METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

Shortcut Biological Nitrogen Removal for sustainable wastewater treatment and achieving energy neutrality

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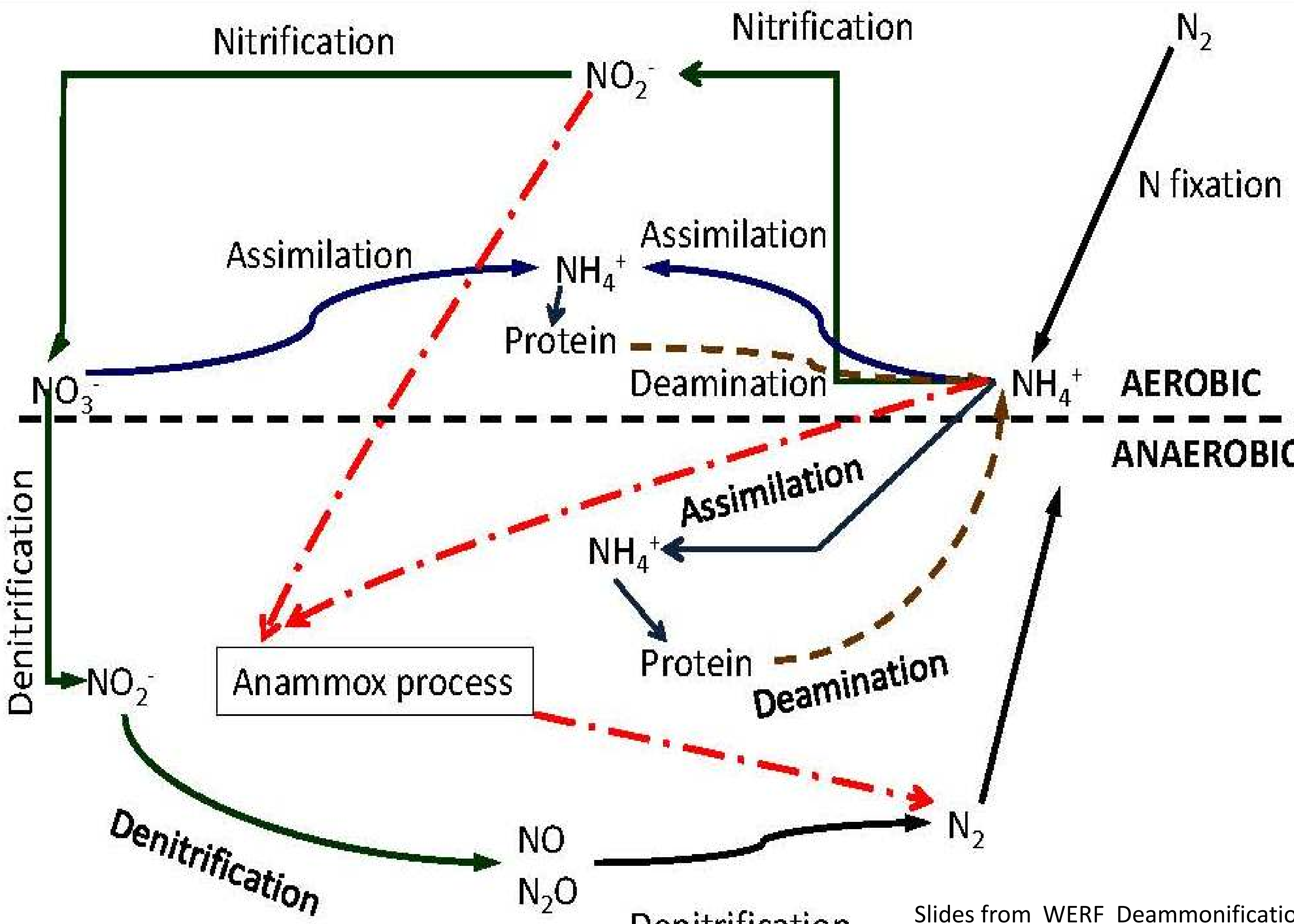
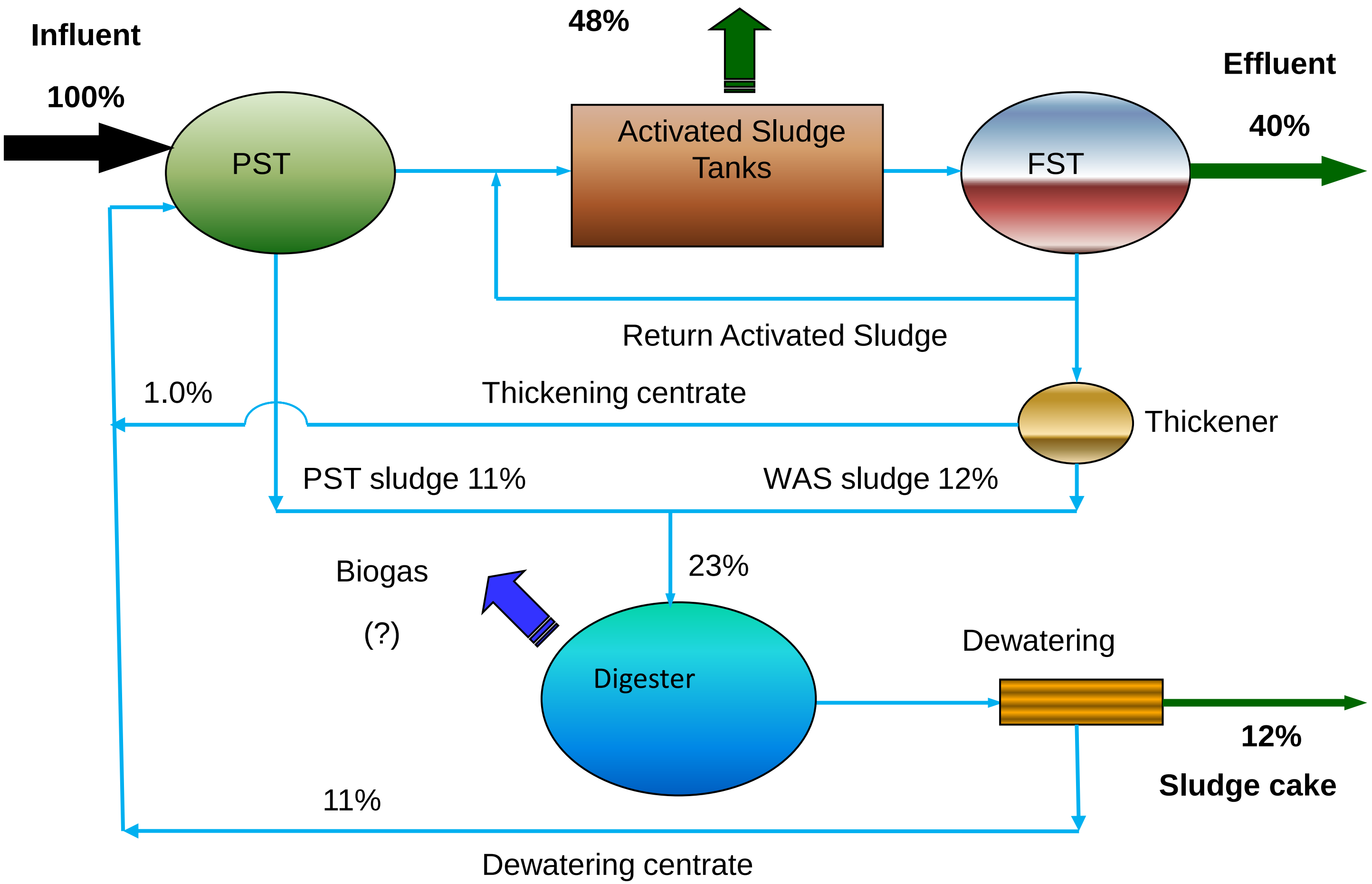
Outline

- Nitrogen and its removal in WWTP
- Shortcut biological nitrogen removal (SCBNR) fundamentals and its benefits
- SCBNR in sidestream
- SCBNR in mainstream
- MWRD Initiatives on implementing SCBNR on both sidestream and mainstream



Slides from WERF Deammonification Compendium, Dec 2012

Sample Nitrogen Cycle in WWTP



Slides from Ulu Pandan WRP, Singapore presented at 2012 IWA world water congress

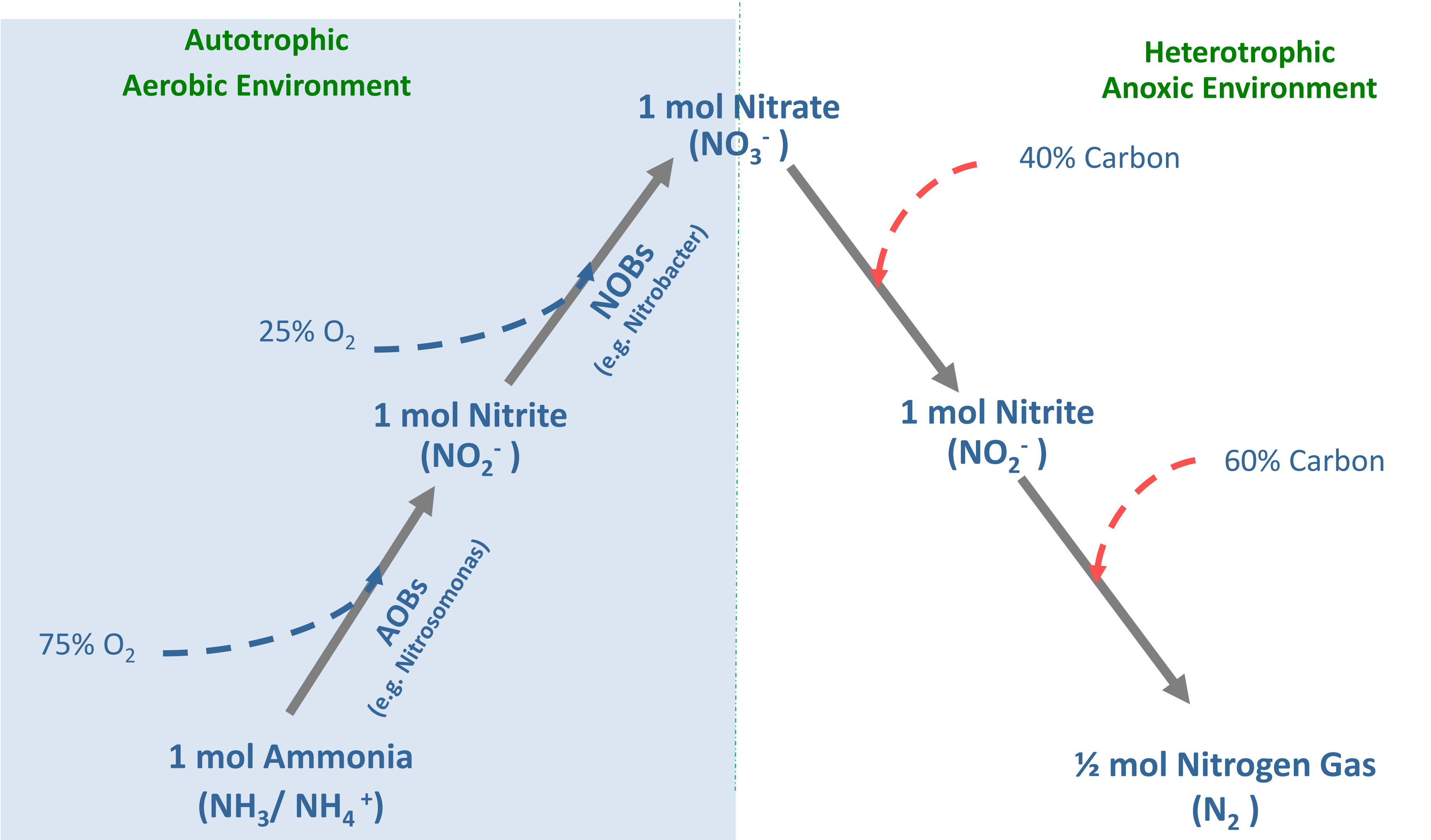
Nitrogen in the 7 District WRP

- **Mainstream**
  - Total nitrogen load (as ammonia and organic nitrogen) to the 7 District Water Reclamation Plants (WRPs) combined is approximately 200 dry tons/day
  - The district annual electrical consumption is over 600 million kWh ($45 million). Aeration consumes nearly 50%, among which, approx. 40-50% is used for nitrification to meet final effluent ammonia limit in the NPDEs permits
  - Limited denitrification; most ammonia and organic nitrogen is converted to nitrate and discharged to the receiving stream
- **Sidestream from post-digestion dewatering**
  - Small flow, but high ammonia strength, average around 1000 mg/L. Currently recycled back to the mainstream and add ammonia load to the mainstream in most plants.

Nitrogen Removal in Activated Sludge WWTP

- **Conventional Biological Nitrogen Removal**
  - Nitrification and Denitrification – Version I
  - Well established Processes (MLE process, Step feed, Bardenpho process, etc)
- **Shortcut Biological Nitrogen Removal**
  - Nitritation and Denitritation (nitrite shunt) – Version II
  - Partial Nitritation and Deammonification – Version III

Fundamentals of Nitrification – Denitrification (Ver I)



Oxygen demand 4.57 g / g NH^+_4-N

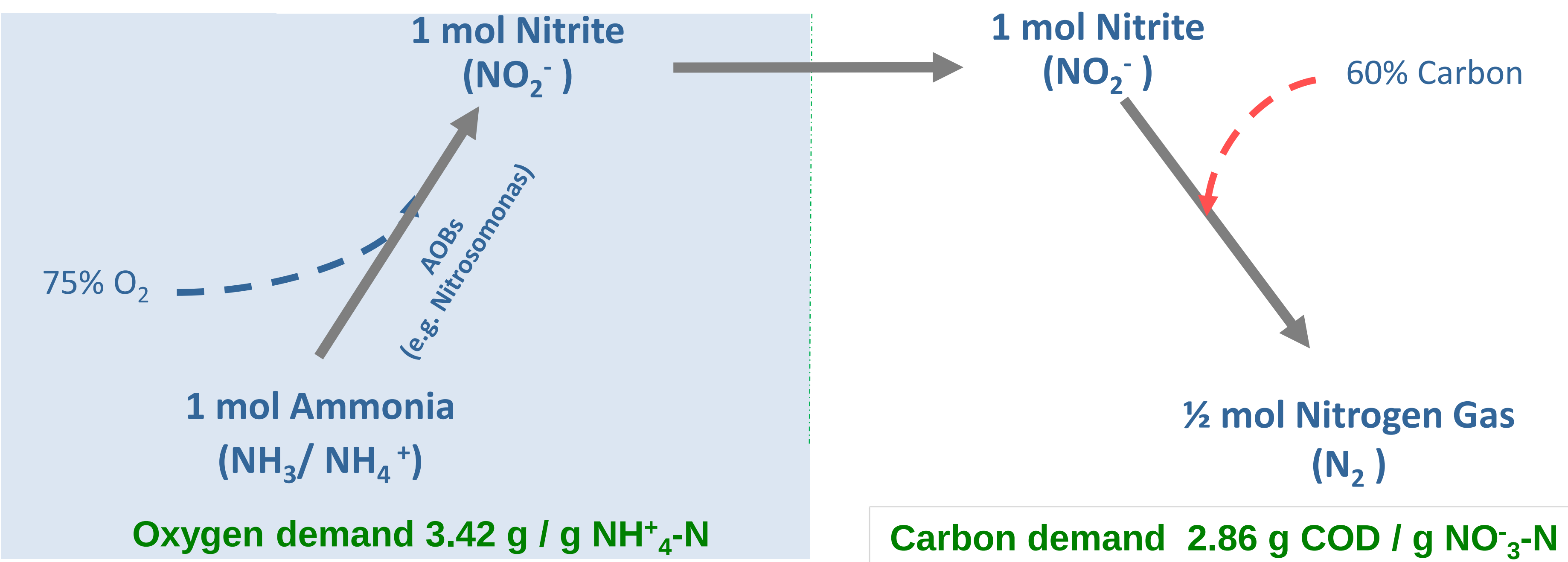
Carbon demand 4.77 g COD / g NO^-_3-N

Fundamentals of Nitritation – Denitritation (Ver II) "Nitrite Shunt"

Autotrophic
Aerobic Environment

Heterotrophic
Anoxic Environment

- **25% reduction in Oxygen**
- **40 % reduction in Carbon demand**
- **40% reduction in Biomass produced**

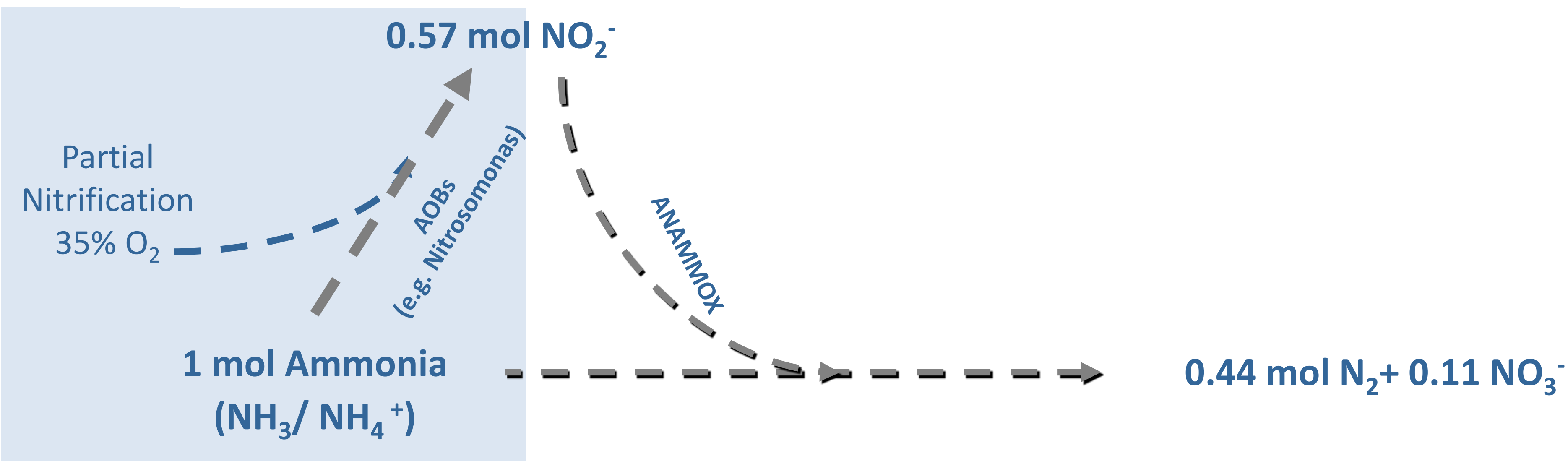


Fundamentals of Partial Nitritation-Deammonification (Ver III)

Autotrophic
Aerobic Environment
Aerobic Ammonia Oxidation

Autotrophic
Anaerobic Environment
Anaerobic **Am**monium **Ox**idation
(ANAMMOX)

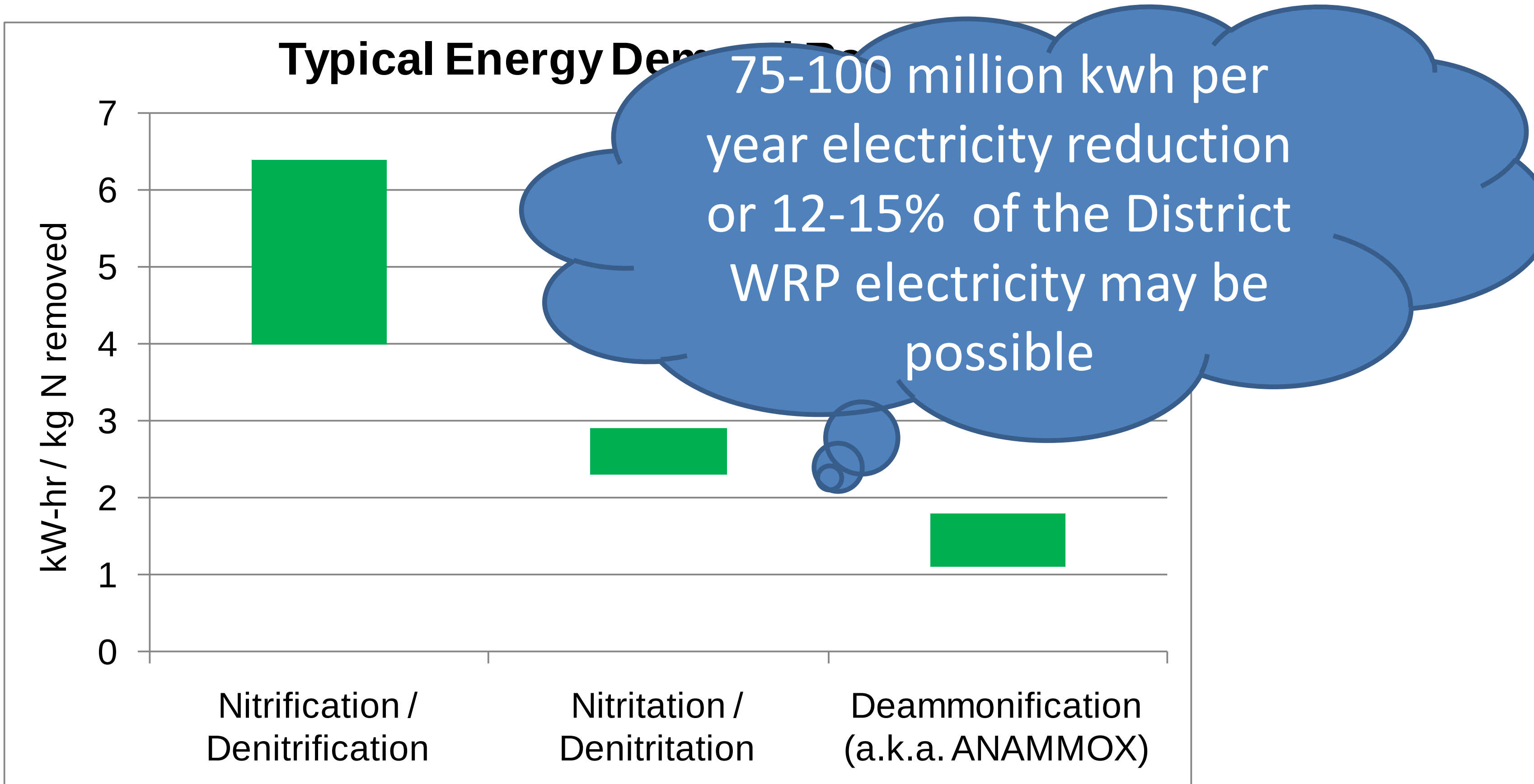
65% reduction in Oxygen
Eliminate demand for supplemental carbon
80% lower Biomass produced



Oxygen demand 1.9 g / g NH^+_4-N

Energy Savings

- Significant reduction in energy demand possible



Slides Courtesy WERF project INFR6R11

SCBNR In Sidestream

- The first full scale sidestream SCBNR using ANAMMOX was constructed in 2001
  - Since 2007, installation rapidly increased. Over 50 installations (WERF, Dec 2012)
- The ANAMMOX® Technologies
  - Anita Mox (attached growth system with mixed biomass of nitrifiers and anammox
  - DEMON (suspended growth system with mixed biomass of nitrifiers and anammox)
  - OLAND (Oxygen-Limited Autotrophic Nitrification-Denitrification)
  - CANON (Completely Autotrophic Nitrogen removal over Nitrite process)
  - Pacques
- Sidestream SCBNR has demonstrated TN reduction of 80% or higher

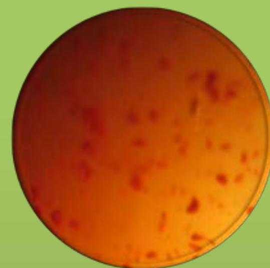
SCBNR In Mainstream

- Following the success of sidestream SCBNR, there have been great interests in mainstream application
- Key process consideration
  - Growth and retention of AOB and anammox
  - Suppression or management of Heterotrophs
  - Suppression of NOB
- Challenges for mainstream
    - Low ammonia
    - concentration in mainstream WW
    - Low operating temp
    - Higher C:N ratio
- Pioneering studies based on full, pilot, or bench scale studies around the world has demonstrated promising results

SCBNR in Mainstream

Large Anammox Granules

e.g. Paques, Nereda granular sludge blanket systems

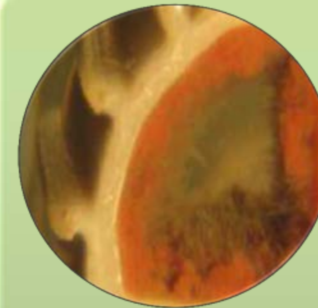


Small Flocculent **Suspended Growth Anammox Granules**

e.g. Activated Sludge

Attached Growth Biofilm

e.g. RBC, MBBR, Biofilter



Suspended & Attached Growth

e.g. IFAS

With or Without Bioaugmentation of AOB and / or Anammox

- ✓ **Delft, Netherlands**
- ✓ **DHV, Netherlands**

- ✓ **DC Water & HRSD, USA**
- ✓ **Changqi, Singapore**
- ✓ **Strass, Austria**
- ✓ **Glarnarland, Switzland**
- ✓ **Delft TU, Netherlands**
- ✓ **American Water (AOA / MBR)**

- ✓ **Ghent University**
- ✓

- ✓ **Veolia pilots**

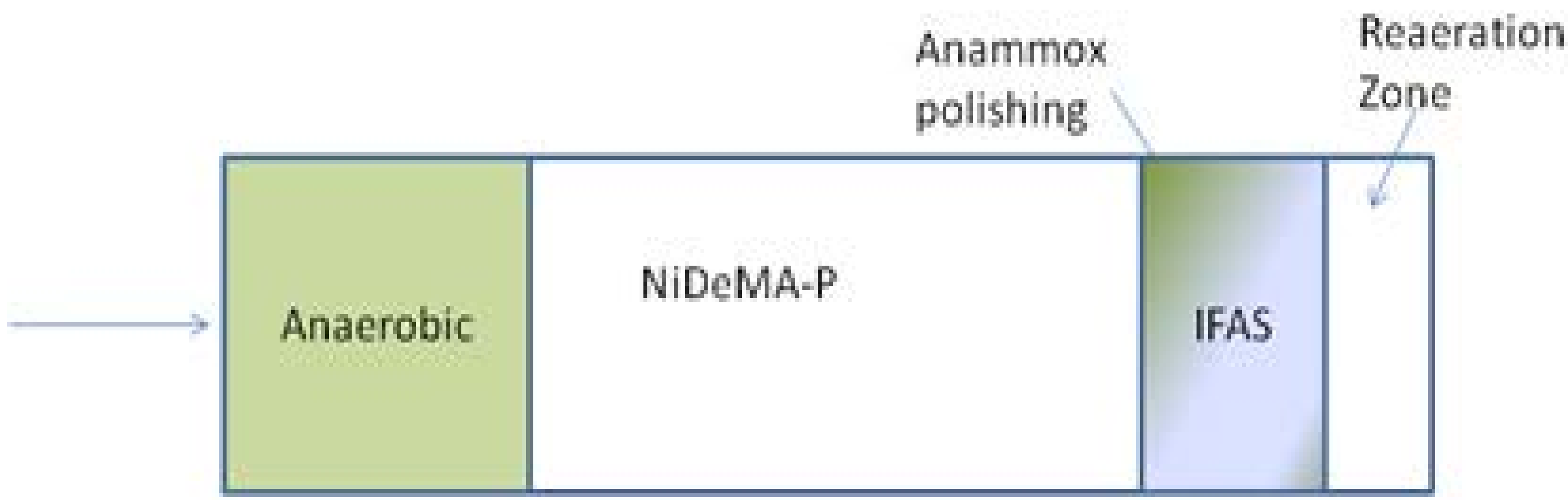
SCBNR–MWRD Initiatives

- Sidestream deammonification
  - Pilot scale study of DEMON in 2012
  - First AnitaMox under construction, will be online in 2015 at the Egan WRP
    - Total N load of 2500 lbs/day
    - Ammonia–N removal eff. 80-85%
    - Total –N removal eff. 70-75%
  - Plan to consider sidestream treatment in Stickney and other facilities

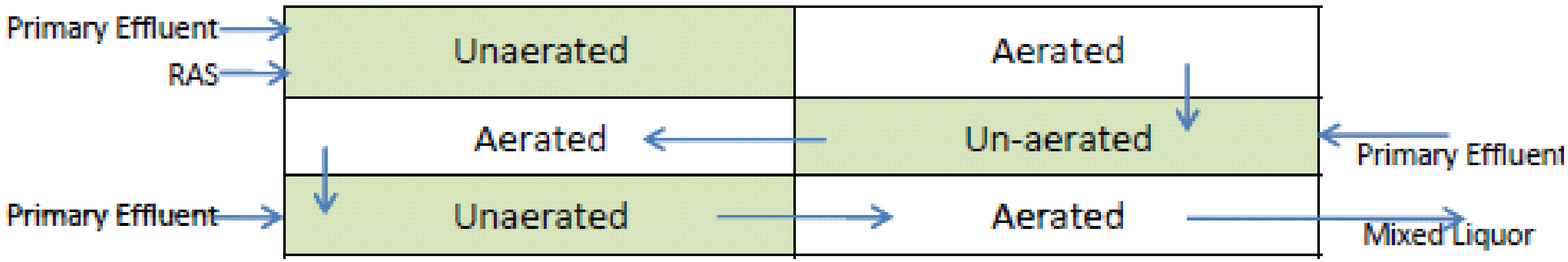
SCBNR –MWRD Initiatives

- Mainstream SCBNR
  - M&R led inter-departmental SCBNR research
  - Try to address:
    - how this process can be applied to current District facilities given our current infrastructure and capabilities
    - How to meet current ammonia limit in NPDES permit
    - How this process ties into our EBPR processes
    - How to implement in cold weather
  - 4 processes have been identified for bench scale and full scale experiments

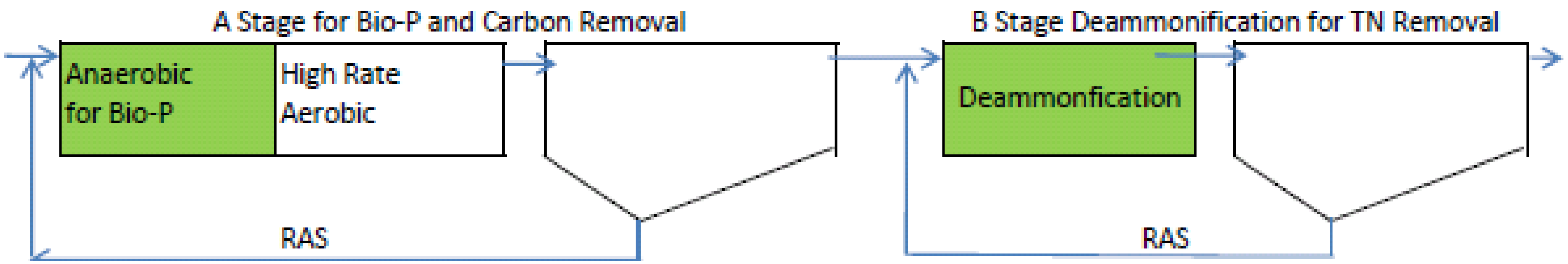
OPTION 1 - ANAEROBIC + NITRITATION/DENITRITATION THROUGH MODULATING AERATION + INTEGRATED FIXED FILM ACTIVATED SLUDGE + REAERATION FOR SHORTCUT BIOLOGICAL NITROGEN REMOVAL PROCESS



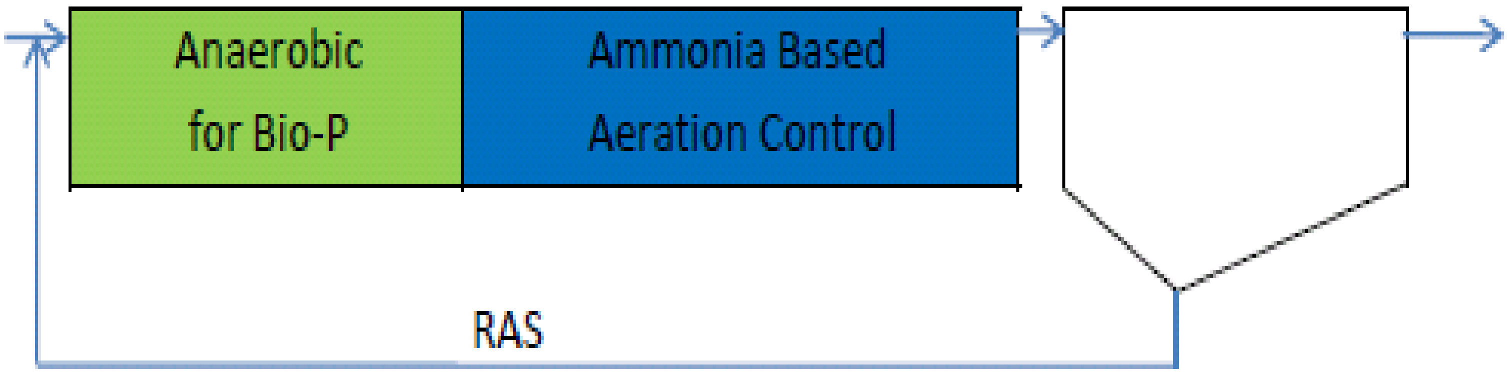
OPTION 2 - STEP-FEED SHORTCUT BIOLOGICAL NITROGEN REMOVAL PROCESS



OPTION 3 - TWO STAGE SYSTEM FOR SHORTCUT BIOLOGICAL NITROGEN REMOVAL PROCESS



OPTION 4 – AMMONIA BASED AERATION CONTROL TO REDUCE ENERGY CONSUMPTION



QUESTIONS?

Thanks goes to:

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Monitoring and Research Department

MWRDGC