Achieving Resource-Positive Water

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DOE, EPA, NSF Workshop

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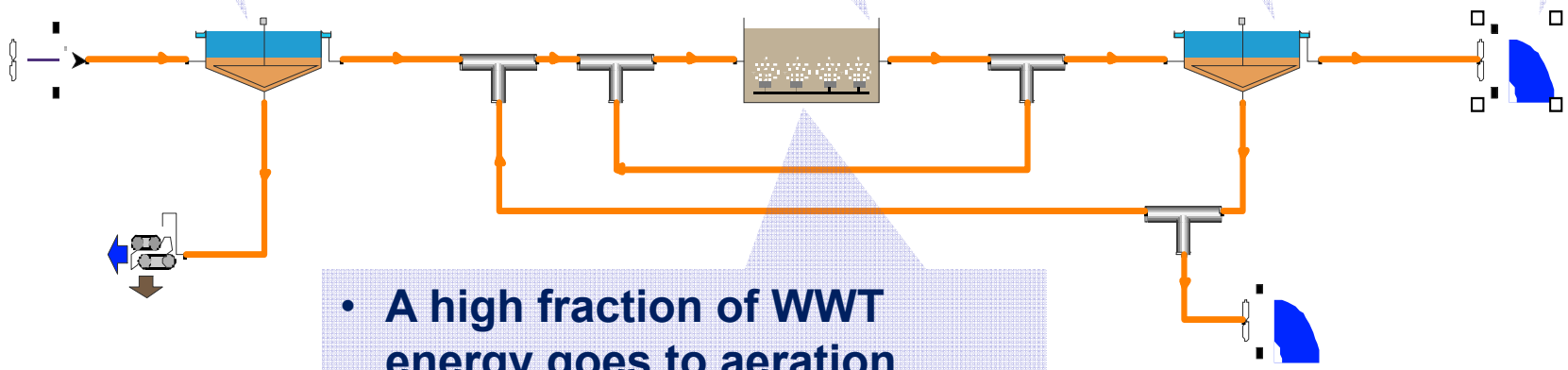
Brief overview of biological sewage treatment

Solids, inerts separation

Aerobic C &N removal (oxidation)

Recycle of bacteria

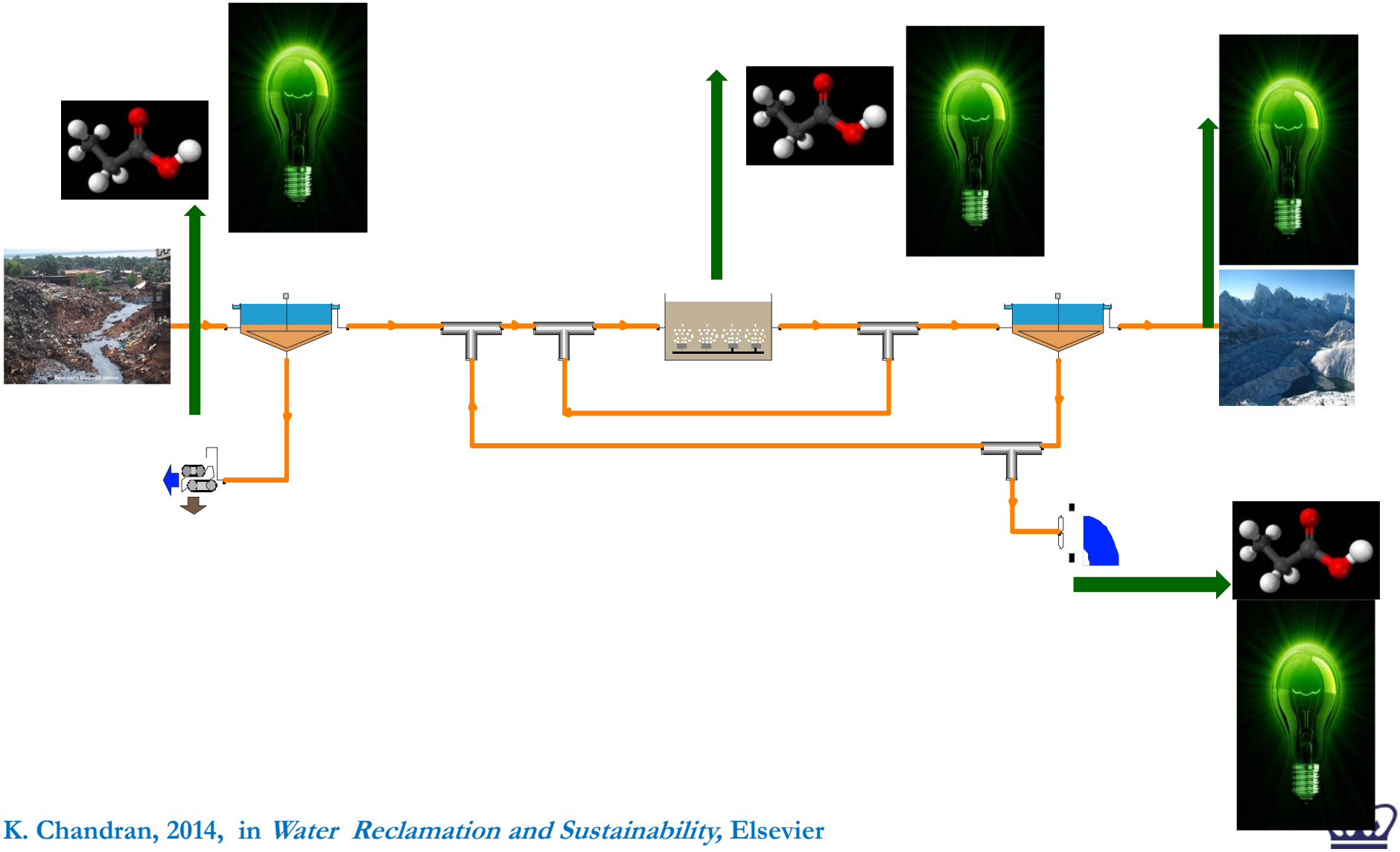
Disinfection and discharge



- **A high fraction of WWT energy goes to aeration**
- **$MM in organic chemical purchase**
- **Bacteria could produce unwanted products (N_2O)**

Envisioning the possibilities

Shifting to Engineered Resource Recovery from 'Waste' Streams



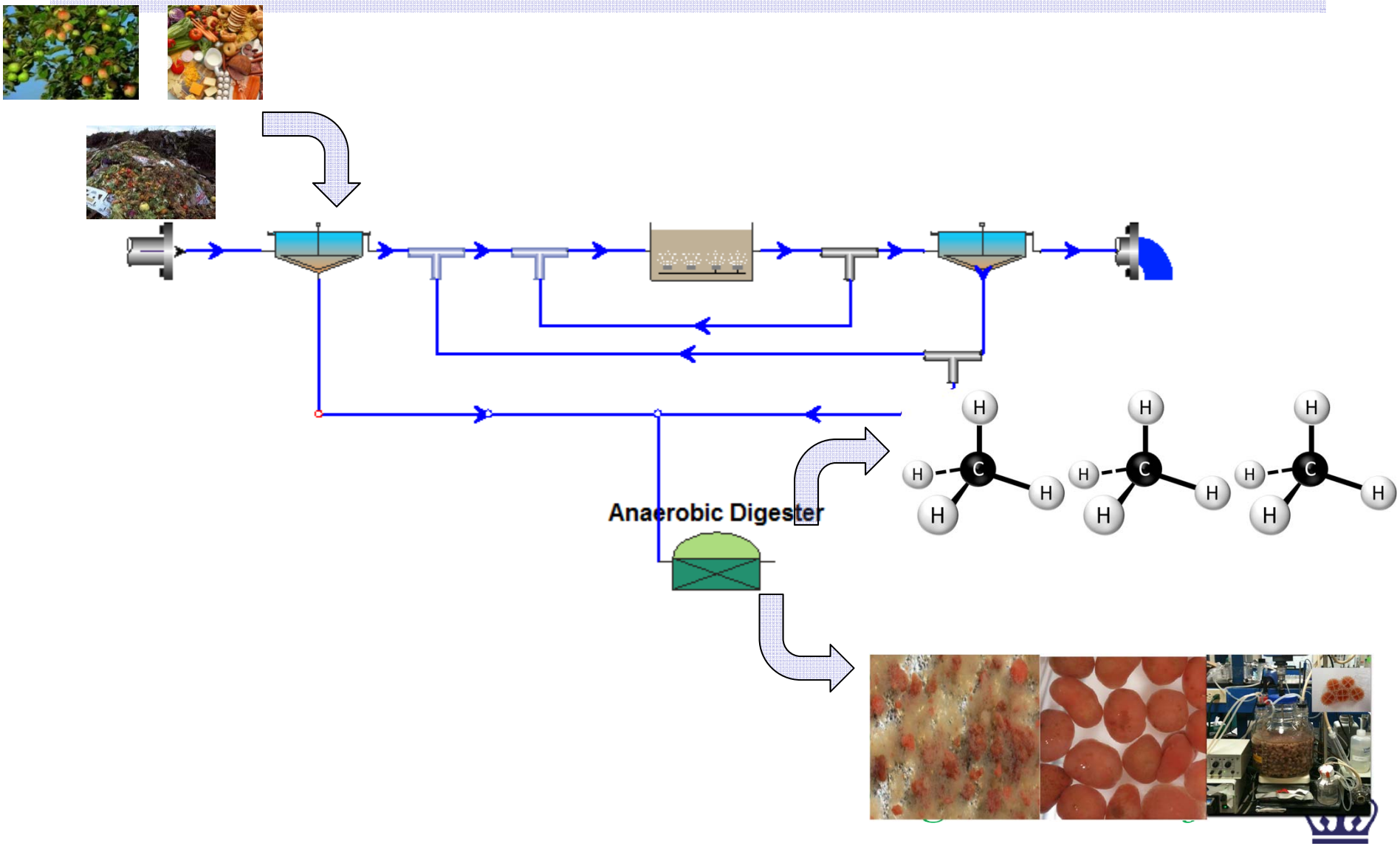
K. Chandran, 2014, in *Water Reclamation and Sustainability,* Elsevier

Energy self-sufficiency for wastewater treatment plants?

Energy present	Energy needed
~ 2500 kWh/MG	~2500 kWh/MG

- **Assuming 34% conversion of organic matter to methane and electricity**
- **Assuming 'conventional' BNR**

Water Quality-Energy

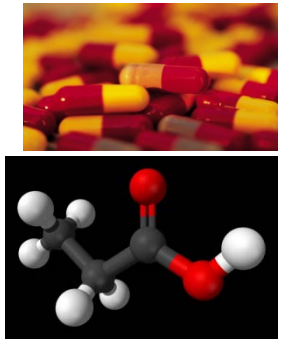


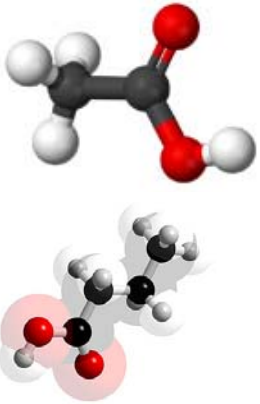
Think beyond CH_4

All based on anaerobic (+) technologies

Biofuels

Biodiesel from food waste at $0.71/L





Commercial chemicals

Fertilizer

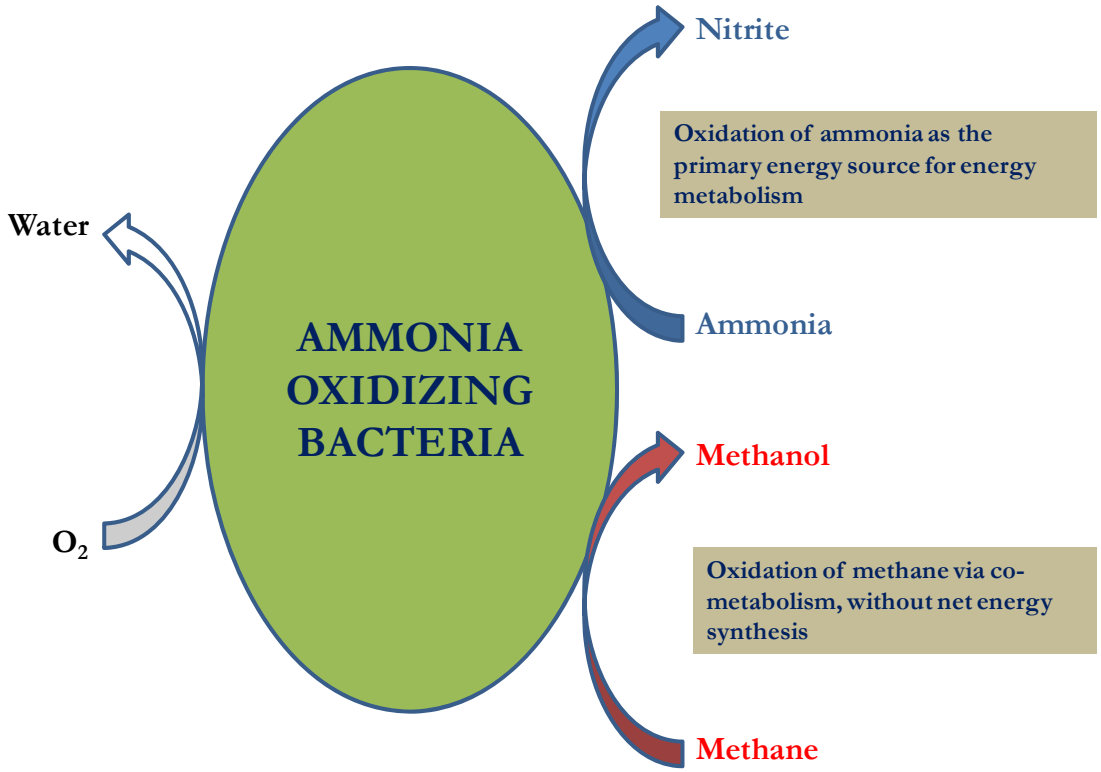
Alternate chemicals from sludge or biomass

Chemical	Platform technology	Application
Succinic acid	Fermentation	Nutraceutical
Ethyl acetate	Fermentation	Solvent
Methyl acetate	Fermentation	Solvent
!,3 propanediol	Fermentation	Industrial monomer
Butyric acid and butanol	Fermentation	Biofuel

- **Challenges remain**
  - **Separation and purification (although sometimes not needed)**
  - **Price of co-substrates (methanol, ethanol, glycerol)**

Biorefining for Chemical Recovery

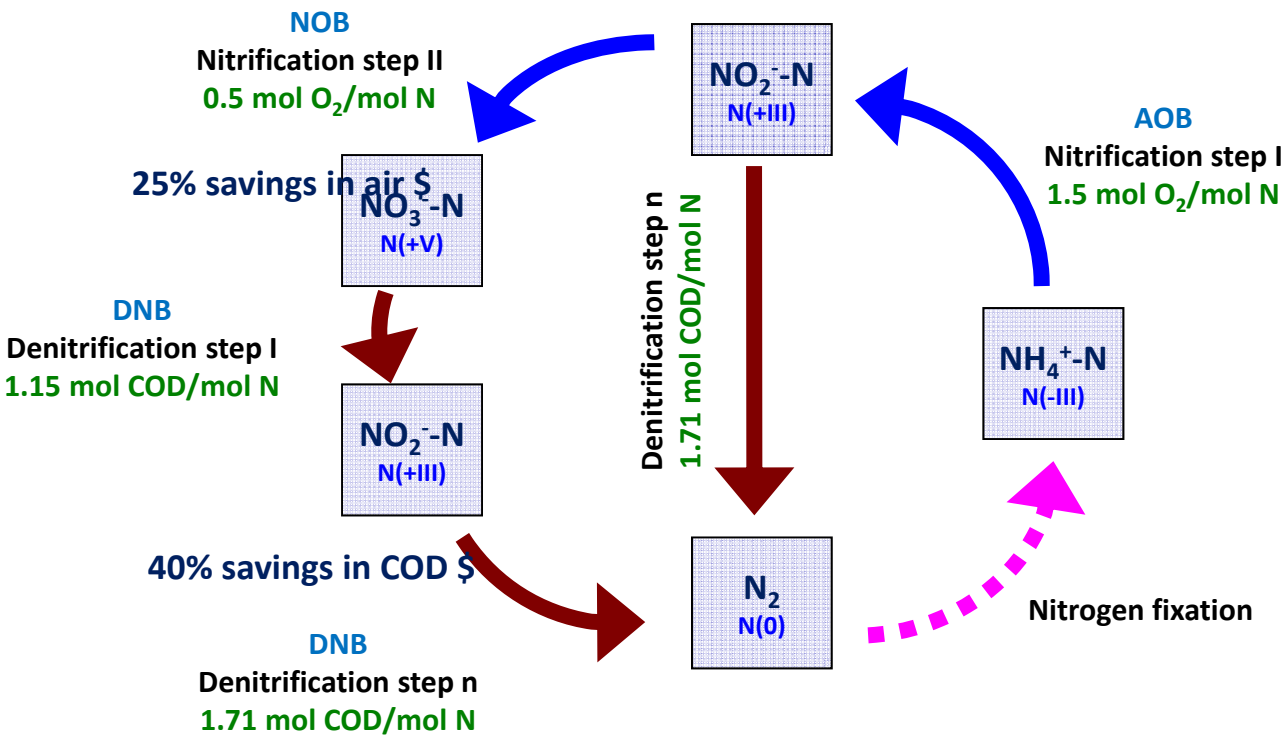
From Greenhouse Gas to Green Fuel



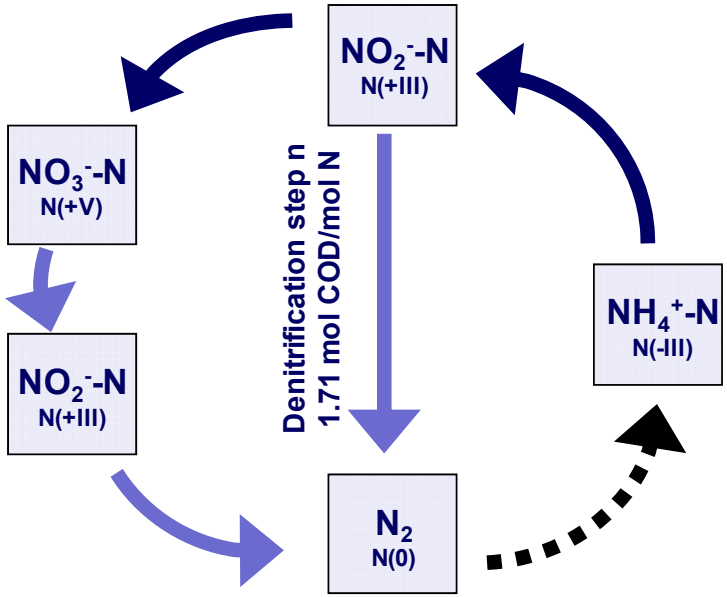
- Concomitant oxidation of CH_4 and CO_2 fixation
- Prospect of combining C &N cycles

WERF Paul Busch Award, 2010
Taher and Chandran, ES&T, 2013, *in press*

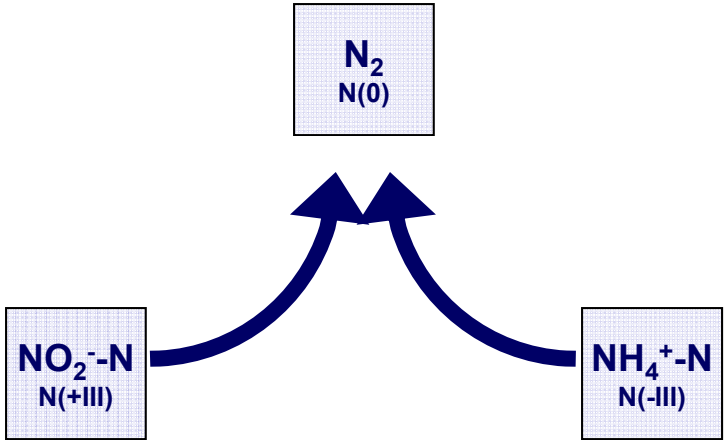
Clean water with lower energy consumption



Conventional BNR vs ANAMMOX



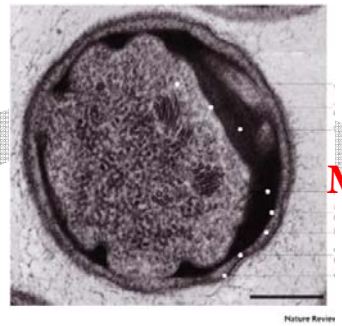
Conventional BNR



ANAMMOX

Rapidly expanding applications of ANAMMOX globally

Research needs and directions



Nature Reviews Microbiology 6, 320-326 (2008)

AMX Kinetics, inhibition
Competition (C, N)
Mechanisms of retention in mainstream systems

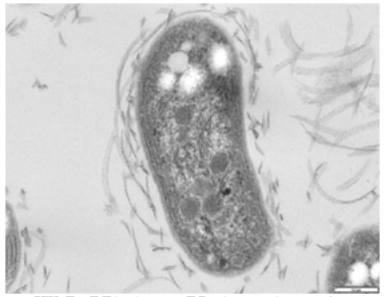
NH_3

NO_2^-

CO_2

O_2

Stan Watson, Woods Hole Oceanographic Institute



W.J. Hickey, University of Wisconsin-Madison, 2006.

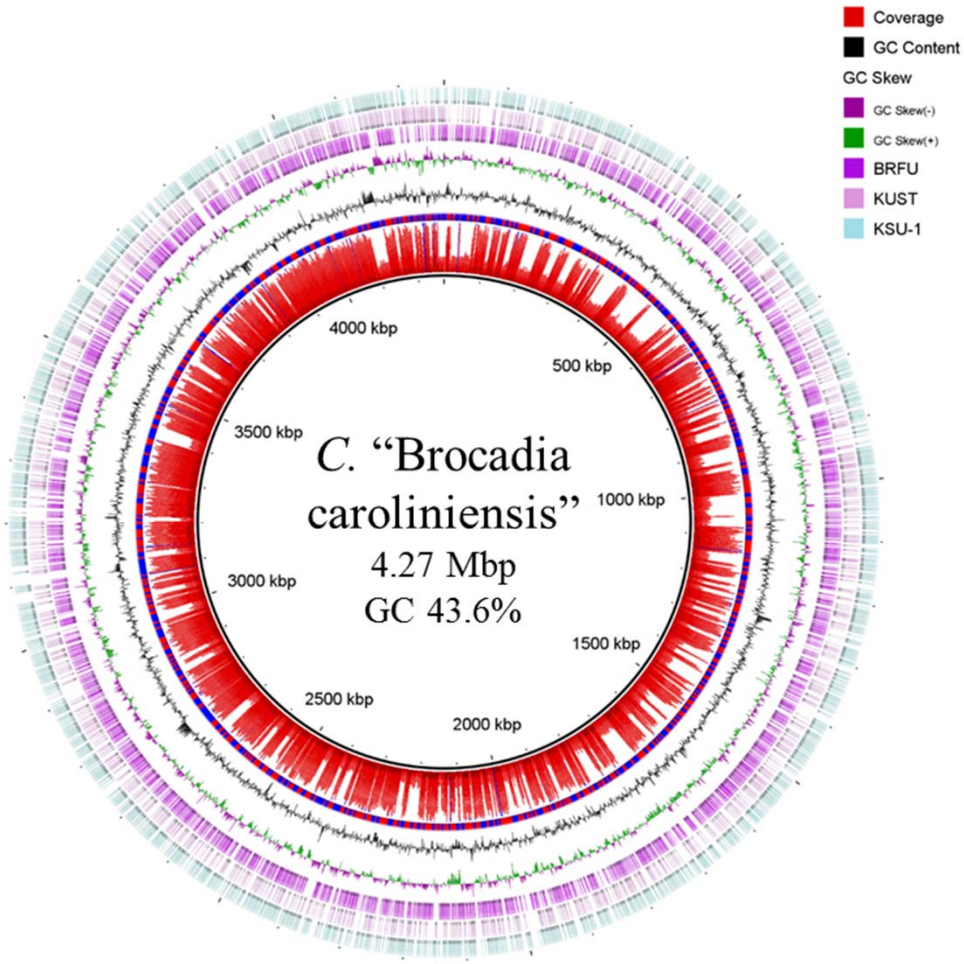
AOB

What else are AOB doing?
Intrinsic methods for NOB out-selection
(Competition, kinetics, inhibition)

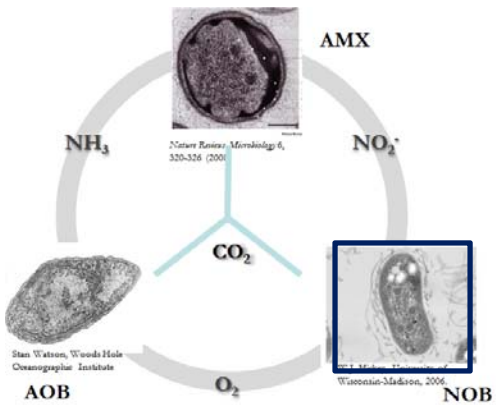
NOB

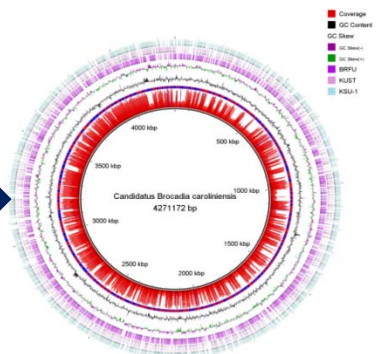
Nitrospira spp.
Kinetics, Inhibition
Mechanisms of out-selection in mainstream systems

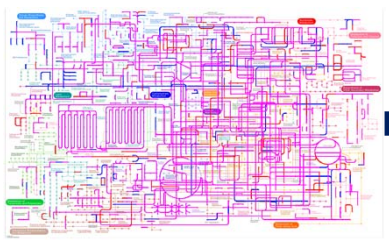
Anammox in unexpected(?) environments



Future perspectives







$$\Theta_{C,\min} = \frac{1}{\mu_{\max} - b}$$

What else can anammox processes do?

The connection to food

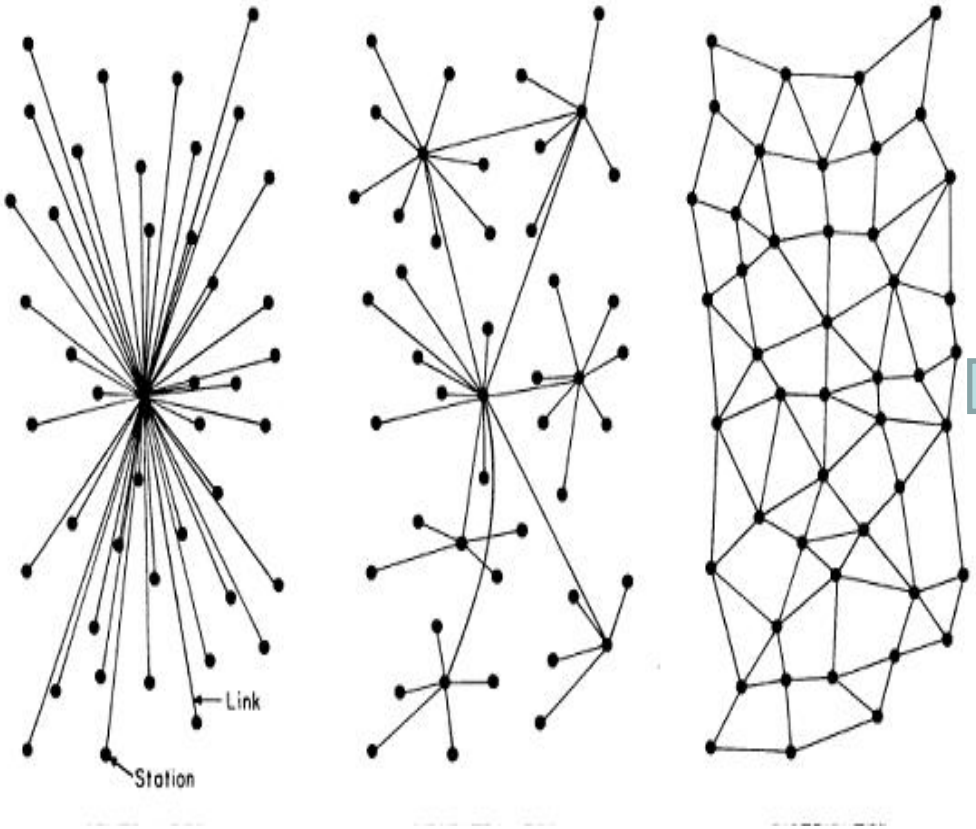
(water-energy-resources-cities)

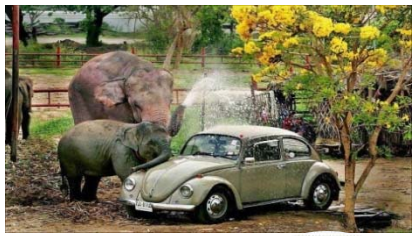
- **Sewage loads in New York City**
  - 1860 tons of organic carbon per day
  - 280 tons of N(-III) per day
  - 60 tons of P(+V) per day

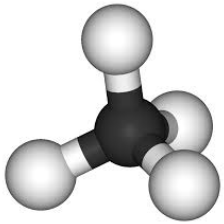
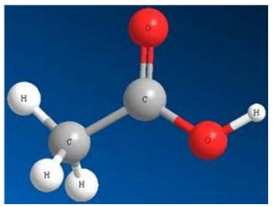
The connection to food

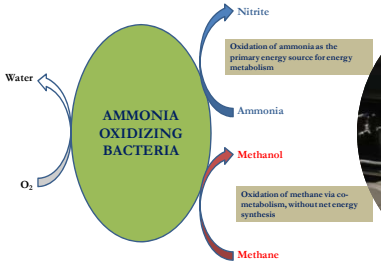
(water-energy-resources-cities)

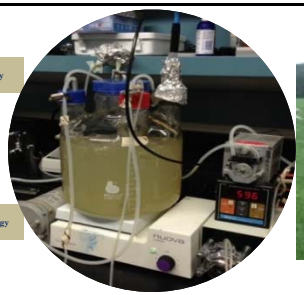
Scale and links









Framework

Gaps and needs

Future Cities

Discussion

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