Nutrient Management in Energy Neutral WWTPs

Lessons Learned and the Path Ahead

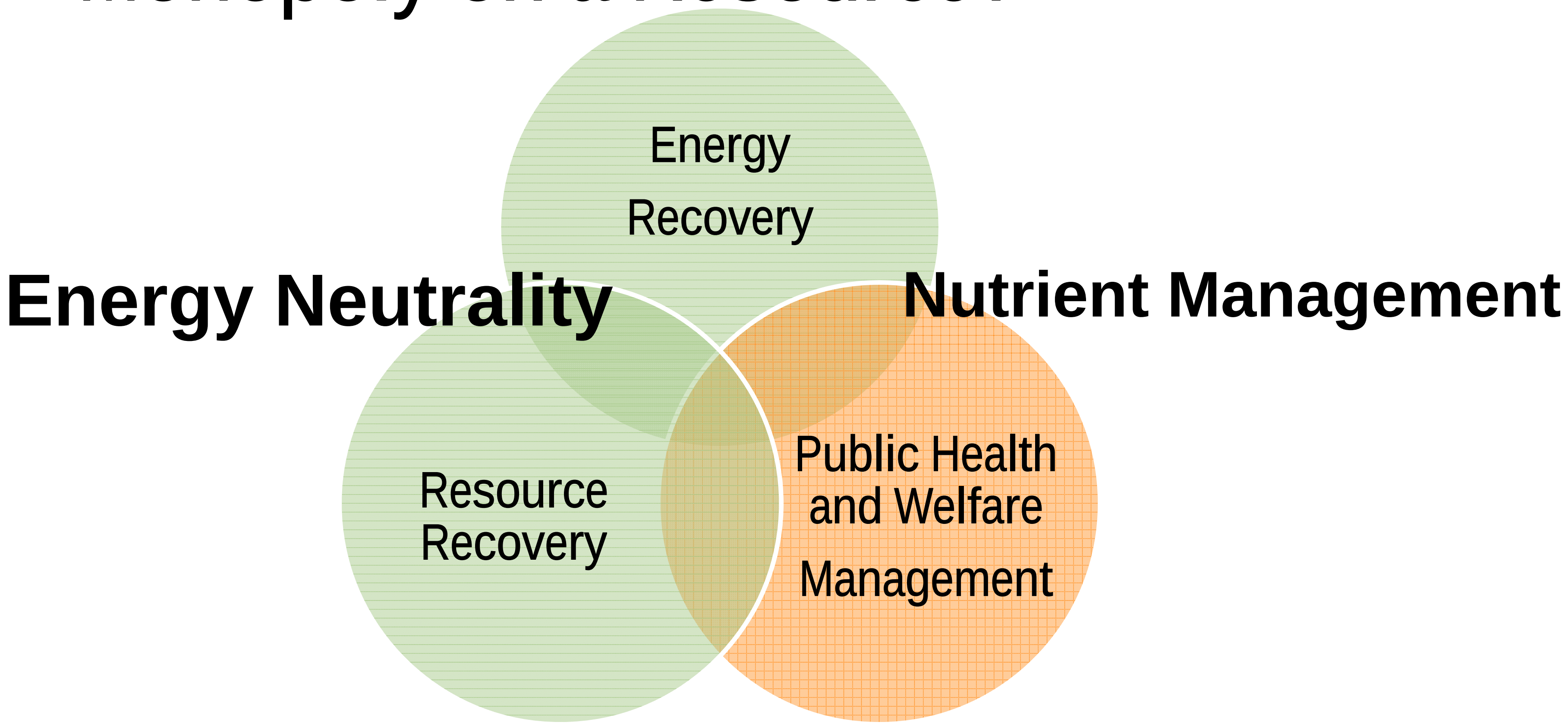
Dimitri Katehis, PhD, PE

Director, Process Engineering

Philadelphia, PA   November 2012

Perceptions….

- Monopoly on a Resource?



More About Perceptions…

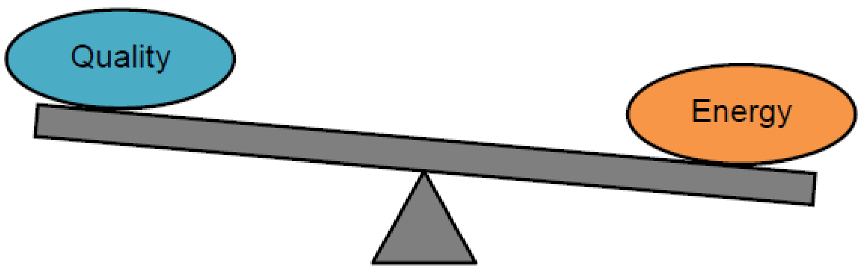


Figure 8. Quality versus energy
(NREL/TP-7A30-53341, January 2012)

(Water and Sustainability: U.S. Electricity Consumption for Water Supply & Treatment—The Next Half Century, EPRI, Palo Alto, CA: 2000. 1006787.)

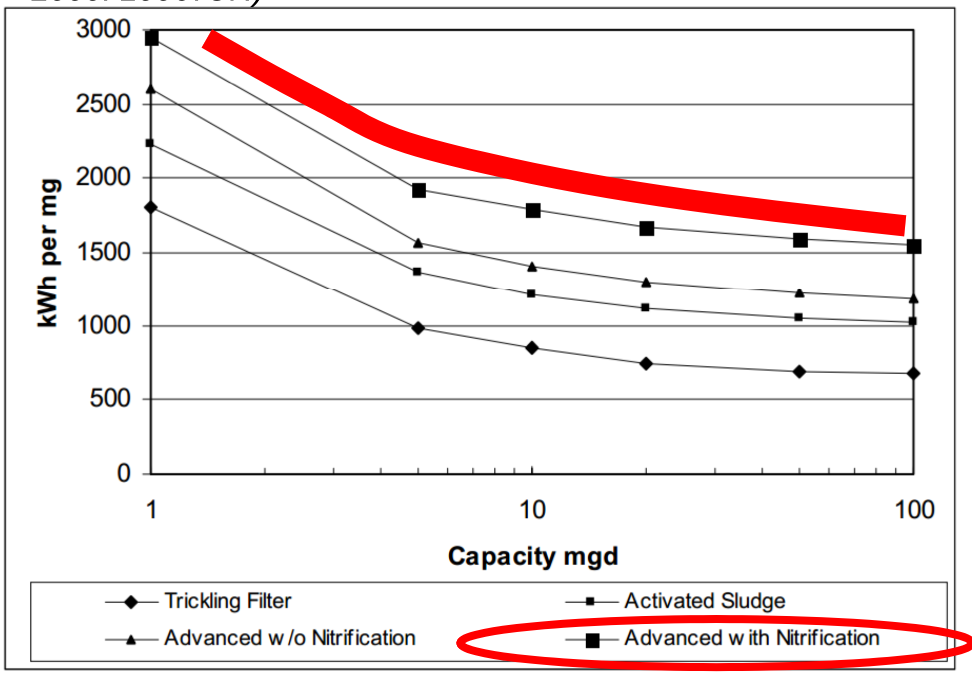
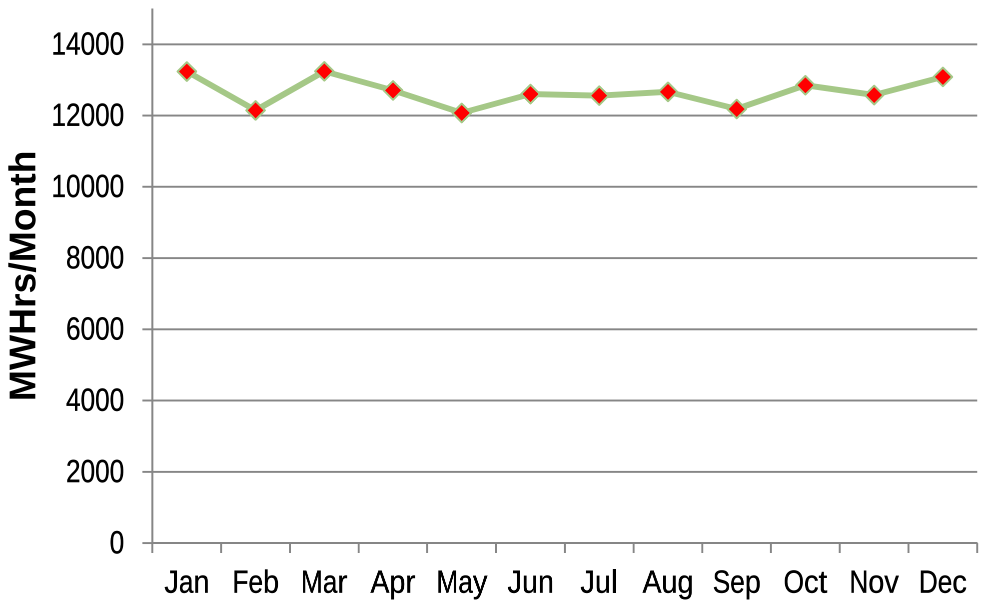
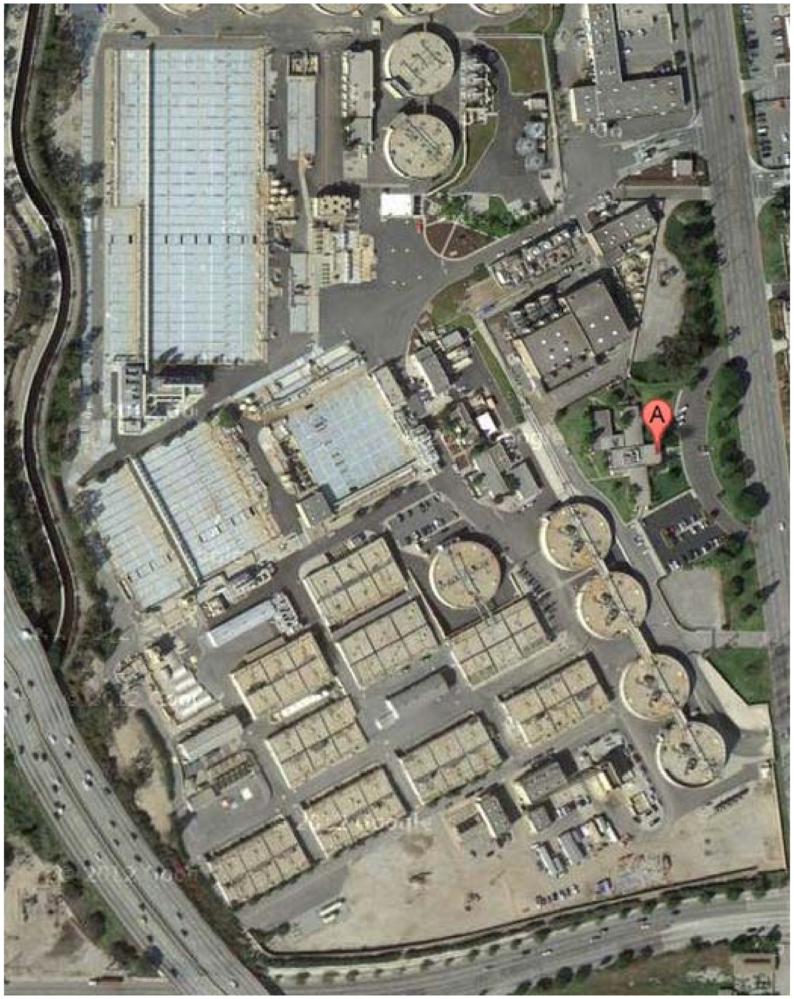


Figure 3-4
Variations in Unit Electricity Consumption with Size for Representative Wastewater Treatment Processes

Reality…..BOD Removal

- JWWTP, Carson, CA



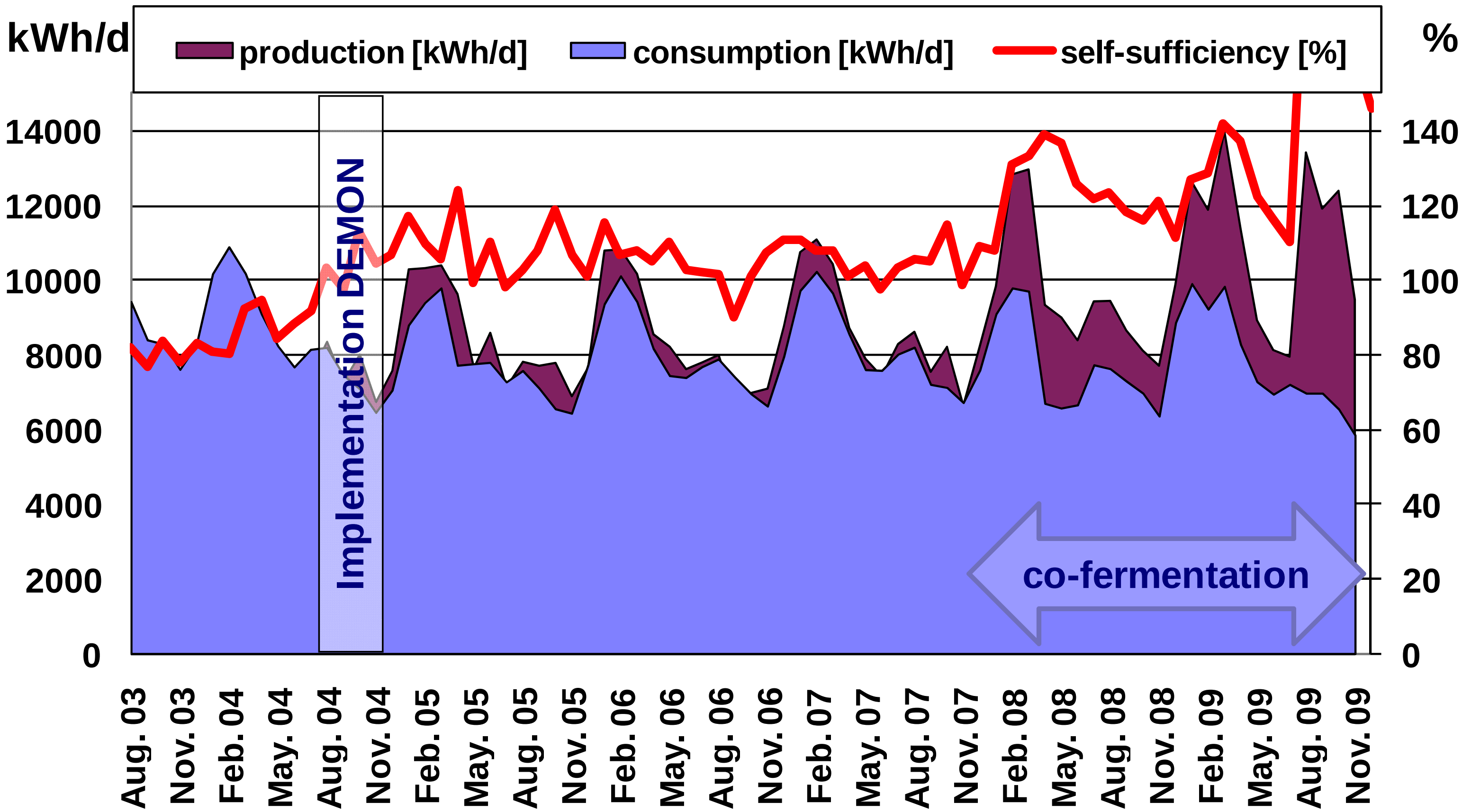


GREELEY AND HANSEN

Reality.....BNR...

- Strass WWTP operated by Abwasserverband Achental-Inntall-Zillertal,
  Strass, Austria.
- 10 mgd in the Winter
  - 250K p.e.
- 5-6 mgd in the Summer

Strass Data and Results



(Dr. Bernhard Wett, Personal Communication, 2011)

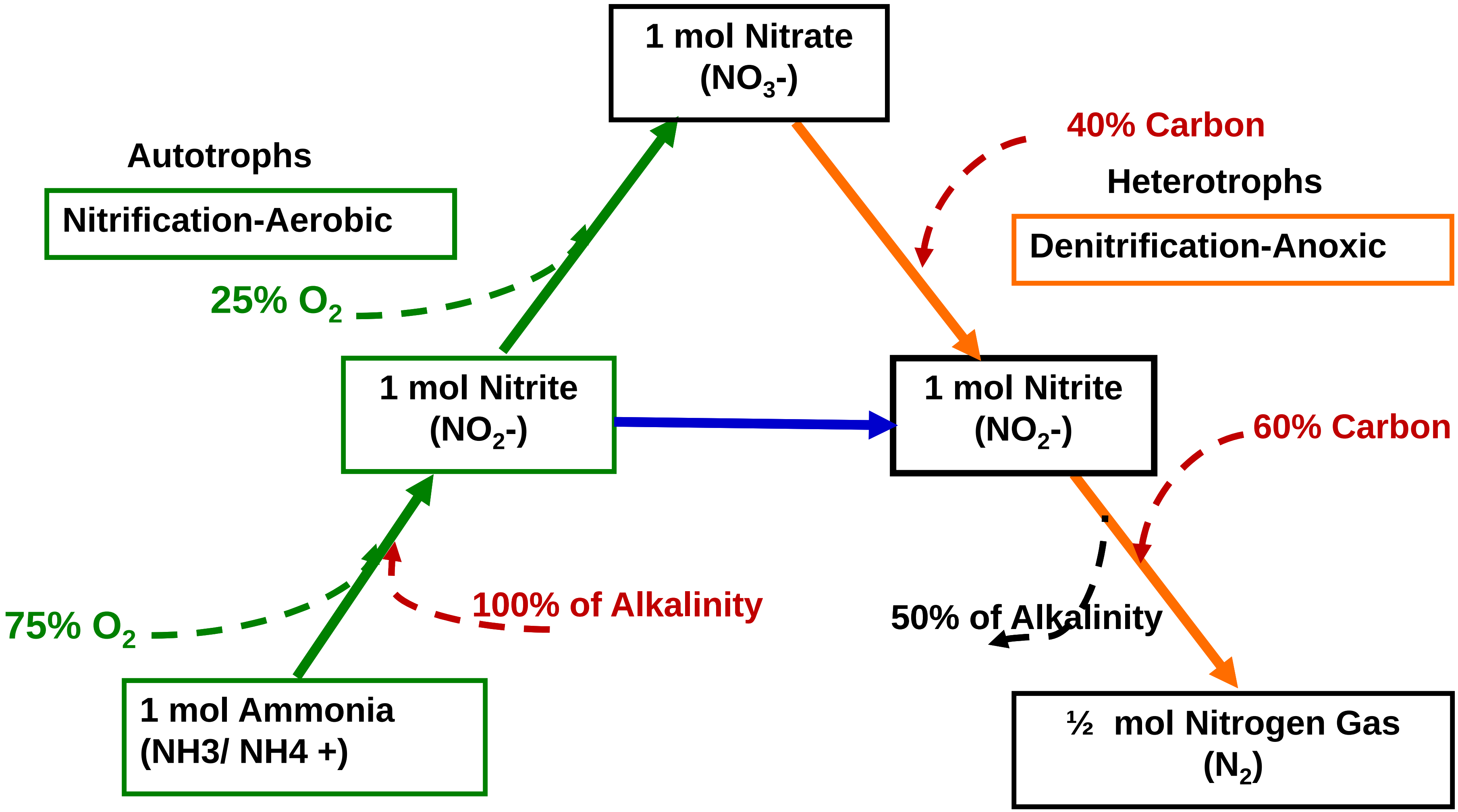
Agenda

- Fundamentals
  - Nutrient Management & Energy
- Baseline
  - Assessing Energy Conservation Measures
- Integrating Innovation
  - Assessing Novel Flowsheets
- Enabling Disruptive Technologies
  - Compatibility With The Technology Trajectory

Fundamentals

- Where is Energy Expended in Nutrient Removal
  - Nitrogen Management
    - Ammonia and Nitrite Oxidation
    - Nitrate and Nitrite Reduction
  - Biological Phosphorus Control

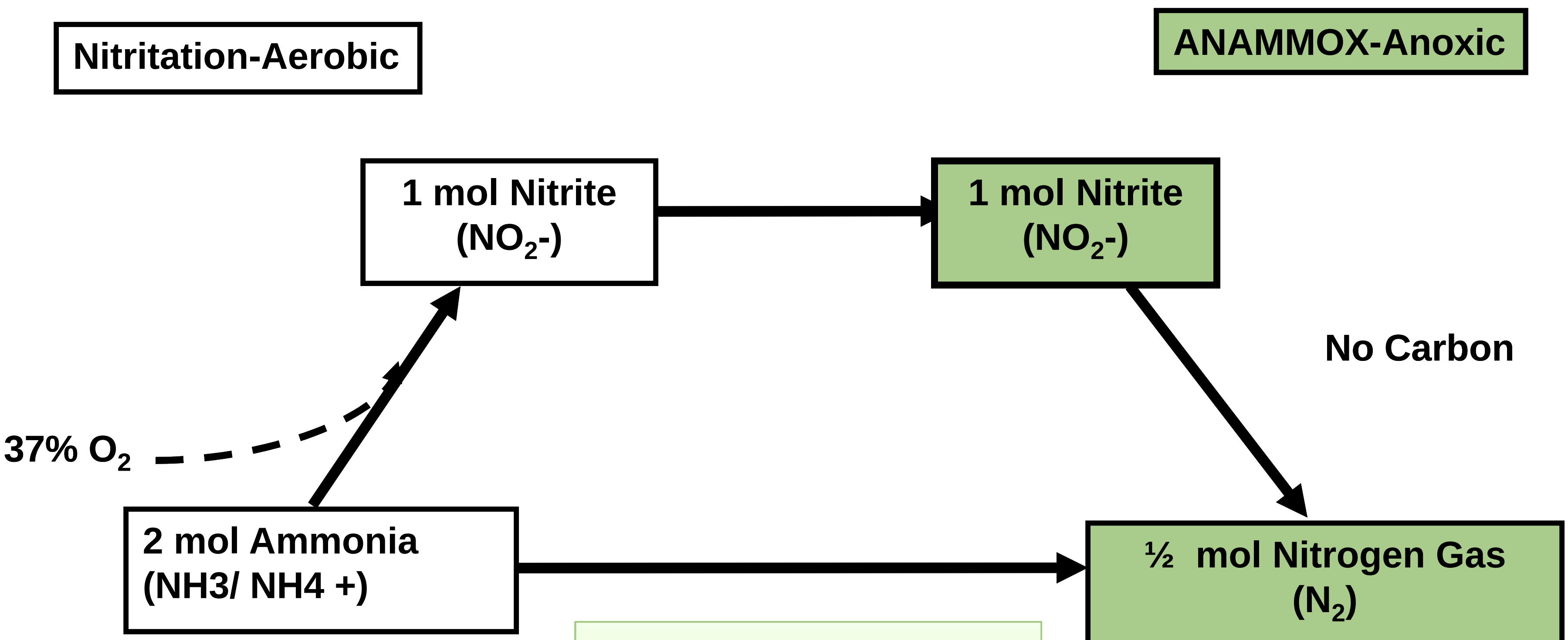
Nitrogen Removal:
From Conventional Pathways To Nitritation/Denitritation



GREELEY AND HANSEN

Deammonification:
Combining Nitritation & ANAMMOX

In a Simplified Representation



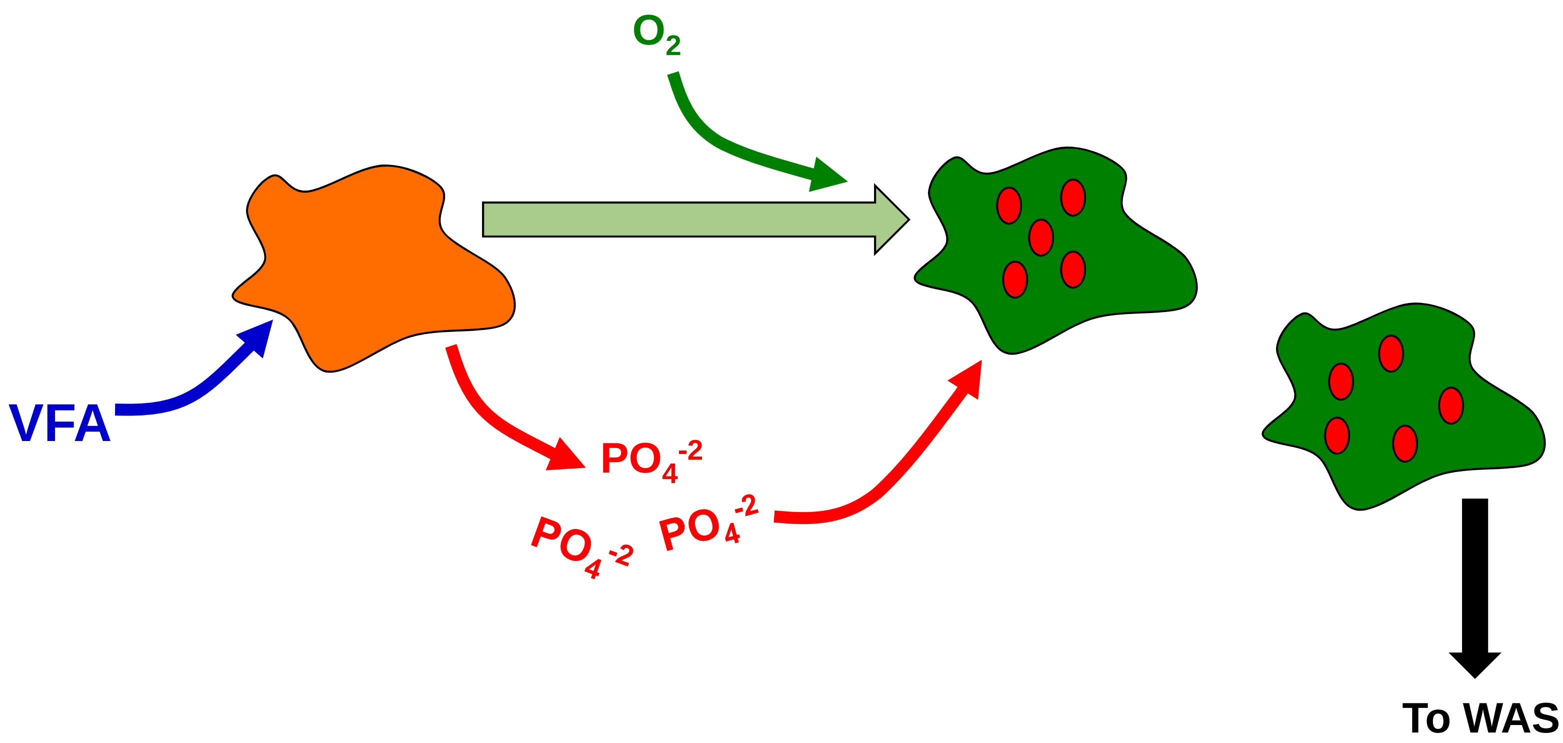
Results:

1. Less Oxygen
2. No Carbon

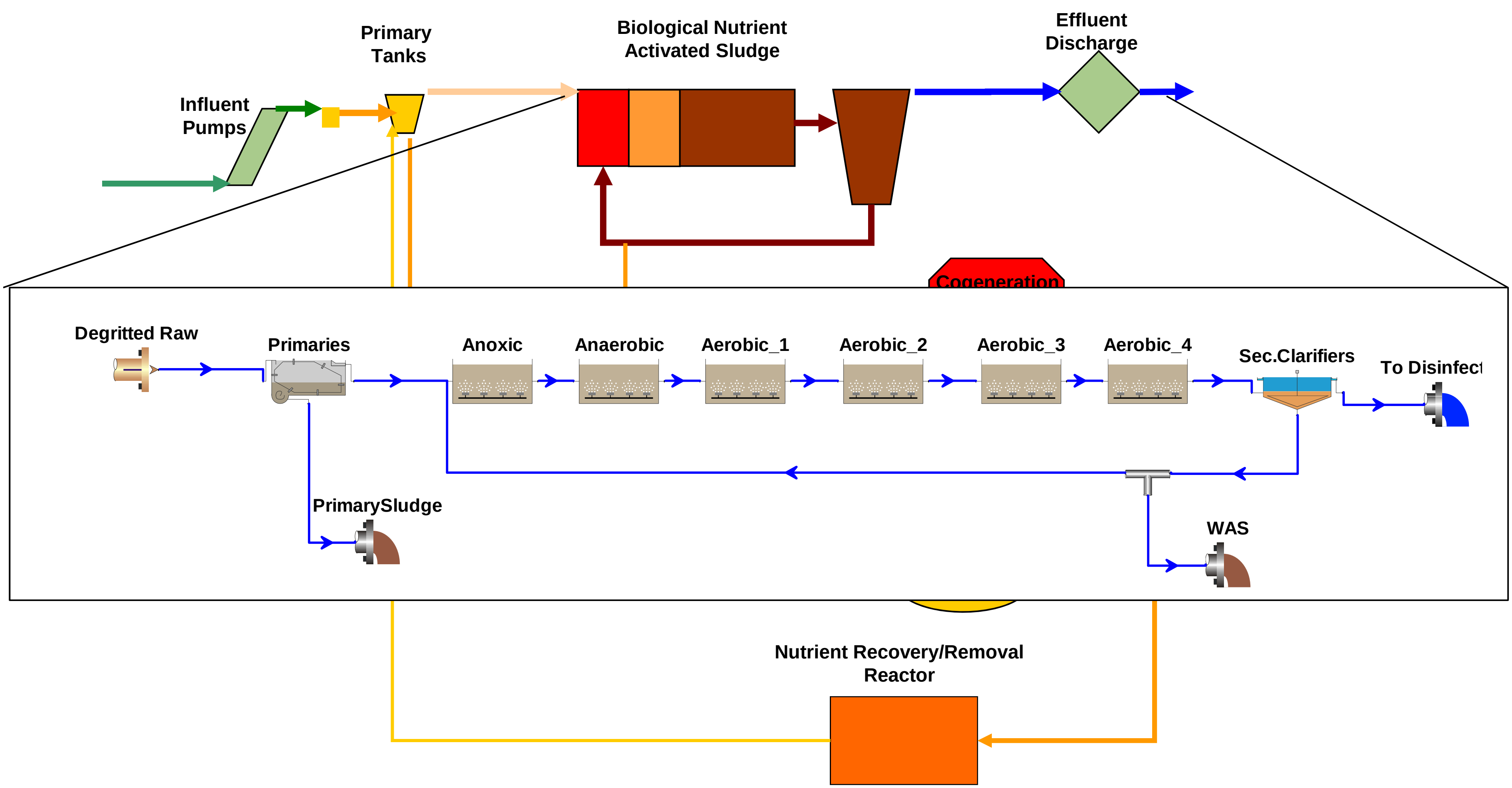
GREELEY AND HANSEN

Enhanced Biological Phosphorus Removal

Energy Optimization Opportunities???

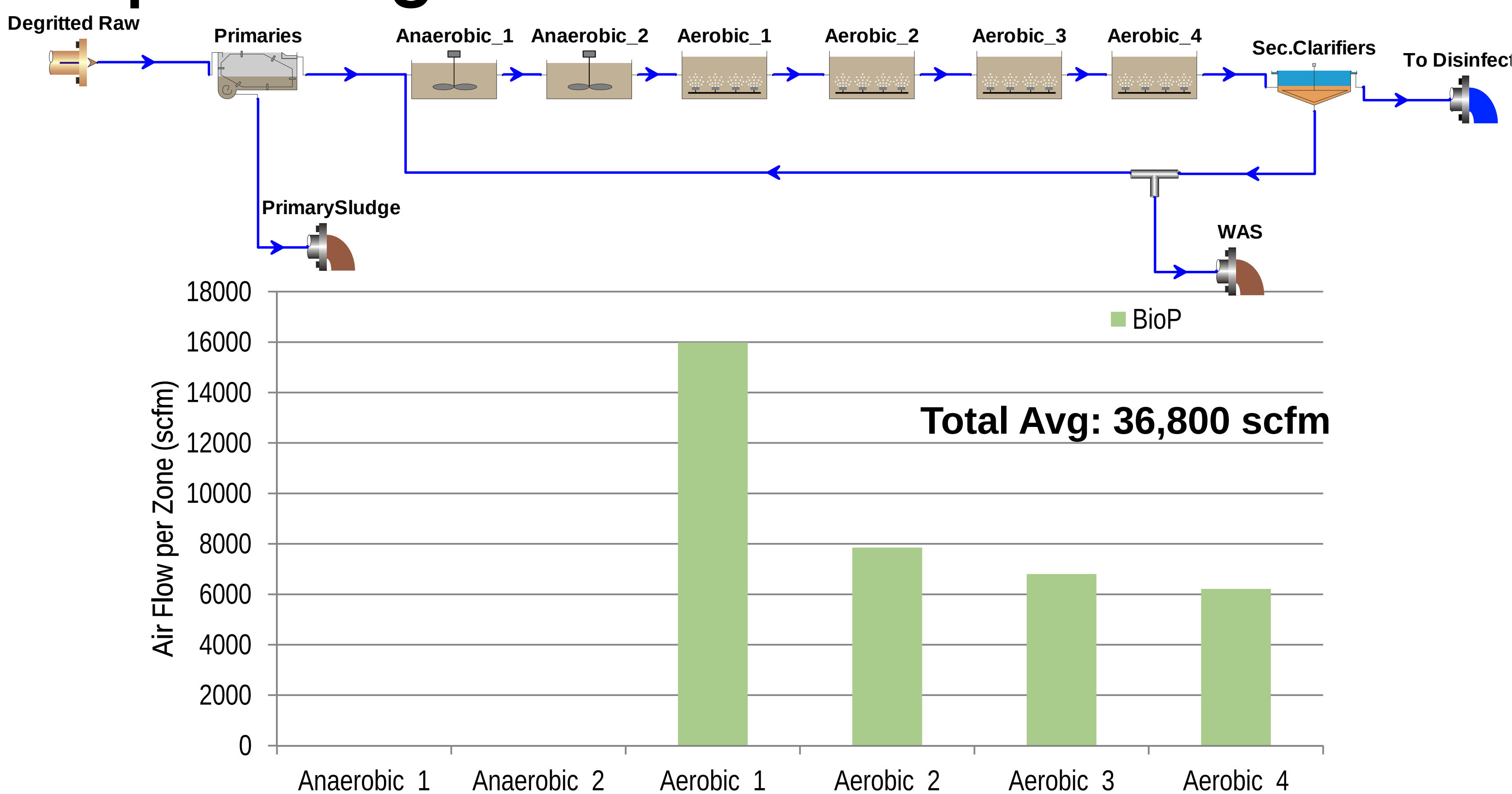


Conventional Process Configuration



Applying Process Simulators

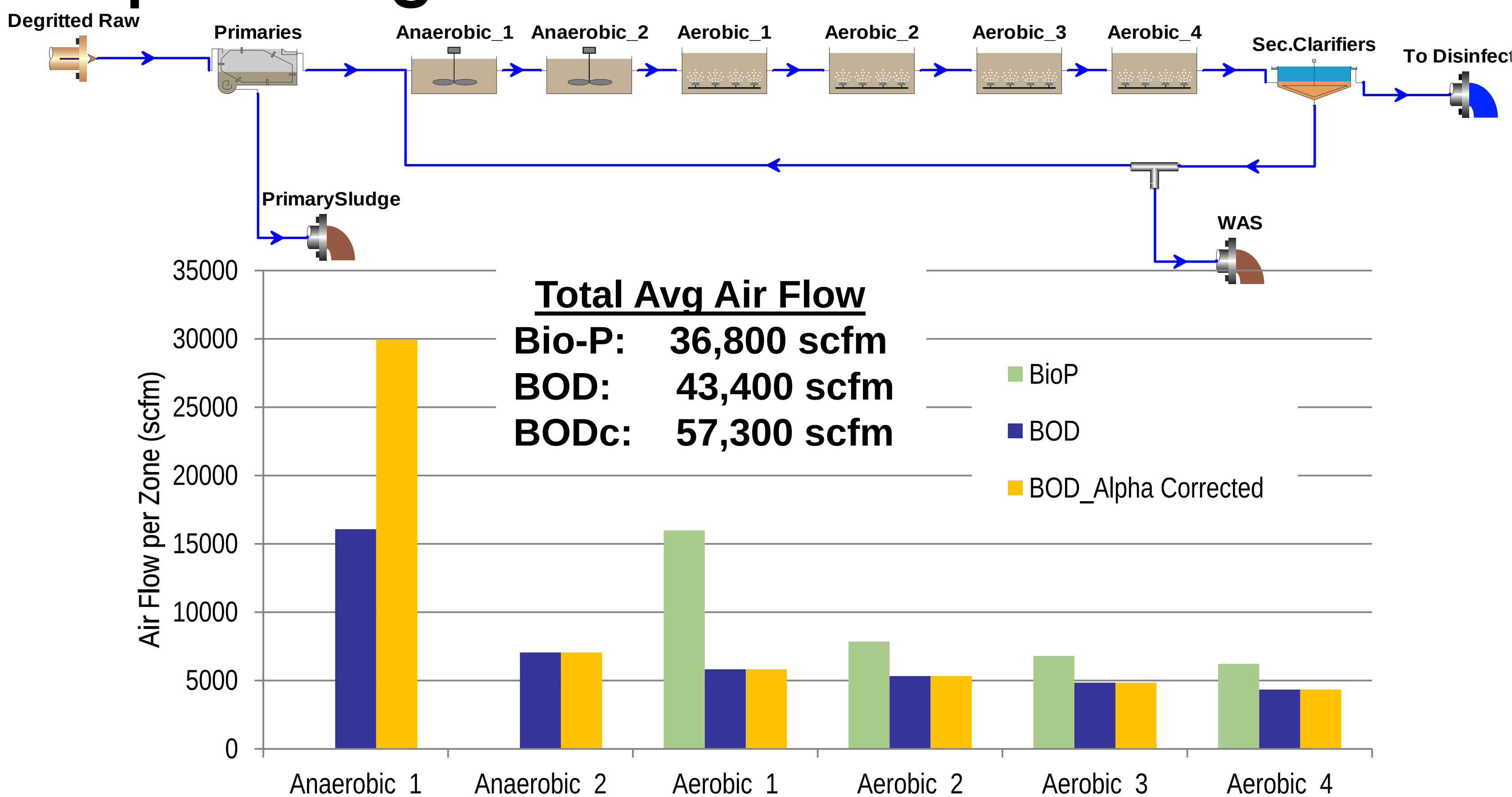
- Operating With EBPR: 100 MGD WWTP



GREELEY AND HANSEN

Applying Process Simulators

- Operating With EBPR: 100 MGD WWTP



Total Avg Air Flow

Bio-P: 36,800 scfm

BOD: 43,400 scfm

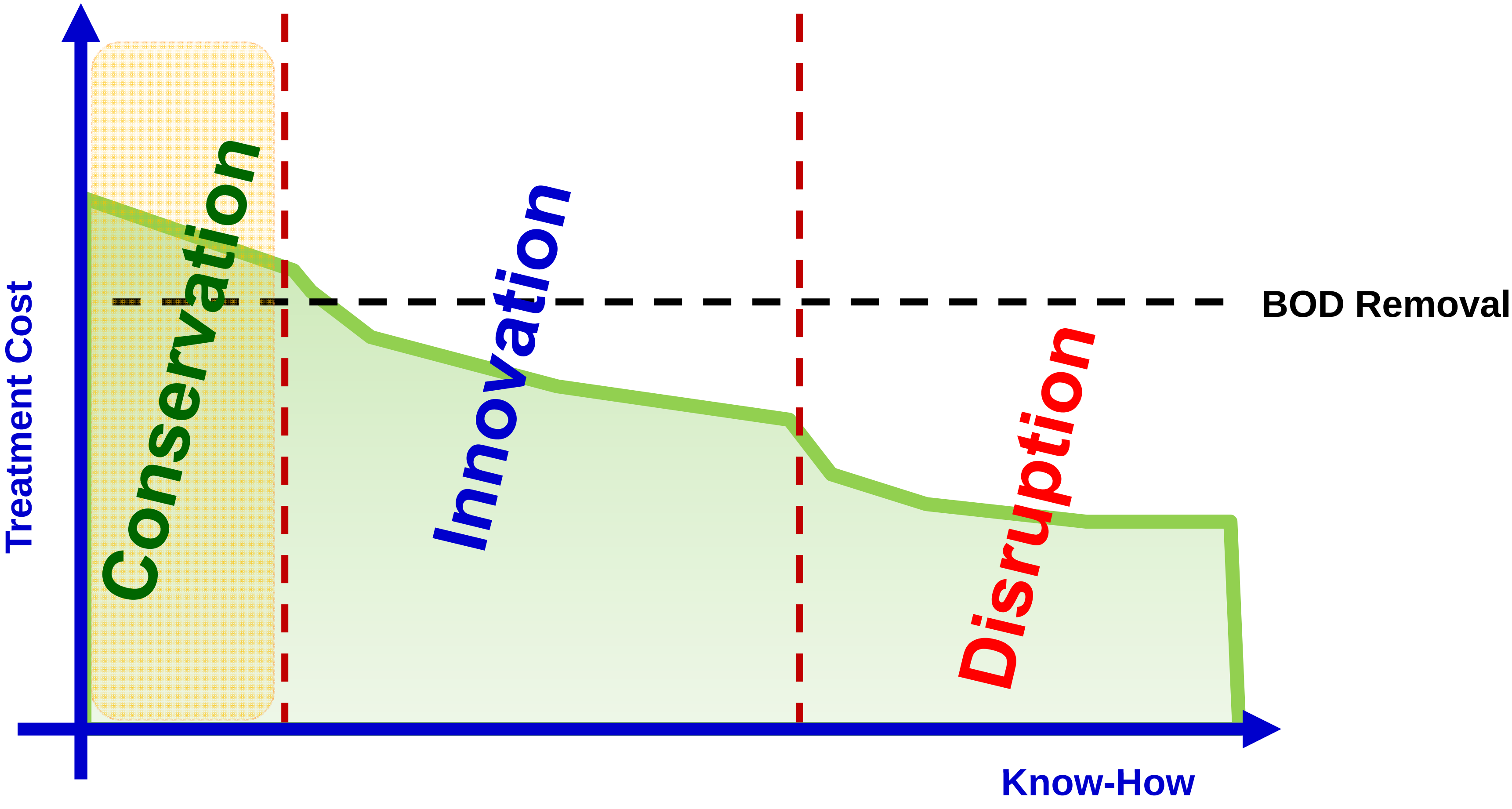
BODc: 57,300 scfm

Applying Process Simulators

- Process Simulators Can Be Powerful Allies if…

- Net Benefit: 20,000 scfm ~ 1200 HP ~ $800K/yr…

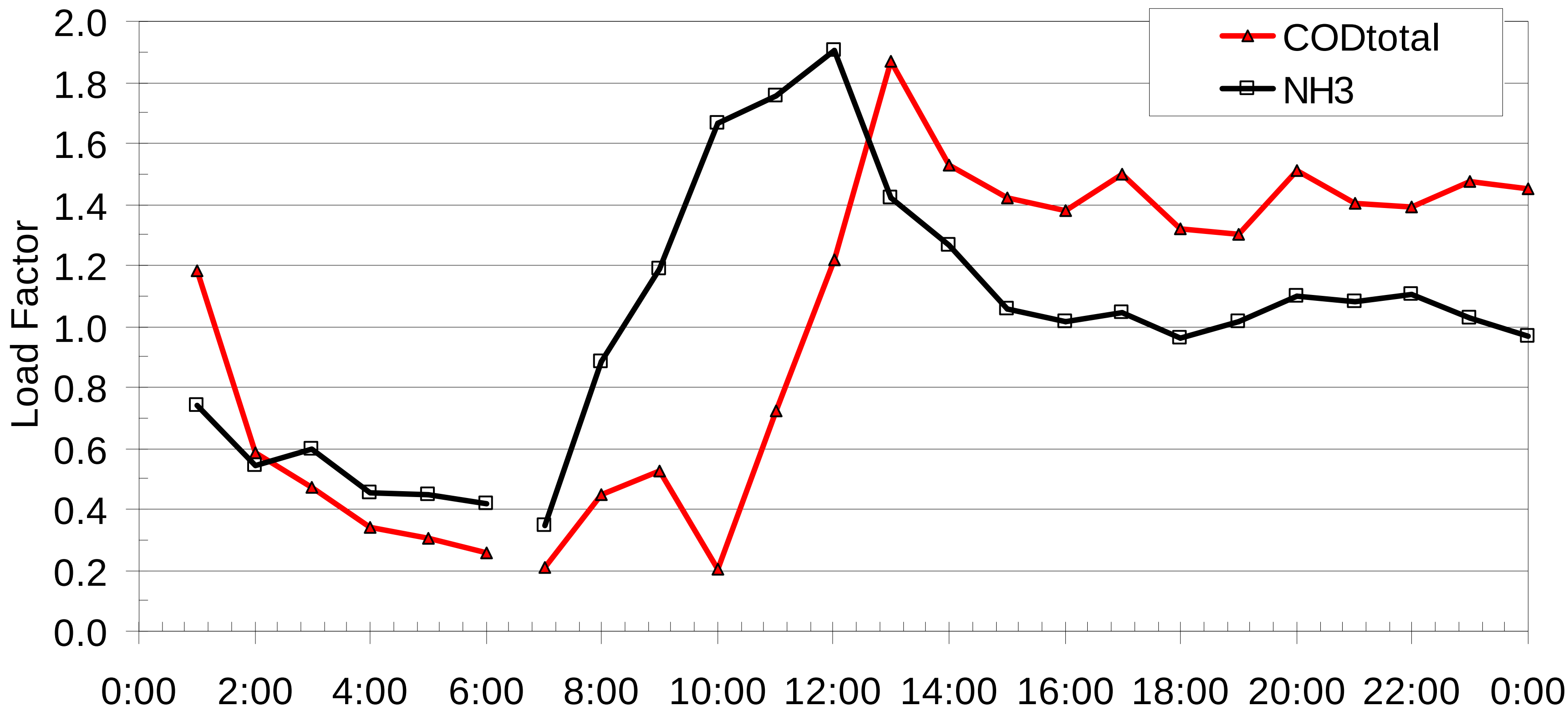
Where Are We?



GREELEY AND HANSEN

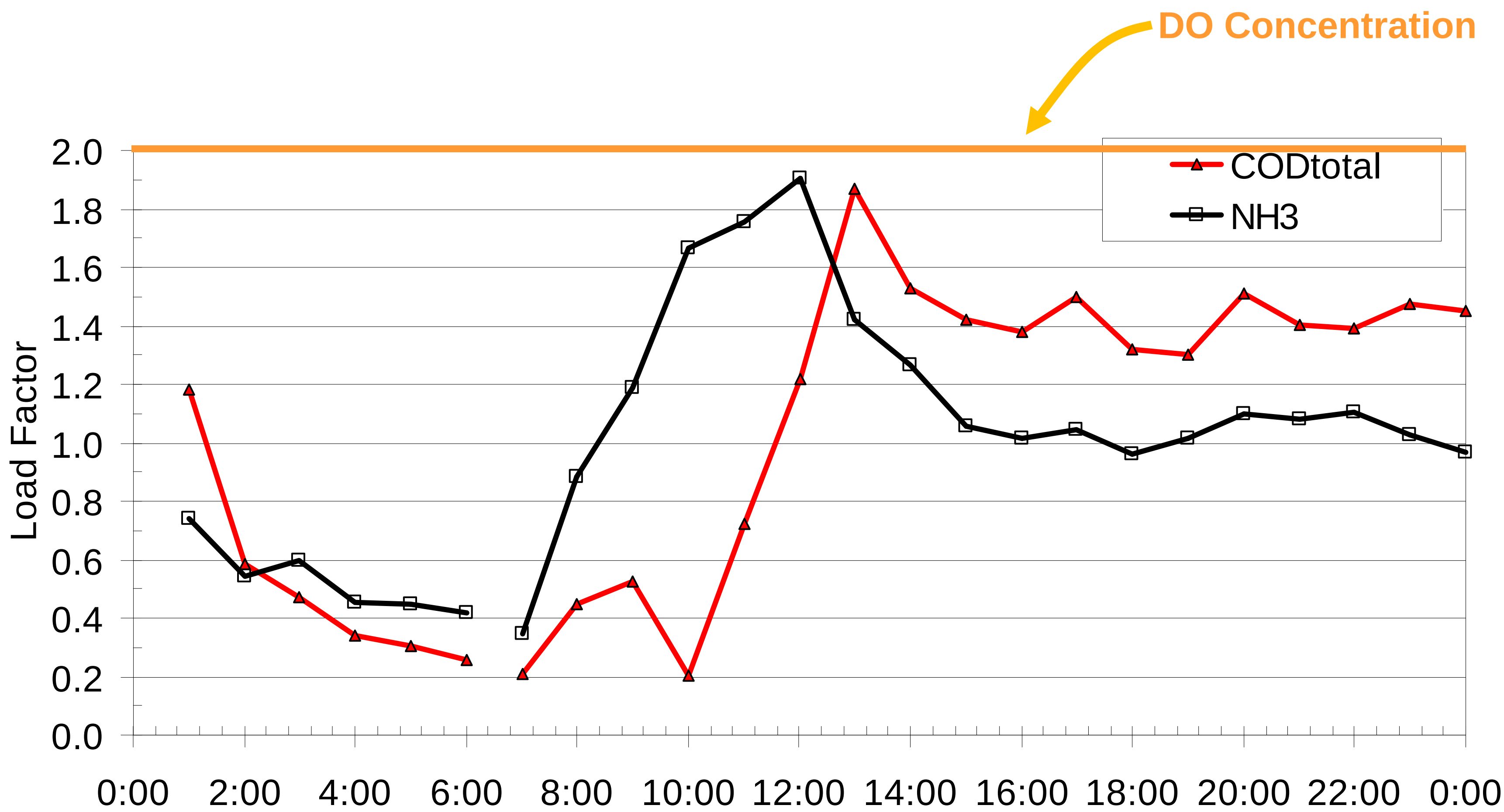
Diurnal Management

- Diurnal Impacts More Readily Identifiable in Urban Systems



GREELEY AND HANSEN

Dynamic DO Control

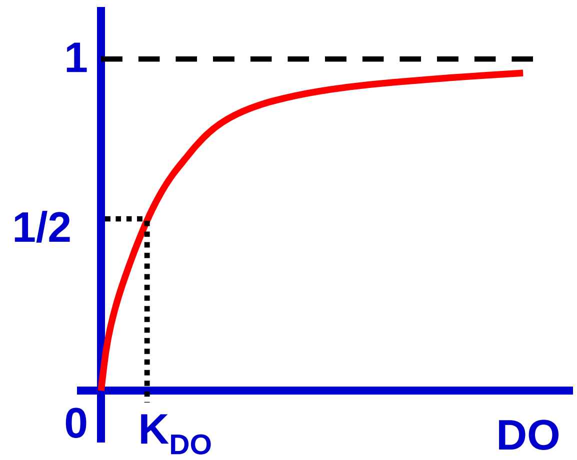


GREELEY AND HANSEN

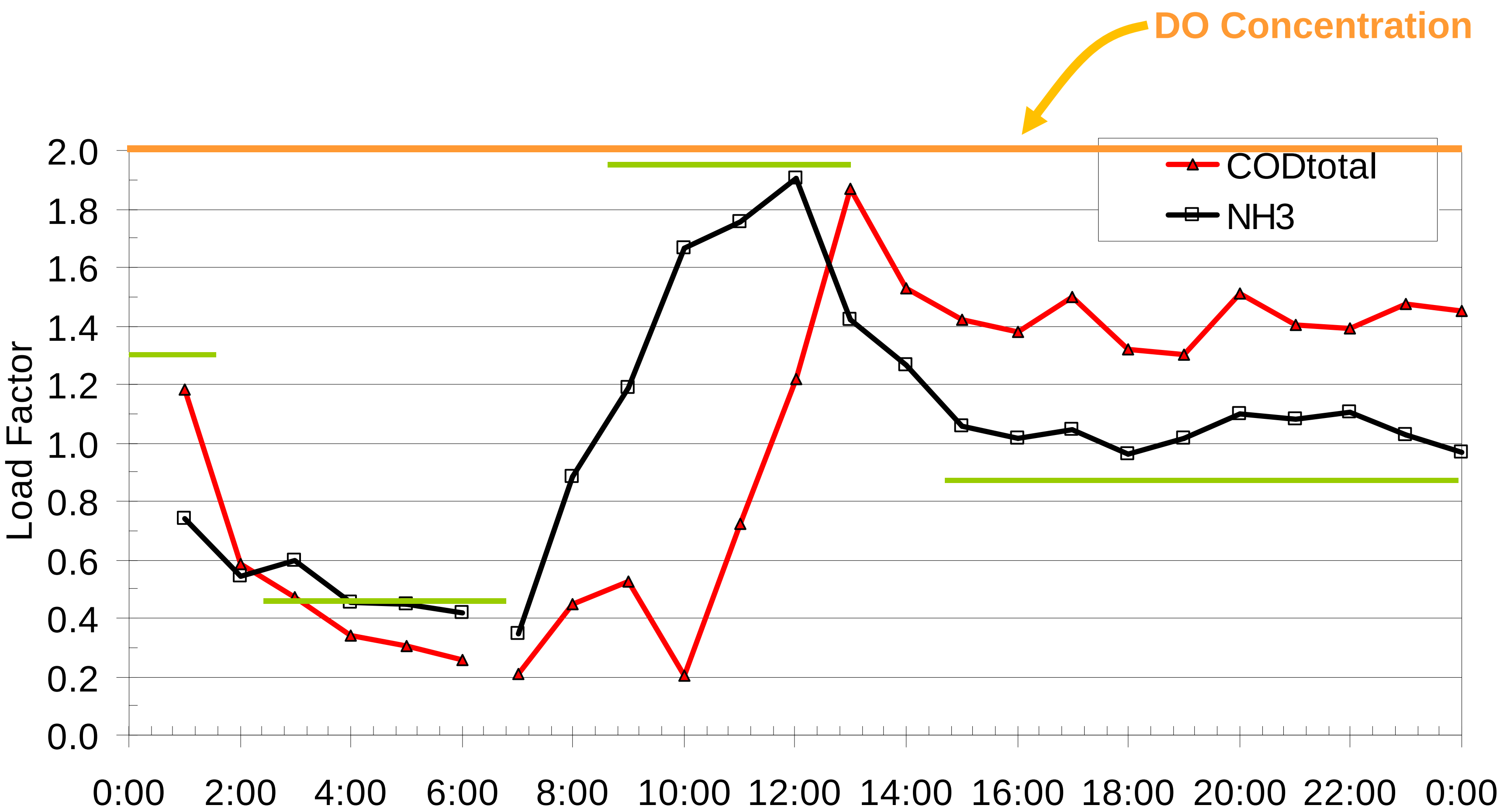
Dynamic DO Control

- Why is DO Concentration Important?

$$r_g = \mu max \left[DO / (K_{DO} + DO) \right]$$

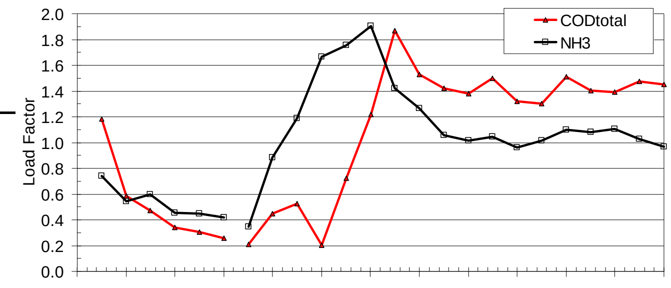


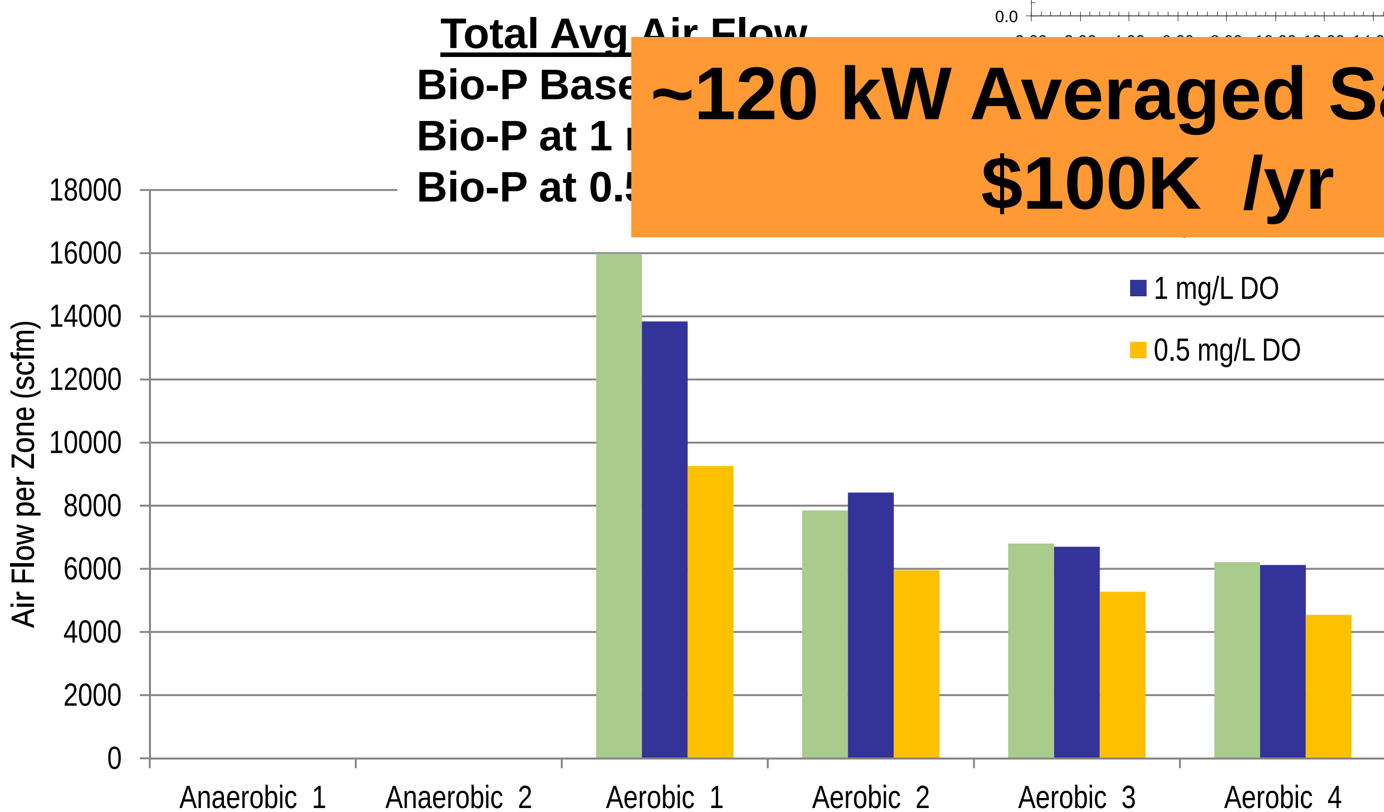
Dynamic DO Control



GREELEY AND HANSEN

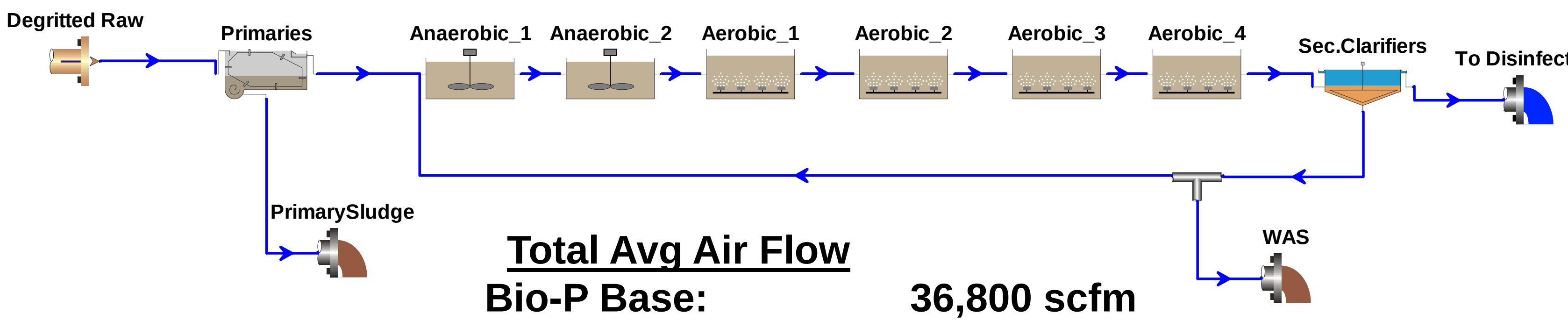
Dynamic DO Control





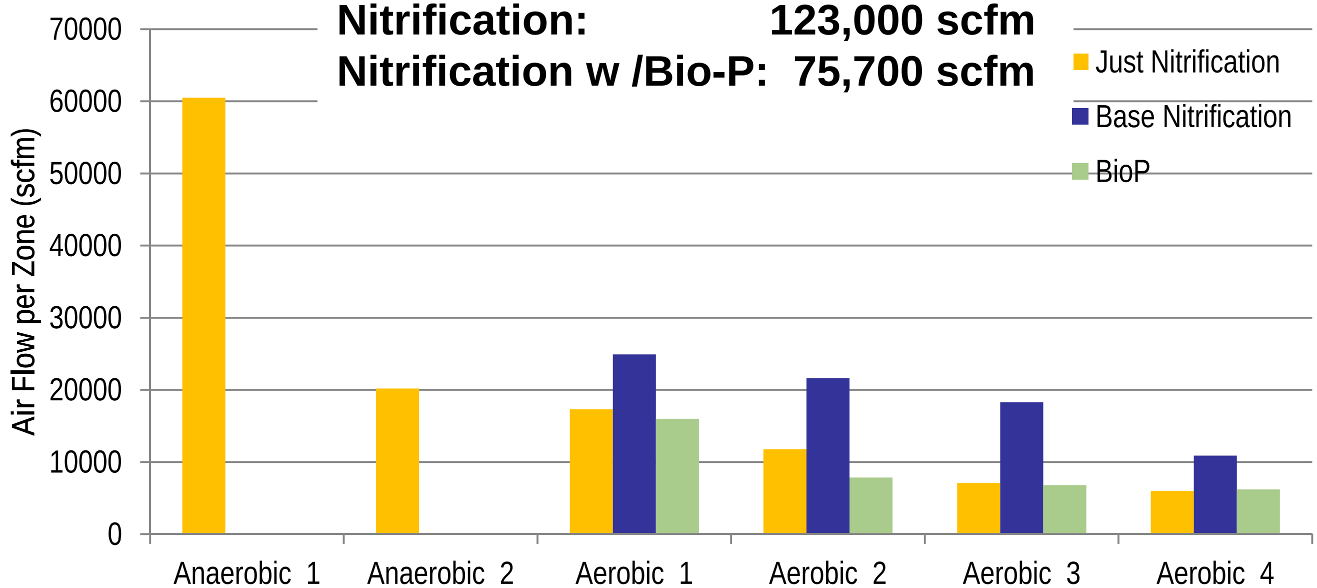
~120 kW Averaged Savings
$100K /yr

How About Nitrogen Removal

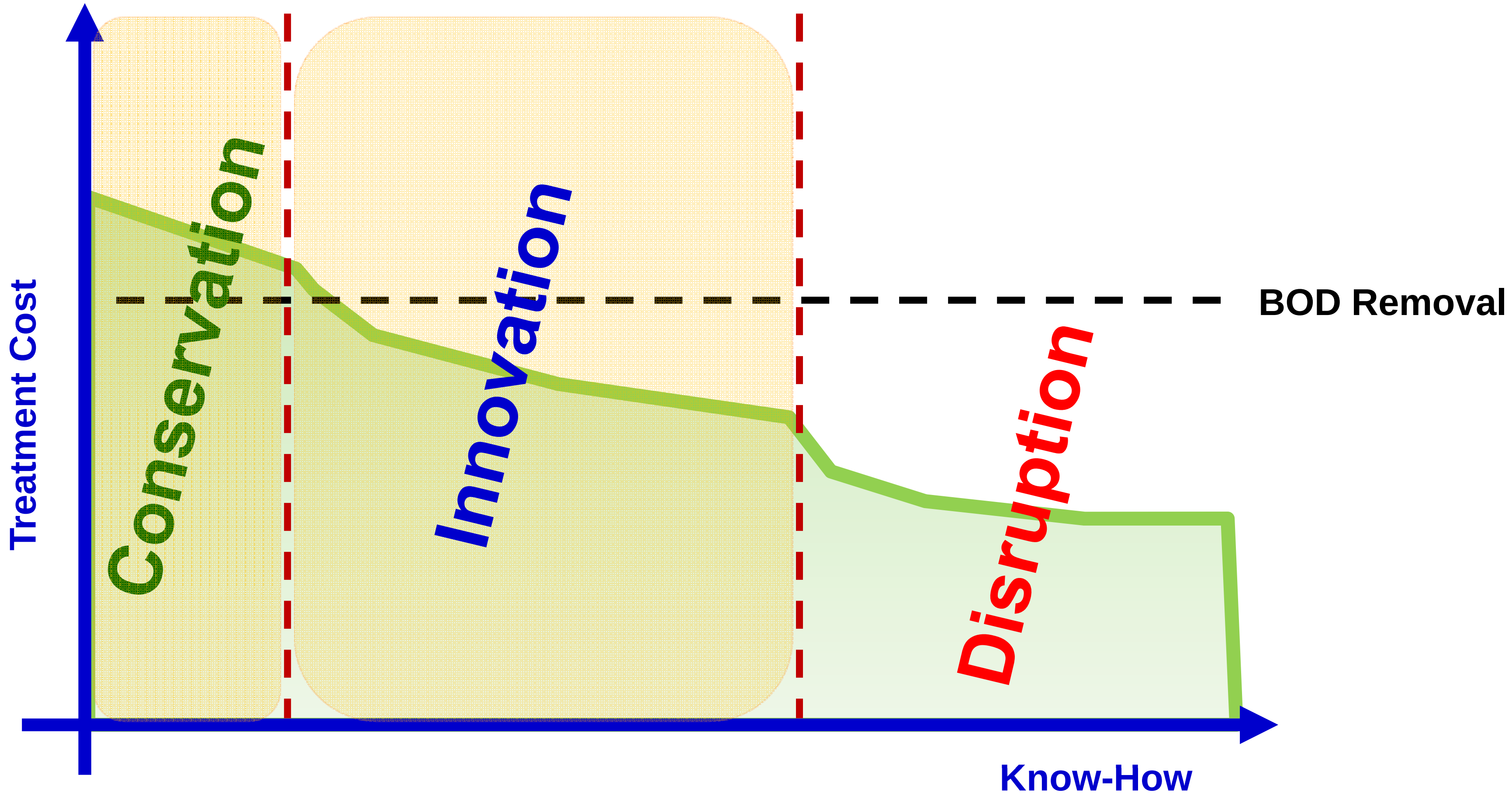


Total Avg Air Flow

Bio-P Base: 36,800 scfm
Nitrification: 123,000 scfm
Nitrification w /Bio-P: 75,700 scfm



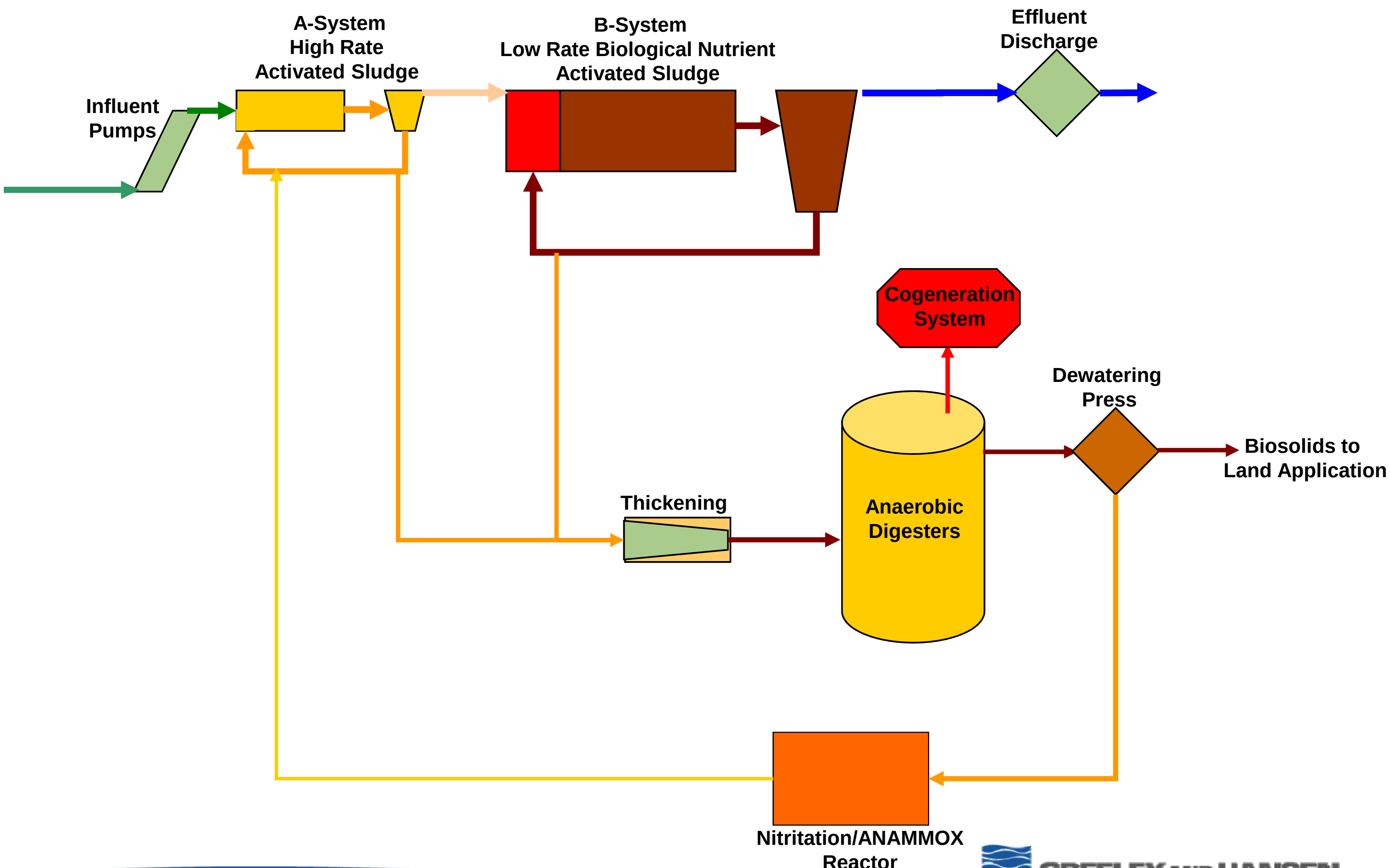
Where Are We?


Treatment Cost
Conservation
Innovation
BOD Removal
Disruption
Know-How

Strass Data and Results

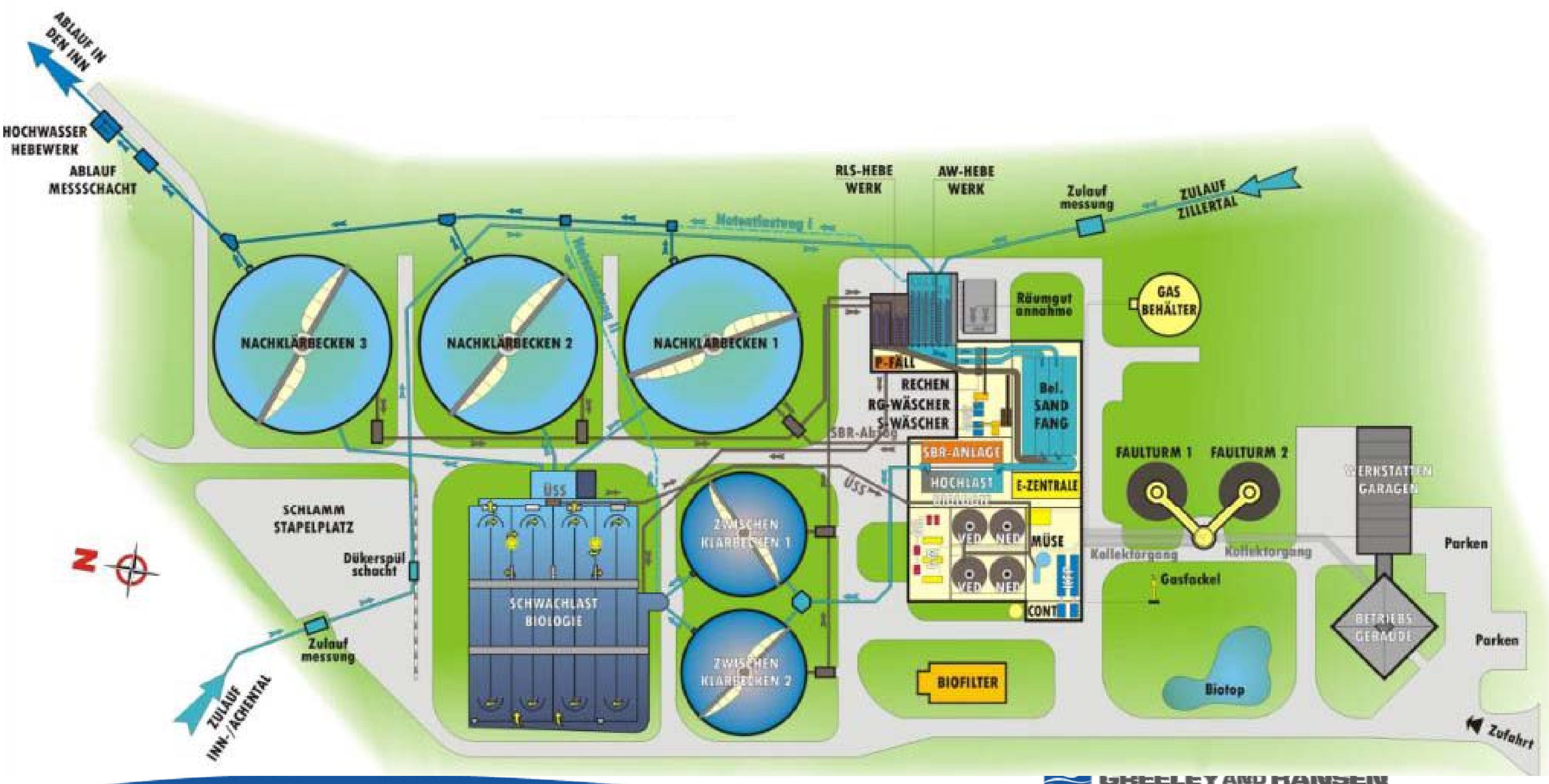
- Strass WWTP operated by Abwasserverband Achental-Inntall-Zillertal, Strass, Austria.
- 10 mgd in the Winter
  - 250K p.e.
- 5-6 mgd in the Summer

Strass Process Configuration



GREELEY AND HANSEN

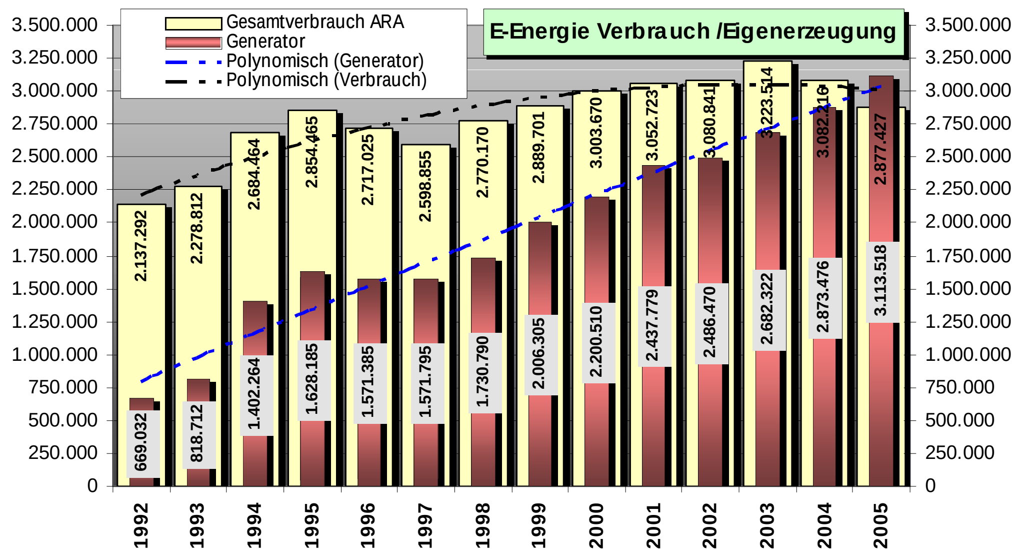
Strass WWTP Layout



GREELEY AND HANSEN

Strass Data and Results

- Plant produces more electricity than it consumes
  - Continuous energy efficiency improvement
  - Co-generation

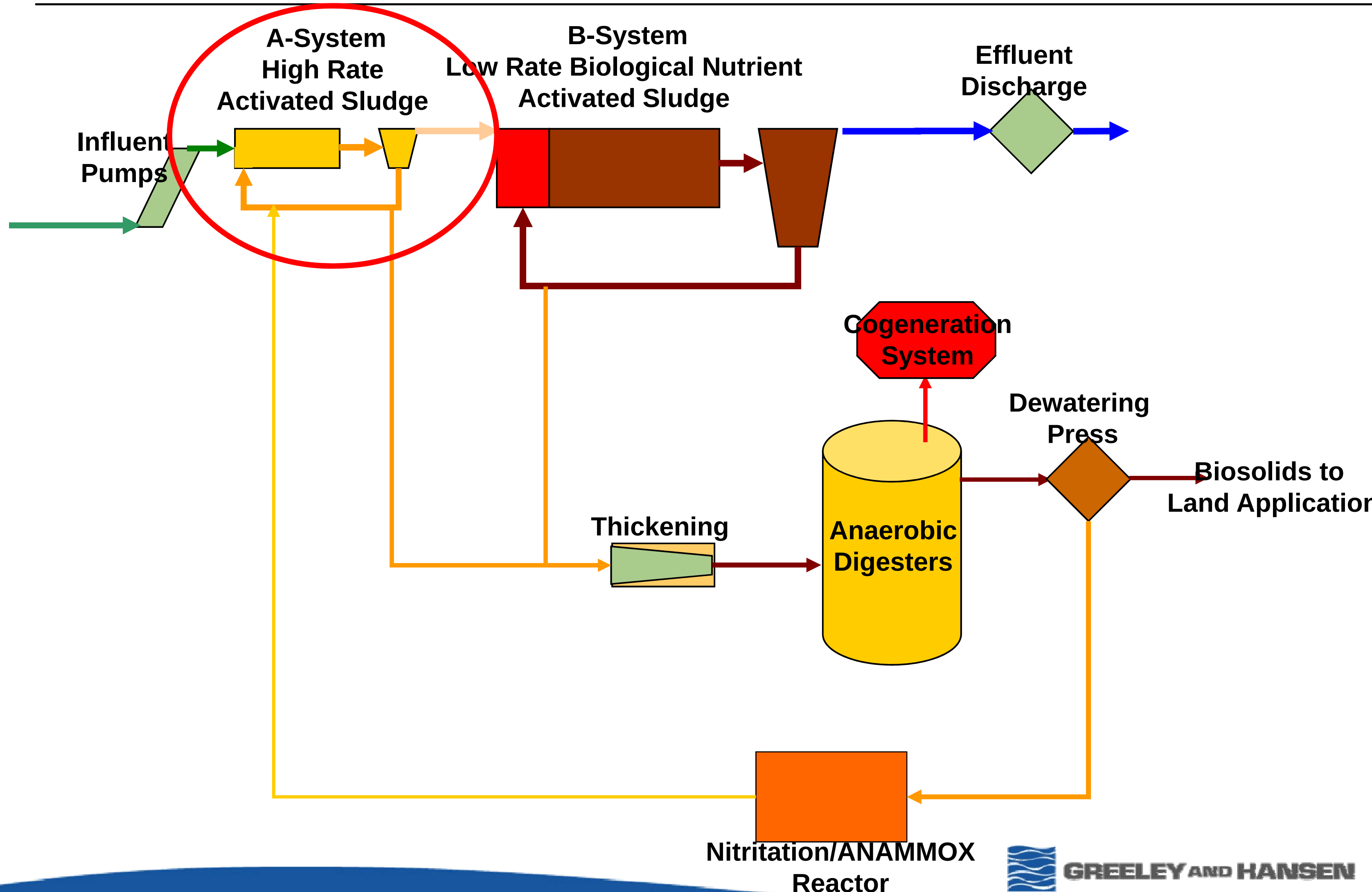


Why Strass ?

- Reduction of chemical costs for sludge thickening by 50%
- Reduction in sludge dewatering costs by 33%
- Reduction in energy consumption on mass treated basis from approximately 6.5 euro/kg NH4-N removed in 2003 to 2.9 euro/kgNH4-N removed in 2007/2008
  - active management of dissolved oxygen (DO) setpoints
  - conversion to ultra-high efficiency strip aeration
- Sidestream treatment
  - 350 kWh/d to 196 kwh/d by implementing Nitritation/anammox (DEMON®)
- Digester gas utilization
  - cogeneration unit, boosting electrical efficiency from 33% to 39% and overall usage efficiency from 2.05 to 2.30 kW-hr/m^3 of digester gas

In a relatively small WWTP; normally considered to be lacking the critical mass necessary to demonstrate innovation

Strass Data and Results

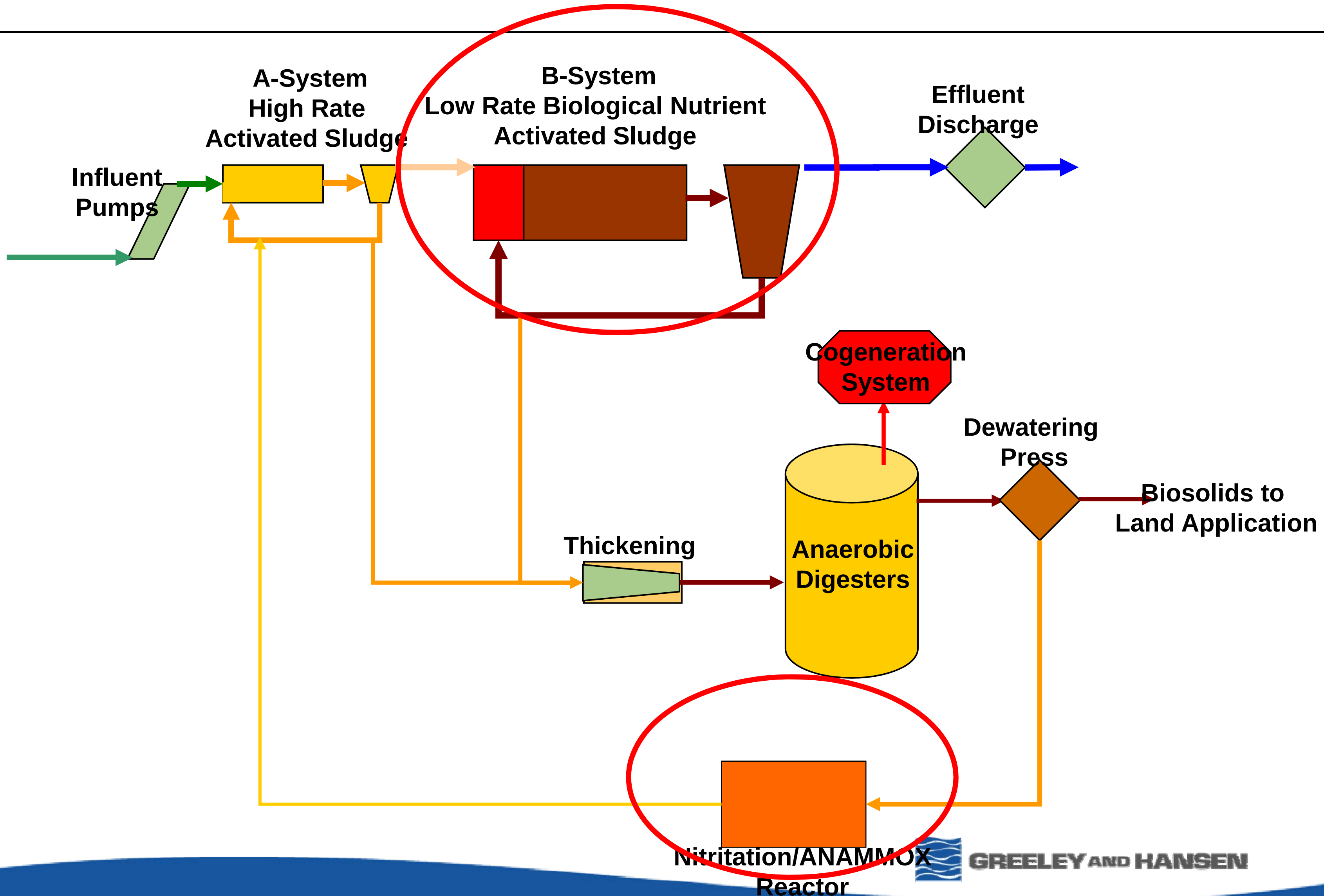


GREELEY AND HANSEN

Goal: Maximize Organics to Digestion

- The A/B Process for Primary & Secondary Treatment
- The A Process:
  - High Rate Activated Sludge
    - 0.5-0.75 Hr HRT; 8-12 Hr SRT
    - Particulate, Colloidal & SOLUBLE Organics Removal Without Chemical Addition
  - Rapid Transfer from Aerobic Conditions to Anaerobic Conditions for Thickening Preserves Organics (COD & Calorific Energy)

Strass Data and Results



GREELEY AND HANSEN

So What's a Sidestream?

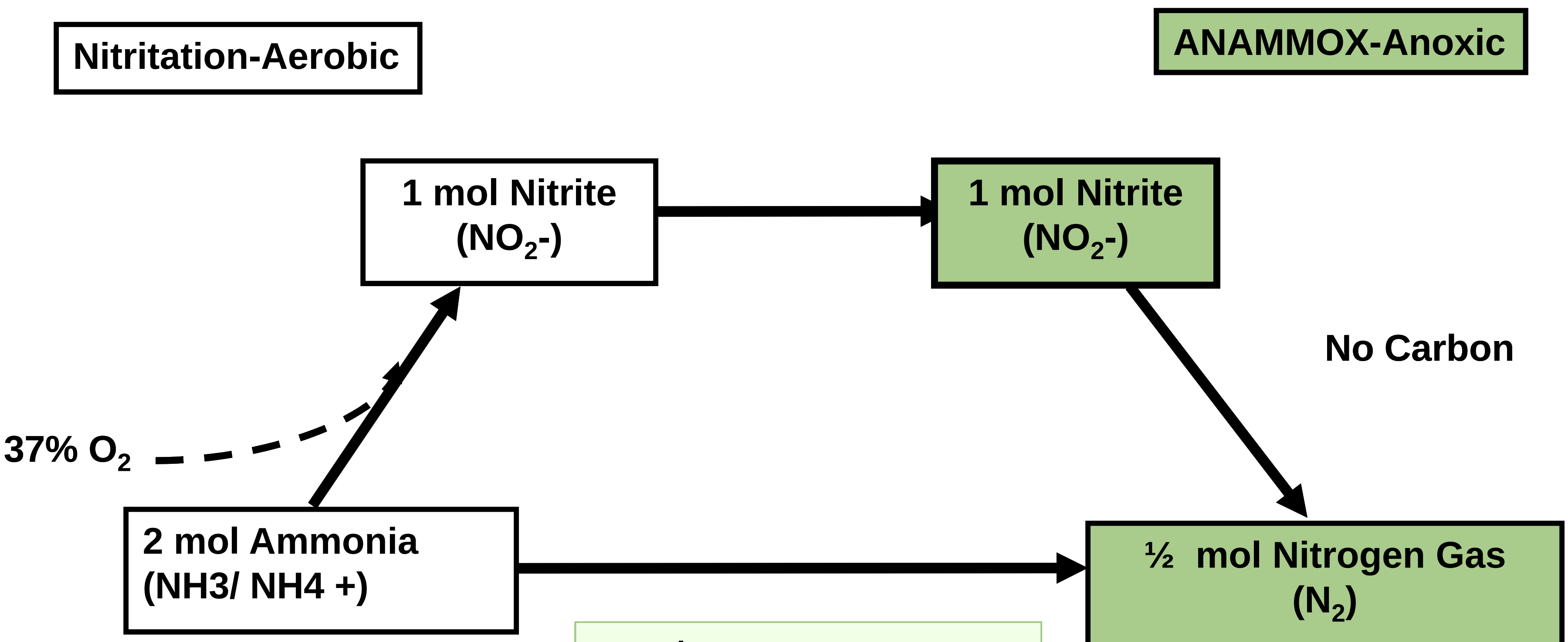
- High Strength Recycle
  - Typically from Anaerobically Digested Dewatering
  - Thermal Processing Decanting
- Typical Characteristics

Temp	25° - 40°C
Ammonia	600 - 2000 mgN/L
Ortho-Phosphate	50 – 1000 mgP/L
Alkalinity as $CaCO_3$	500 – 4000 mg/L
TSS	500 – 5000 mg/L

Deammonification:

Combining Nitritation & ANAMMOX

In a Simplified Representation



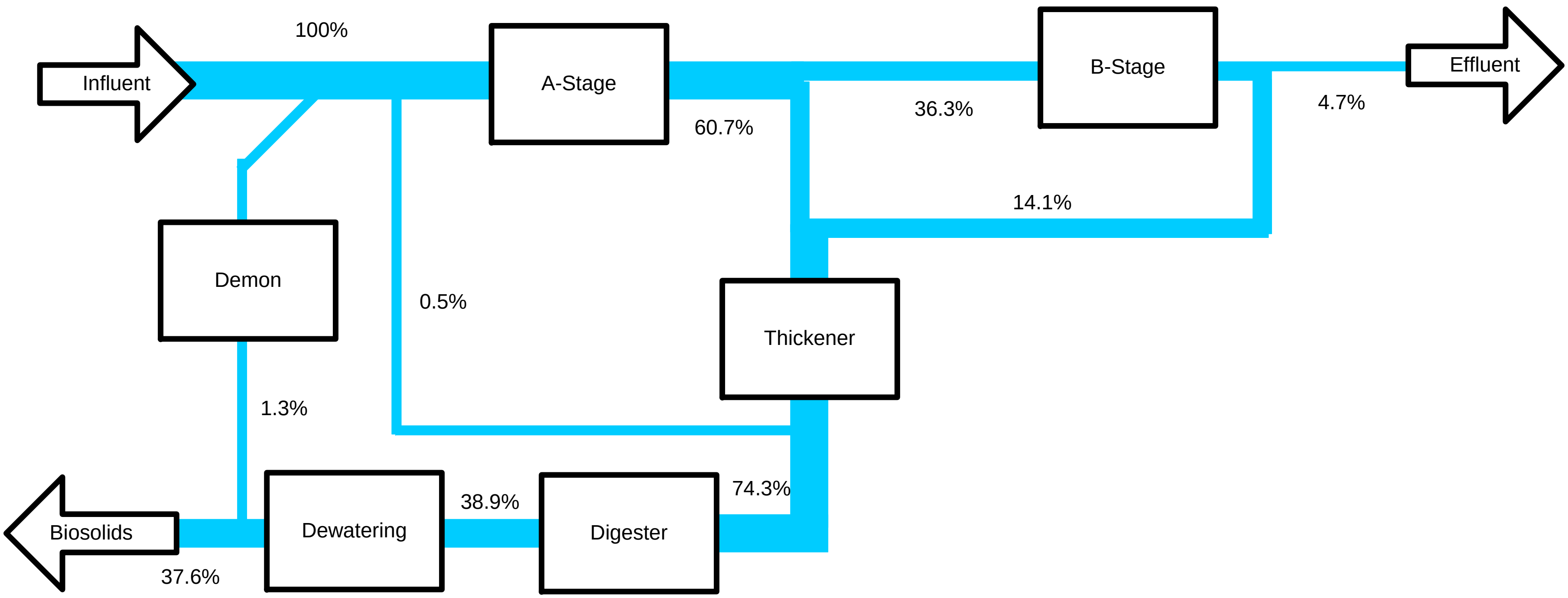
Results:

1. Less Oxygen
2. No Carbon

Use of Advanced Process Analysis Tools

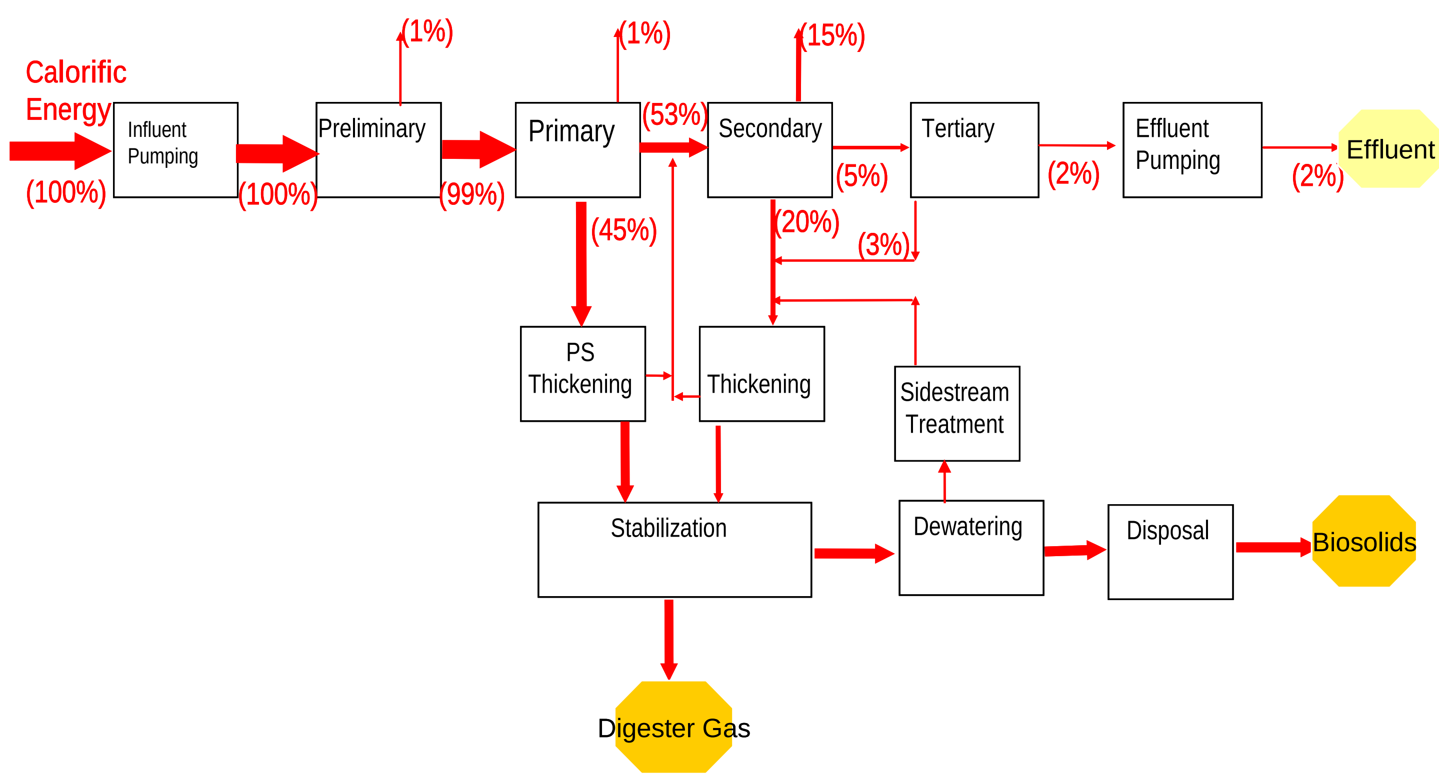
- Conduct COD, Calorific and Electrical Consumption/Generation Balance
- Identify Sinks, Potential Sources of Energy and Opportunities
- Graphical Format for Operations Team to Consult/Interpret
- Trending of Balances Over Time to Assess "Minor" Tweaks

COD Balance



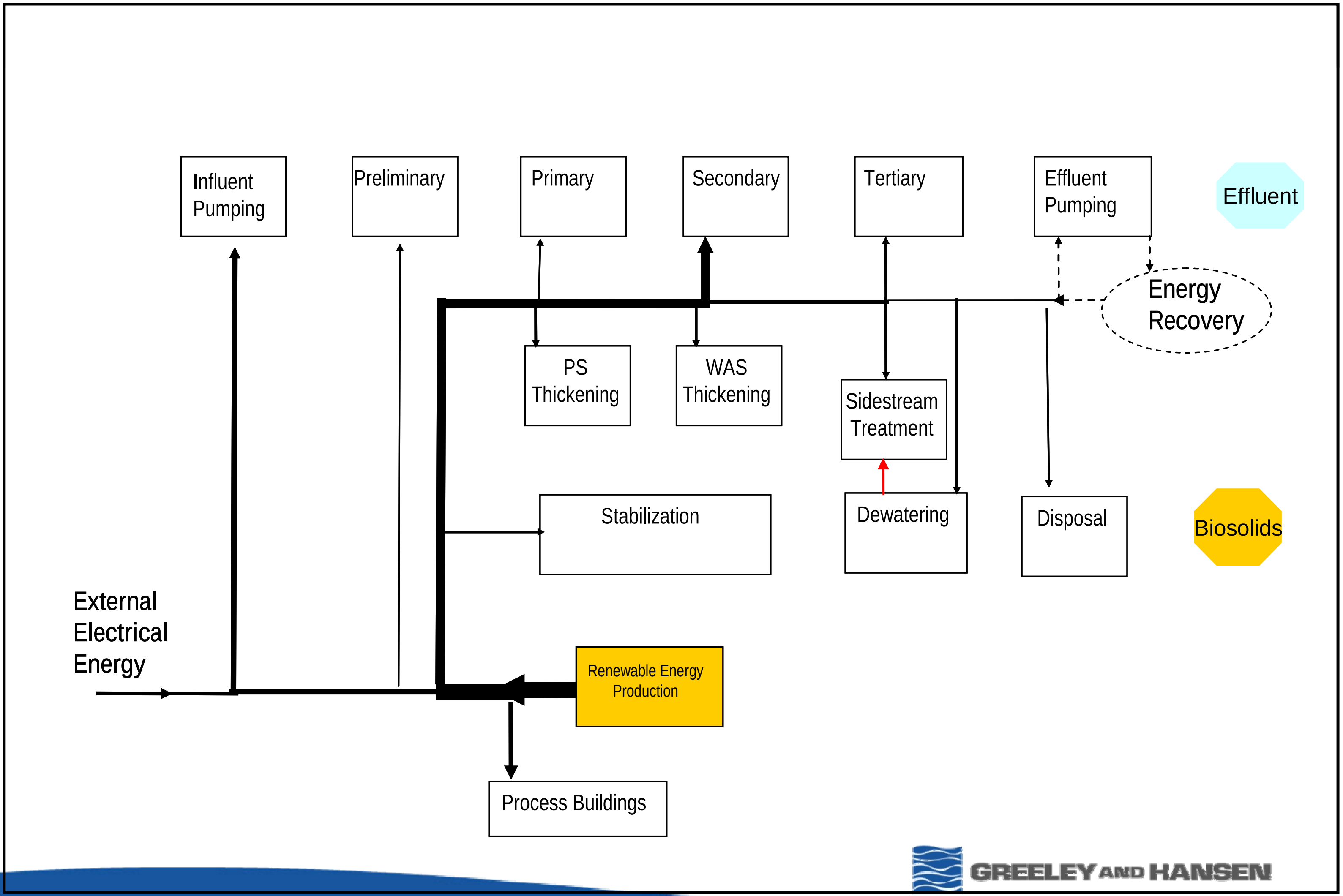
GREELEY AND HANSEN

Calorific Energy Balance



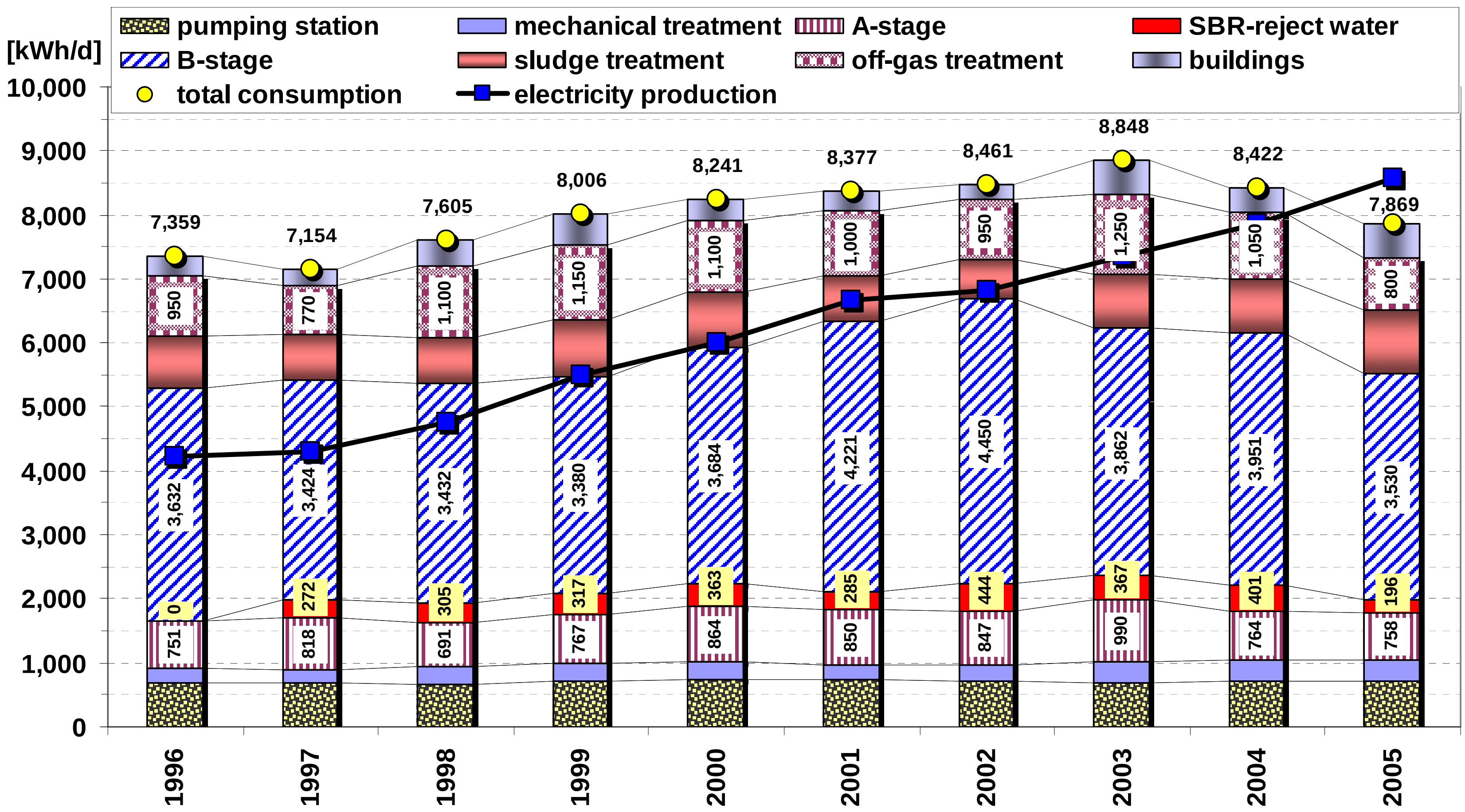
GREELEY AND HANSEN

Electrical Energy Balance



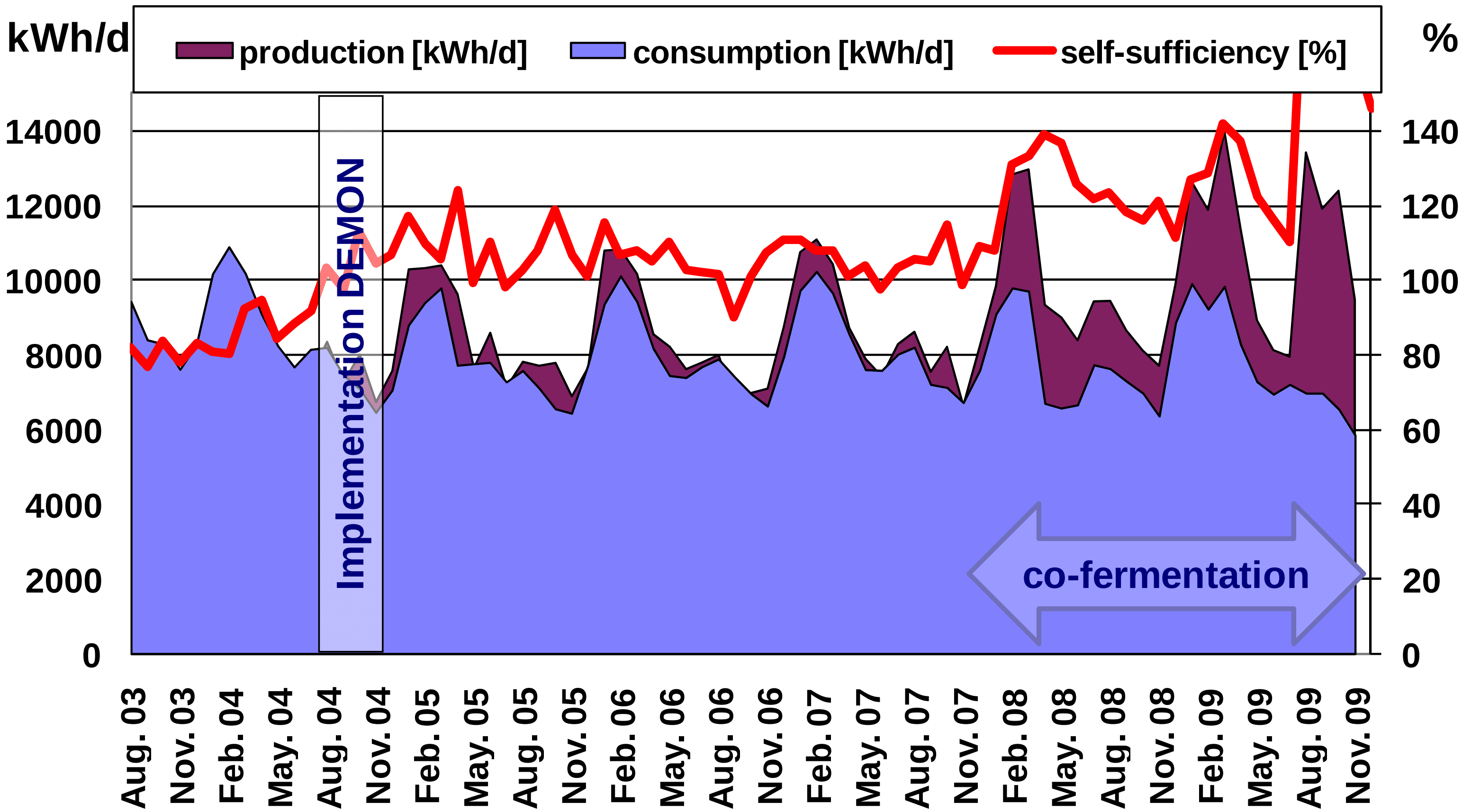
GREELEY AND HANSEN

Achieving Energy Neutrality



GREELEY AND HANSEN

Achieving Energy Neutrality



(Dr. Bernhard Wett, Personal Communication, 2011)

GREELEY AND HANSEN

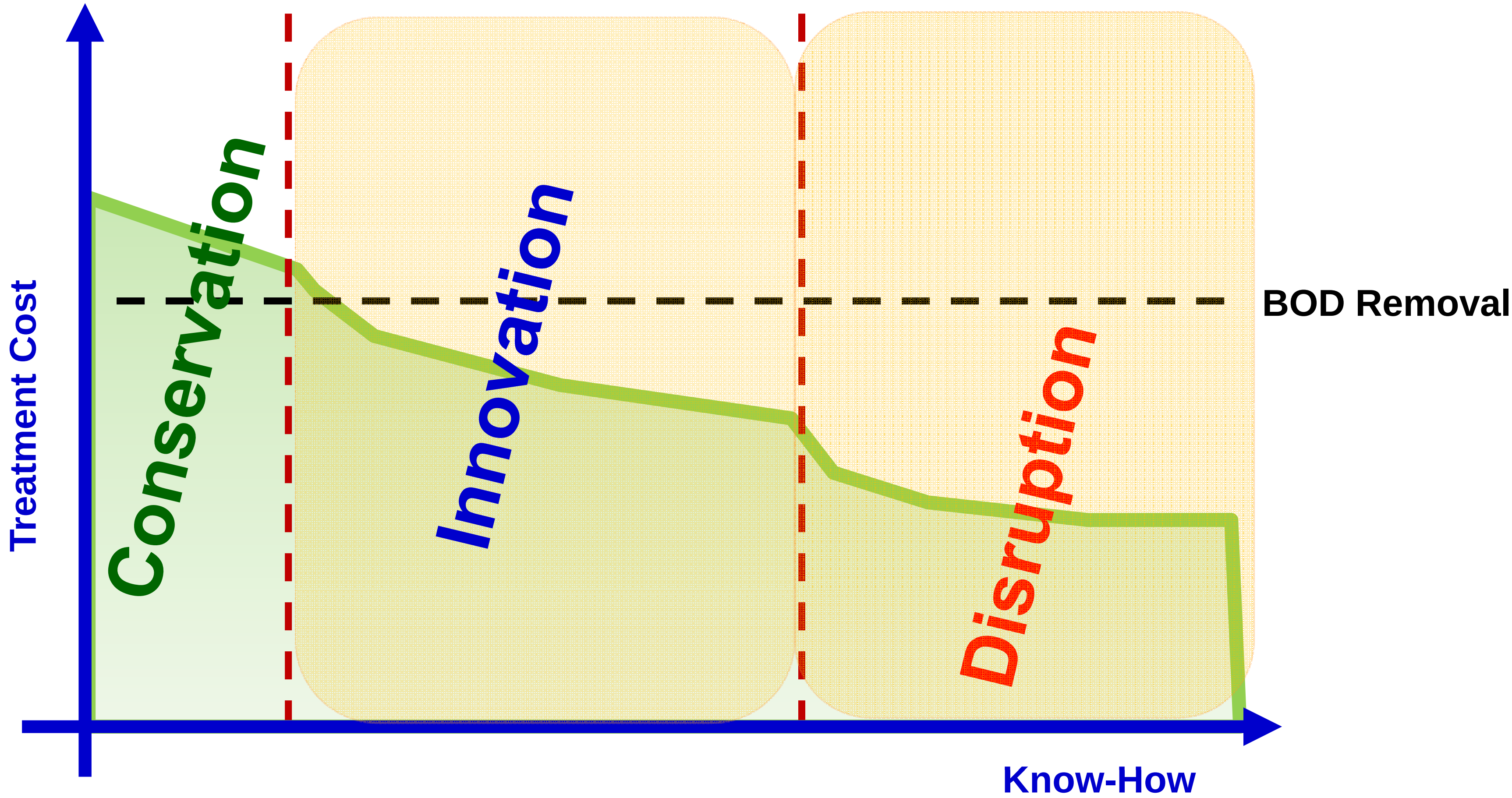
Achieving Sustainable Nitrogen Removal

- Integrating Innovation
- Electrical Demand
  - High Efficiency Strip Panel Aeration
  - Effective Control of the Mass Loading Diurnal
- Carbon Balance
  - <u>Preserving</u> and Routing Organic Carbon to Digestion for Biogas Production

Net Result: Cost Effective Nitrogen Removal

GREELEY AND HANSEN

Where Are We?

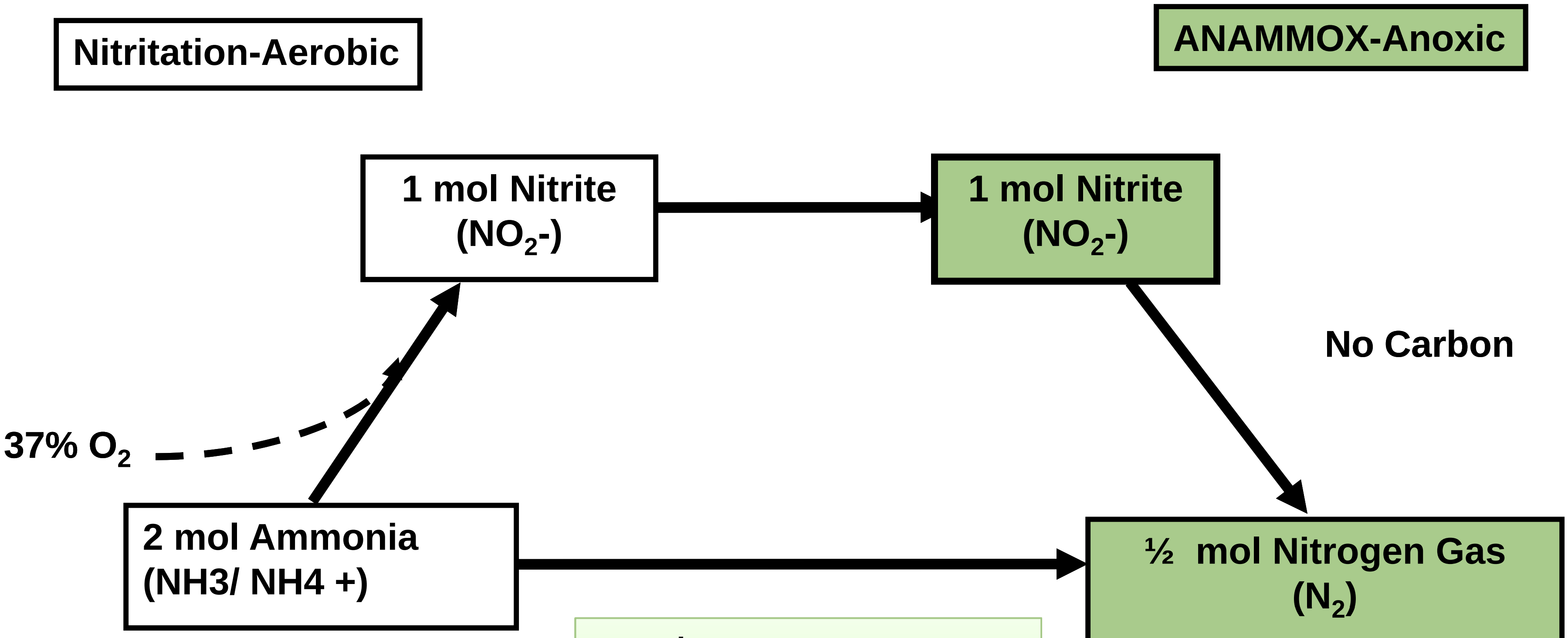


GREELEY AND HANSEN

The Future:
Back to Our Side of the Pond

Deammonification:
Combining Nitritation & ANAMMOX

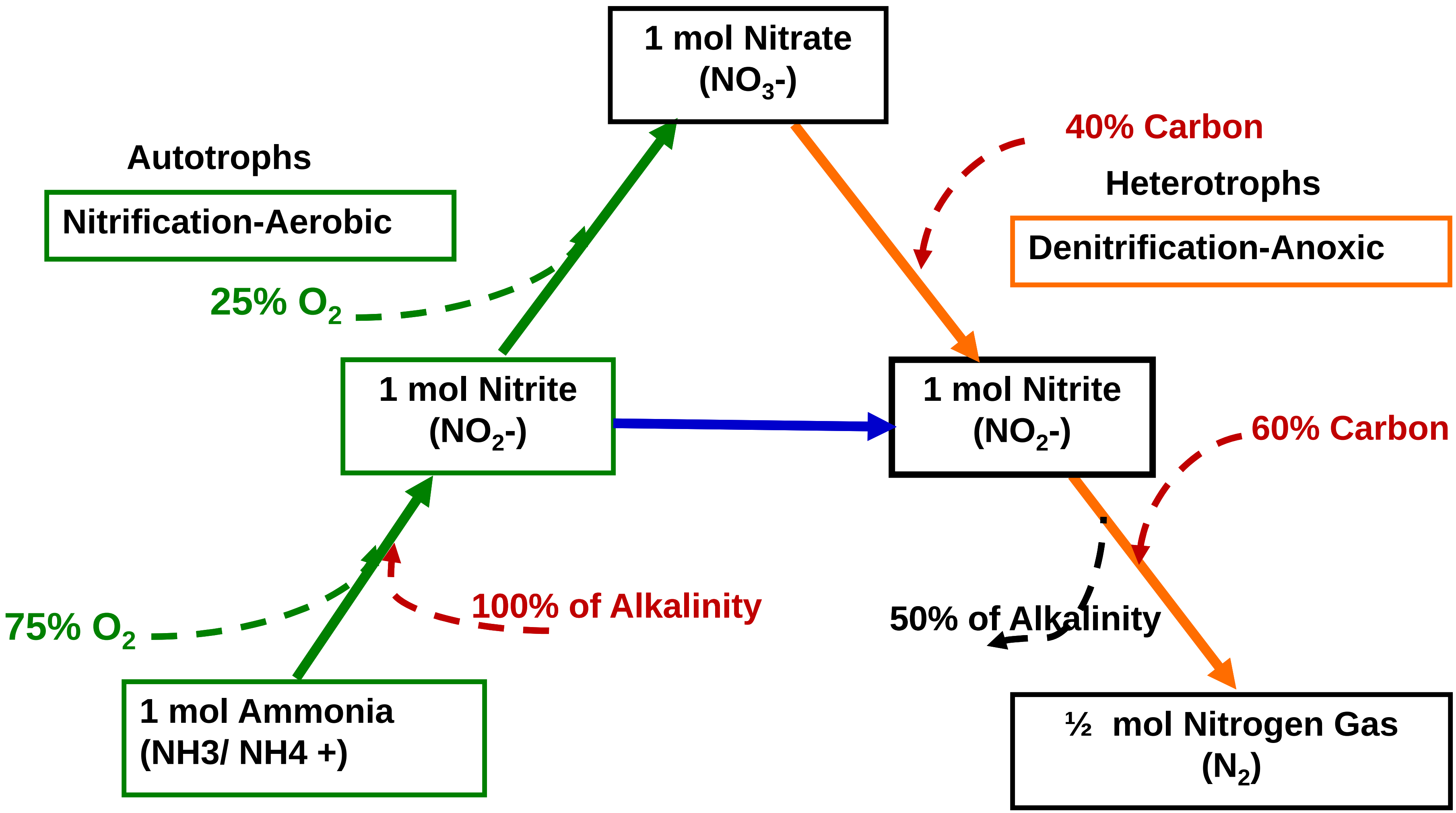
In a Simplified Representation



Results:
1. Less Oxygen
2. No Carbon

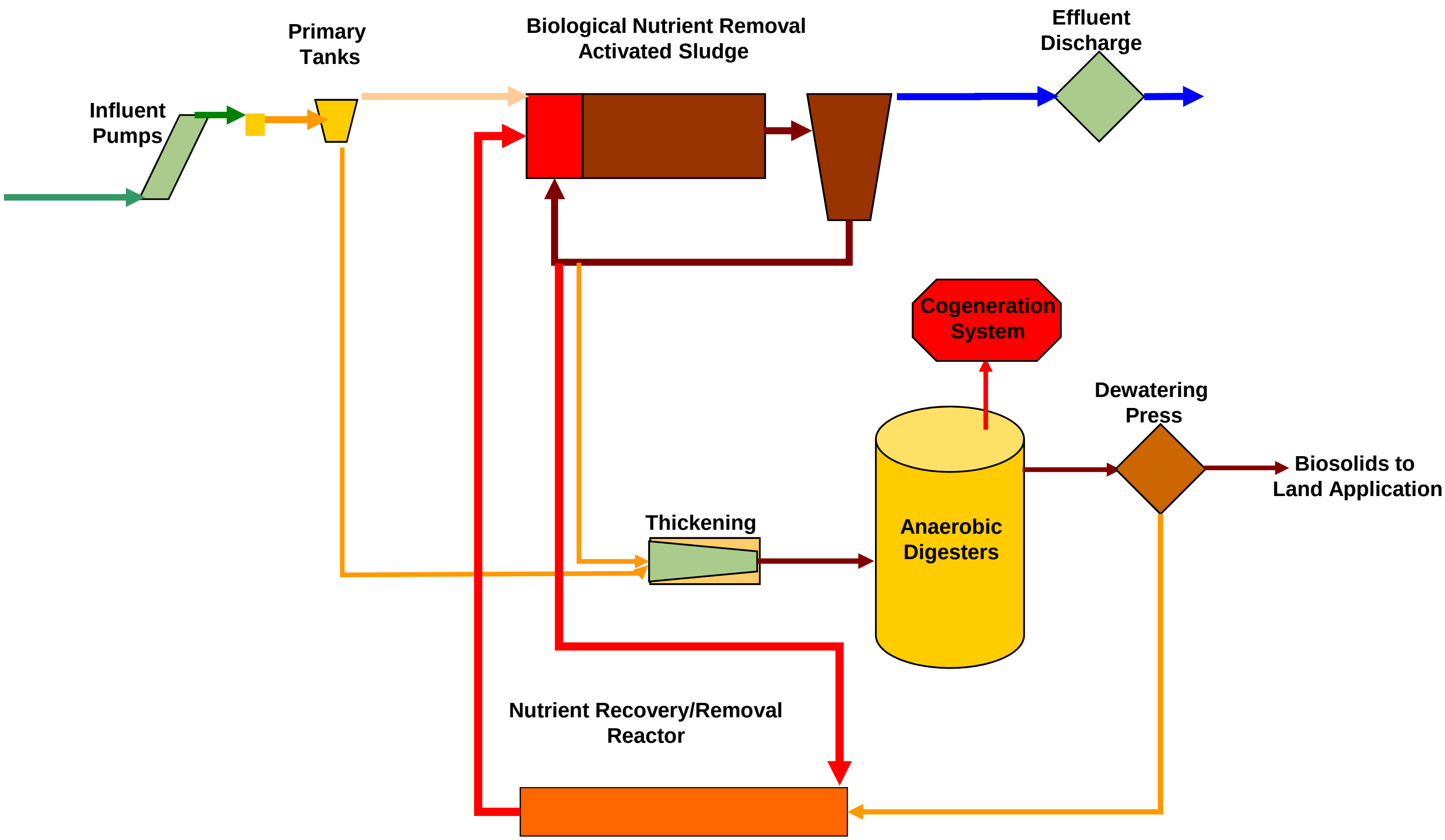
Nitrogen Removal:

From Conventional Pathways To Nitritation/Denitritation

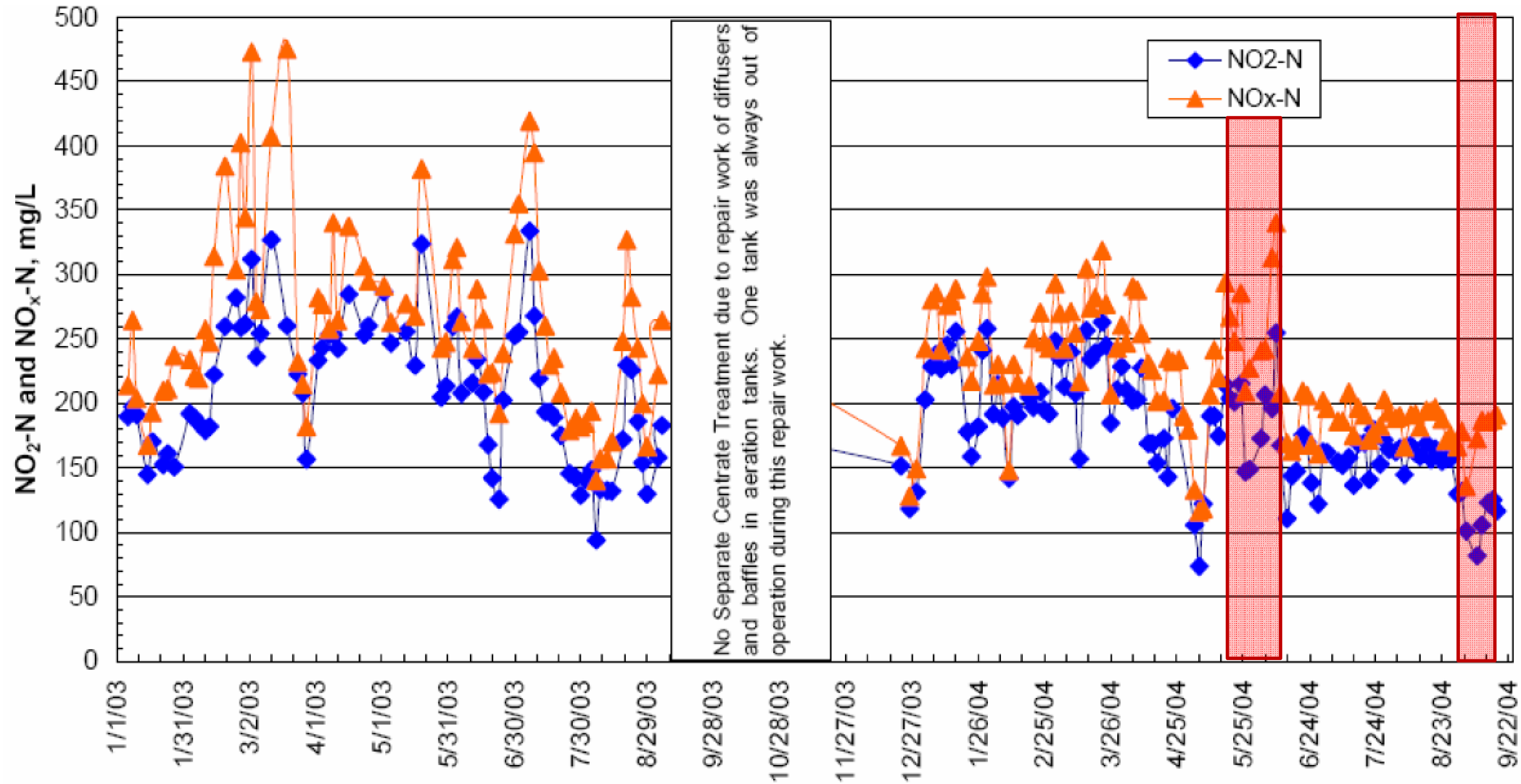


GREELEY AND HANSEN

<u>Almost</u> Conventional Process Configuration

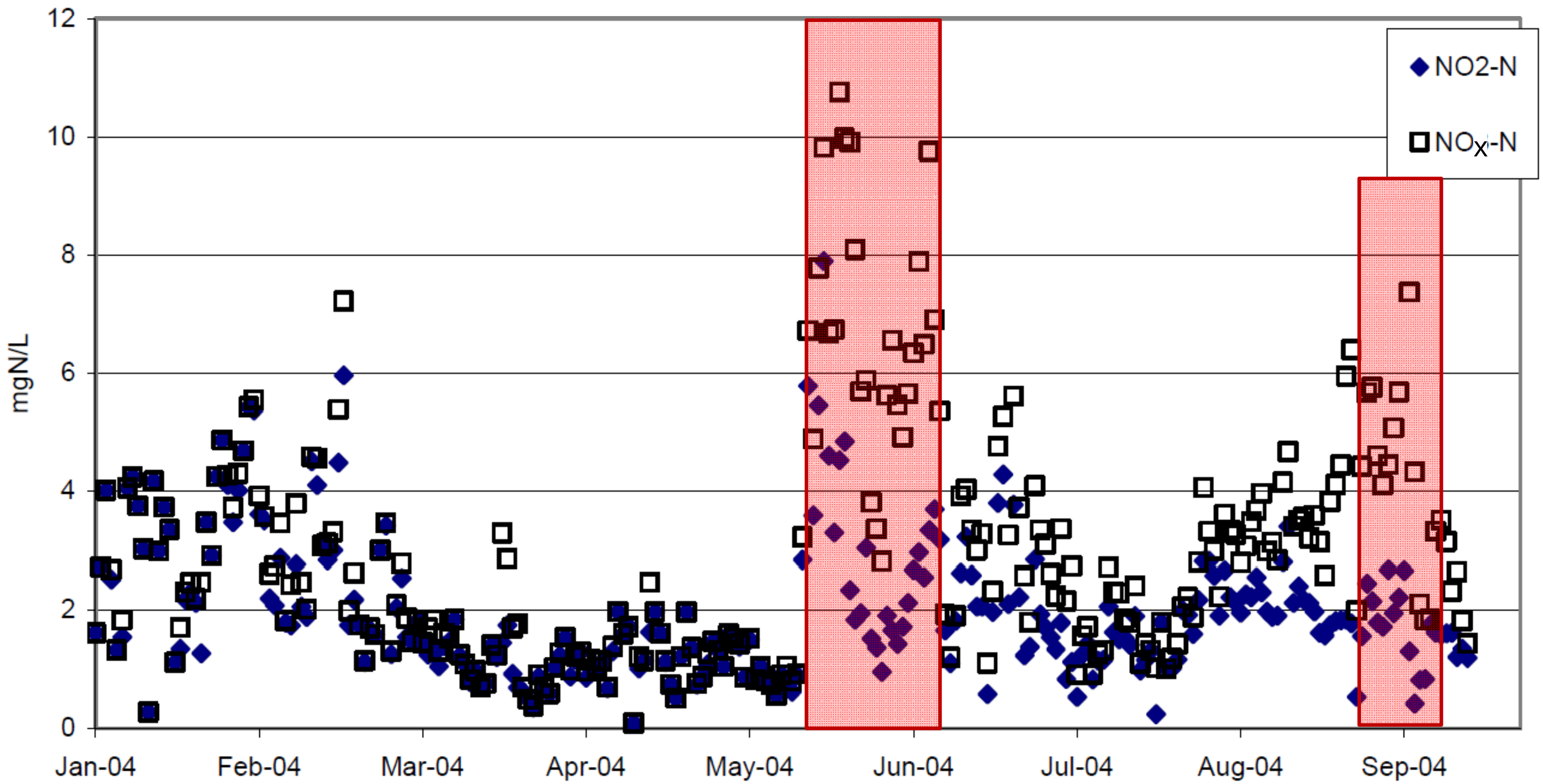


Combined Sidestream and Mainstream Nitritation/Denitritation



GREELEY AND HANSEN

Combined Sidestream and Mainstream Nitritation/Denitritation



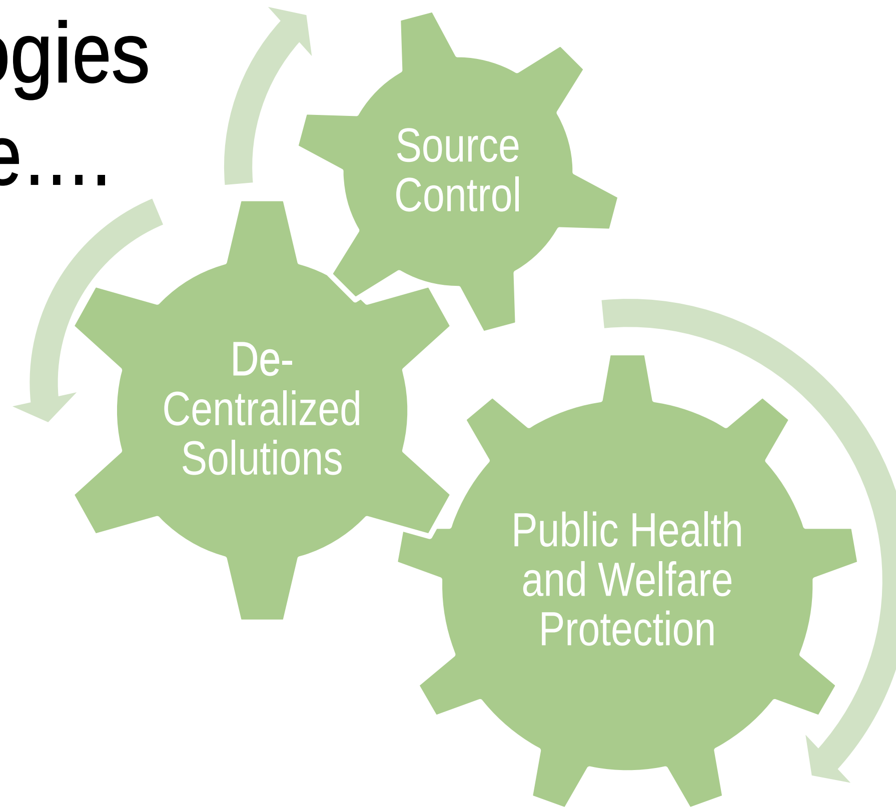
GREELEY AND HANSEN

Eye on the Future

- Low SRT Mainstream Nitritation/Denitritation Demonstrated at Full Scale
  - Minimize Carbon Oxidation
  - Maximize Use of Inherent WW Carbon
- Commercially Viable Main Stream Deammonification At the Cusp
  - Torrent of Research Activity on Deammonification

Eye on the Future

- Disruptive Technologies By Definition Will Be…. *Disruptive!*



An Amazing Time to Be an Engineer

Discussion