The Potential Role of Ammonia Electrolysis in the Treatment of Ammonium-Containing Wastewaters

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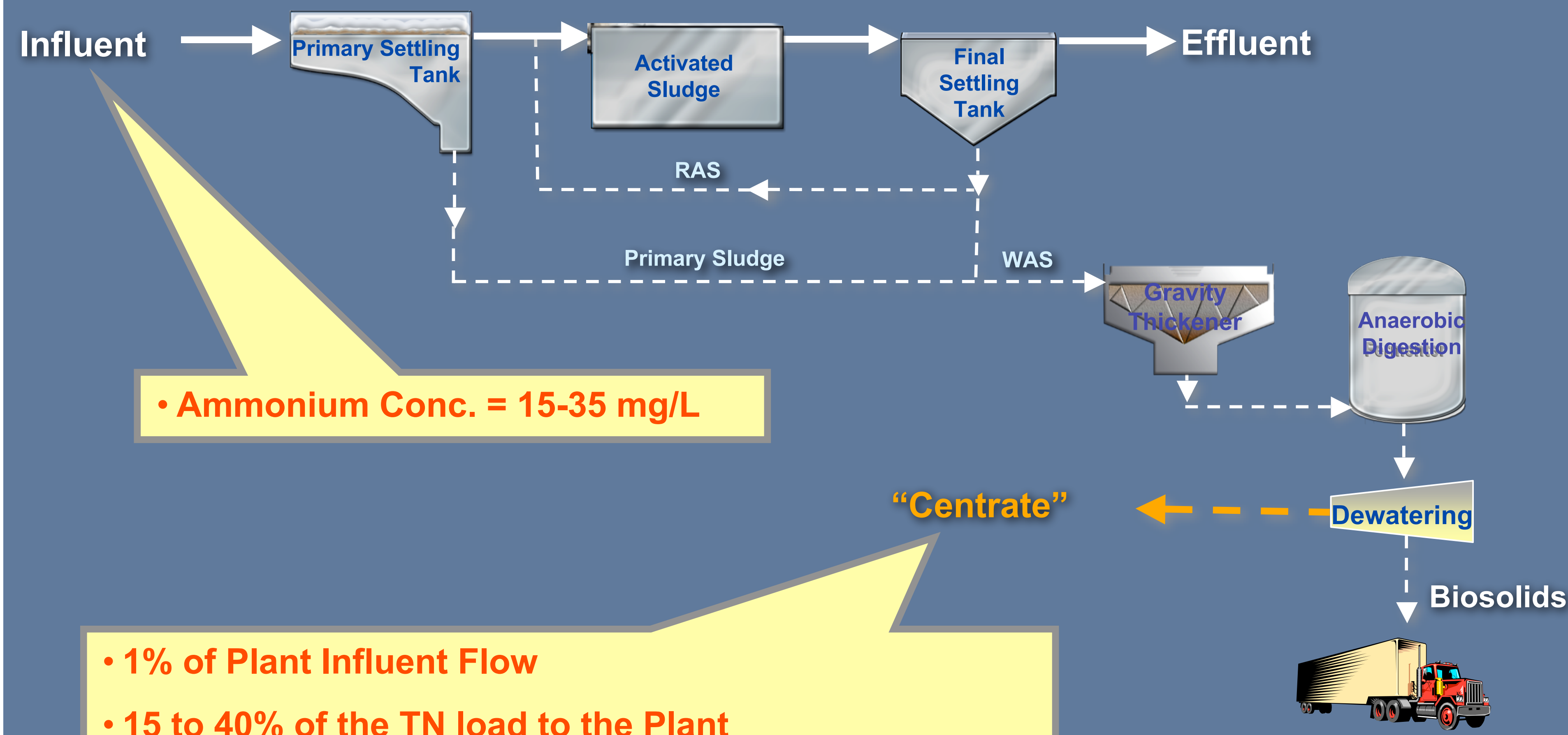
Presentation Overview


- **Introduction**
- **Ammonia Removal**
  - Biological processes
  - Physical-Chemical processes
- **Ammonia Electrolysis**

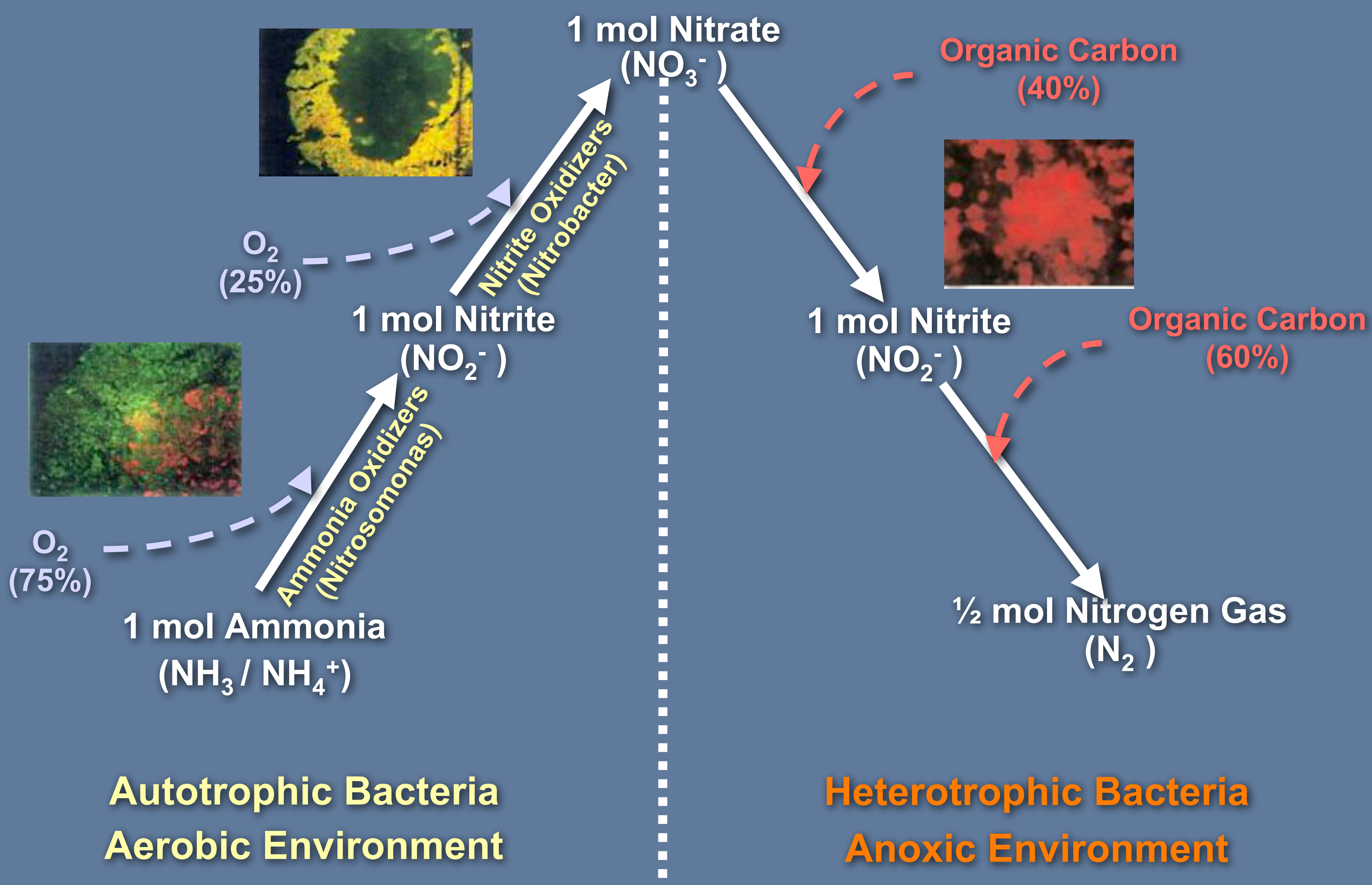
Biological Wastewater Treatment



- Ammonium Conc. = 15-35 mg/L

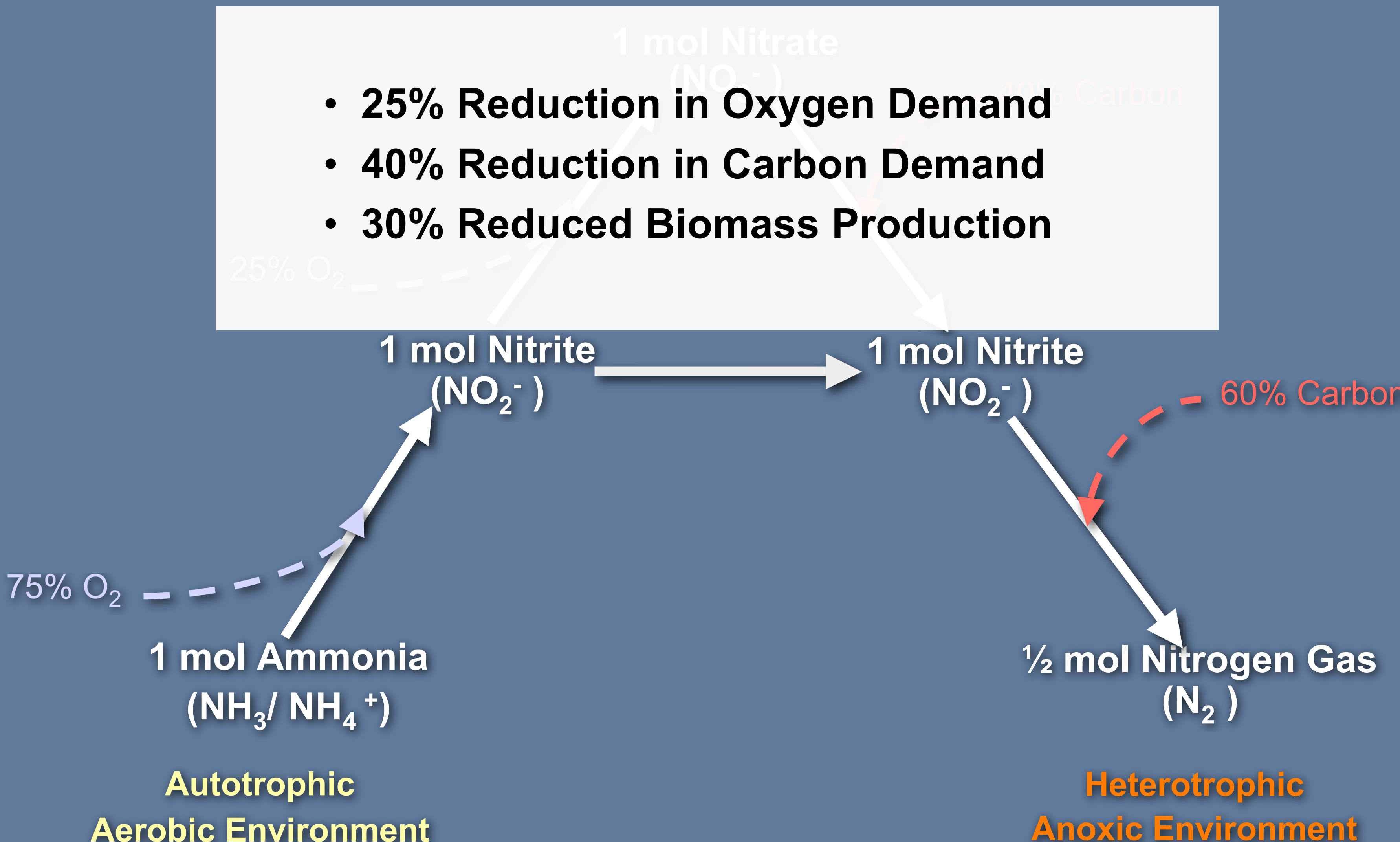
- 1% of Plant Influent Flow
- 15 to 40% of the TN load to the Plant
- Ammonium Conc. = 1,000 to 3,000 mg/L
- Similar to landfill leachate and liquid stream from animal manure digestion

Nitrification – Denitrification in the Main Plant



Nitritation – Denitritation Process for Centrate Treatment in a Separate Bioreactor

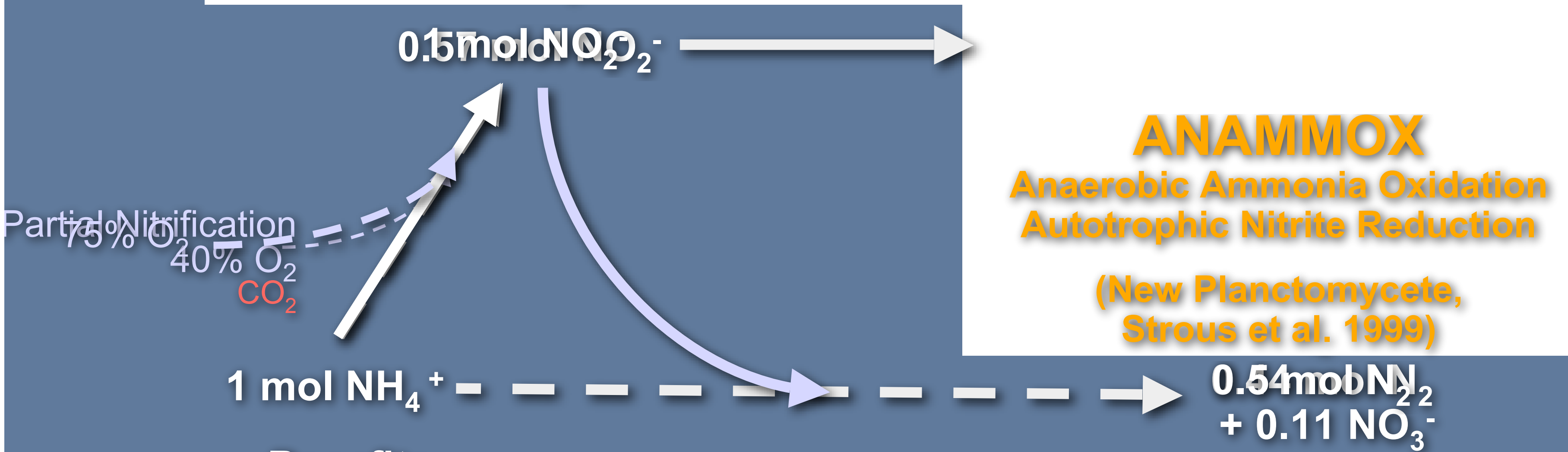
- **25% Reduction in Oxygen Demand**
- **40% Reduction in Carbon Demand**
- **30% Reduced Biomass Production**



Partial Nitritation – ANAMMOX Process for Centrate Treatment in a Separate Bioreactor

$$NH_4^+ + 1.32\ NO_2^- + 0.066\ HCO_3^- + 0.13\ H^+$$

$$\longrightarrow 0.26\ NO_3^- + 1.02 N_2 + 0.066\ CH_2O_{0.5}N_{0.15} + 2.03\ H_2O$$



Benefits;

- 60% Reduction in Oxygen Demand
- Almost 100% Reduction in Carbon (e^- donor) Demand
- > 80% Reduced Biomass Production

Bernhard Wett, 2005

Energy and Chemical Requirements for the Nitrification – Denitrification Process

Case Study: Centrate Treatment at the District of Columbia Water and Sewer Authority Blue Plains Advanced Wastewater Treatment Plant

- 310 million gallons per day (average dry weather flow)
- Two-stage biological reactor system consisting of organic substrate removal following by nitrification-denitrification

- **Plant effluent ammonia and nitrate concentrations ≤ 0.5 mg/L, each, by 2014**
- **Centrate ammonia loading (projected 2014 value) of 12,200 kg/day (26,800 lbs/day)**

Energy and Chemical Requirements for the Nitrification – Denitrification Process

If centrate is treated in the main plant:

- Power demand for aeration (fine bubble diffusers):
  - ~ 36,800 kW-hr/day or ~ 3 kW-hr/kg-ammonia
  - Annual power cost @ $0.10/kW-hr: **$1.34MM/year**
- Methanol demand for denitrification:
  - 8,600 gal/day
  - Annual methanol cost @ $1.20/gal: **$3.77MM/year**

If centrate is treated in a separate bioreactor:

- Nitritation – denitritation or partial nitritation – ANAMMOX can be used to reduce power and chemical consumption
- ~ 6 million gallons of tank volume required

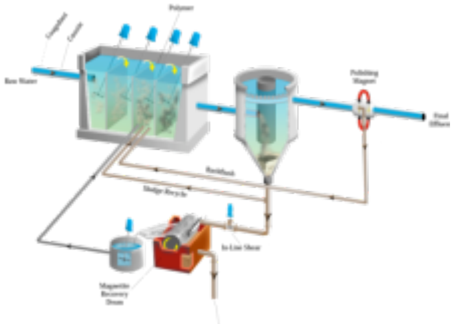
Alternatives to Biological Treatment

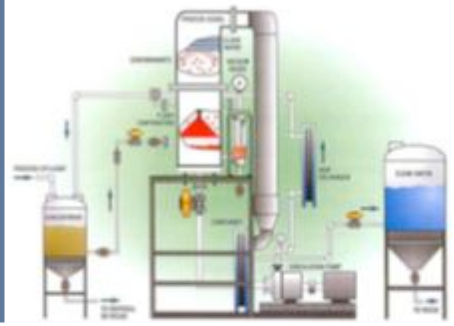
- **Recover and beneficially reuse both ammonia & phosphate**
  - Only 100 years of Phosphorus resources available

- **Product recovery technologies**
  - Air Stripping/Acid Absorption
  - Vacuum flash distillation / acid absorption
  - Magnesium ammonium phosphate (struvite) precipitation

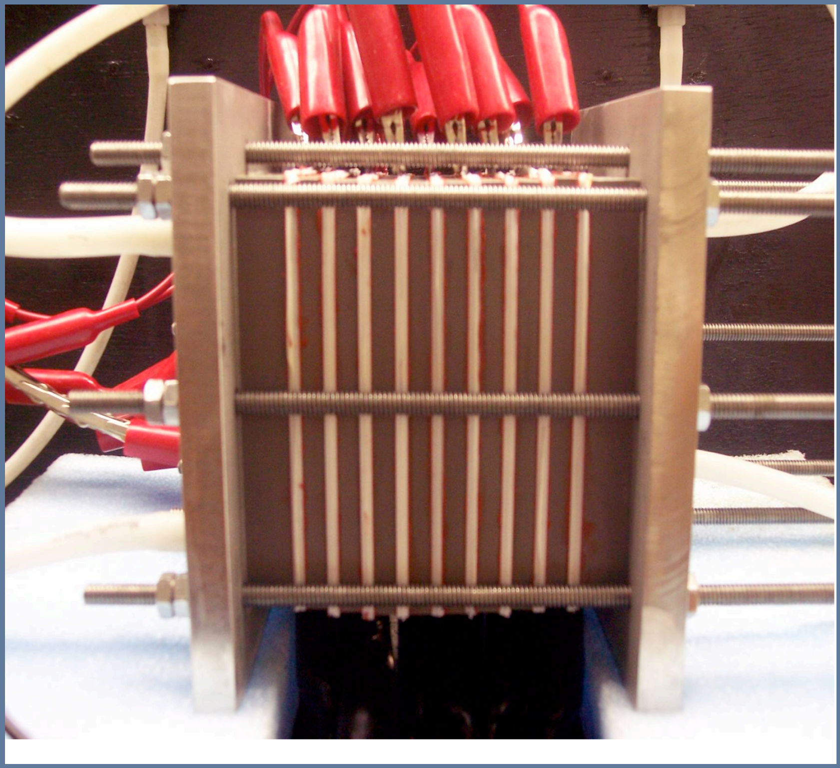
- **Use nutrient-rich products as fertilizers**

- **Utilize NH_3 as a fuel source**
  - Ammonia Electrolysis to generate H_2
  - DCWASA Centrate: potential to generate up to 2,150 kg/day (4,730 lb/day) of H_2

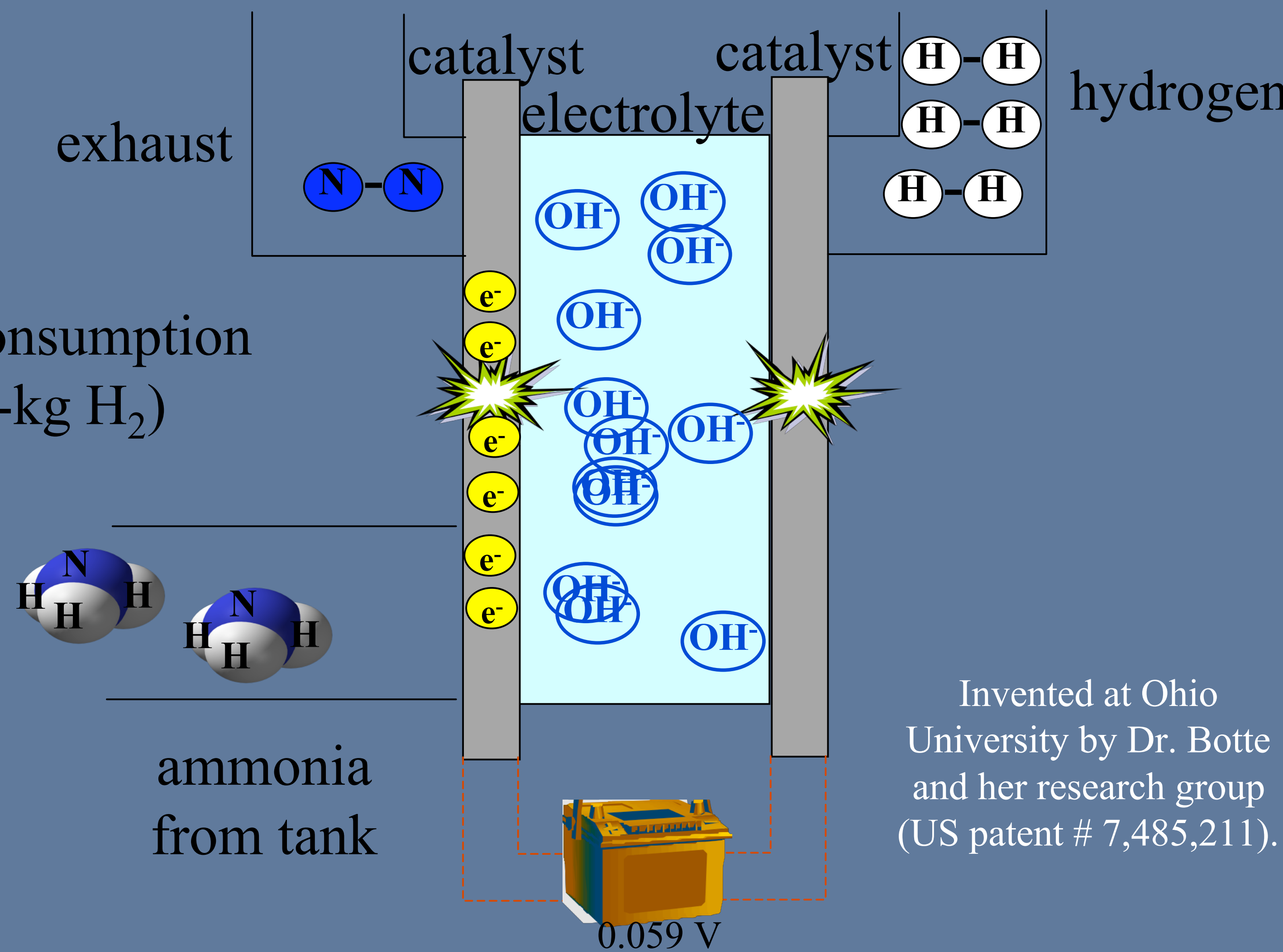




Ammonia Electrolysis Technology



Technology



Low energy consumption
(1.55 kWh-kg H_2)

Invented at Ohio University by Dr. Botte and her research group (US patent # 7,485,211).

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Ammonia Electrolysis

Reactions

- Anode: Ammonia Oxidation

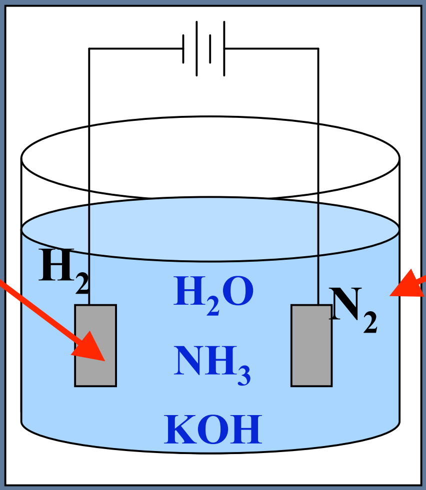
$$2NH_3 + 6OH^- \rightarrow N_2 + 6H_2O + 6e^- \quad E^0 = -0.77 \text{ vs SHE}$$

- Cathode: Water Reduction

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \quad E^0 = -0.82 \text{ V vs SHE}$$

- Overall Reaction

$$2NH_3 \rightarrow N_2 + 3H_2 \quad E^0 = 0.059 \text{ V}$$



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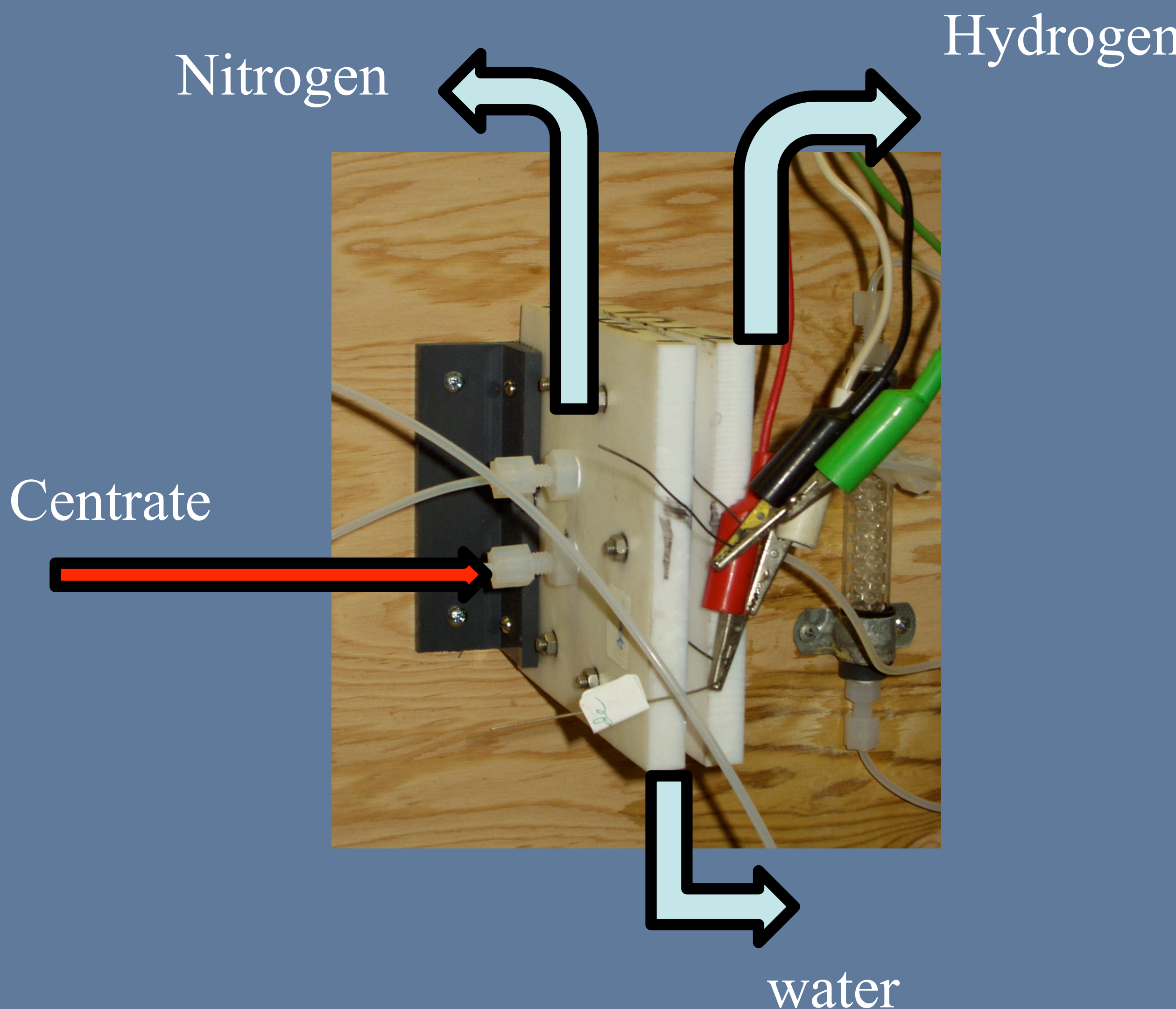
Advantages of Technology

- Minimization of hydrogen storage problem
- Zero Hazards emissions
- Fuel Flexibility
- Low temperature operation
- Compatibility with renewal energy sources (e.g. solar, wind)
- Works a variety concentration values of ammonia
- Fertilizer plants and municipal waste water treatment stations could potentially produce their own energy from waste

Results

- The feasibility of the technology for the removal of ammonia has been demonstrated.
- Ammonia concentrations can be reduced under 1 mg/l.
- Operating conditions for the use of the AEC for the removal of ammonia has been optimized.
- Over 99.3% removal of ammonia has been achieved.

Case Study 1: Without Recovery



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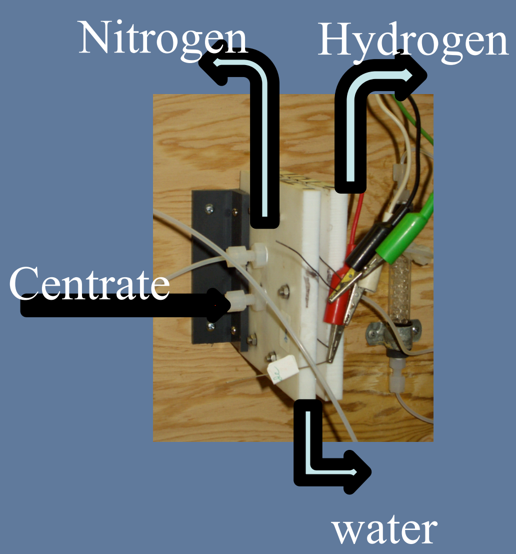
Case Study 1: Without Recovery



Variable/Parameter	Value
NH_3 removal (kg/day)=	12,200
Unit Size (kW)=	1,600
Energy (kW-h per kg NH_3)=	3.2
N_2 (kg/day)=	420
H_2 (kg/day)=	90
Cost Electricity ($ per kW-h)=	0.1
Electricity Cost ($ per year)=	1.42 MM
pH Adjustment ($ per year)=	1.89 MM
Total Cost ($ per year)=	3.31 MM
Savings ($ per year)=	1.88 MM

35% cheaper

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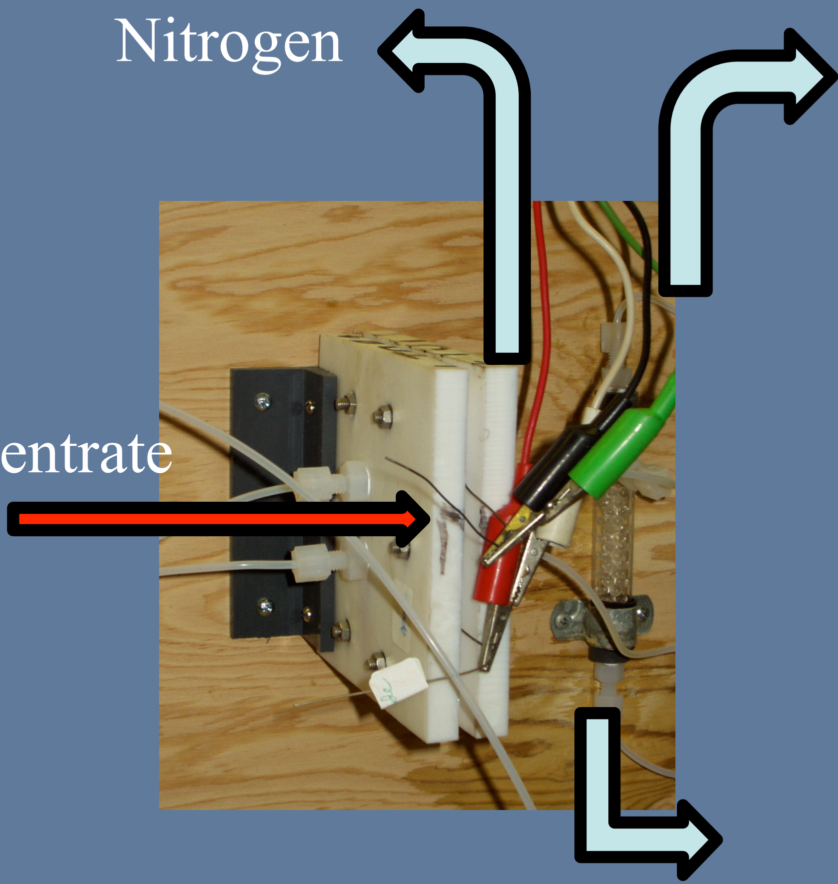
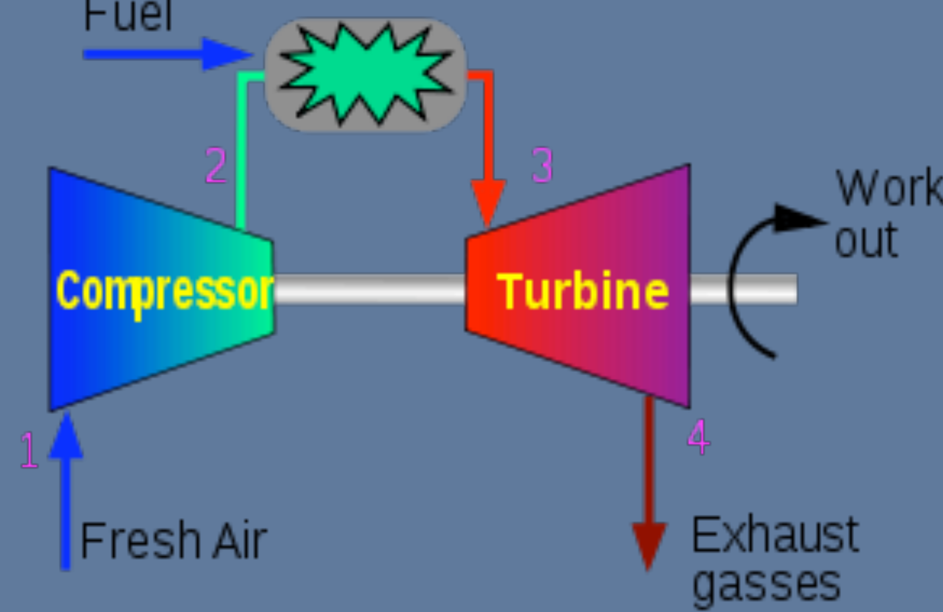
Case Study 2: Combined Heat and Power





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Case Study 2: Combined Heat and Power

Variable/Parameter	Value
NH_3 removal (kg/day)=	12,200
Unit Size (kW)=	1,600
Efficiency Power (%)=	40
Energy Consumed (kW-h per kg NH_3)=	3.2
Energy Produced (kW-h per kg NH_3)=	2.4
Net Energy Consumed (kW-h per kg NH_3)=	0.8
Cost Electricity ($ per kW-h)=	0.1
Electricity Cost ($ per year)=	0.36 MM
pH Adjustment ($ per year)=	1.89 MM
Total Cost ($ per year)=	2.25 MM

56% cheaper

Conclusions

- Ammonia Electrolysis is more efficient for the removal of ammonia from waste, direct conversion to benign nitrogen
- Ammonia concentrations can be reduced under 1 mg/l.
- Process can generate heat and power
- Operational costs at least 56% lower than traditional methods
- Easy to operate (on/off access)
- No Nitrous and nitric oxides produced

QUESTIONS

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