Biosolids Management in the WWTP of the Future

PRESENTED BY:

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PRESENTED TO:

OWEA Biosolids Conference

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Presentation Outline

- Background
- Brief review of energy recovery
- Nutrient recovery
  - Why
  - Technology life cycle
  - Technology review
- Conclusion

WWTP of the Future

What is the Problem We are Trying to Solve?

Population Growth + **Urbanization** + **Consumption** + **"Linear System"**

Linear System = Take + Treat + Use + Treat + Waste

Integrated Water and Resource Management

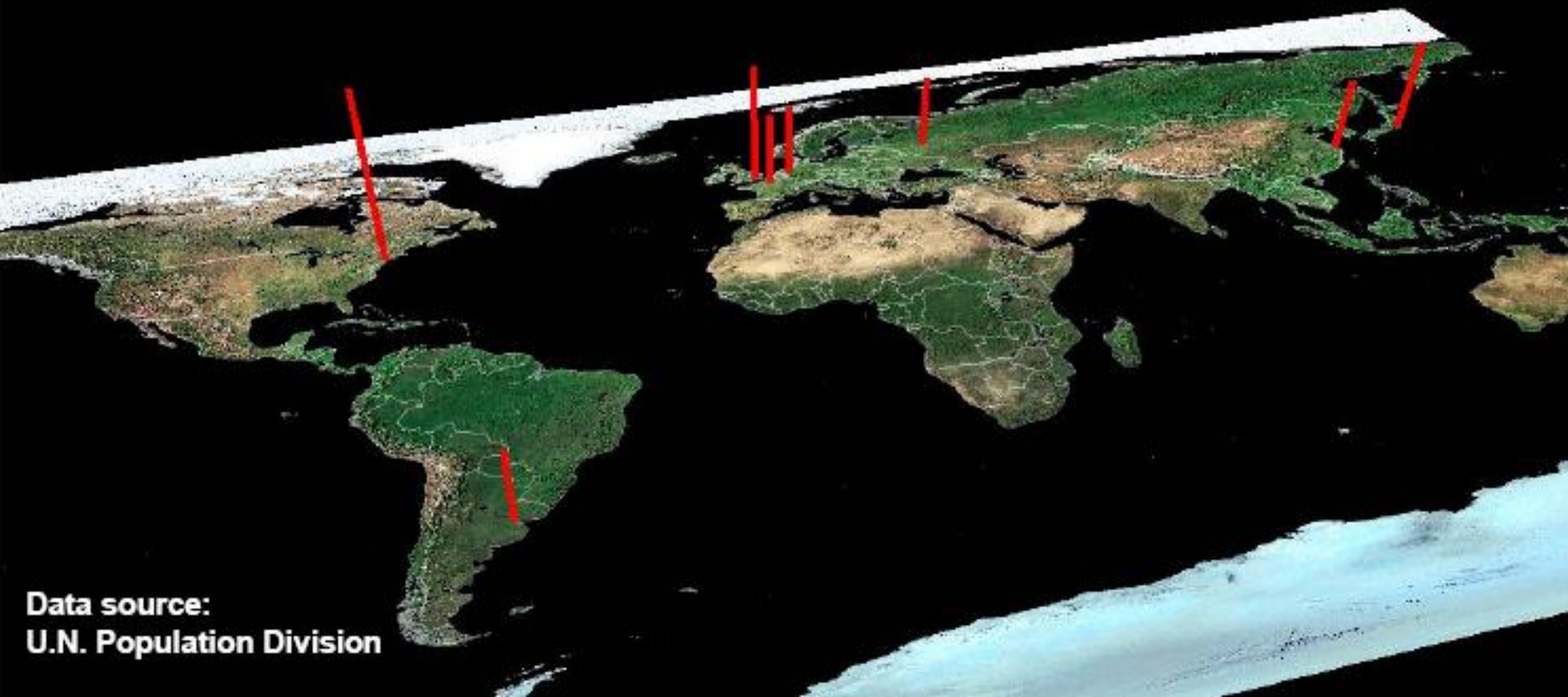
= **Water Stress** + **Resource Consumption** + **Nutrient Dispersal**

Development of World Cities

Münchener Rück
Munich Re Group

1950

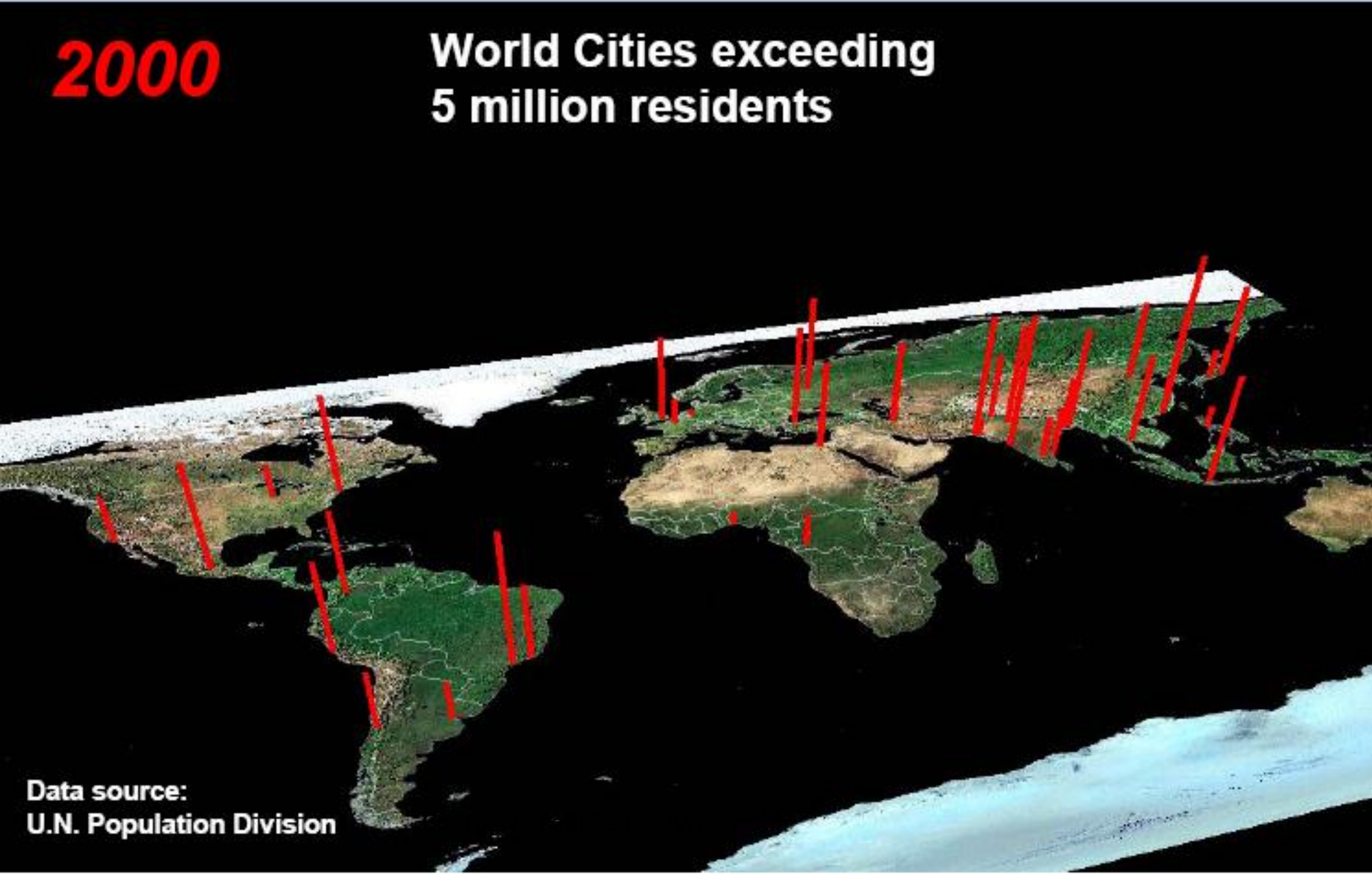
World Cities exceeding 5 million residents



Data source:
U.N. Population Division

Development of World Cities

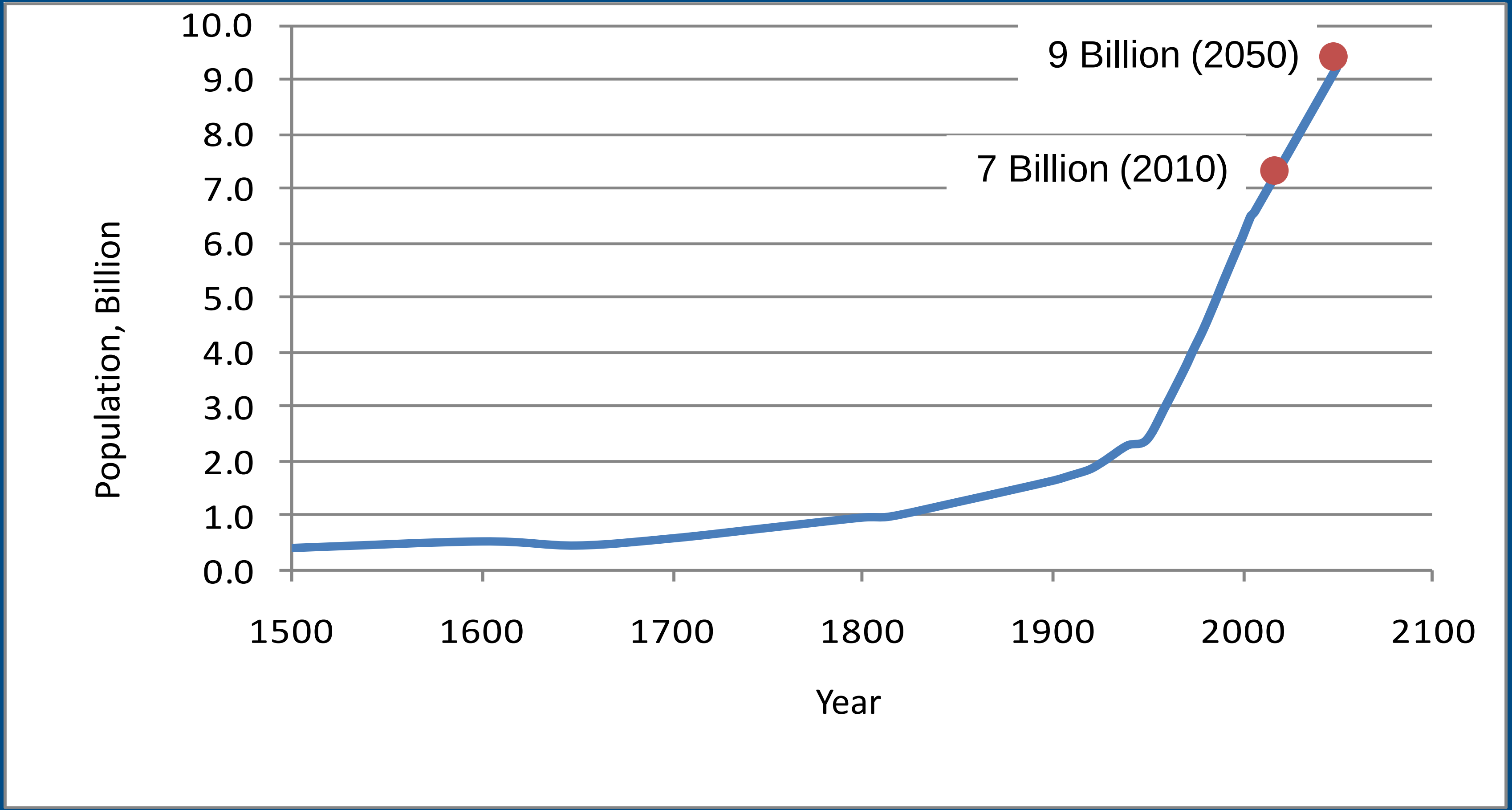
Münchener Rück
Munich Re Group



Development of World Cities

Münchener Rück
Munich Re Group

Population Explosion



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Can a System That Serves:

- Global Population < 2 Billion
- Mostly Rural
- Lacking Modern Technology

Be the Solution When:

- Global Population ~ 10 Billion
- Mostly Urban
- Experiencing Greater Resource Constraints?

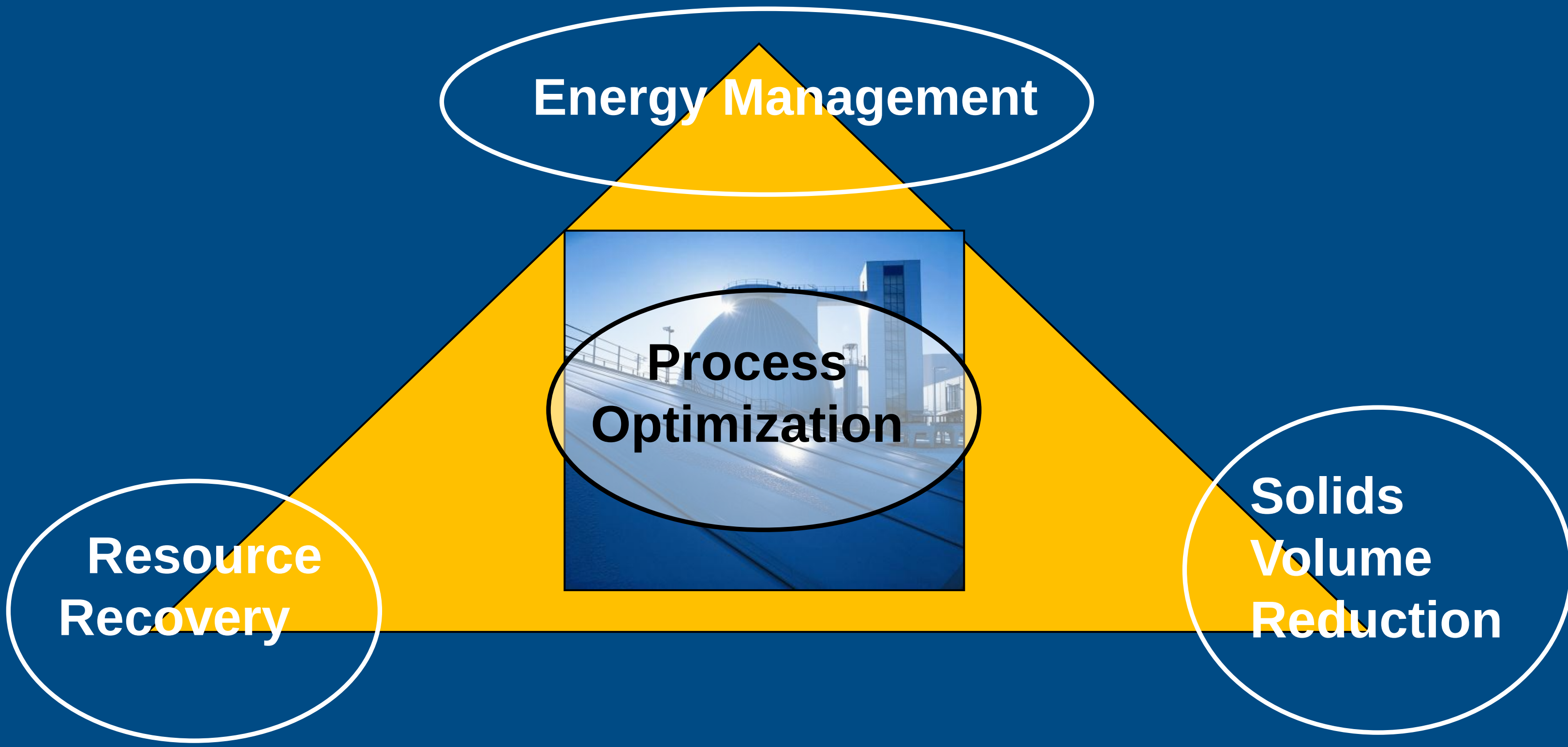
Key Elements of WEF Position Statement

1. Redefines wastewater treatment plants as water resource recovery facilities (WRRFs)
2. Affirms that energy derived from WRRFs is a renewable energy source
3. States that biosolids should be recognized as biomass under all applicable government and commercial definitions
4. Asserts that state and federal agencies should fully endorse all renewable energy associated with WRRFs
5. Encourages WRRFs to set a goal of becoming energy neutral or net energy producers
6. Encourages more research into emerging technologies on energy recovery from wastewater
7. Encourages continued participation by water sector in traditional energy conservation and recovery at WRRFs

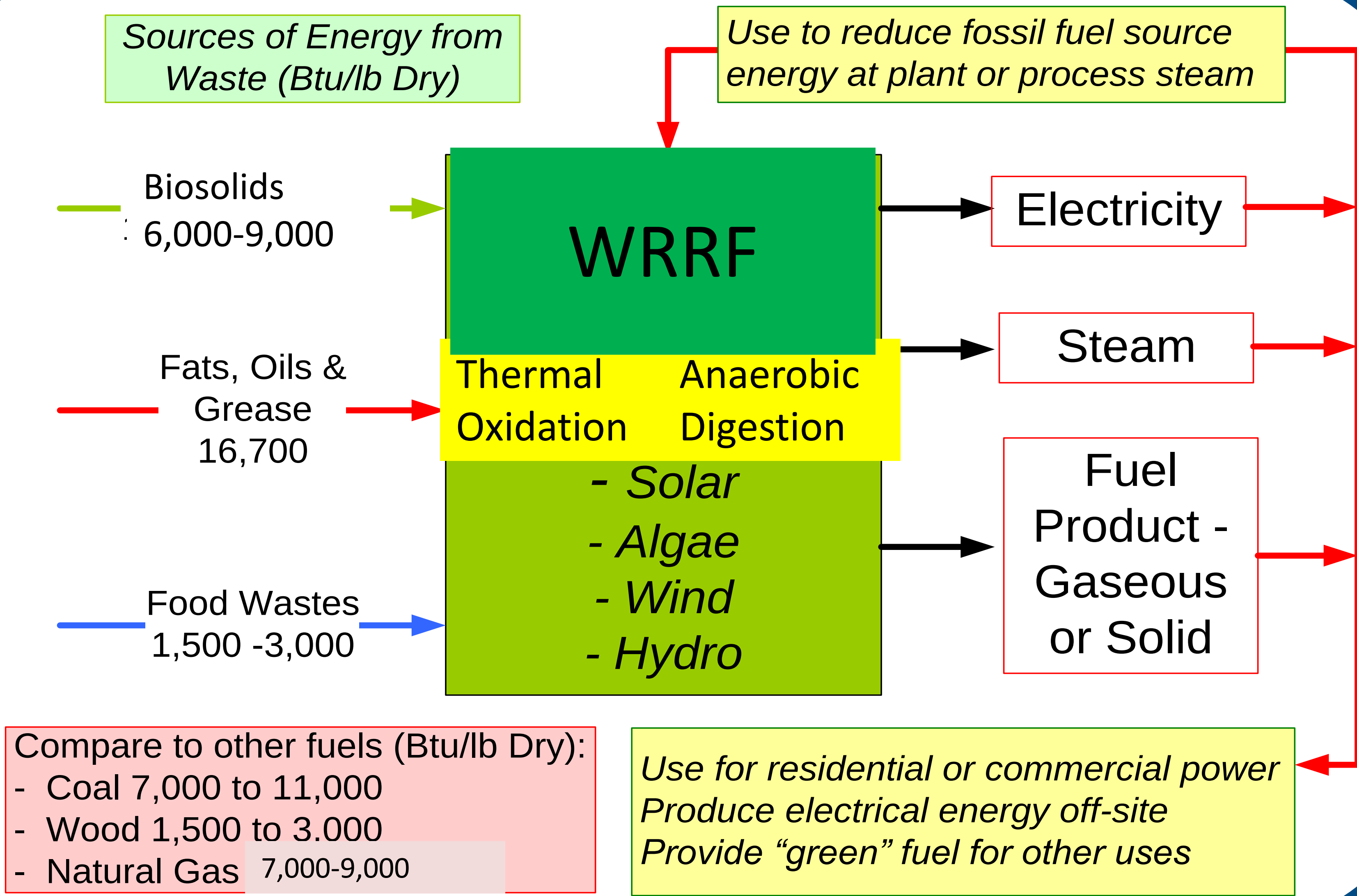
WWTP of the Future in a Resource and Energy Constrained World

- Water Conservation
- Distributed Stormwater Management
  - Low Impact Development
  - Rainwater Harvesting
- Water Reclamation and Recycling
- Energy Neutral or Energy Positive
- Carbon Sequestration for Energy Production
- Nutrient Recovery
- Source Separation
- Decentralized treatment
  - Distributed liquid treatment
  - Centralized solids treatment

WERF Optimization Challenge



General Energy Balance for WRRF



The Future of Nutrient Recovery Influences and Drivers

- Minimize use of chemicals
  - Chem.-P to Bio-P removal
- Struvite scaling
- Impact of phosphorus scarcity
  - Increased cost
  - Security
- Viability of continued land application
  - Availability of suitable land
  - Phosphorus limitation
- Nitrogen cycle disruption

The Future of Nutrient Recovery
Influences and Drivers

- Highly marketable end-product
- Fertilizer industry greenhouse gas emissions
- Future regulations (favorable)
  - Sweden: 60% of P recycled from wastewater by 2015
- Nutrient recovery an integral component of sustainable WWTP of the future
- Decentralized treatment with centralized sludge treatment

The Future of Nutrient Recovery

Barriers

- Economics
- Competing priorities
- Lack of regulatory drivers
- Lack of knowledge
- Followers rather than leaders
- Lack of adequate full scale experience
- Averse to adding new processes
  - Staffing constraints
- Lack of public support
- Vague timeline (50 - 100 years?)

The Importance of Phosphorus

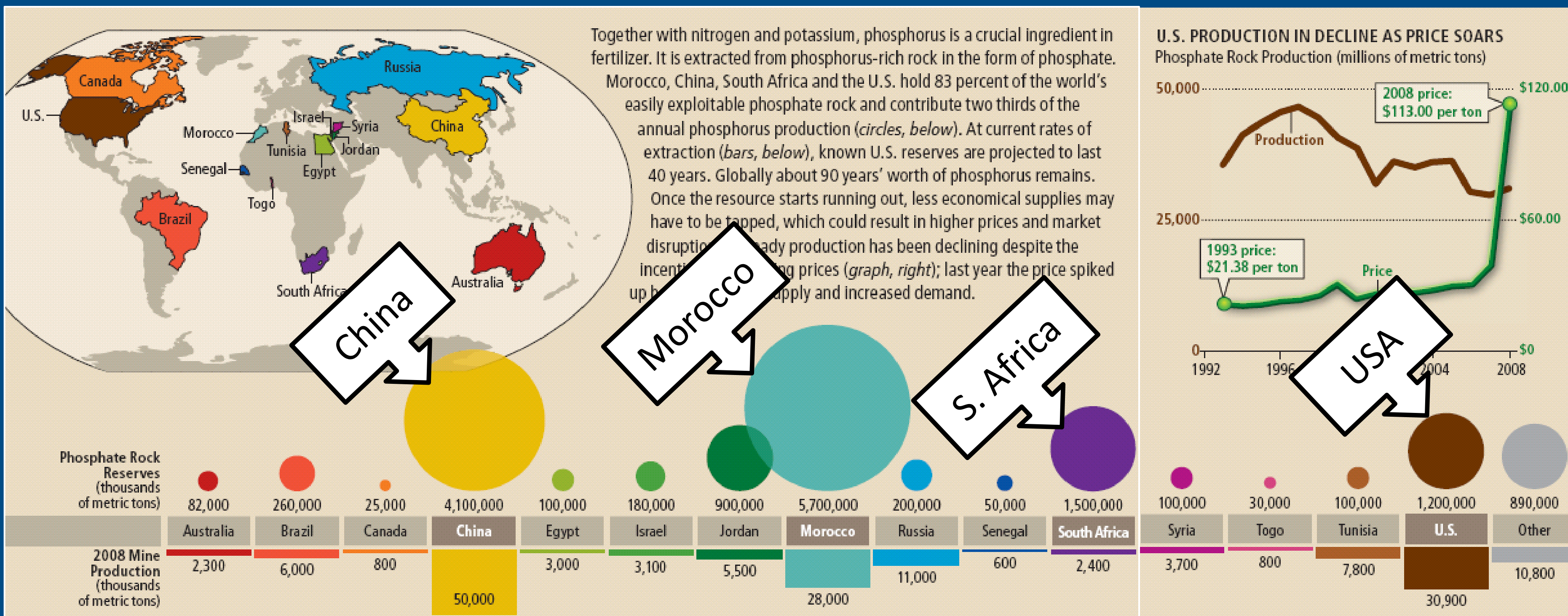
- Essential element of all life forms:
  - Genetic material, ATP, Bones
- A primary nutrient required for plant growth
- Detergents, crop protection, pharmaceuticals, flame retardant, etc.

An average human body contains 650g of Phosphorus.

Phosphorus is a Precious Element

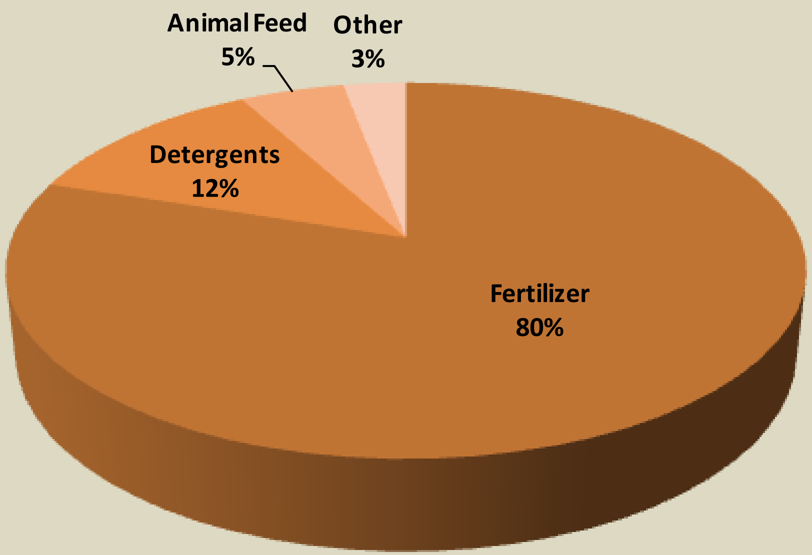
- **Essential** – no substitutes, natural or synthetic
- **Non-Renewable**

Phosphorus Reserves and Production Worldwide



Vaccari, 2009

Current Phosphorus Use Profile



Present Phosphorus Use Profile

Fertilizer use expected to increase due to

- Rapid population growth
- Increased intensive agriculture

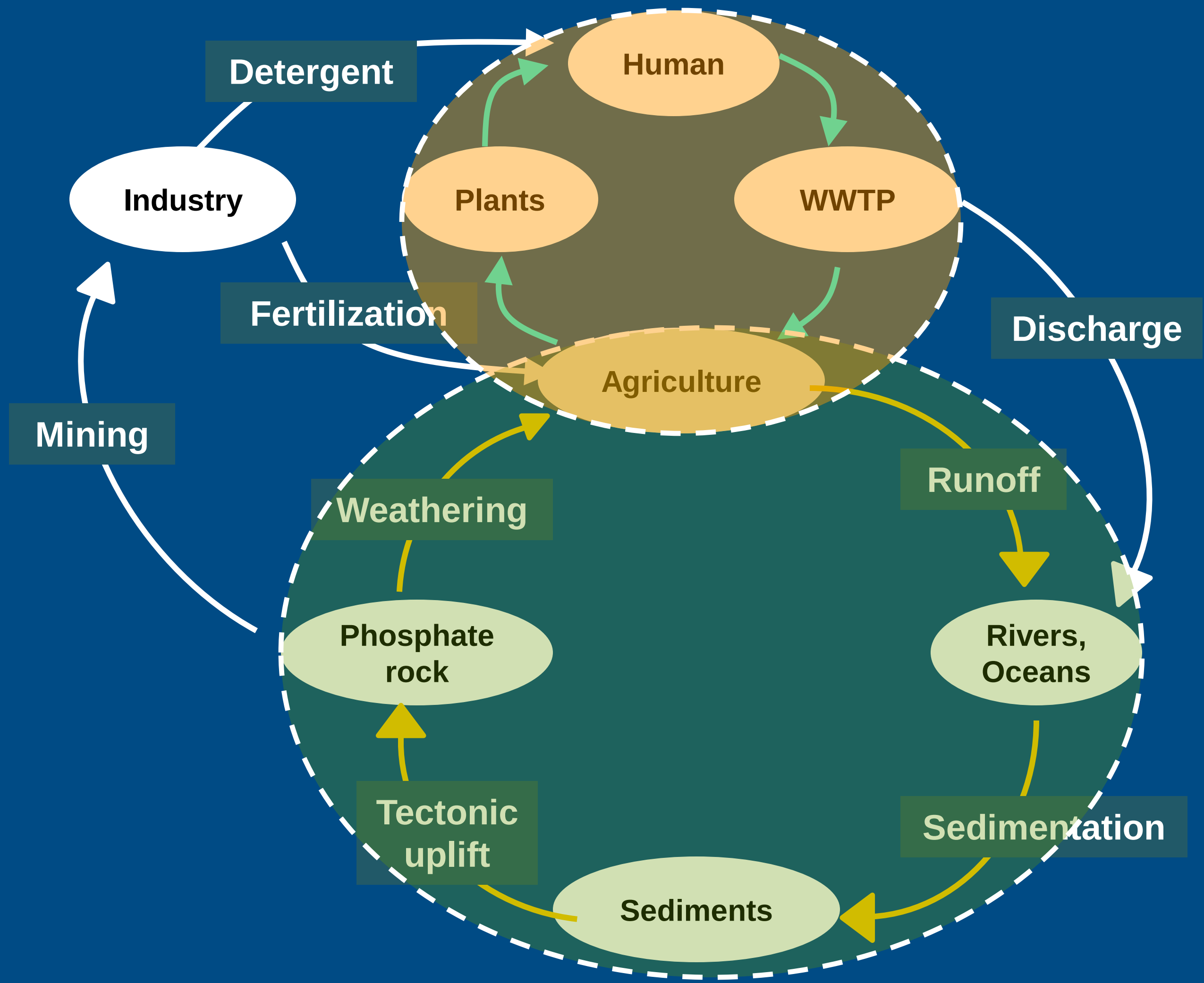
The Phosphorus Crisis

- Phosphorus resources are declining both in quality and accessibility

> Availability of high quality P:
> - 100 years globally
> - 40 year in the US

- Poor quality sources have increasing amounts of contaminants (Cd, U, Ni, Cr, Cu, Zn)
  - Higher cost of recovery
- Global response:
  - Sweden: 60% of P recycled from wastewater by 2015
  - China: 135% export tariff
  - Use of special urine separation toilets (Japan and Europe)

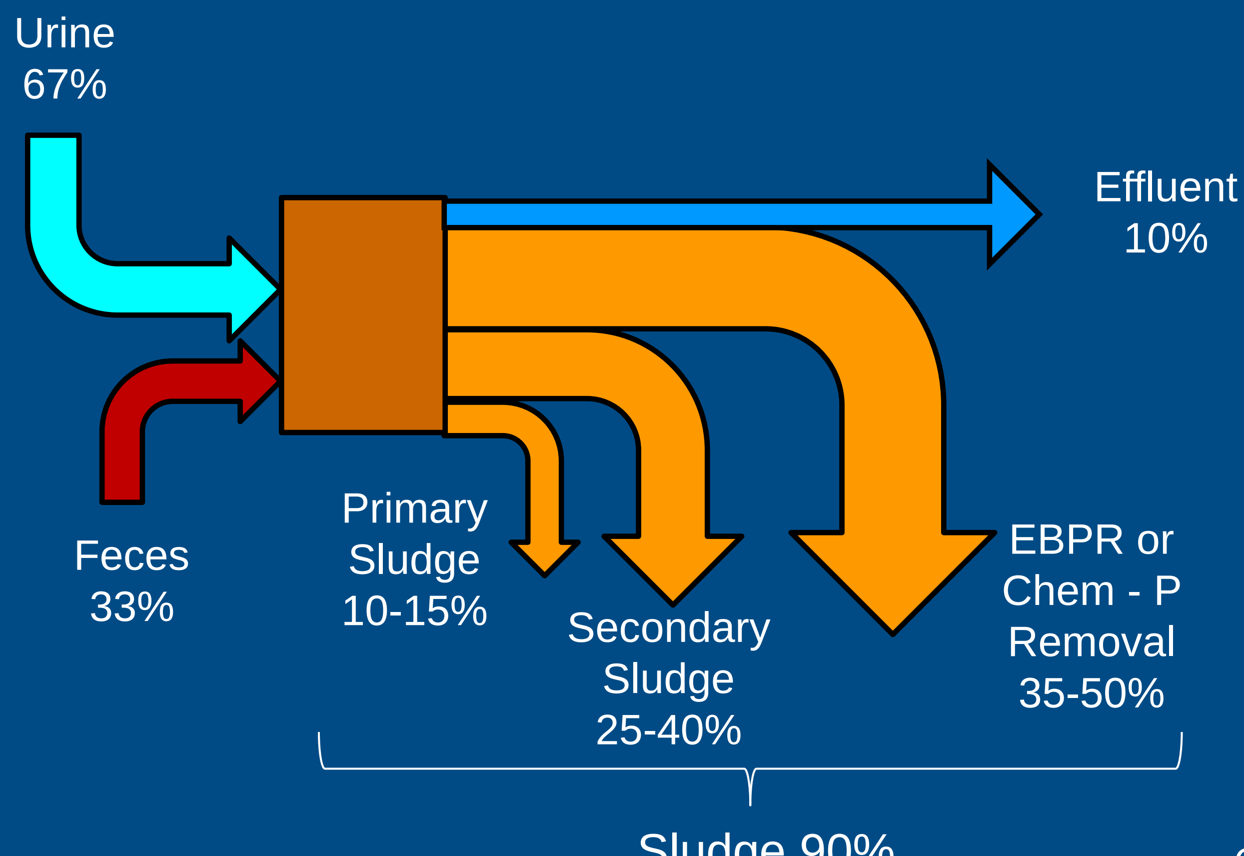
Is There Really a Loss of Phosphorus?



Cornel *et al* (2009)

Phosphorus Distribution in Domestic Waste

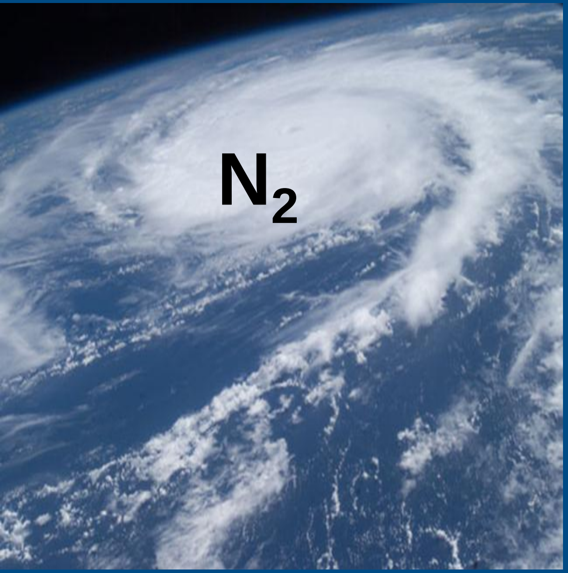
400,000 tons/year of phosphorus in US sewage



Cornel *et al* (2009)

Nitrogen is Essential to Life

Contained in our DNA



- Present as N_2 gas in the atmosphere – infinite source
- Unusable by most organisms
- Need to convert to Reactive N (Nr)

Nr = Nitrogen bonded to carbon (C), oxygen (O) or hydrogen (H) atoms; e.g. NH_3

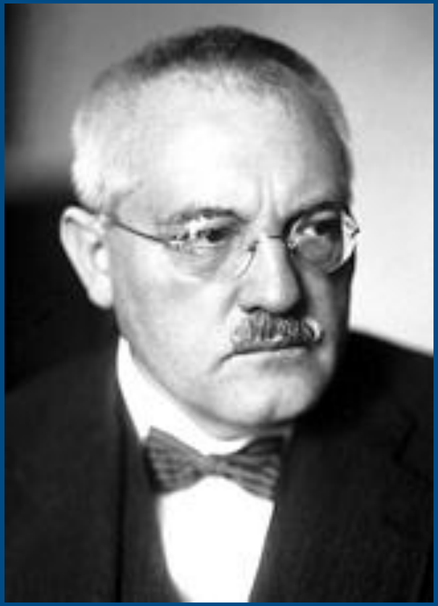
Natural conversion of N_2 gas to Nr:

- Lightening
- N-Fixation

Inadequate to sustain life - need human intervention

Global Nr Production

Fritz Haber
Nobel Prize - 1918



Carl Bosch
Nobel Prize (joint) - 1931

www.nobelprize.org

Global Nr Production

Haber – Bosch Process

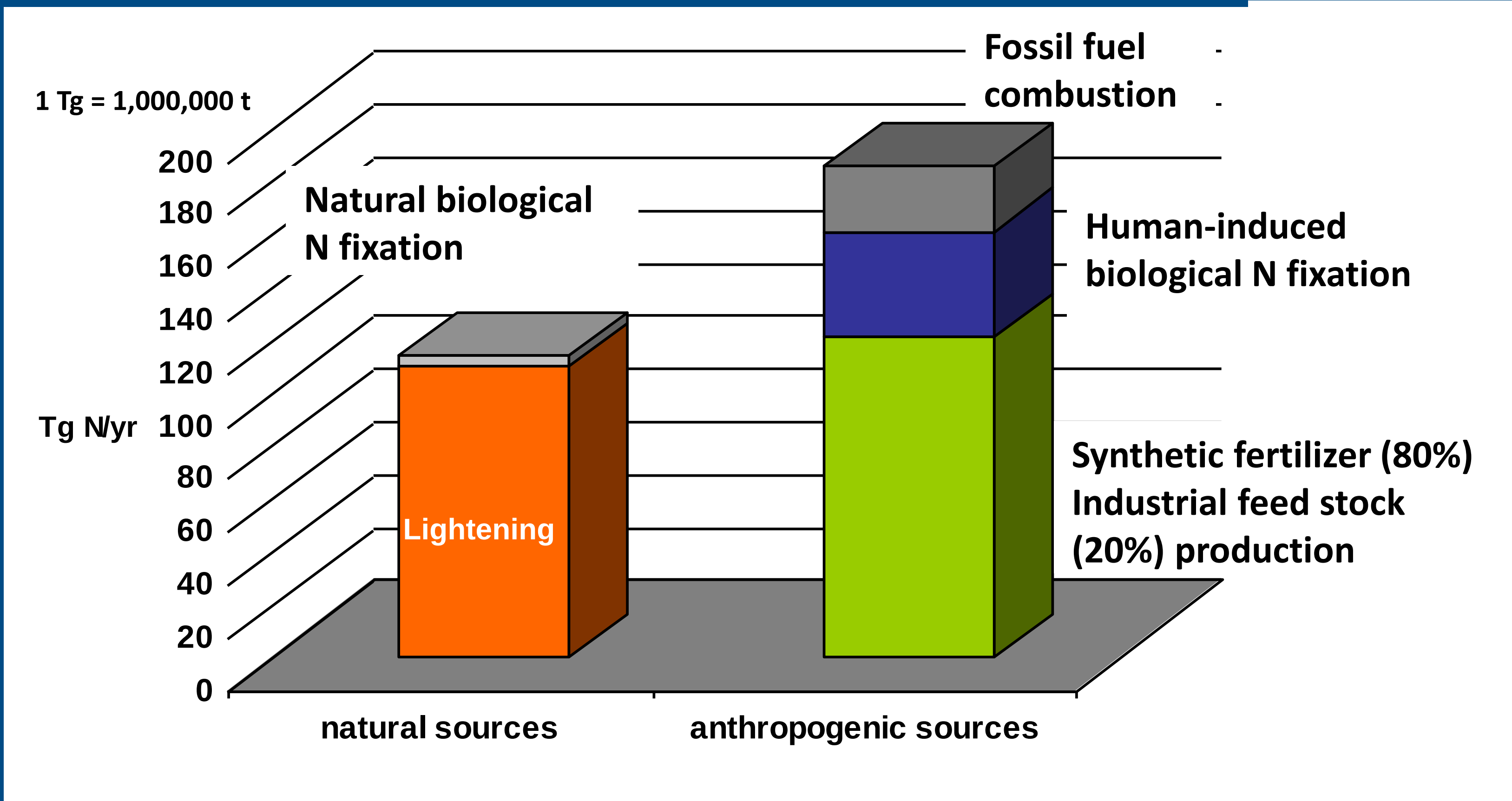
450ºC, 250 atm

$$N_2 + 3H_2 \rightarrow 2NH_3$$

N source = air

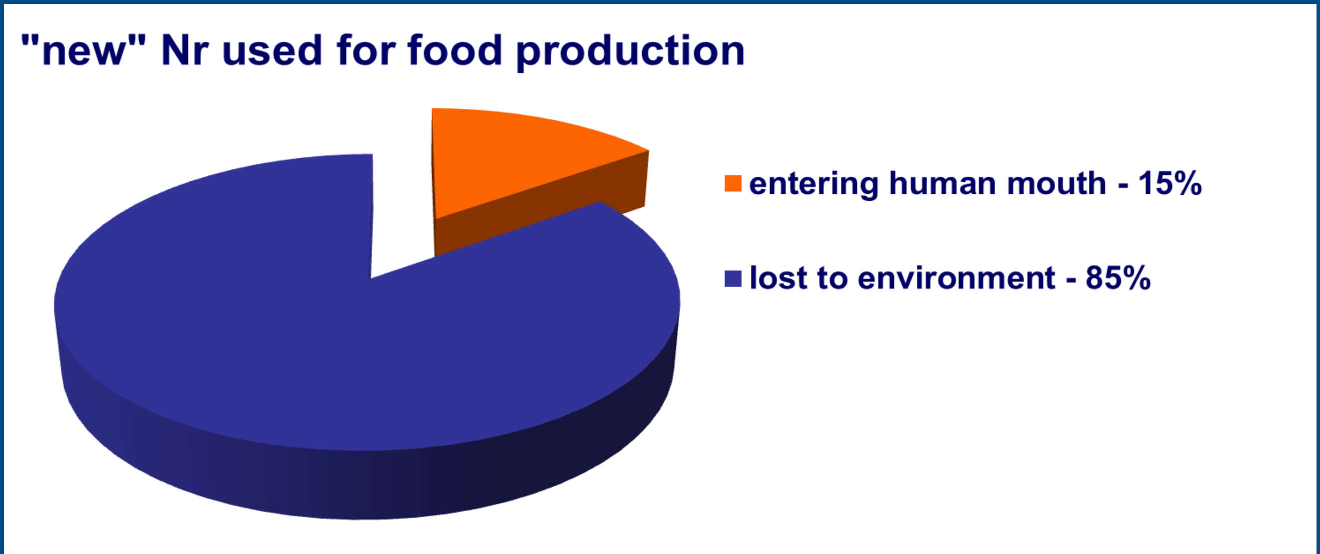
H source = natural gas

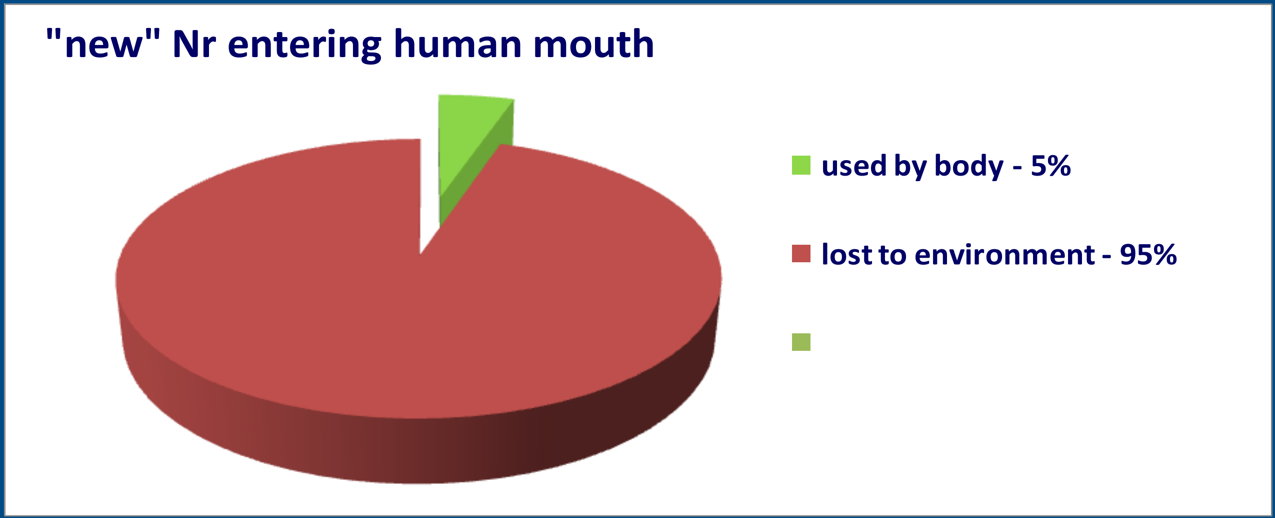
Global Nr Production



Adapted from Barton and Atwater (2002) and Galloway et al (2008)

The Fate of Reactive Nitrogen (Nr)





Environment is also the sink for all of the Nr created by fossil fuel combustion.

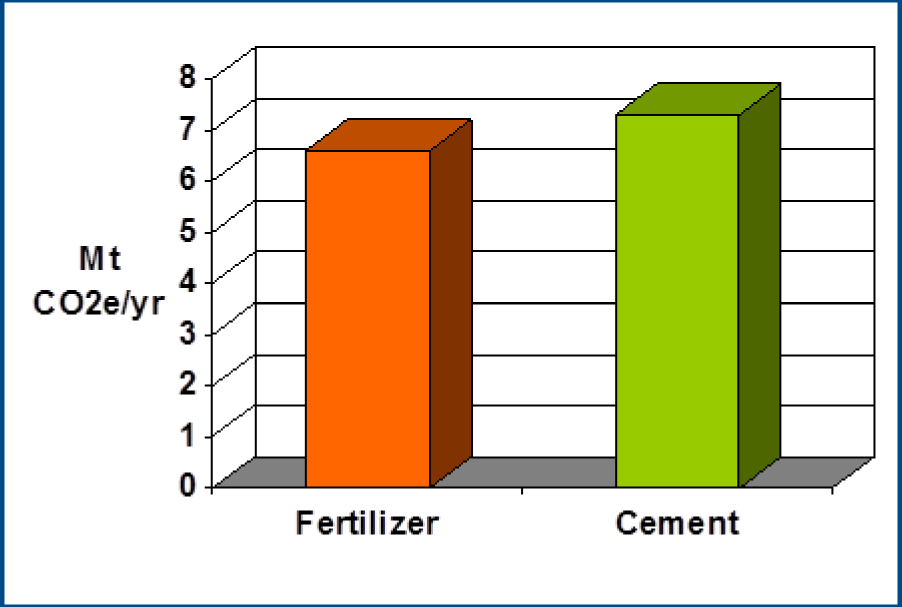
adapted from Galloway et al (2004)

Impact of Global Nitrogen Imbalance

Nitrogen loss = Increased synthetic fertilizer production:

- High energy demand = 12 kWh / kg ammonia N (Phillips et al, 2011)
- High embedded GHG emissions = 1.4 to 2.6 kg CO_2e / kg ammonia N (Wood and Cowie, 2004)

Canadian GHG Emissions

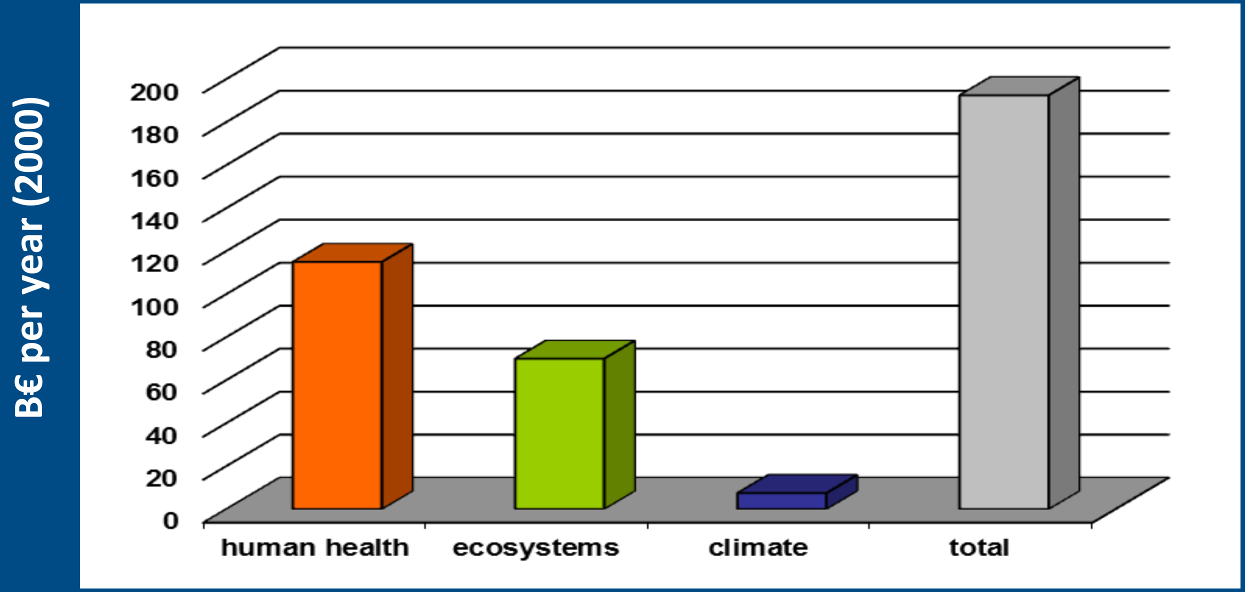


adapted from Environment Canada (2008)

Continuing Business as Usual will..

- Continue to alter the global nitrogen balance
- Result in nitrogen accumulation in the environment causing environmental & health impacts.

Estimated social damage costs of environmental Nr emissions to European Union countries (mid-range values)



Adapted from Sutton et al (2011)

Human Intervention Needed to Minimize the Impact on Global N Balance

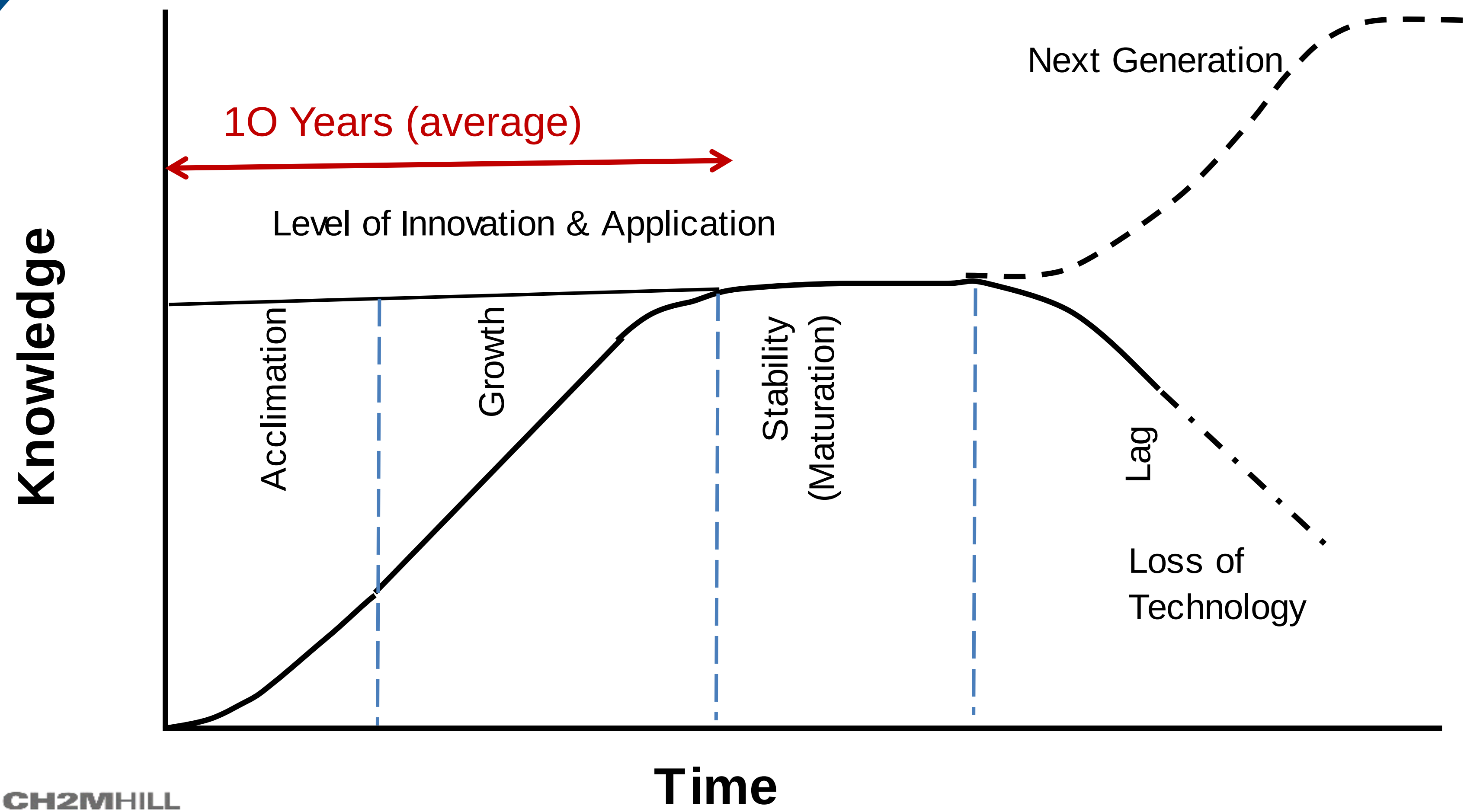
Wastewater management is one of the intervention points

Conversion to N_2 via treatment

Recovery

Technology Life-Cycle Model

Technology development is a 100 to 10 to 1 game!



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	Life Phase			
Technology	Acclimation	Growth	Stability	Lag
Gravity Belt Thickening			✓	
Rotary Press		✓		
Belt Filter Press			✓	
Vacuum Filter				✓
Centrifuge Dewatering			✓	
Recuperative Thickening		✓		
Acid-Gas Digestion				✓
Temperature Phased Anaerobic Digestion		✓		
Co-Digestion	✓			
Dual Digestion		✓		
Auto-thermal Aerobic Digestion	✓			
Thermal Hydrolysis	✓			
Thermal Drying			✓	
Class A Heat Treat System	✓			
Sludge Disintegration	✓			
Microsludge™	✓			
Open Cel™	✓			
Lyso™	✓			
Ultrasonics	✓			
Ostara™	✓			
Co-generation			✓	
Fuel Cell	✓			
Solar Photovoltaics		✓		
Gasification	✓			
Biosolids Composting			✓	

Phosphorus Recovery Alternatives

Precipitation

Crystallization

- Struvite
- Apatite

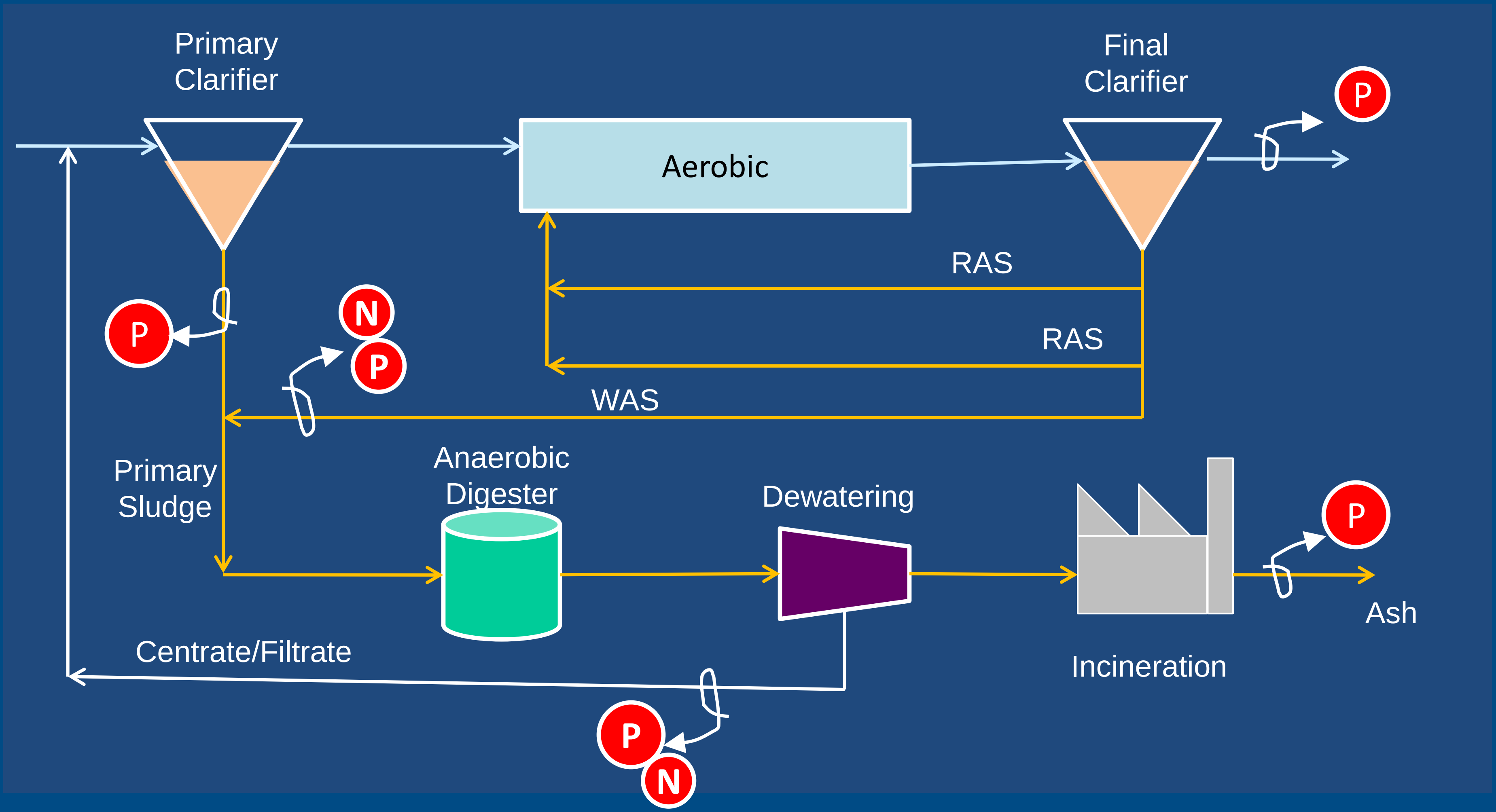
Solids Separation

Adsorption

- Sorption
- Ion Exchange

Chemical desorption
Magnetic separation

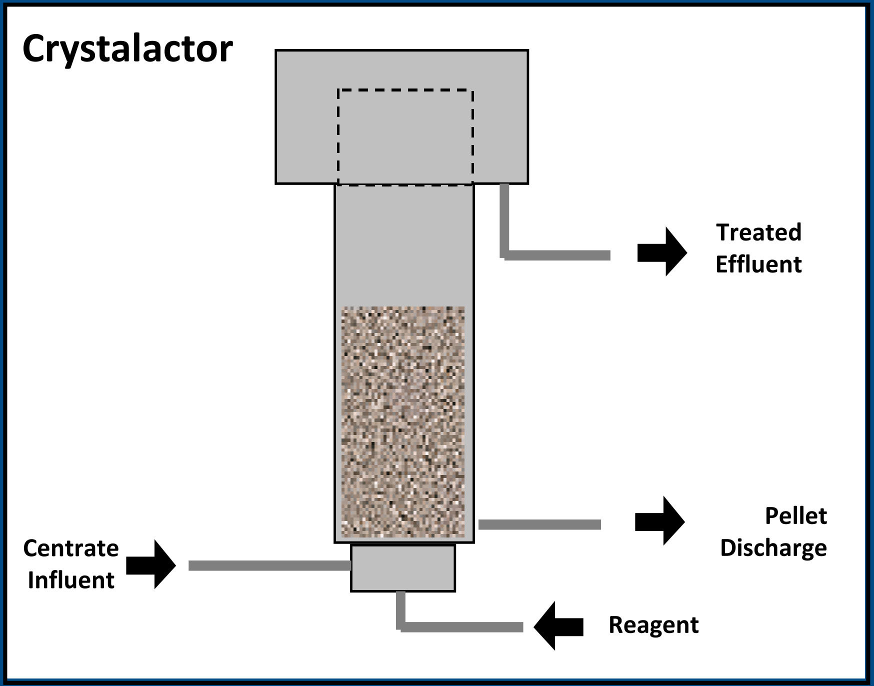
Potential Locations for P Recovery

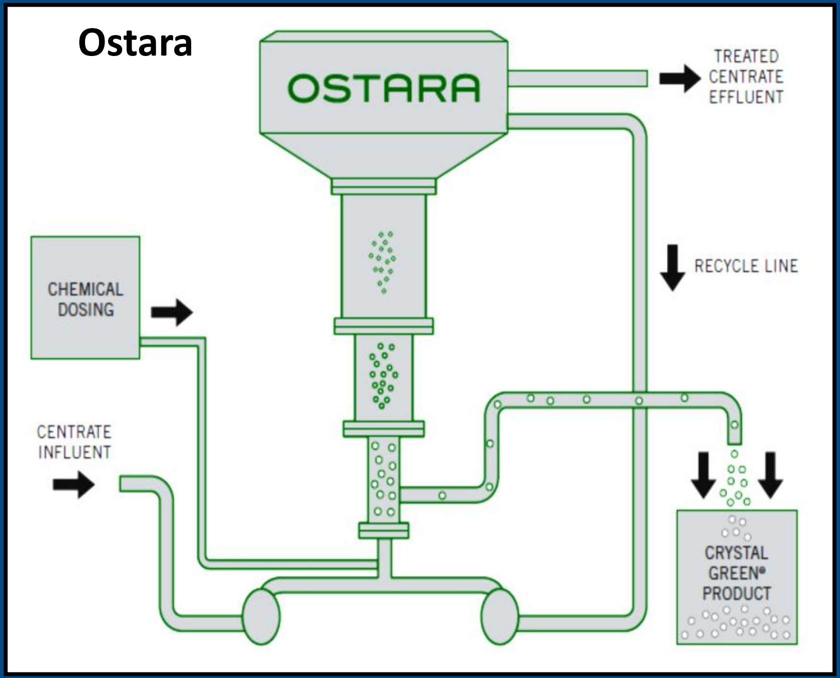


Proven P Recovery Technologies

Technology	Feed Stream	Product	External Inputs
Crystalactor	RAS	$CaPO_4$	Lime, sand
PhoStrip	RAS	$CaPO_4$	Lime
Ostara	Centrate, filtrate	Struvite	MgCl, NaOH
Ostara	WAS	Struvite	MgCl, NaOH
Multiform Harvest	Centrate, filtrate	Struvite	MgCl, NaOH
Procorp	Centrate, Filtrate	Struvite	MgCl, NaOH

Fluidized Bed Reactor





Struvite Recovery Installations

Ostara

- Operational
  - Gold Bar, Edmonton
  - Durham WWTP, Portland, OR
  - York, PA
  - Nansemond, HRSD, VA
- Under construction
  - Rock Creek, Portland, OR
  - Saskatoon, Calgary, Winnipeg
  - Madison

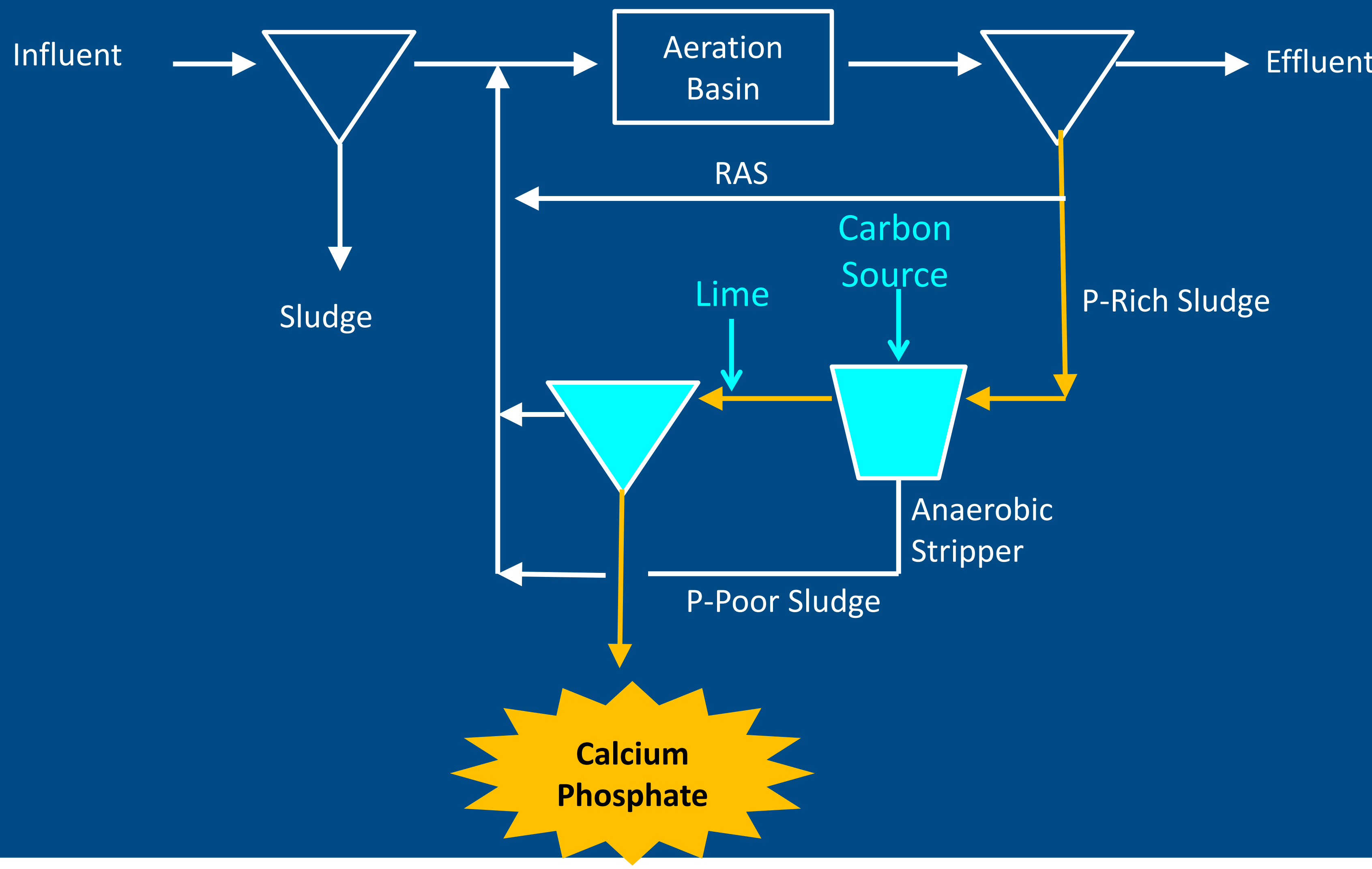
Multiform Harvest

- Under Construction
  - Boise, ID

Procorp

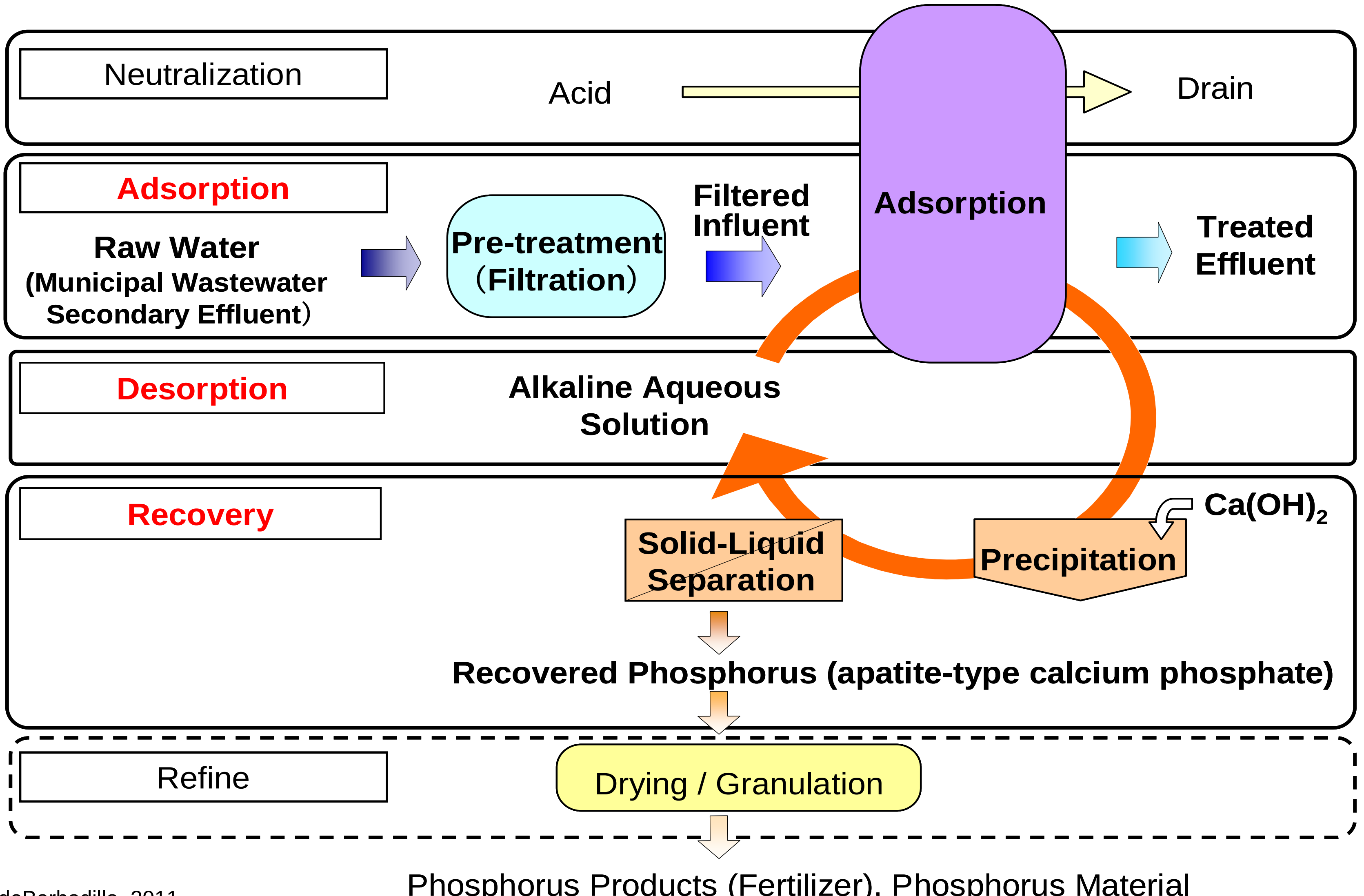
- Under design - 1

PhoStrip



Influent
Aeration Basin
Effluent
RAS
Sludge
Carbon Source
Lime
P-Rich Sludge
Anaerobic Stripper
P-Poor Sludge
Calcium Phosphate

Adsorption Technology



deBarbadillo, 2011

Other P Recovery Technologies

Technology	Origin	Feed Stream	Product	External Inputs
KREPO	Sweden	Primary sludge	Ferric Phosphate	Heat, pressure, H_2SO_4, NaOH
Seaborne	Germany	Digested sludge	Struvite	Heat, H_2SO_4, NaOH, $Mg(OH)_2$
Kemicond	Sweden	Primary sludge	Ferric Phosphate	H_2SO_4, H_2O_2, polymer
BioCon	Denmark	Incinerator ash	H_3PO_4	H_2SO_4, ion-exchange
SEPHOS	Germany	Incinerator ash	$AlPO_4$, $Ca_3(PO_4)_2$	H_2SO_4, NaOH, Ca^{2+}
Adsorption	Japan	Effluent	$Ca_3(PO_4)_2$	Acid , NaOH, Ca^{2+}

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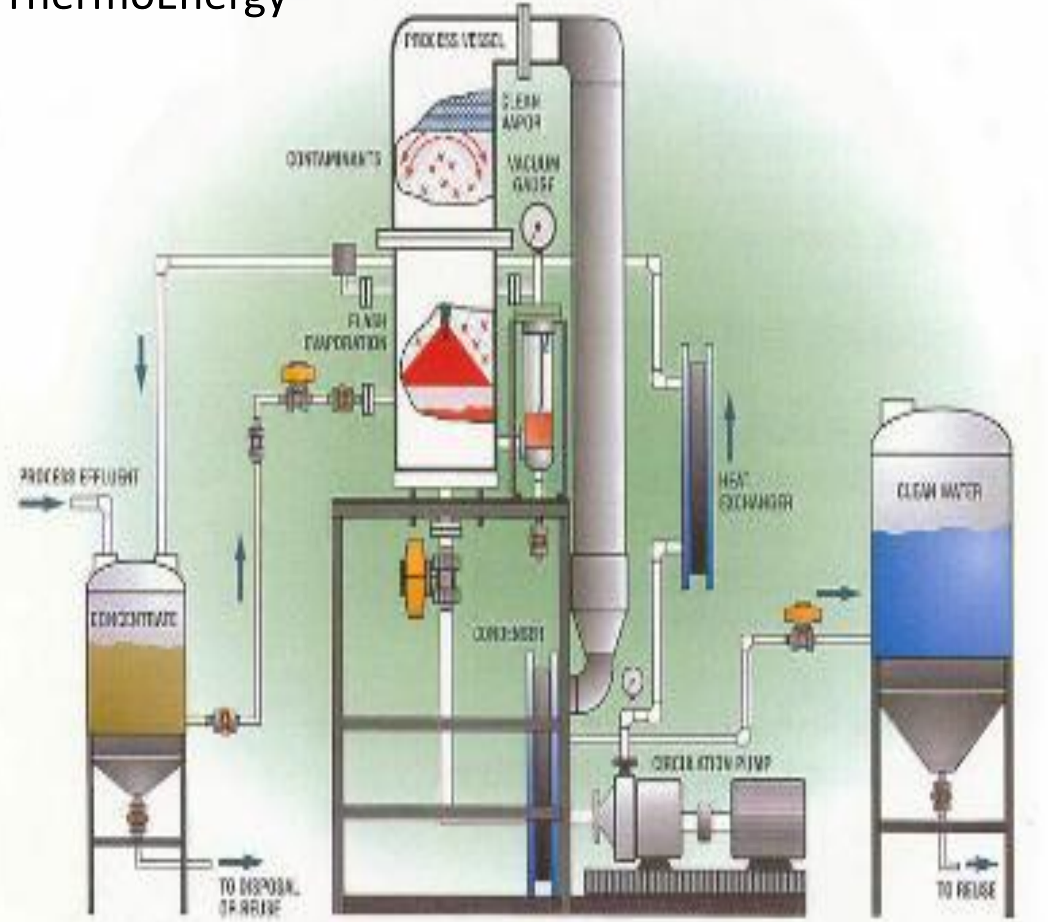
Nitrogen Recovery Alternatives

- Stripping
  - Air
  - Steam
- Adsorption
  - Sorption
  - Ion Exchange
- Precipita-tion
  - Struvite

Ammonia Recovery Process (ARP)

ThermoEnergy



- Ammonia in centrate removed by ion exchange adsorption
- Zinc sulfate & sulfuric acid used to regenerate media
- Regeneration solution vaporized to crystallize ammonium sulfate

Conclusion

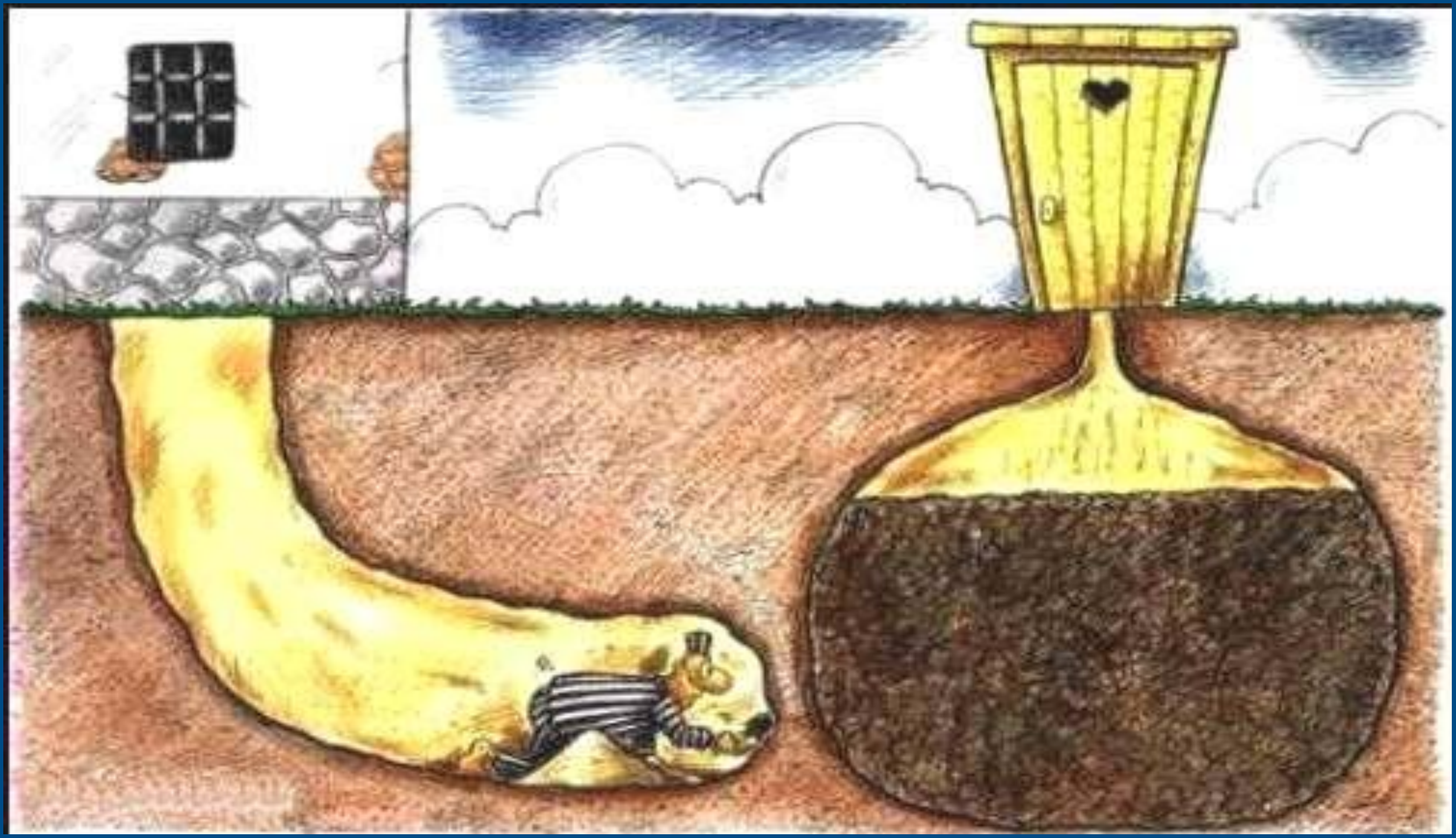
- Population explosion and rapid urbanization is forcing us to go from a comfortable position of abundant resources to a stressful position of scarcity.
- Biosolids management of the future will continue to remain true to its core principles of public health and environmental protection
- However, in order to remain sustainable, current practices must evolve to cope with the practical realities of the 21st century and beyond
- Rebranding to better define the role of WWTP of the future – Resource Recovery Facility with focus on recovery of nutrients, energy & water
  - ‘

A President Understood the Looming Phosphorus Crisis Over 70 years Ago

"I cannot overemphasize the importance of phosphorus not only to agriculture but also the physical health and economic security of the people of the nation."

Franklin D. Roosevelt, 1938

Questions



Planning <u>Always</u> Avoids Problems!