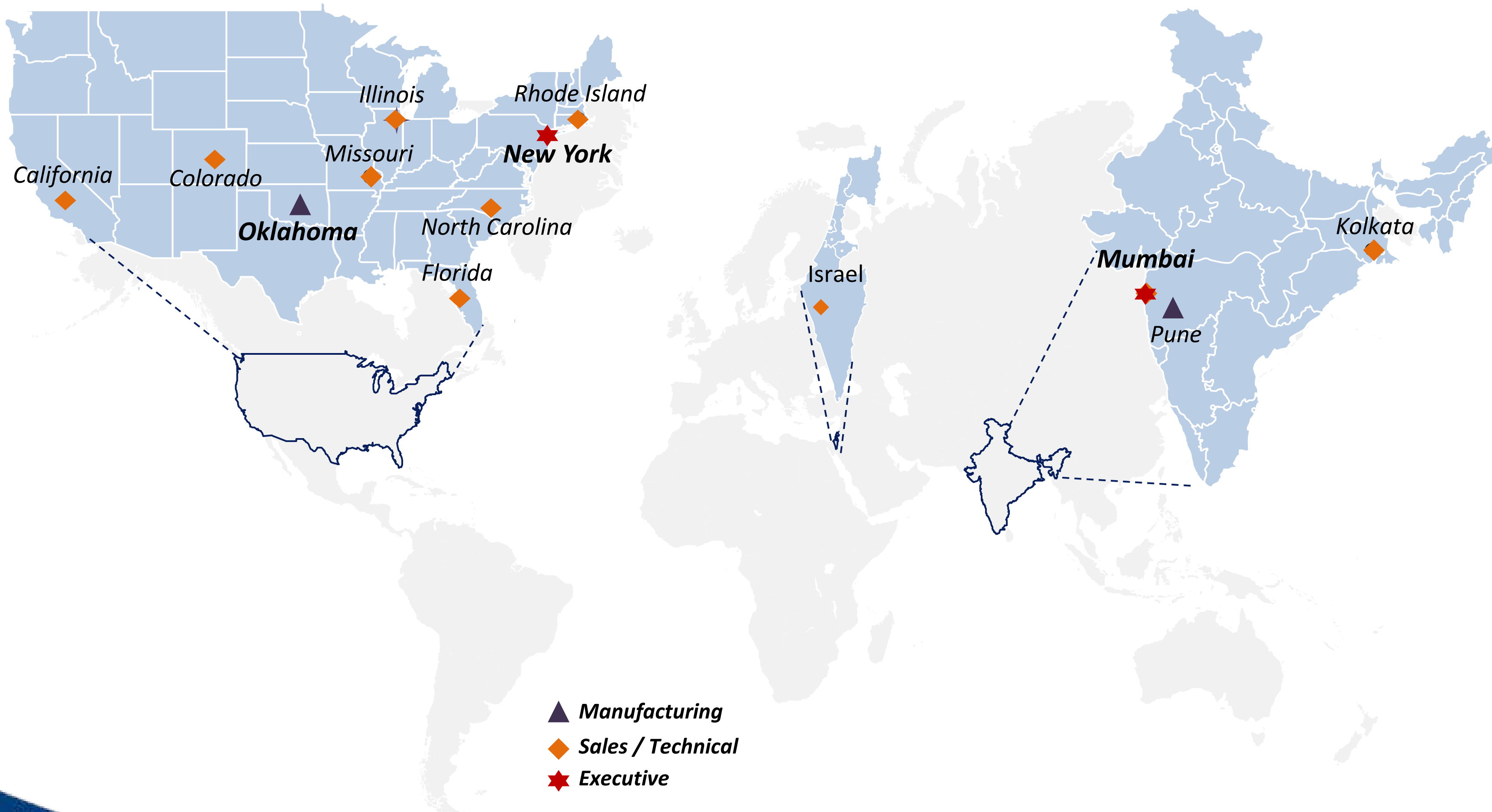
Locations



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ME-2
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Award Winning World-Class Manufacturing

Quality * Safety * Cost * Schedule * Innovation

Headquarters: Oklahoma City, OK USA

- Global Leader in MBBR/DAF Technology
- BNR Specialists
- Advanced R&D Capabilities
- Experienced Process Engineering
- World-wide Delivery Team

WWW is one of the Fastest Growing US Companies

2013

Inc. 5000

#25 Top 100 Environmental Services Companies

#21 Top 100 Oklahoma Companies

2012

Inc. 5000

#52 Top 100 Manufacturing Companies

#13 Top 100 Oklahoma Companies

Inc. HirePower

#4 Top 10 Oklahoma Companies

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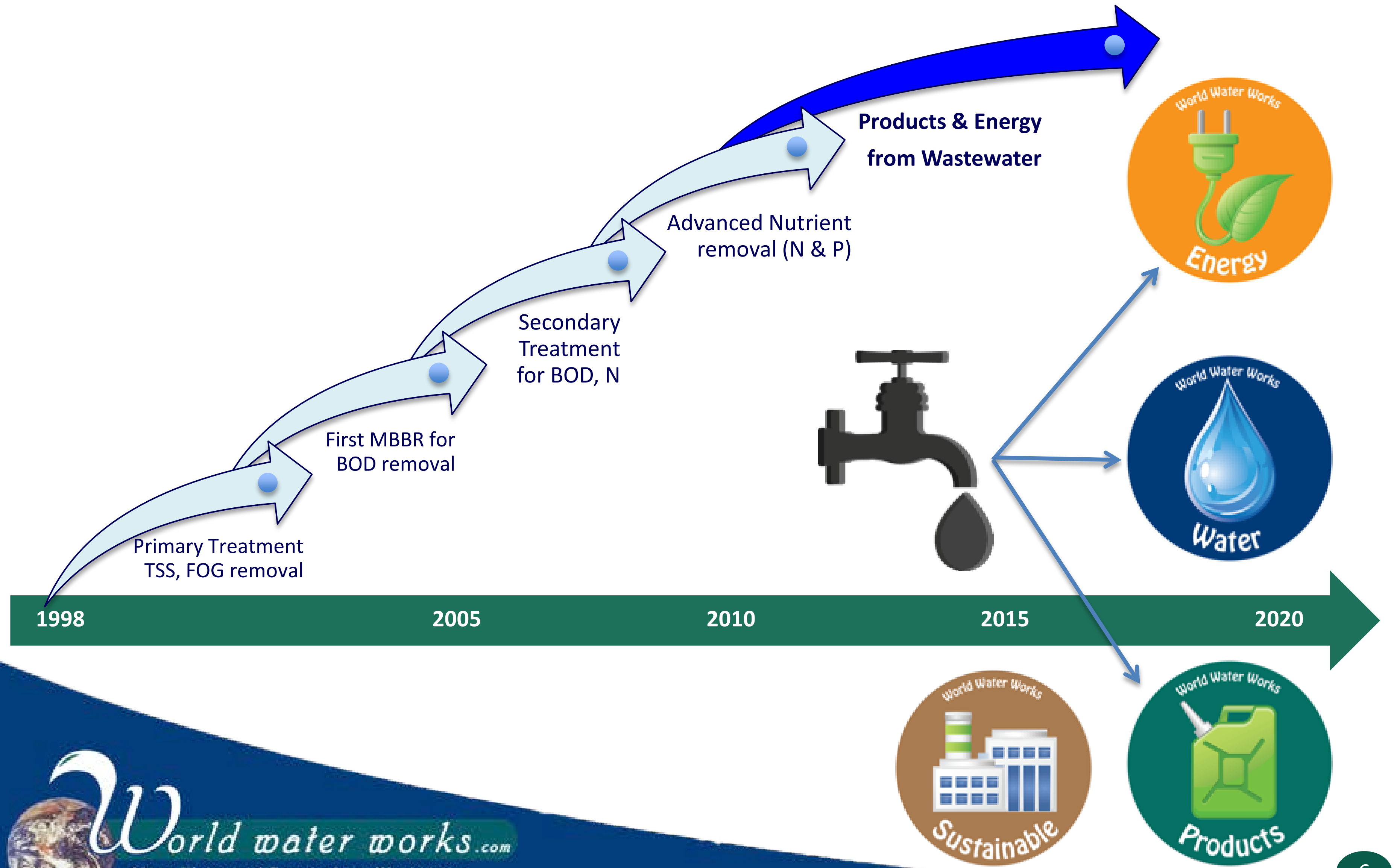
Strategic Direction



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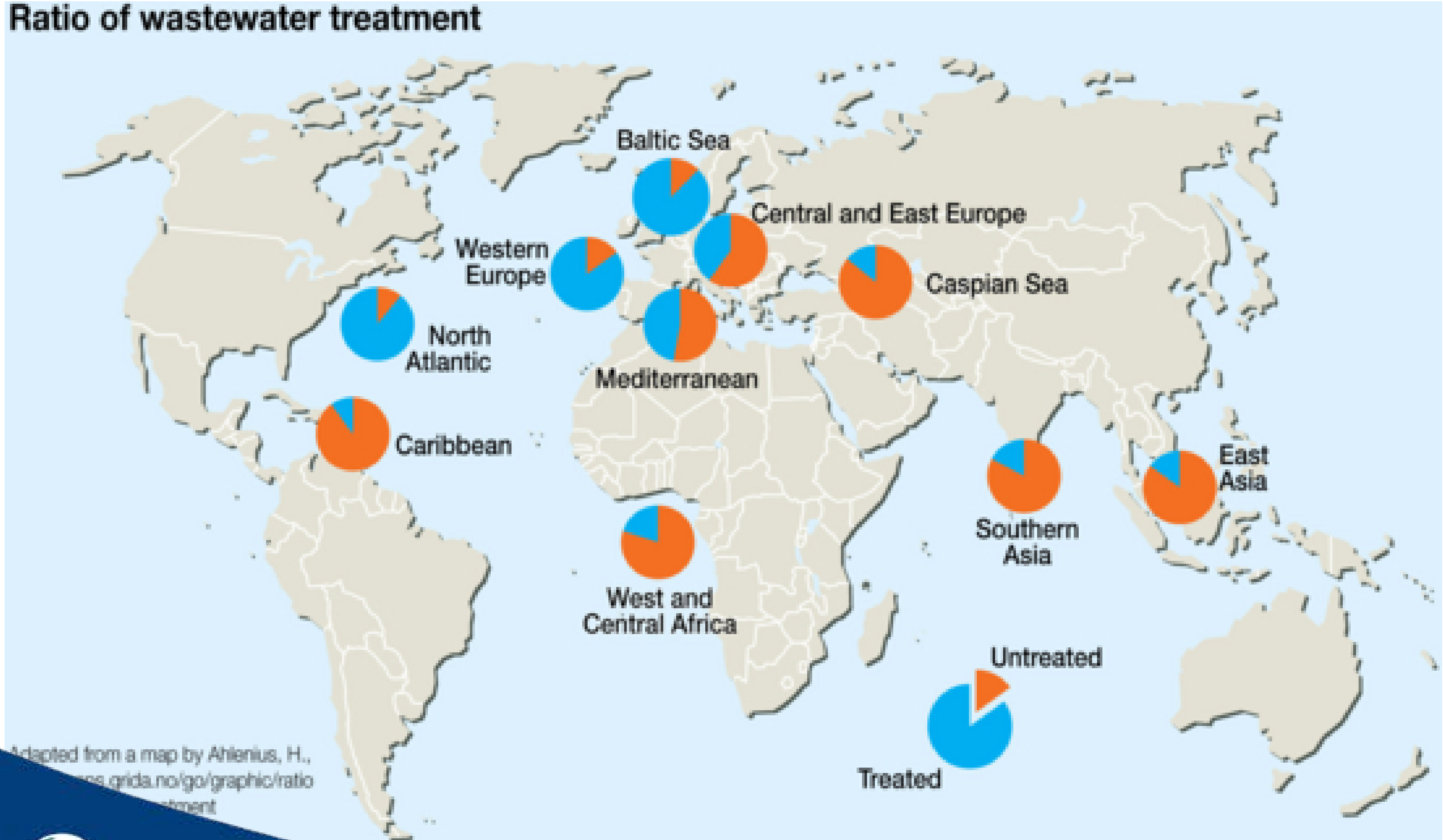
The Need of a Solution: Our Passion - Our Future



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Note Worthy Information

- The organic compounds present in raw domestic wastewater contain approximately 14.7 kJ/kg COD of energy
- All the wastewater produced in 2004 by the world's 6.8 billion people contained a continuous supply of energy somewhere in the range of 70 - 140 GW.
- The largest US based power plant produces 6.8 GW.
- By 2035, the world's energy consumption will increase by 35 percent, which in turn will increase water use by 15 percent according to the International Energy Agency.

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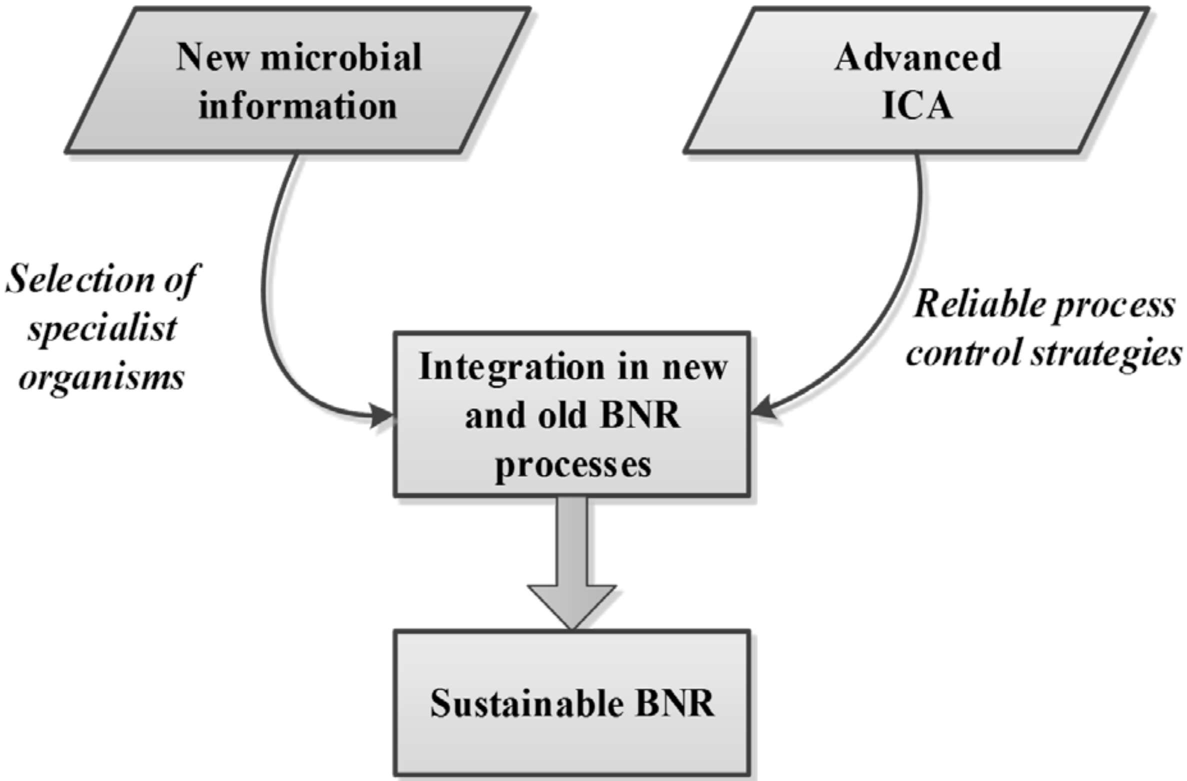
Improved Understanding of Biochemical Process



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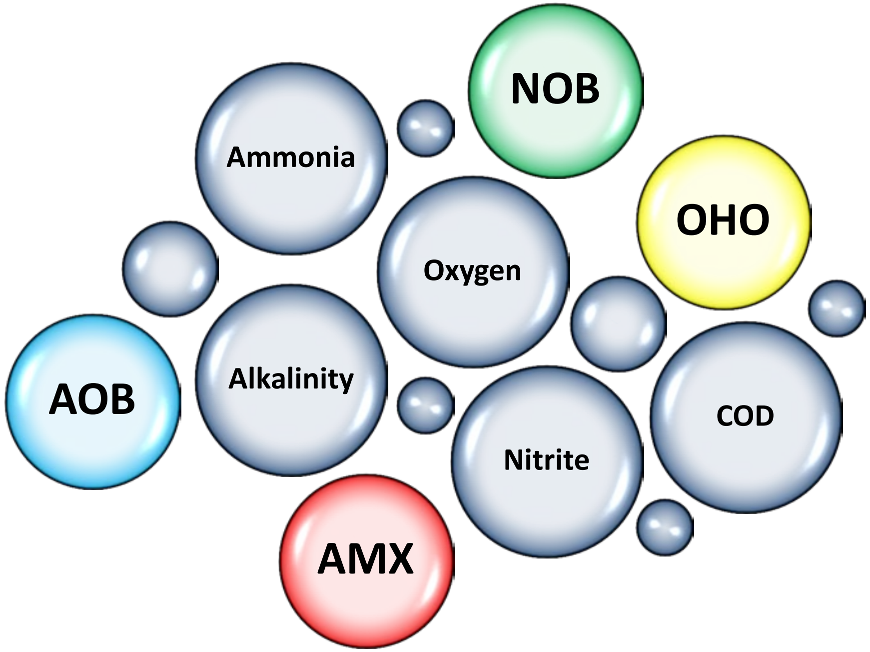
Optimization of Substrate Utilization



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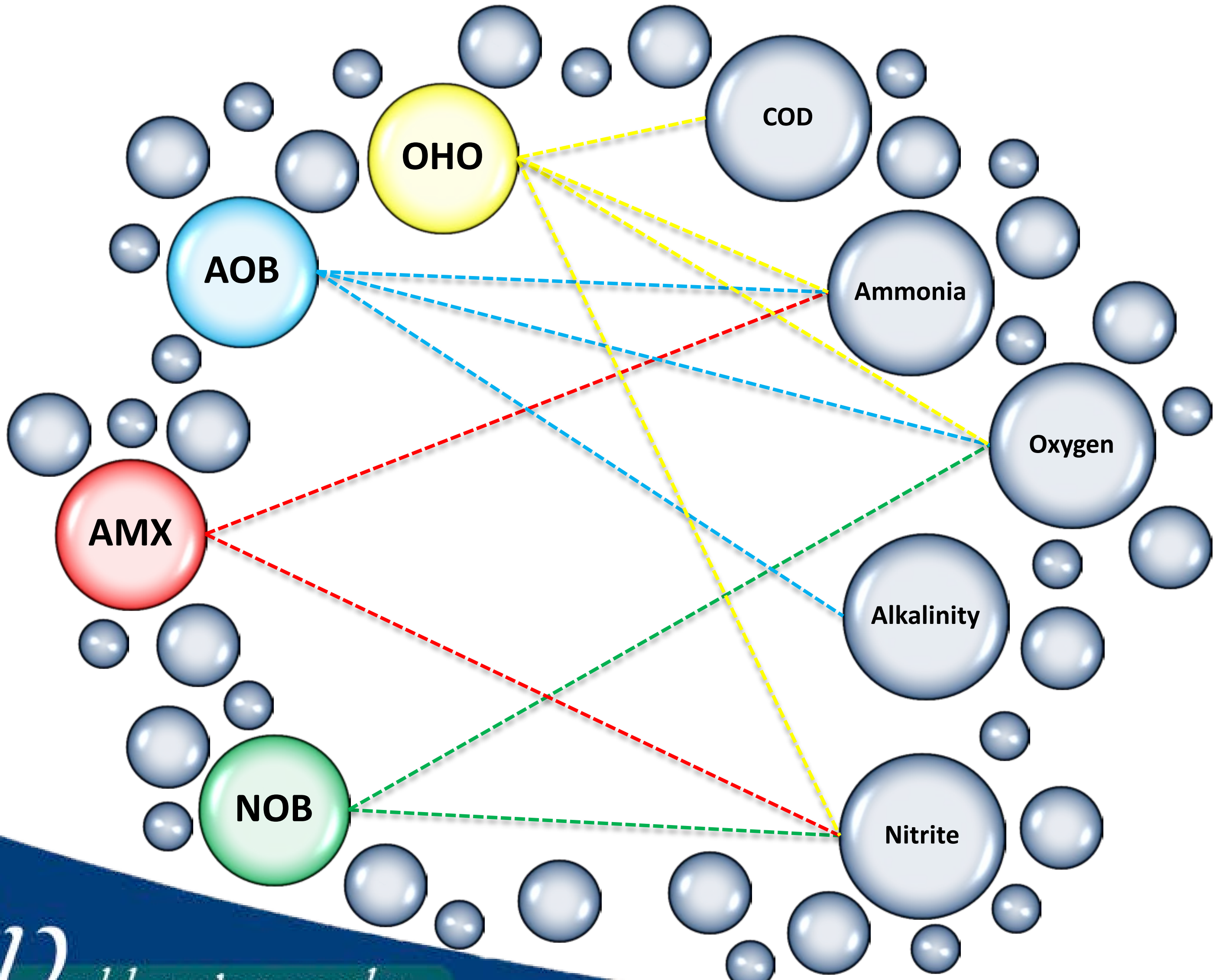
A Complex Web of Substrate Utilization



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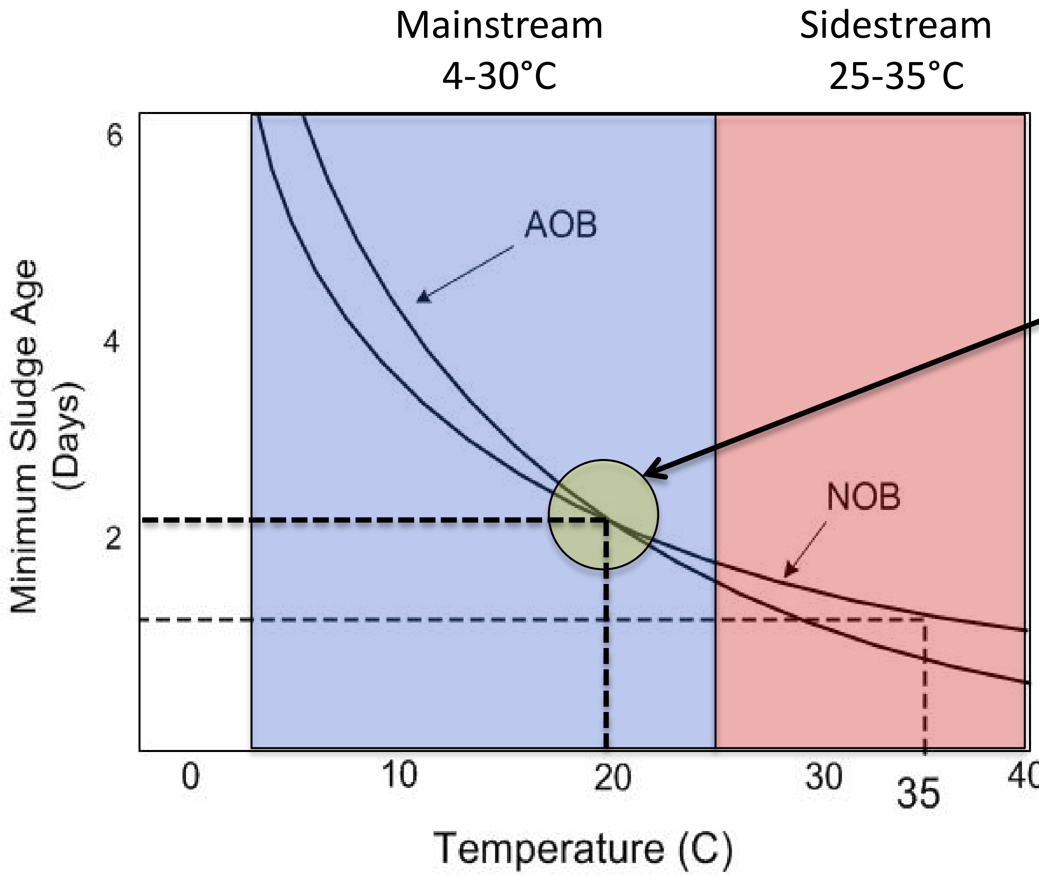
AOB vs. NOB - AvN



Transition temperature where the AOB growth rate is faster than the NOB growth rate with increasing temperature.

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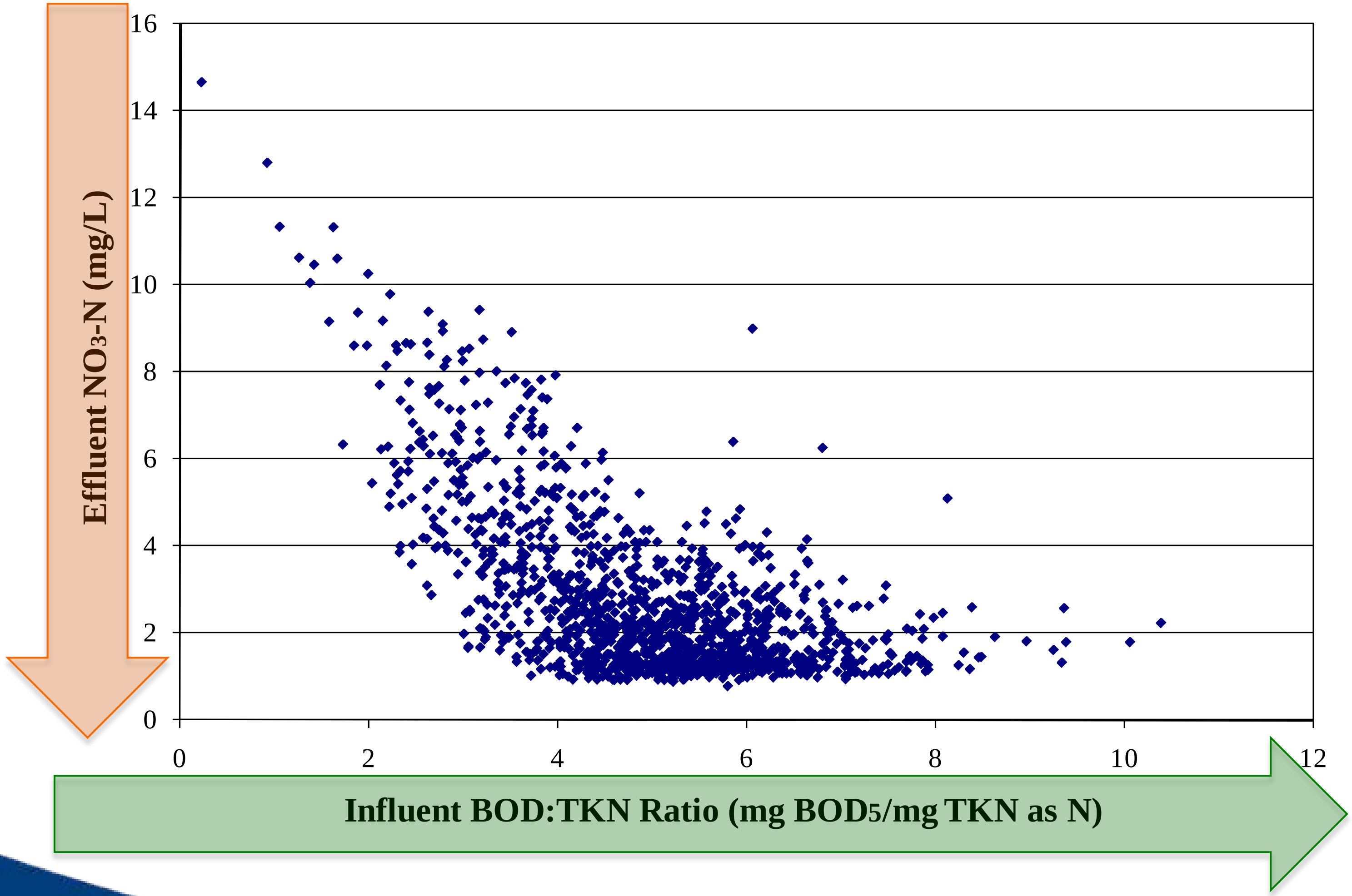
Main Goal of AvN

- Nitrify only the amount of nitrogen that can be denitrified.
  - Minimizes energy consumption
  - Achieves lowest possible TN with the given influent C:N ratio
  - Maximize carbon redirection to anaerobic digestion
  - Conserves alkalinity

C:N Ratio Critical for Energy Neutrality



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AvN Capabilities

Biological process	Nitrification-Denitrification	Nitritation-Denitritation*	Nitritation-Denitritation + Nitrogen Polish/anammox*
Influent C/N ratio	>10	5 to 10	3 to 8
Main action	Dynamically optimize anoxic/aerobic volume	Dynamically optimize anoxic/aerobic volume NOB out-selection	Dynamically optimize anoxic/aerobic volume NOB out-selection Nitrogen polish, AMX and/or AOB bioaugmentation
Benefits	Improvement of efficiency of influent carbon utilization for denitrification Reduction in supplemental carbon Tighter design criteria Reduced supplemental alkalinity	Low carbon required for nitrogen removal Opportunity for upstream carbon capture and electricity production Small tank volume Reduced supplemental alkalinity	Very low carbon required for nitrogen removal Opportunity for upstream carb capture and electricity product Small tank volume Reduced supplemental alkalin
Control	AvN aeration control and AvN SRT control (optimized for effluent ammonia limit if needed)	AvN aeration control and AvN SRT control optimized for NOB out-selection and/or effluent ammonia limit	AvN aeration control and AvN SRT control optimized for NO out-selection AOB and AMX bioaugmentat from sidestream deammonifica

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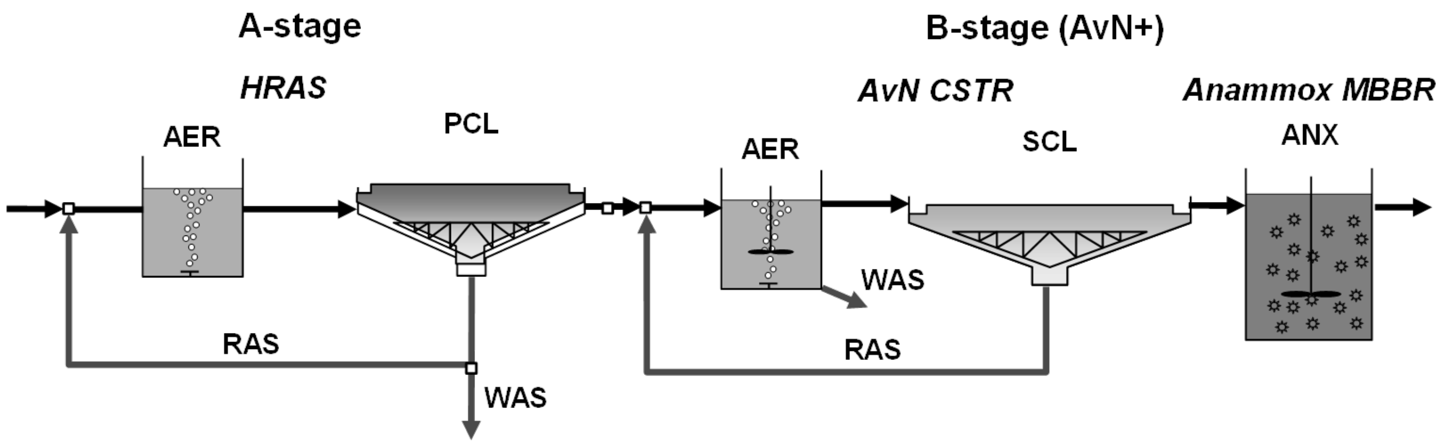
AvN Energy Balance



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AvN Capabilities

AvN™

- **Nitrification /Denitrification**
  - Oxygen Demand = 4.18 gO_2/gN
  - COD = 2.86 gCOD/gN (no yield)
  - Alkalinity = 7.07 (-3.57) $gCaCO_3$/gN
- **Nitrite Shunt**
  - Oxygen Demand = 3.16 gO_2/gN
  - COD = 1.72 gCOD/gN (no yield)
  - Alkalinity = 7.07 (-3.57) $gCaCO_3$/gN
- **Partial Nititation/Deammonification**
  - Oxygen Demand = 1.94 gO_2/gN
  - COD = 0 gCOD/gN (no yield)
  - Alkalinity = 3.68 $gCaCO_3$/gN

Summary:
Oxygen Demand Reductions: 24%; 54%
COD Demand Reduction: 40%; 100%
Alkalinity Demand Reduction: 0%; 48%

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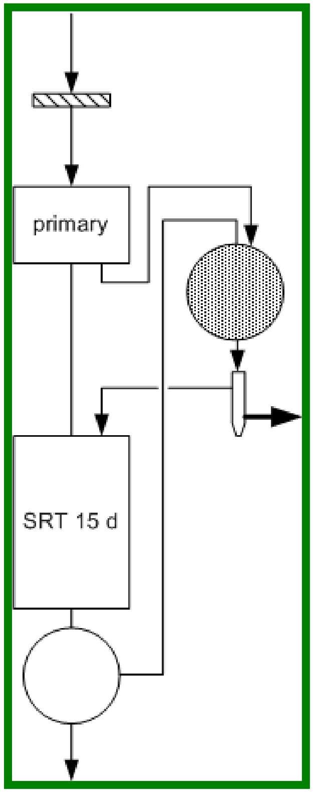
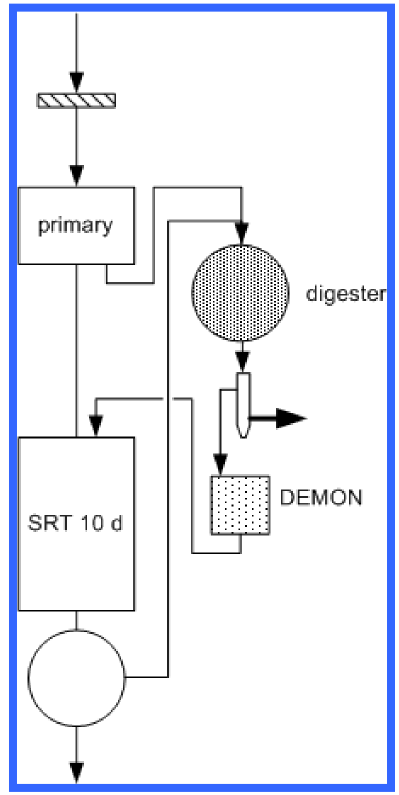
AvN Energy Balance

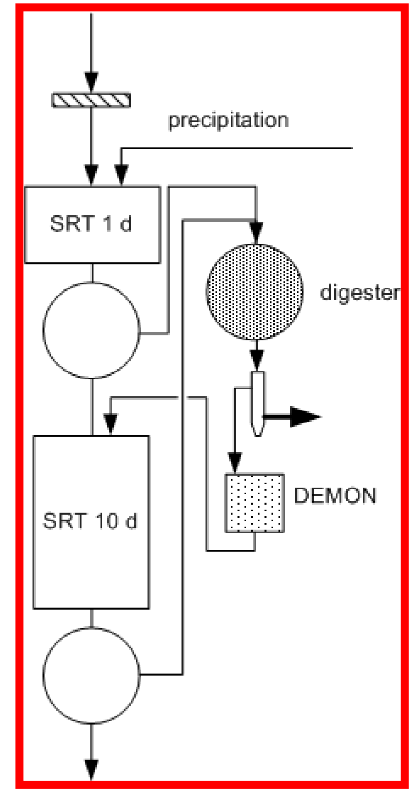
Case A



Case B



Case C



AvN Energy Balance

Case A: Conventional Treatment

Case B: Conventional Treatment w/ Anammox Sidestream

Case C: Optimized Treatment w/ AvN for Mainstream Treatment Control

Oxygen and energy need	Mass Flux ($g\ p^{-1}d^{-1}$)			Energy ($Wh\ p^{-1}d^{-1}$)		
	Case A	Case B	Case C	Case A	Case B	Case C
Aeration for COD removal	40	30	15	-40	-30	-15
Aeration for nitrogen removal*	22	22	16	-22	-22	-16
Pumping and mixing energy	-	-	-	-20	-20	-15**
Methane-COD and electrical energy production from biogas	30	40	55	+38	+51	+70
Net energy	-	-	-	-44	-21	+24

*Nitrate effluent for cases A and B: 2.5 $g\ p^{-1}d^{-1}$; for case C: 1.1 $g\ p^{-1}d^{-1}$

**Lower because of recirculating flows

Key to Energy Self-sufficiency is Carbon Redirection

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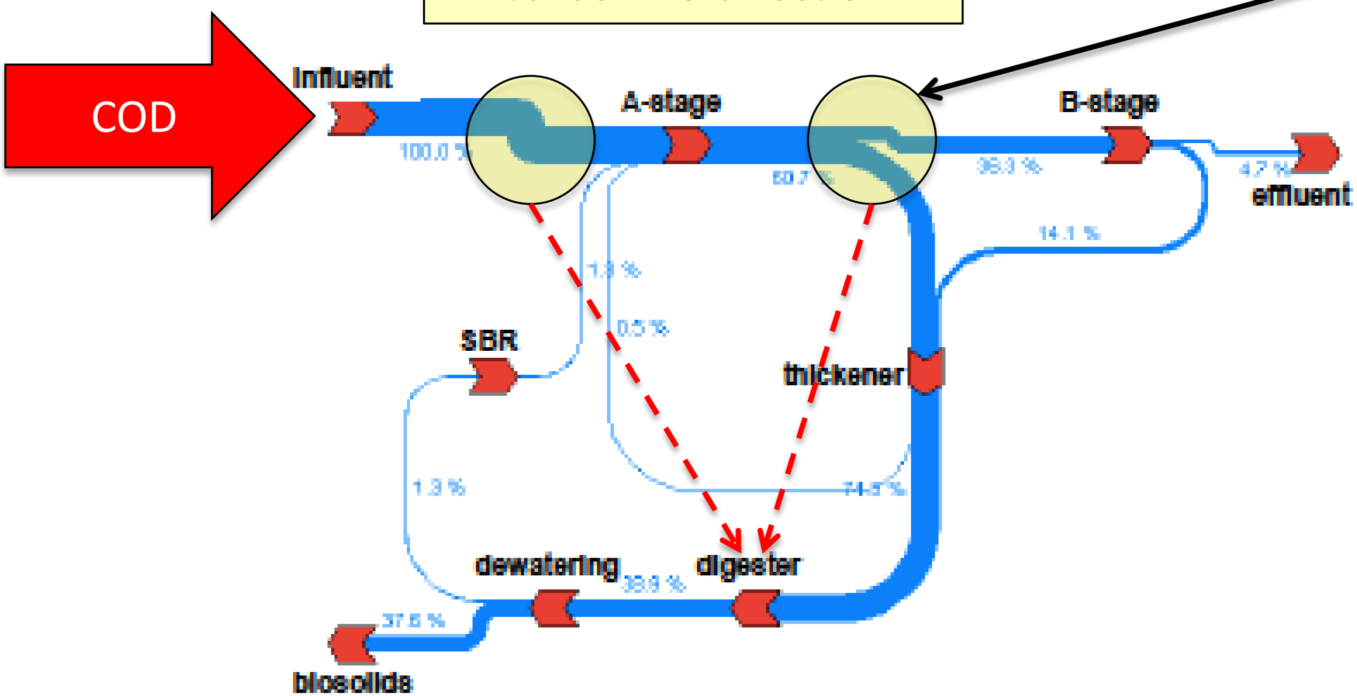
AvN Energy Balance – Carbon Re-direction

Case C: WWTP Strauss

Important to maintain "ideal" C:N ratio for lowest TN and energy

Location for Optimized Carbon Re-direction



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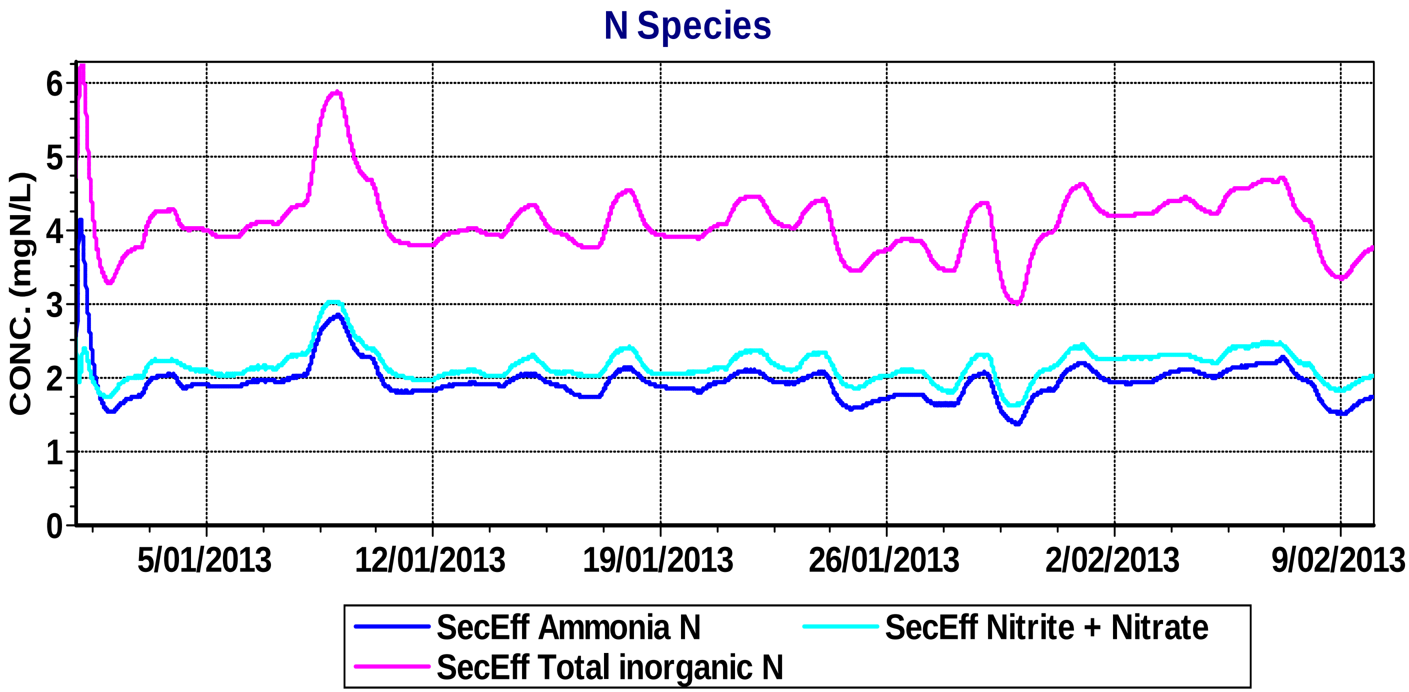
AvN: Effluent N species



AVN Controller Success:

Effluent NH_3-N – Effluent NO_x-N = 0

Note: The effluent TN for this case is approximately 4 mg/L. For cases where the TN limit are lower, effluent polishing will be required

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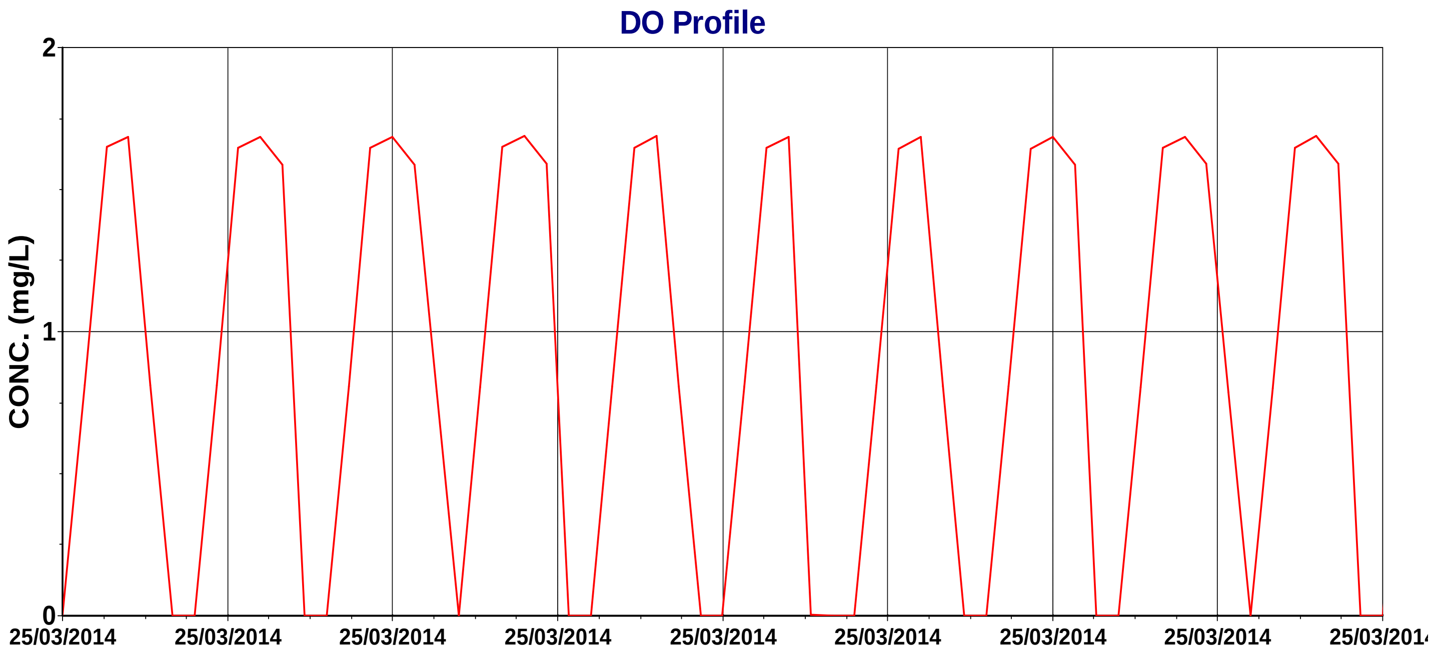
AvN: Dissolved Oxygen Profile



Transient Anoxia:

Note: The DO concentration need to increase to ≤ 1.5 mg/L quickly and decrease quickly in order to provided a competitive advantage to the AOBs

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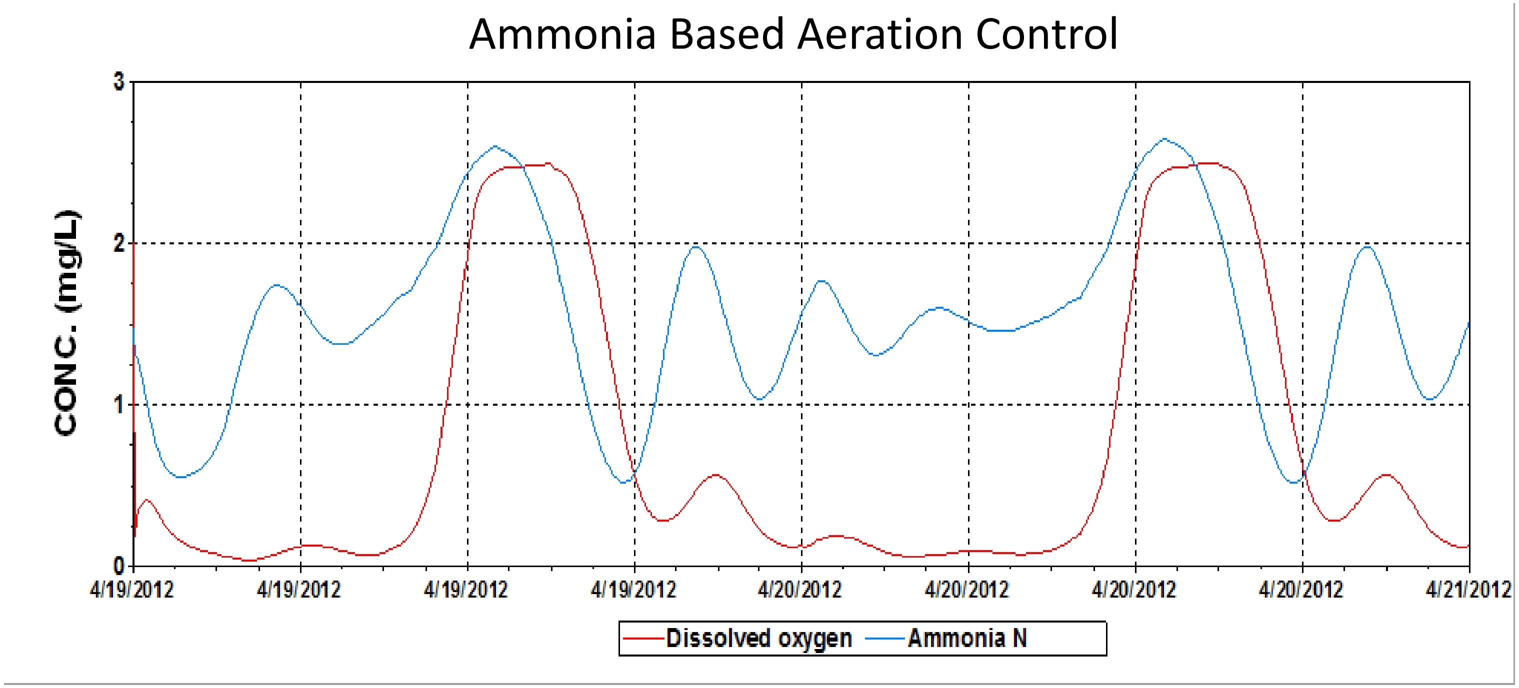
DO and Effluent Ammonia Profile with ABAC



ABAC Controller:

Note: Controller reacts to increase level of ammonia in the influent. There is no predictive strategy for this process as it always appears to be playing catchup.

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The AvN "Take Away"

Parameter	CAC	ABAC	AVN
COD:NH3-N Ratio	8.5		
NH3 Loading (kgN/d)	1973		
Total SRT (days)	8.0		
Target DO (mg/L)	2.0	0 - 1.5	0 - 1.5
COD:TIN Removal Rate	25	18	8
NOB:AOB Ratio[1]	0.60	0.58	0.40
Effluent NH_3-N (mg/L)	0.2	1.5	2.1
Effluent NOx-N (mg/L)	12.5	8.5	2.1
TIN Removal (%)	57.6	66.7	86.0
Sodium Hydroxide (mg/L $CaCO_3$)	120	70	NA[2]
Average Airflow Rate (scfm)	16000	12500	10500

[1] NOB:AOB ratio of 0.6 indicates no NOB out-selection and hence, no nitrite-shunt. The lower the NOB:AOB ratio is the higher the degree of NOB out-selection and nitrite-shunt are
[2]No alkalinity addition

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WWTP Strass

WWTP Strass, Austria

- 10 MGD Winter, 5 MGD Summer
- Mainstream treatment by an A+B process
- Net energy positive plant since 2005
- DEMON Mainstream & Side stream

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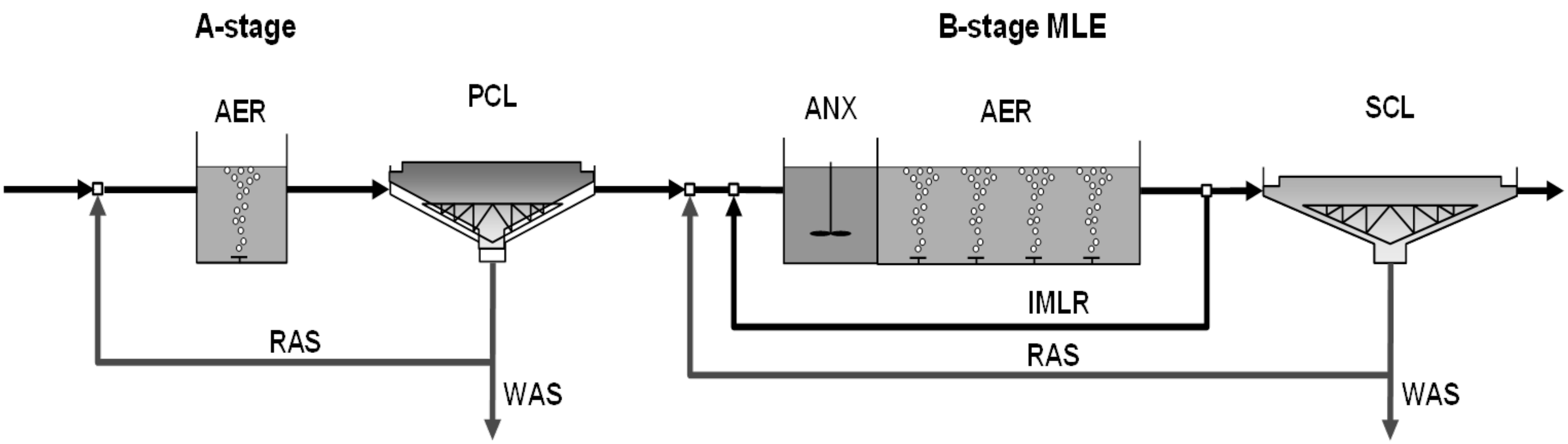
Adsorption Stage + Bio-Oxidation Stage (A+B Process)



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A+B Process Benefits

- A-stage operation breaks down complex organic molecule into readily biodegradable substrate which could be used for denitrification in the B-stage.

- Could reduce the required specific aeration tank volume to as low as 65 L/PE as compared to 150-200 L/PE for a single-stage processes.

- Increase nitrification rates by 1.5-2 times as compared to a single stage system.

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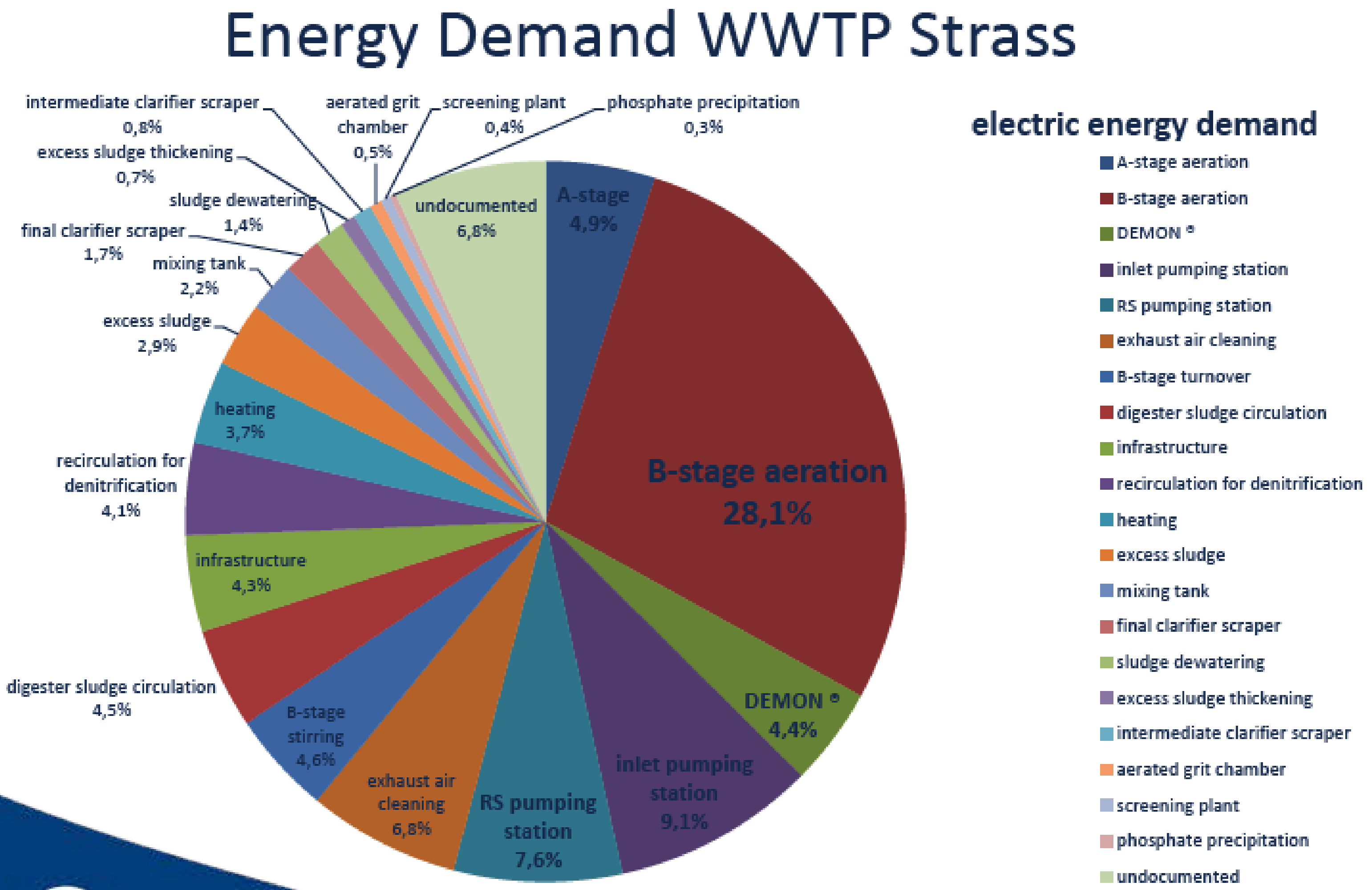
WWTP Strass, Austria



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Chronology of Optimization Measures

First was the awareness building and process-wise electricity metering.

1. 1991 ABAC to help manage limited carbon for denitrification.
2. 2001 Installation & Operation of CHP unit: 330 kW
3. 2004 Installation & Operation of Demon for sidestream treatment.
4. 2008 Start of Anaerobic Co-digestion.
5. 2009 Installation & Operation of new CHP units: 625 kW
6. 2012 Installation & Operation of Mainstream Demon.
7. 2012 Thickening upgrade for improved SRT Control.

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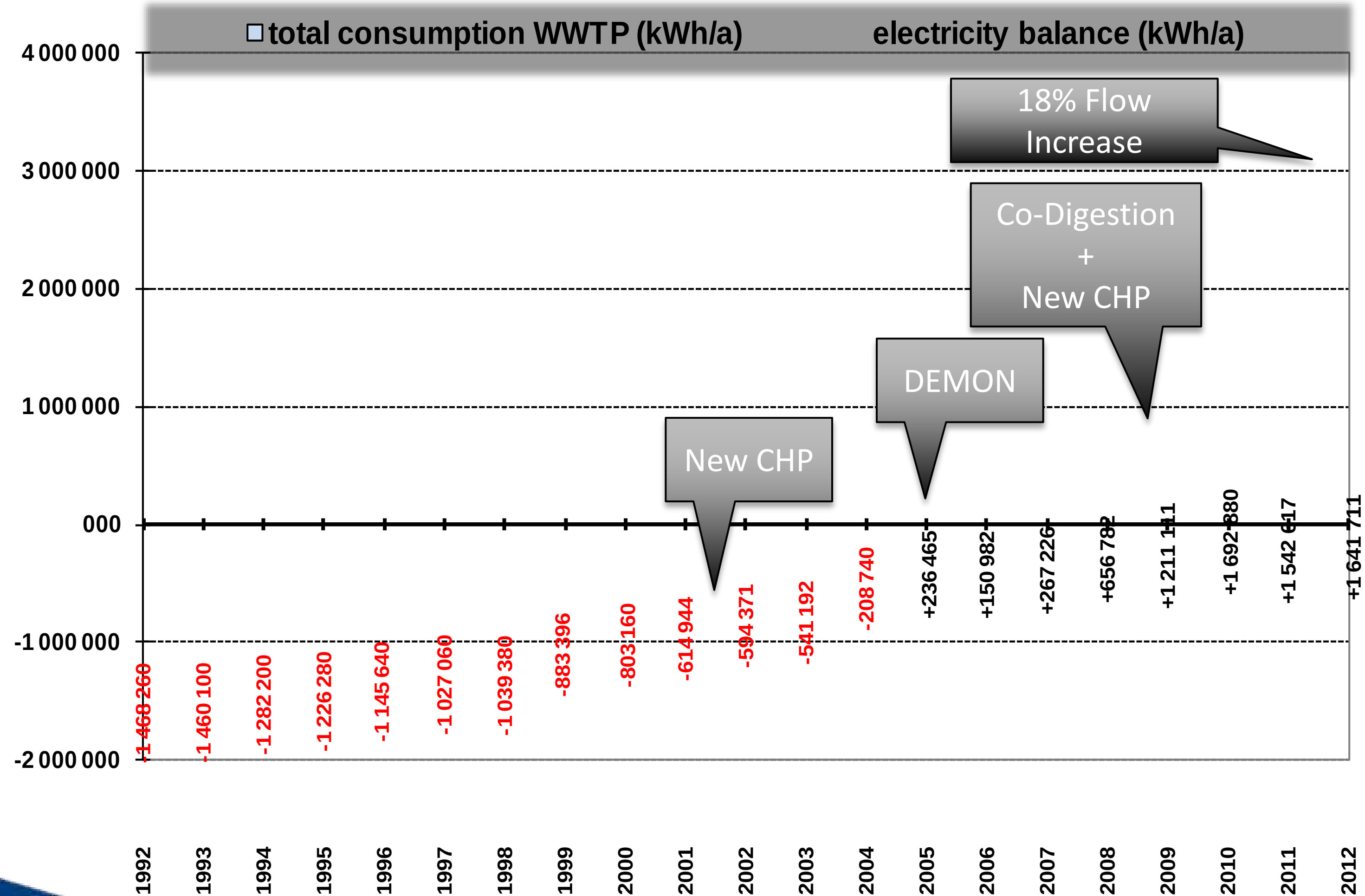
WWTP Strauss – Energy Balance



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Accomplishments at WWTP Strass

- Reduction in energy consumption on a mass treated basis from approximately 6.5 euro/kg NH4-N removed in 2003 to 2.9 euro/kg NH4-N removed in 2007/2008 – 55% Reduction

- Sidestream treatment
  - 350 kWh/d to 196 kWh/d by implementing DEMON

- Digester gas utilization
  - Cogeneration unit, electrical efficiency from 33% to 40% and overall usage efficiency from 2.05 to 2.3 kwh/m3 of digester gas

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Thank you

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DEamMONification - DEMON®

Unique Design Features

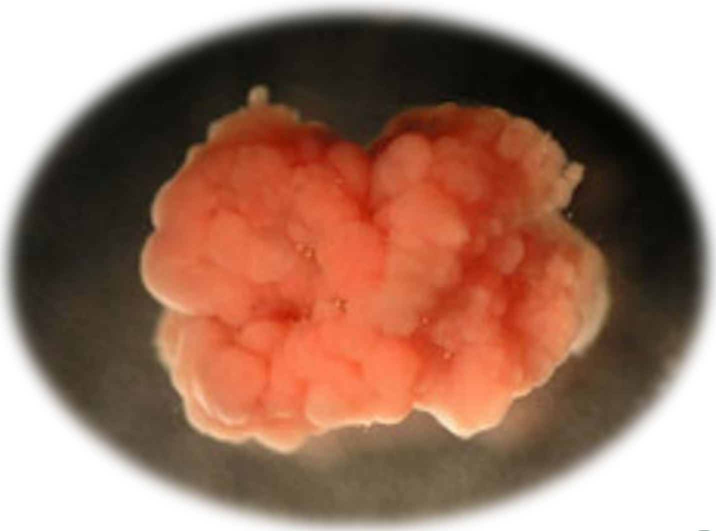
- Process Short Circuits Nitrification/Denitrification Cycle
- Cyclone Maintains Anammox Bacteria in System
- Automated PLC Control System Developed and Tuned over 5 Years
- Simple and Flexible SBR Based Design, Quick Start Up
- CO_2 Fixation

Awards

- AAEES - Sustainability Award 2013
- Honorable Mention Total Energy Award 2013
- Nominated World Energy Globe Award 2007

Benefits

- Lowest Cost TN Removal Available
- 60% Less Energy Consumption
- 90% Less Sludge Production
- Zero Chemical Addition



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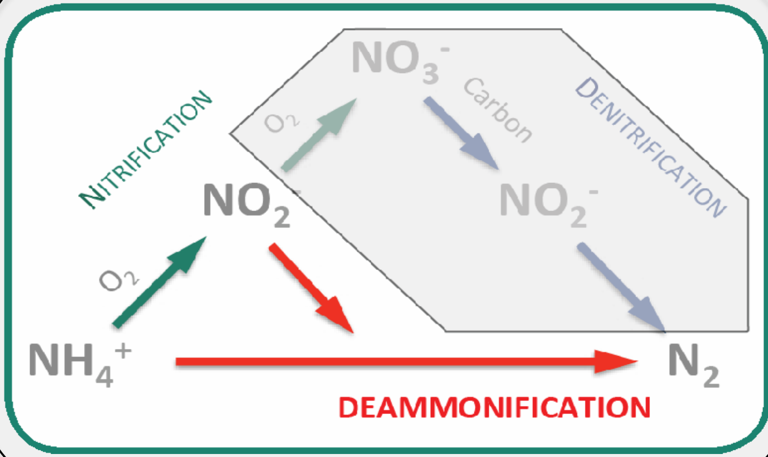
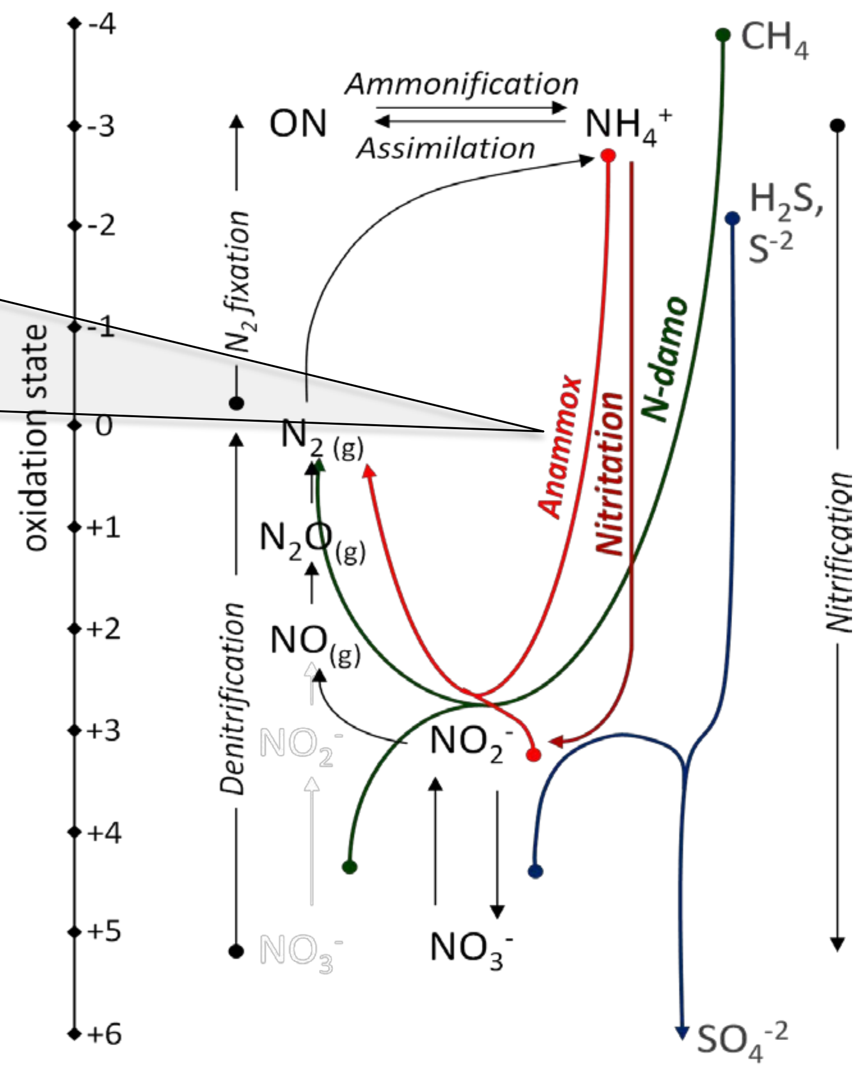
Nitrogen Cycles



$$1.0NH_4^+ + 1.32NO_2^- + 0.66HCO_3^- + 0.13H^+ \rightarrow 1.02N_2 + 0.26NO_3^- + 0.66CH_2O_{0.5}N_{0.15} + 2.03H_2O$$



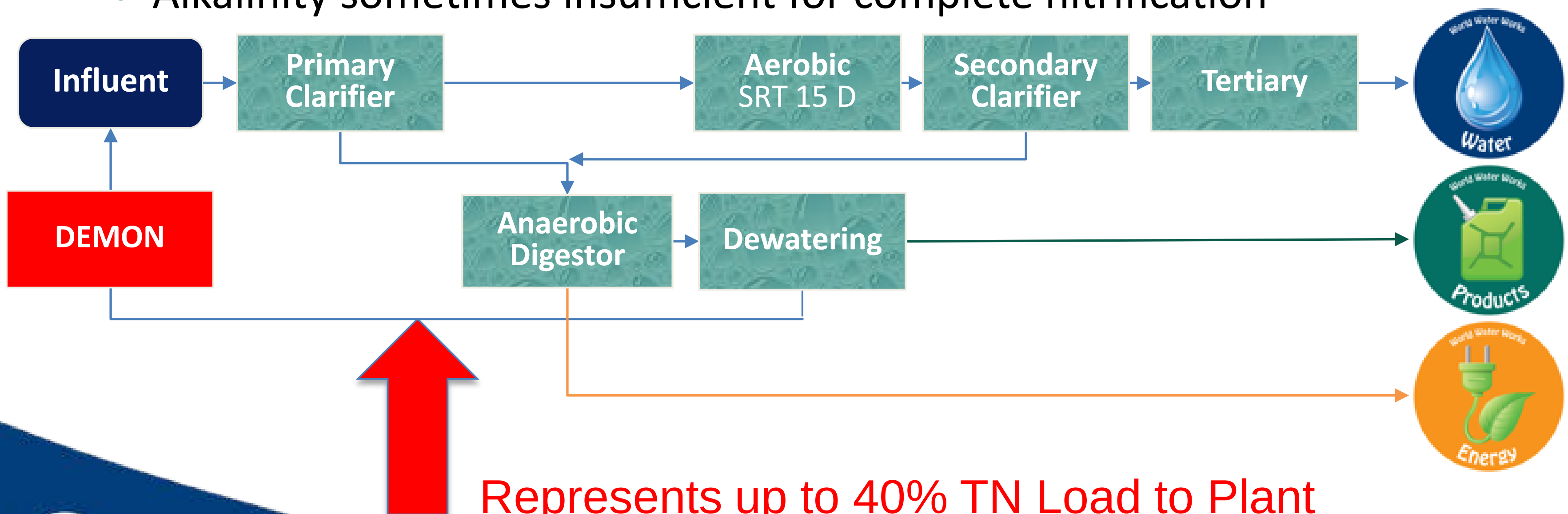
Nitrogen cycles (based on Grady et al., 2011).

Why DEMON®?

Anaerobic sludge digestion is very beneficial;

However, recycling of high ammonia stream has many "bad" effects:

- Reduction in C/N ratio which minimizes denitrification potential – thus requiring external carbon for meeting effluent Nitrogen limits
- Shock loads to system due to infrequent dewatering
- Alkalinity sometimes insufficient for complete nitrification



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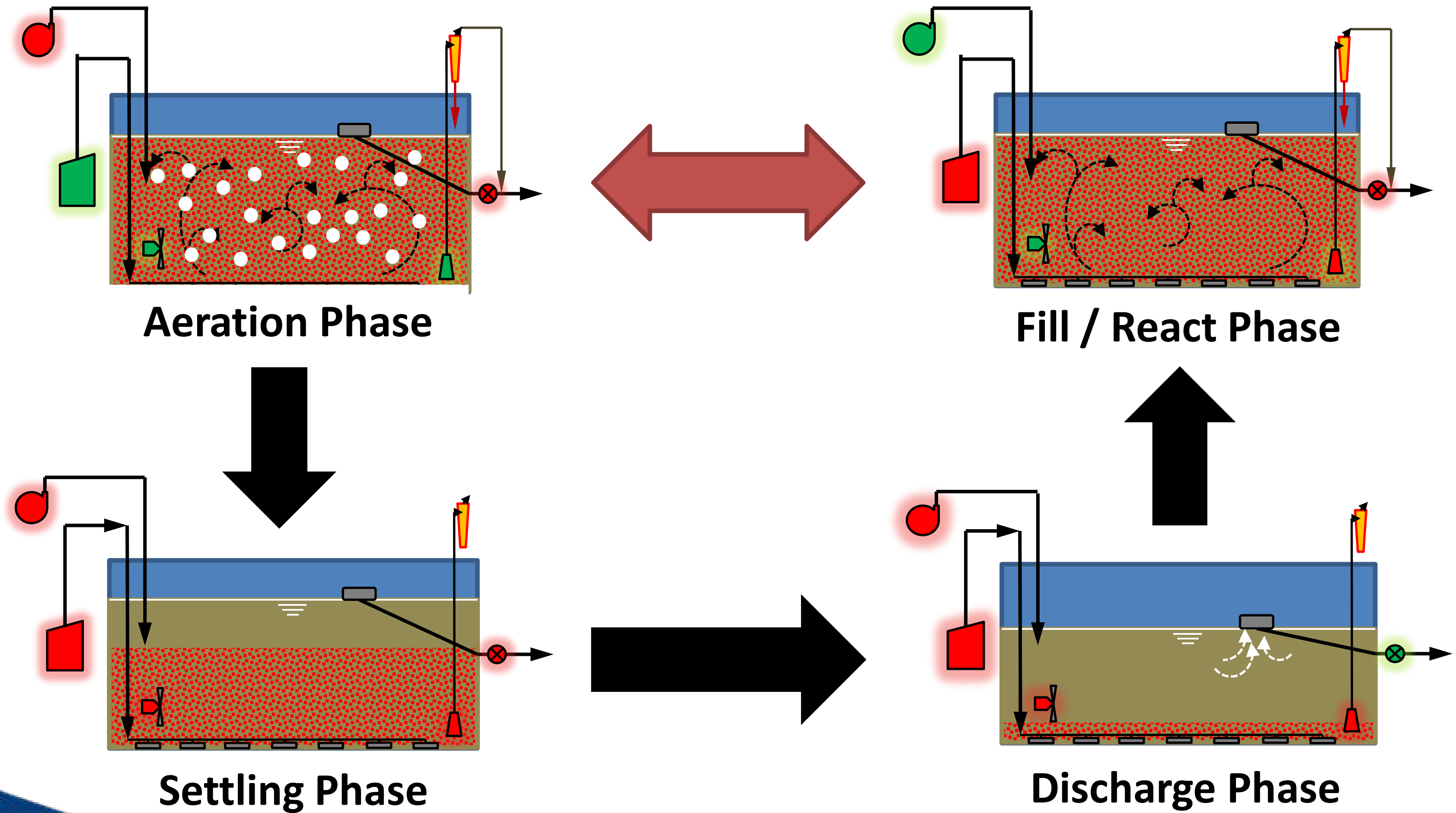
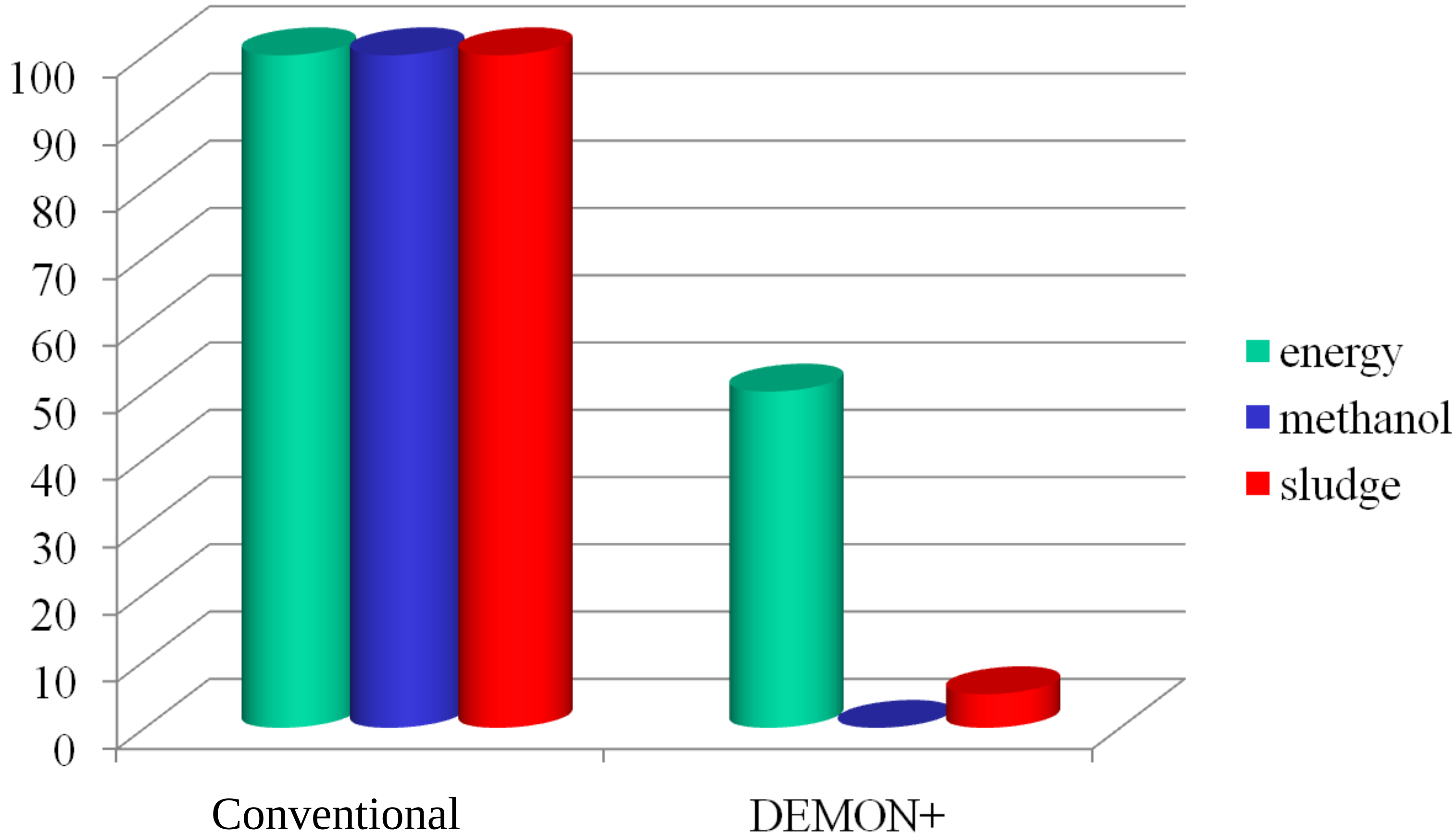
DEMON Operational Strategy - SBR



Comparison of Consumables



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