

# Biosolids Management in the WWTP of the Future

PRESENTED BY:

Samuel Jeyanayagam, PhD, PE, BCEE  
Vice President/Senior Principal Technologist  
CH2M HILL

PRESENTED TO:

OWEA Biosolids Conference  
November 8, 2011



# 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?



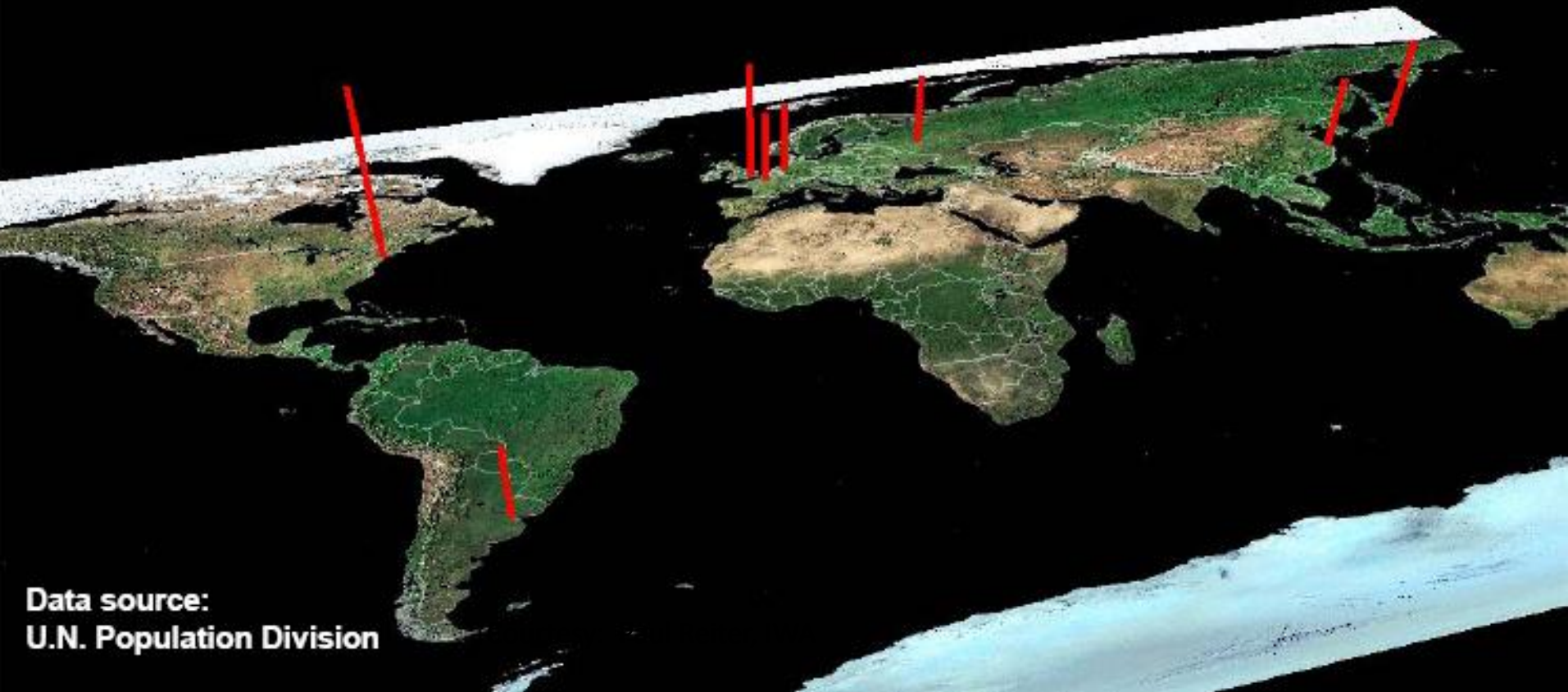
Linear System = Take + Treat + Use + Treat + Waste

Integrated Water and Resource Management



**1950**

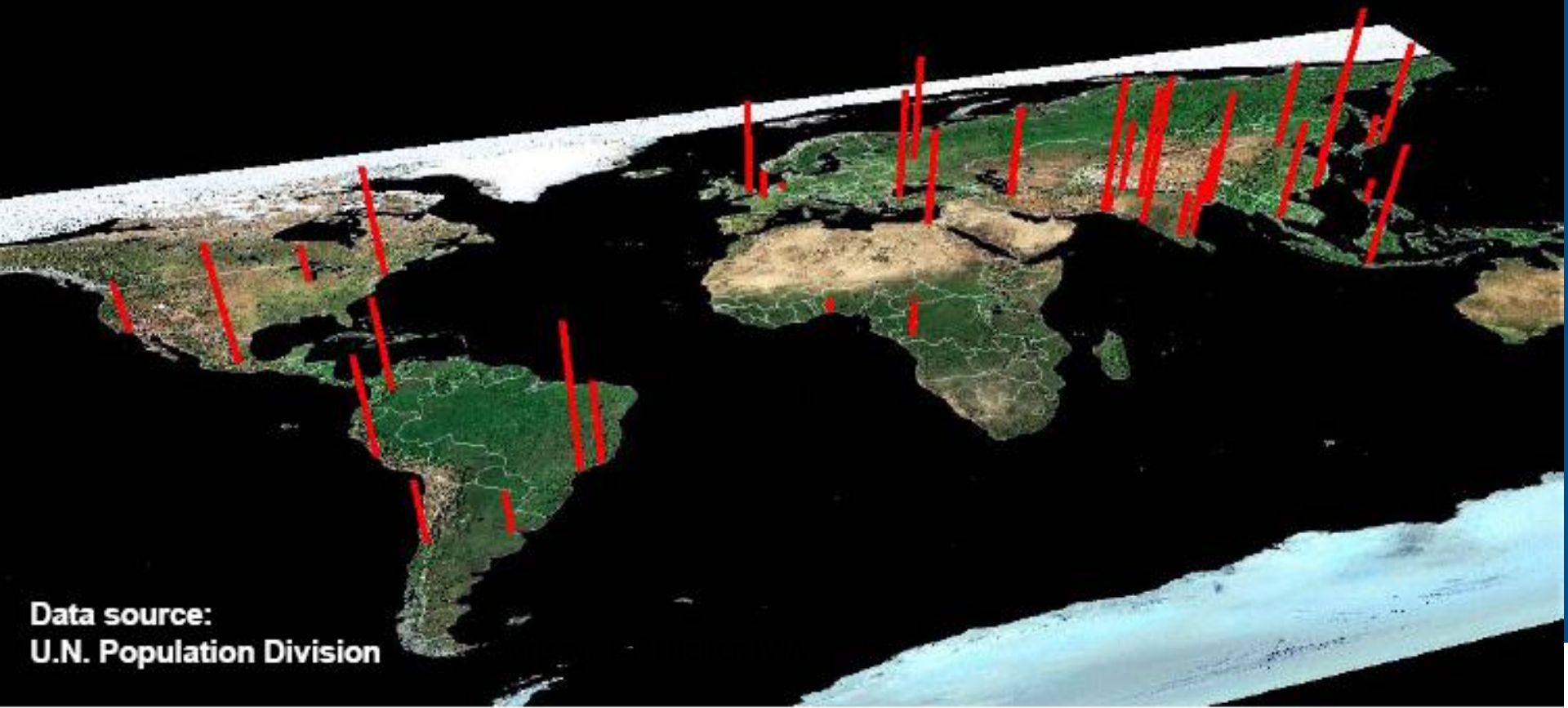
**World Cities exceeding  
5 million residents**



Data source:  
U.N. Population Division

**2000**

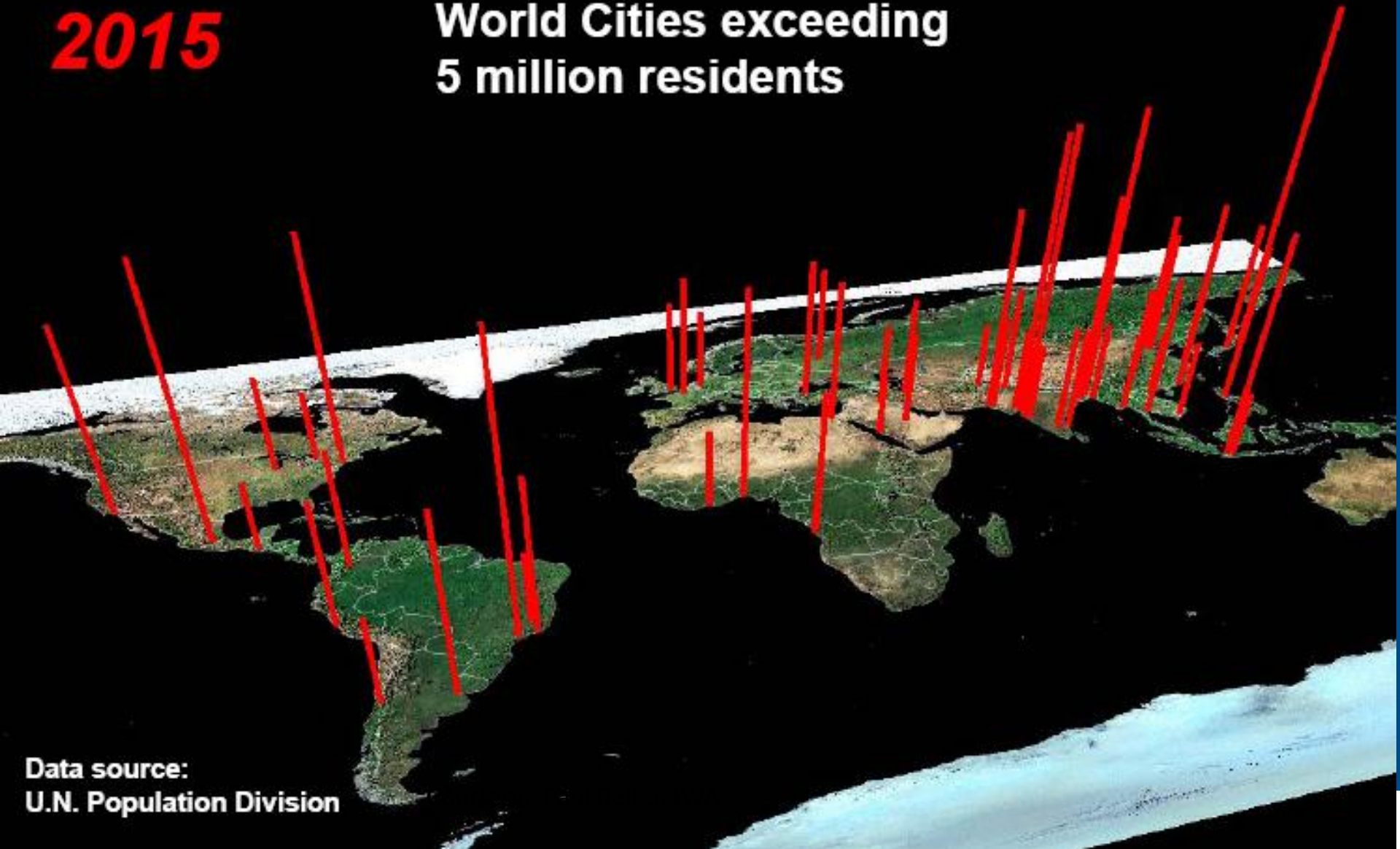
**World Cities exceeding  
5 million residents**



Data source:  
U.N. Population Division

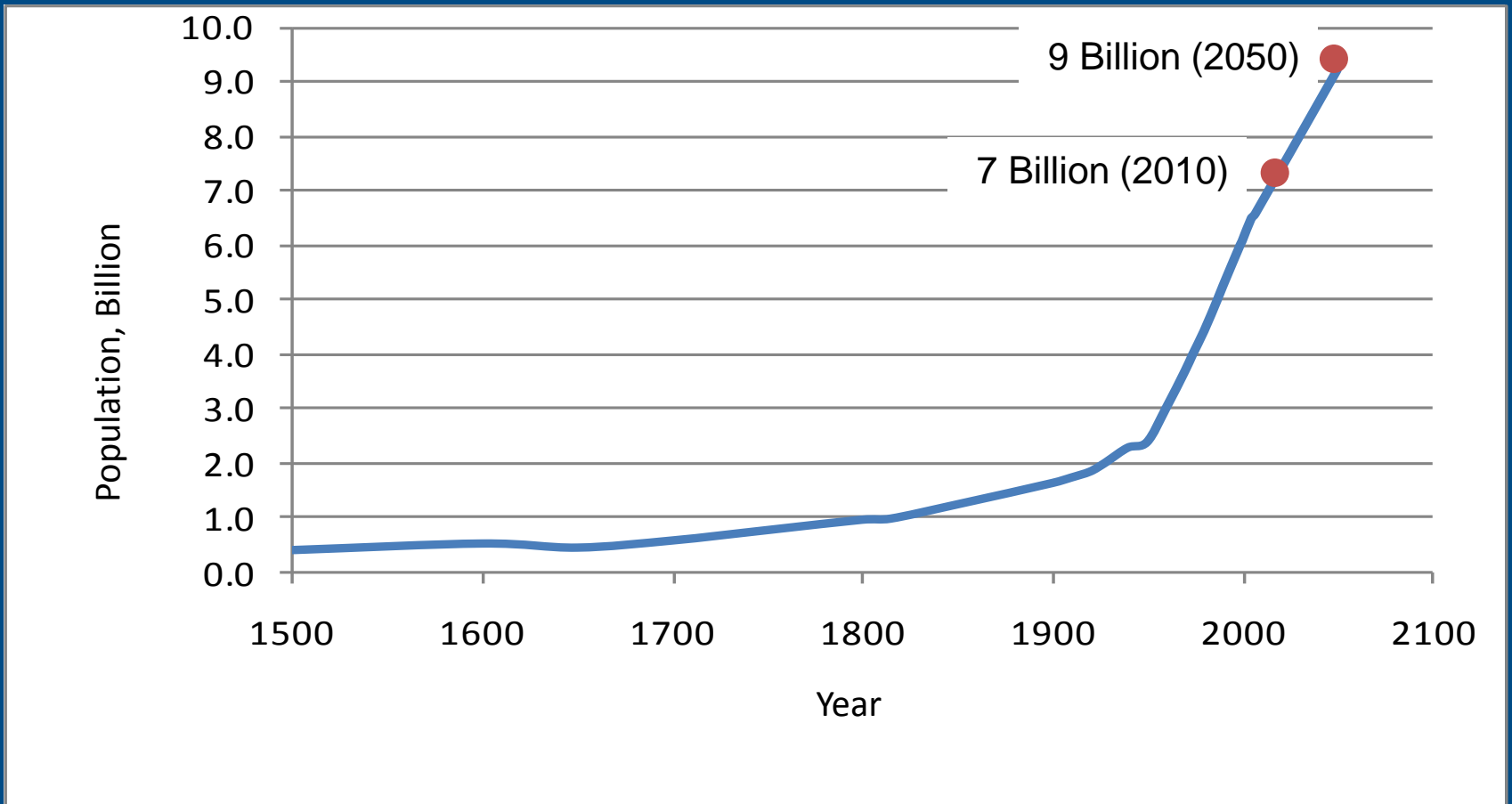
**2015**

**World Cities exceeding  
5 million residents**



Data source:  
U.N. Population Division

# Population Explosion



## 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?

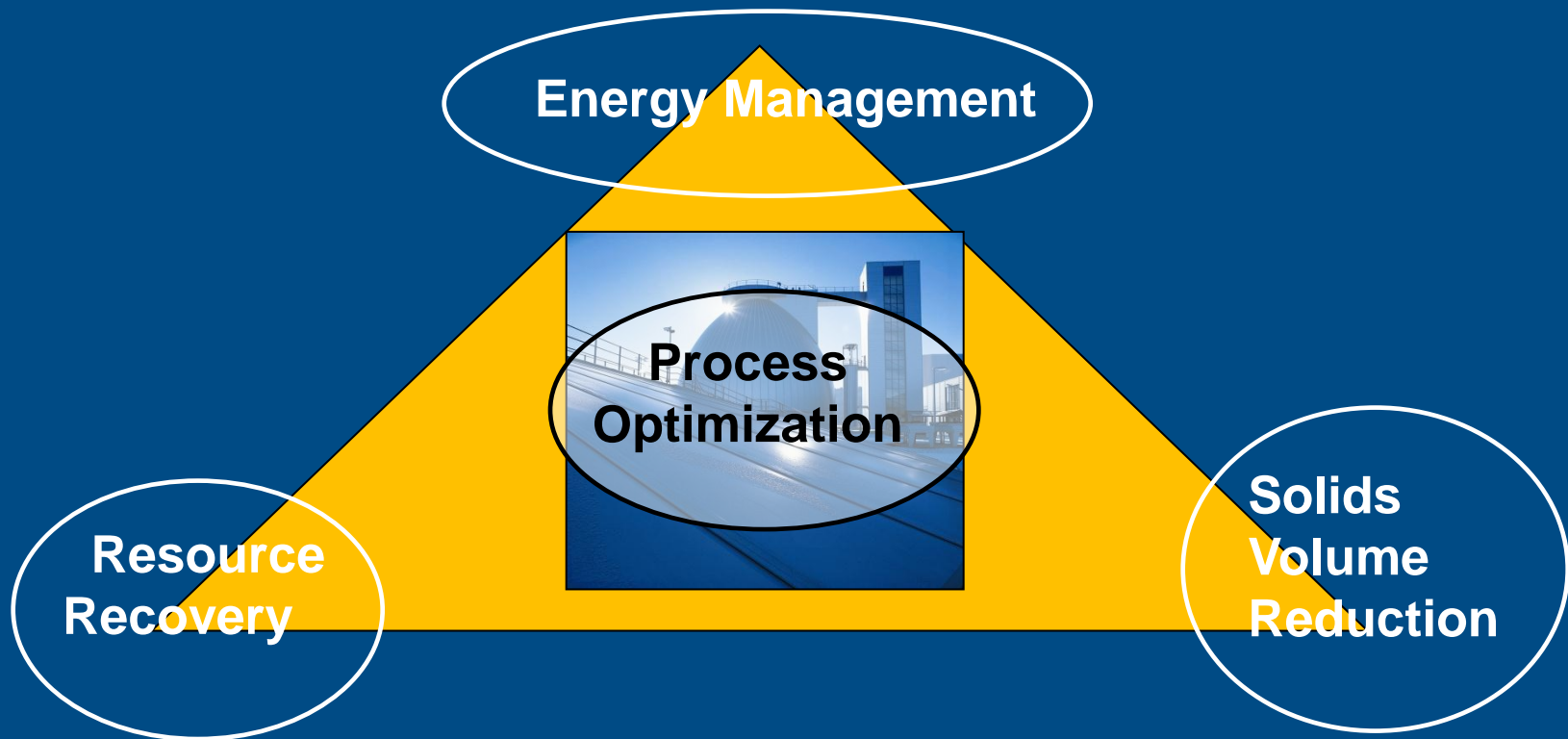
# Key Elements of WEF Position Statement

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

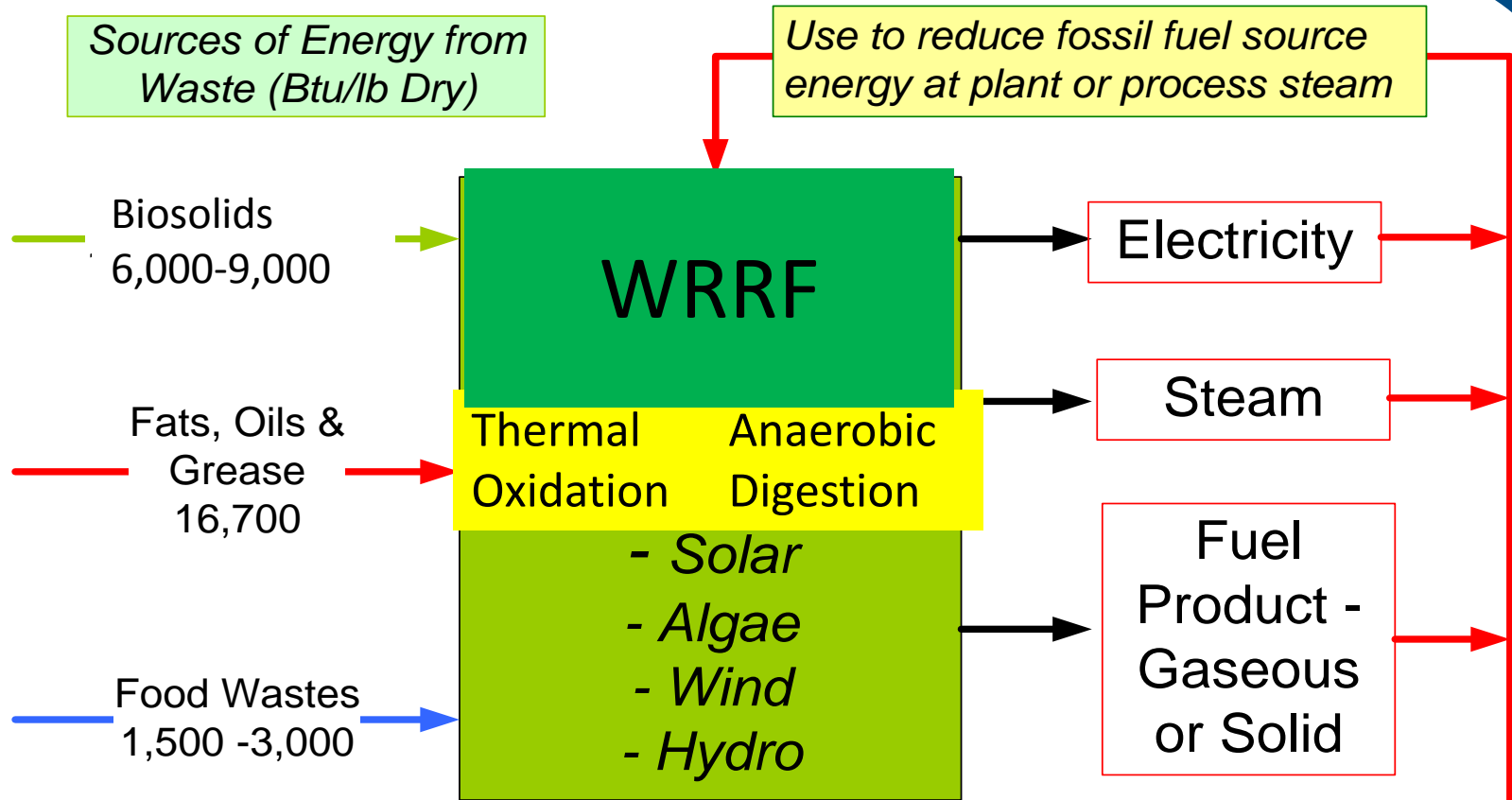
# WWTP of the Future in a Resource and Energy Constrained World

- 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



Compare to other fuels (Btu/lb Dry):

- Coal 7,000 to 11,000
- Wood 1,500 to 3,000
- Natural Gas 7,000-9,000

Use for residential or commercial power  
 Produce electrical energy off-site  
 Provide "green" fuel for other uses

# 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

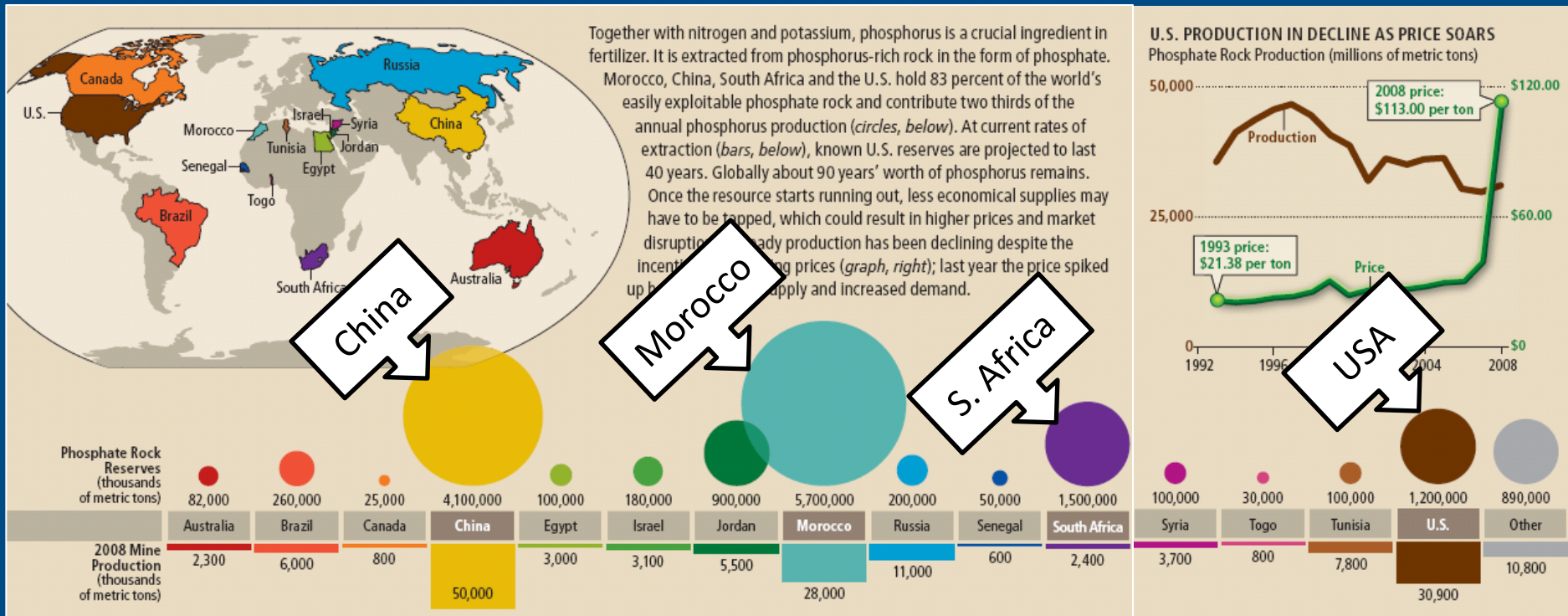
- Essential element of all life forms:
  - Genetic material, ATP, Bones
- A primary nutrient required for plant growth
- Detergents, crop protection, pharmaceuticals, flame retardant, etc.

**An average human body  
contains 650g of Phosphorus.**

# Phosphorus is a Precious Element

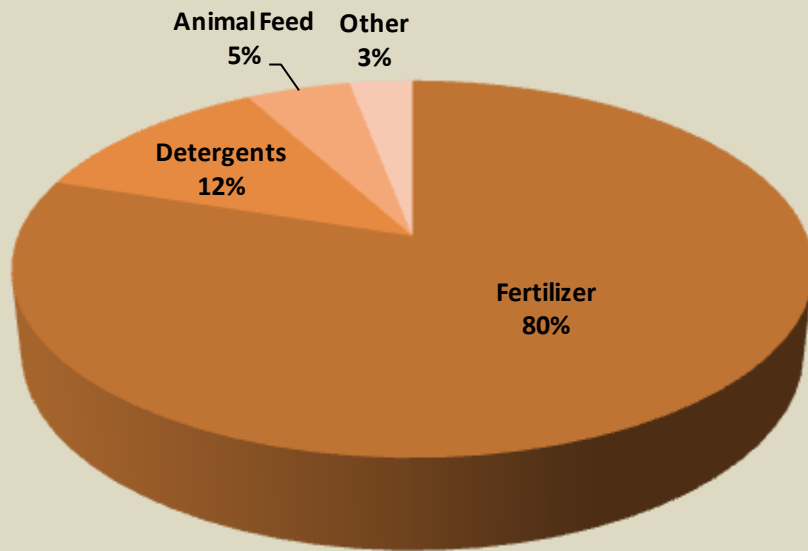
- **Essential** – no substitutes, natural or synthetic
- **Non-Renewable**

# 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

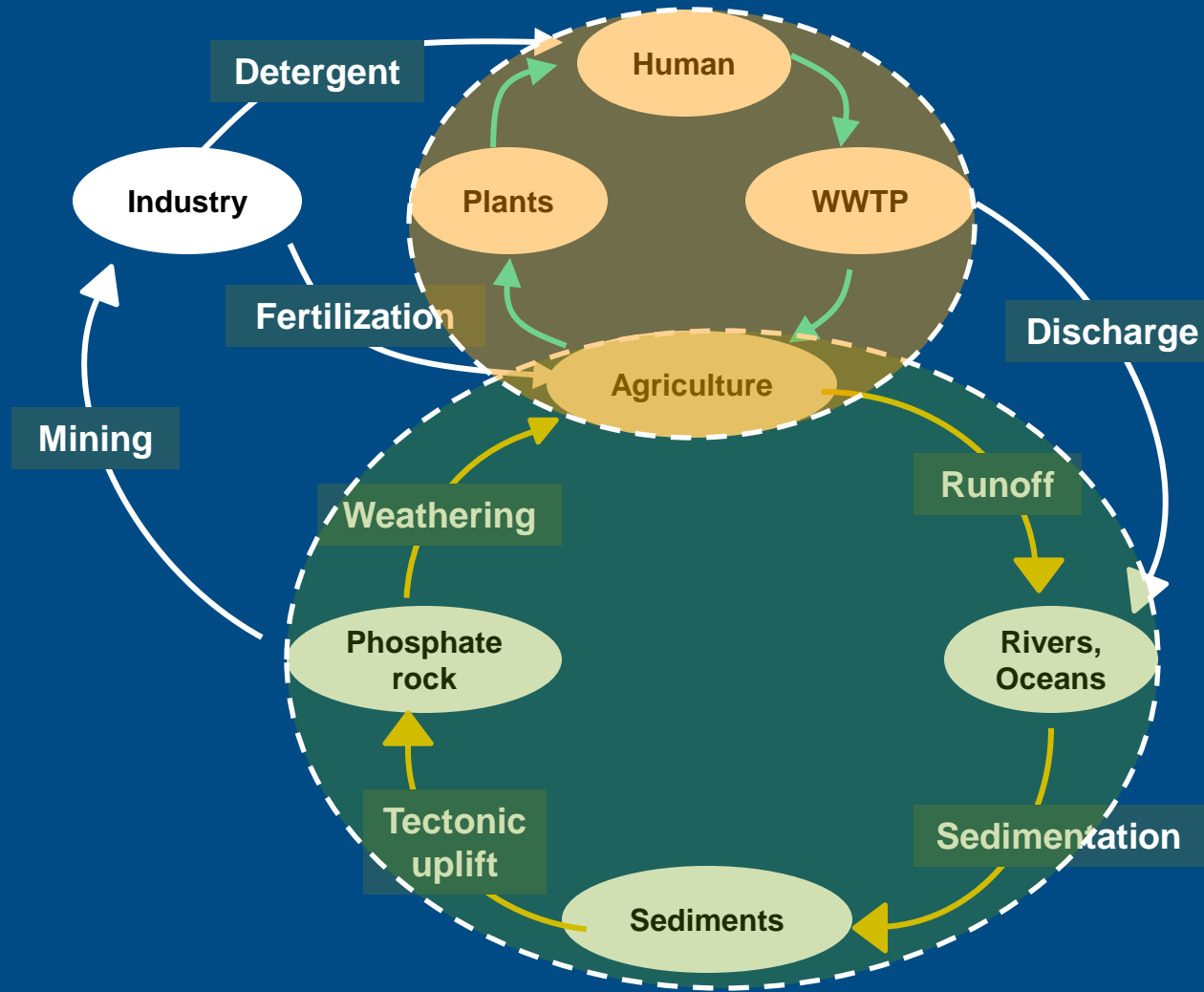
- Phosphorus resources are declining both in quality and accessibility

## 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)

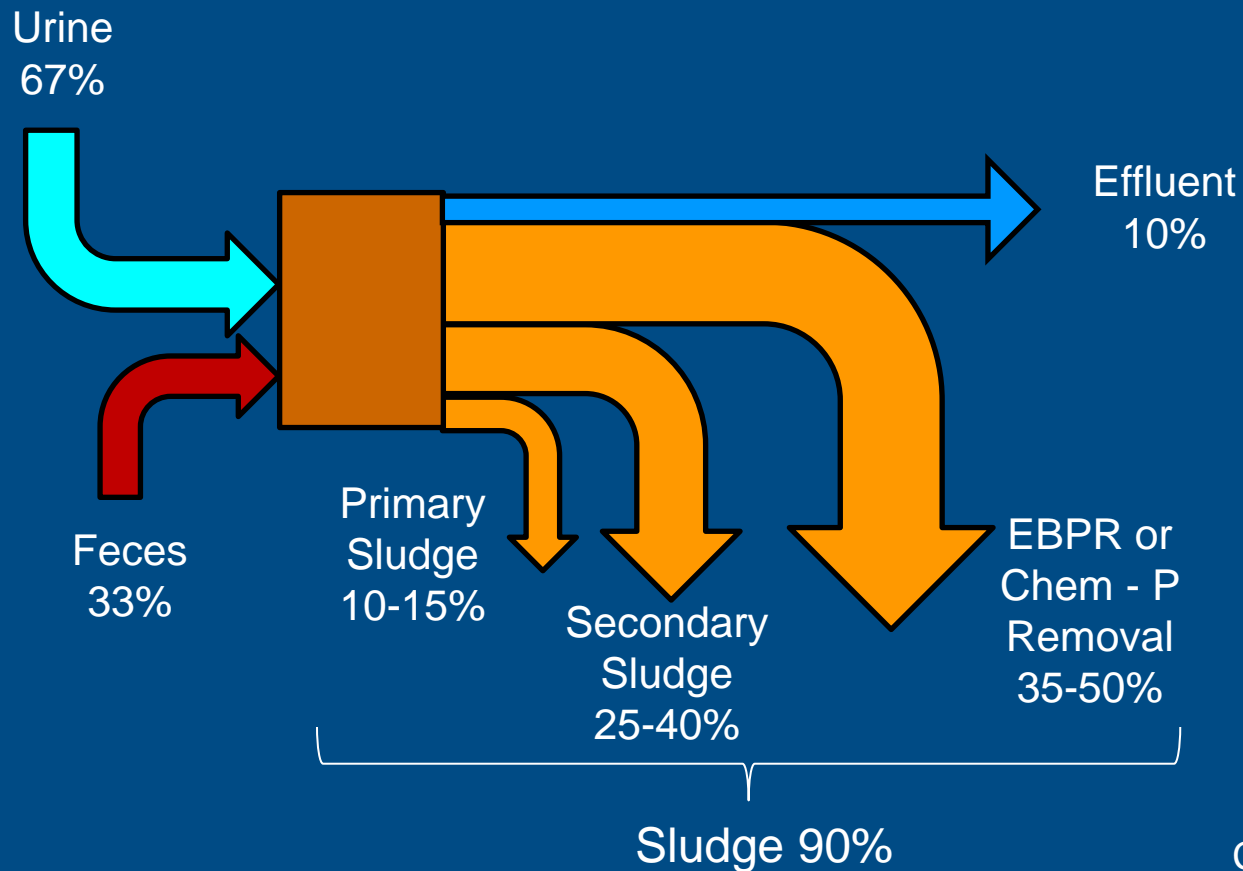
# Is There Really a Loss of Phosphorus?



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:

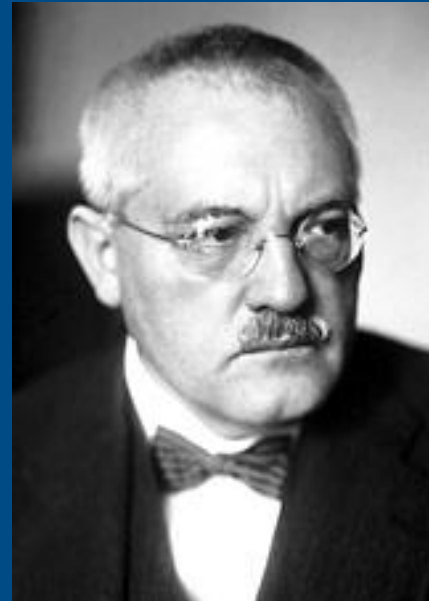
- Lightening
- N-Fixation

Inadequate to sustain life -  
need human intervention

# Global Nr Production



**Fritz Haber**  
**Nobel Prize - 1918**

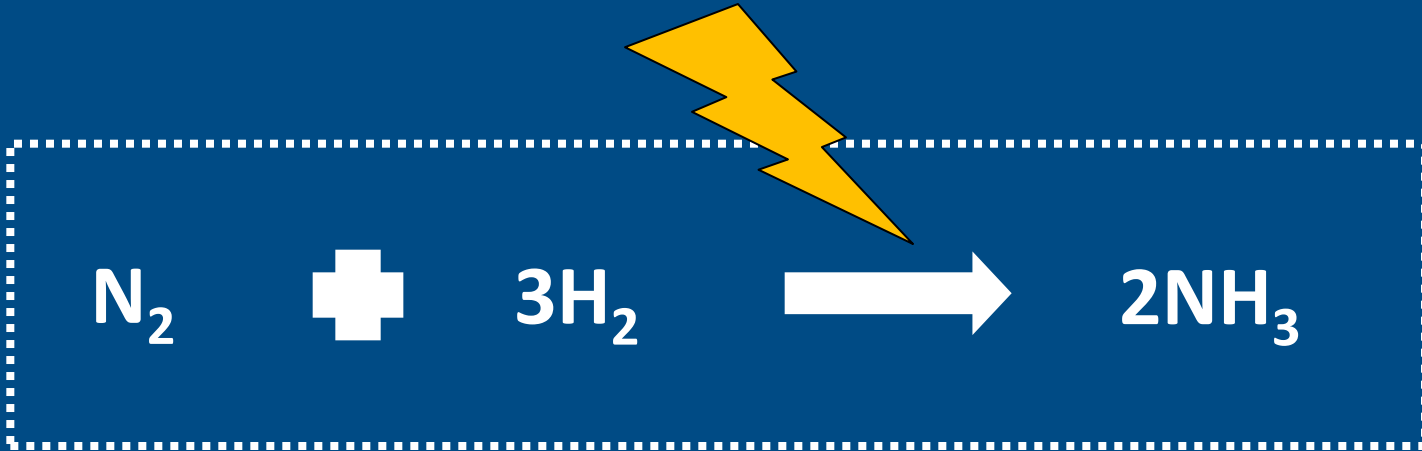


**Carl Bosch**  
**Nobel Prize (joint) - 1931**

# Global Nr Production

## Haber – Bosch Process

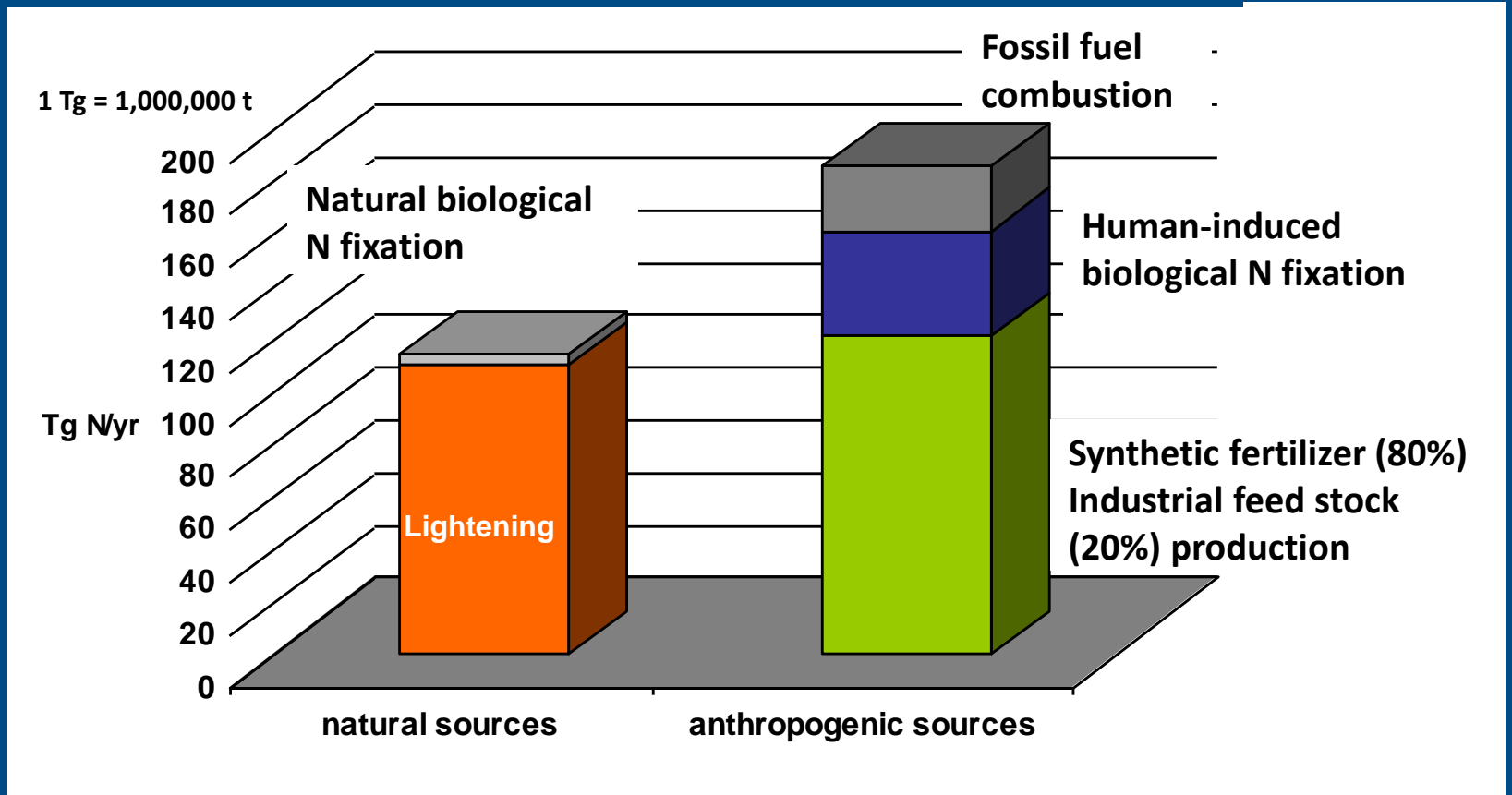
450°C, 250 atm



N source = air

H source = natural gas

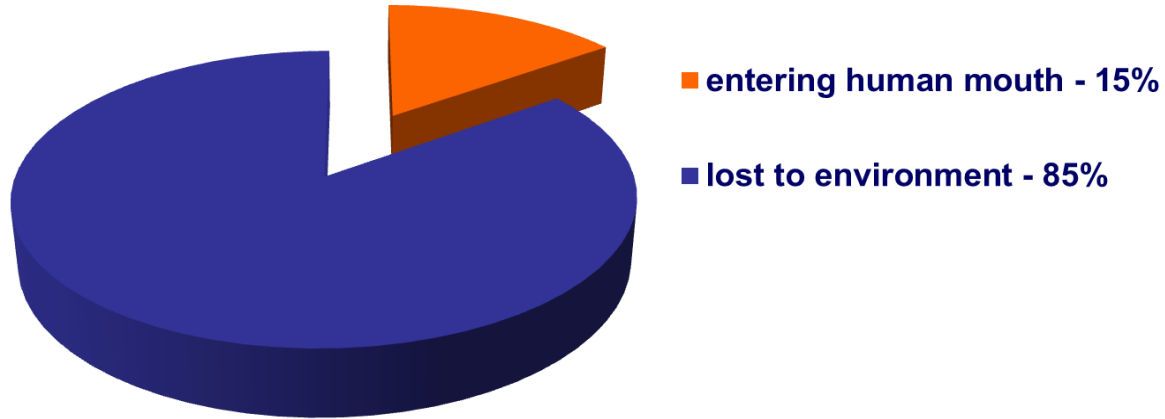
# Global Nr Production



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

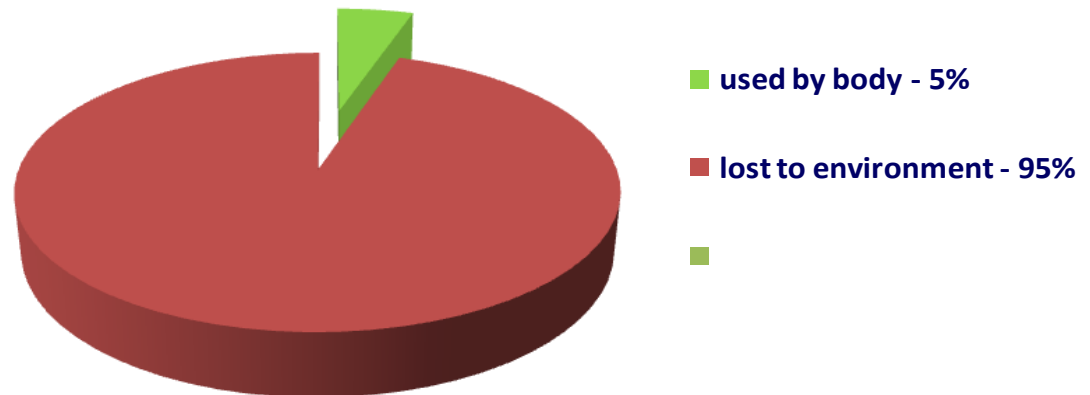
# The Fate of Reactive Nitrogen (Nr)

## "new" Nr used for food production



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

## "new" Nr entering human mouth



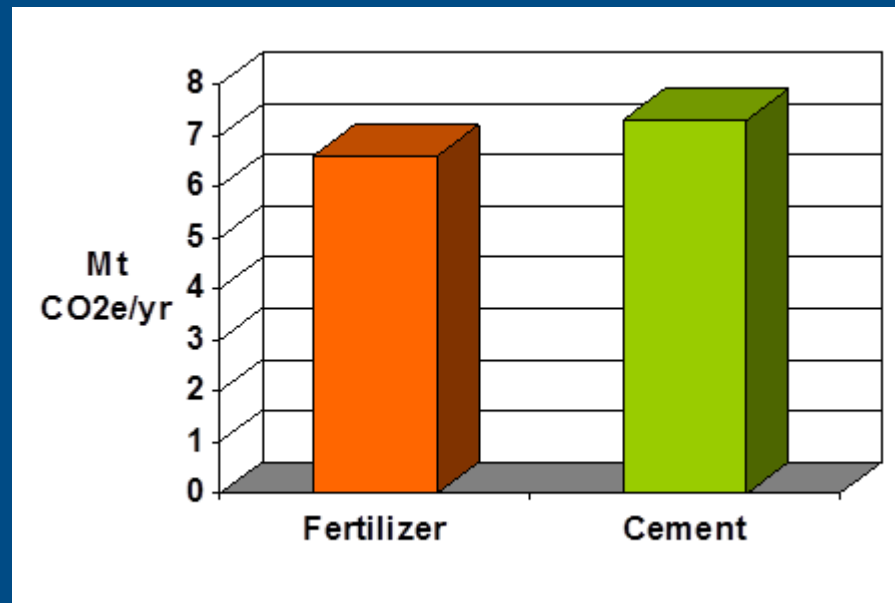
adapted from Galloway et al (2004)

# 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<sub>2</sub>e / kg ammonia N (Wood and Cowie, 2004)

Canadian GHG  
Emissions

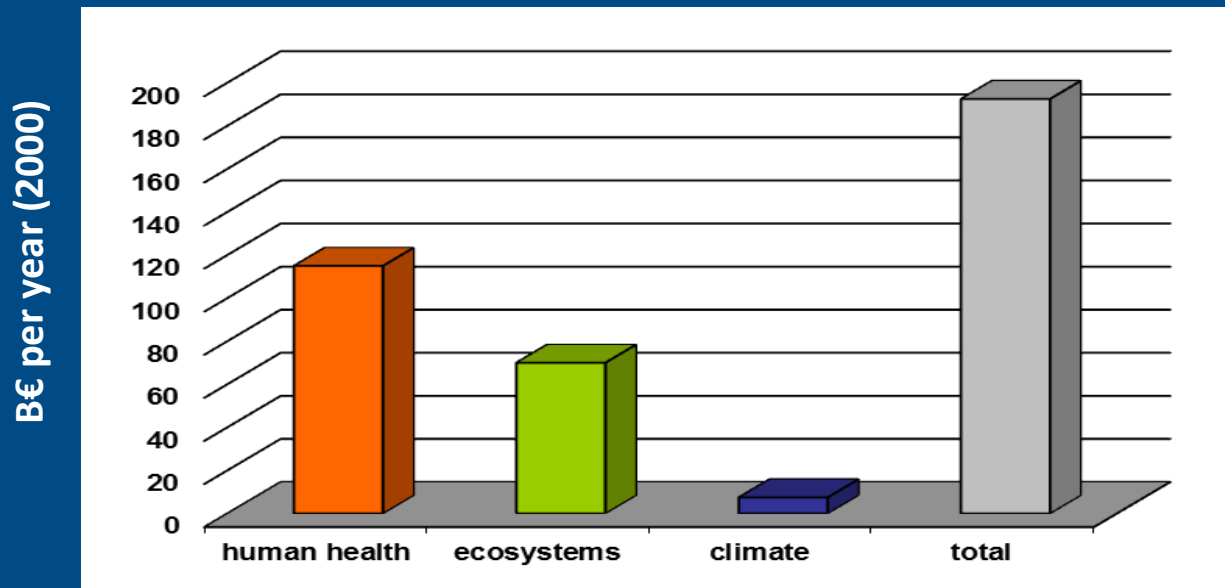


adapted from Environment Canada (2008)

# Continuing Business as Usual will..

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

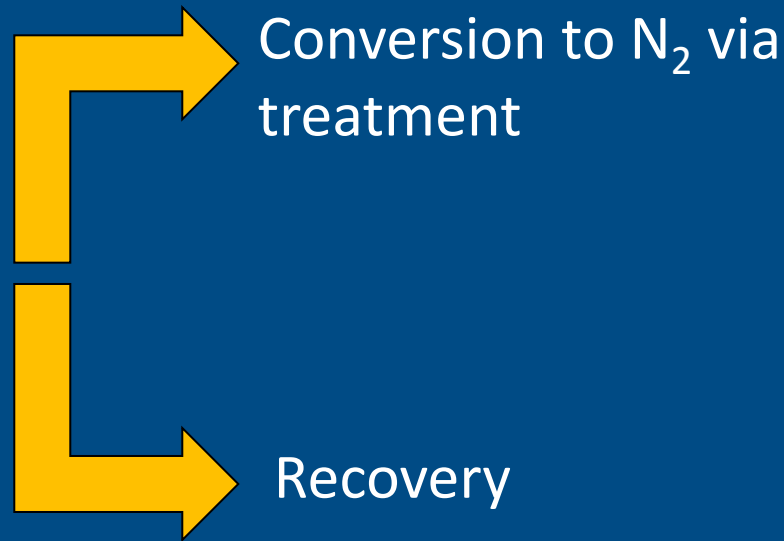
Estimated social damage costs of environmental Nr emissions to European Union countries (mid-range values)



Adapted from Sutton et al (2011)

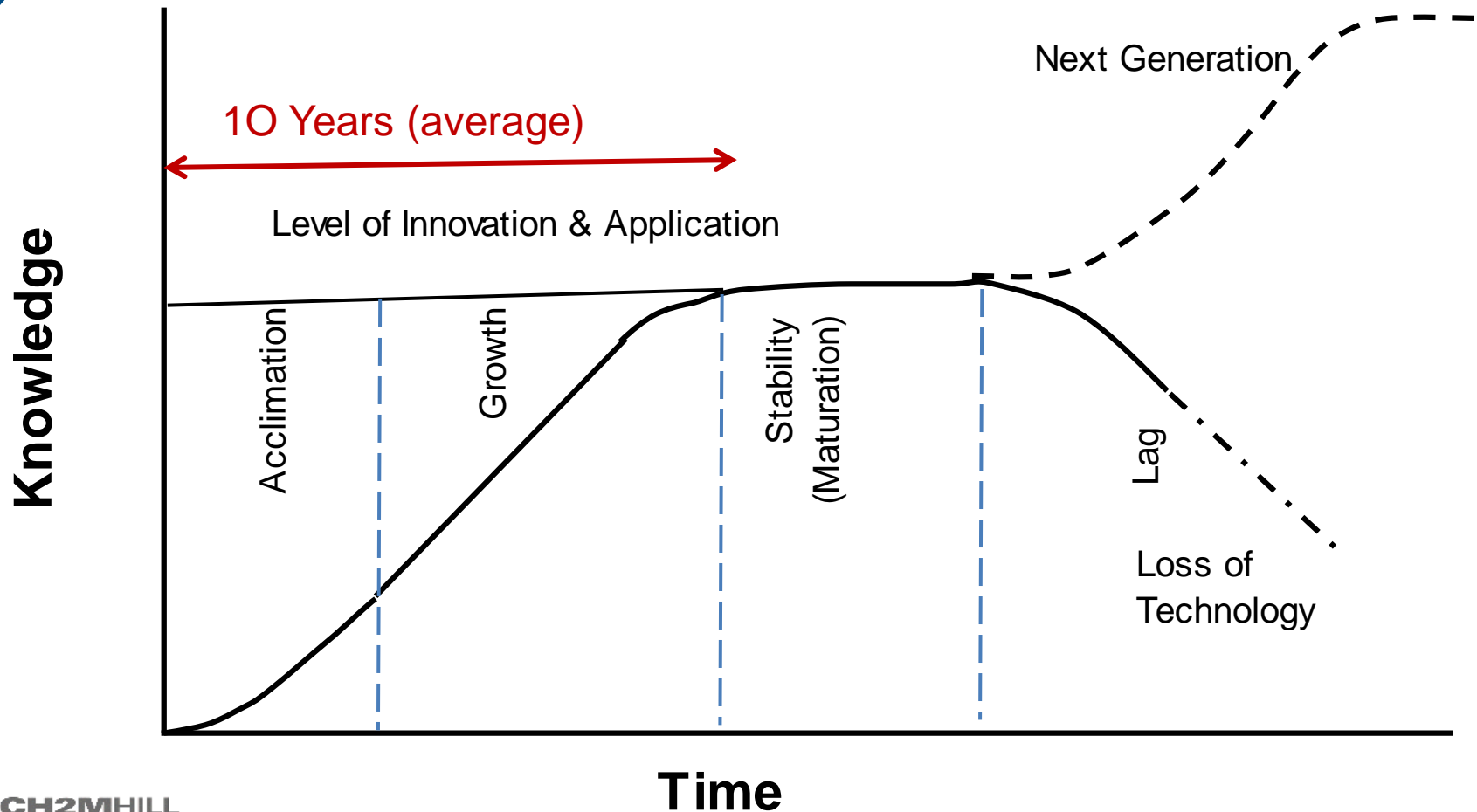
# Human Intervention Needed to Minimize the Impact on Global N Balance

Wastewater management is one of the intervention points



# Technology Life-Cycle Model

Technology development is a 100 to 10 to 1 game!



Technology	Life Phase			
	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 <sup>TM</sup>	✓			
Open Cel <sup>TM</sup>	✓			
Lyso <sup>TM</sup>	✓			
Ultrasonics	✓			
Ostara <sup>TM</sup>	✓			
Co-generation			✓	
Fuel Cell	✓			
Solar Photovoltaics		✓		
Gasification	✓			
Biosolids Composting			✓	

# Phosphorus Recovery Alternatives

Precipitation

Crystallization

Struvite

Apatite

Solids Separation

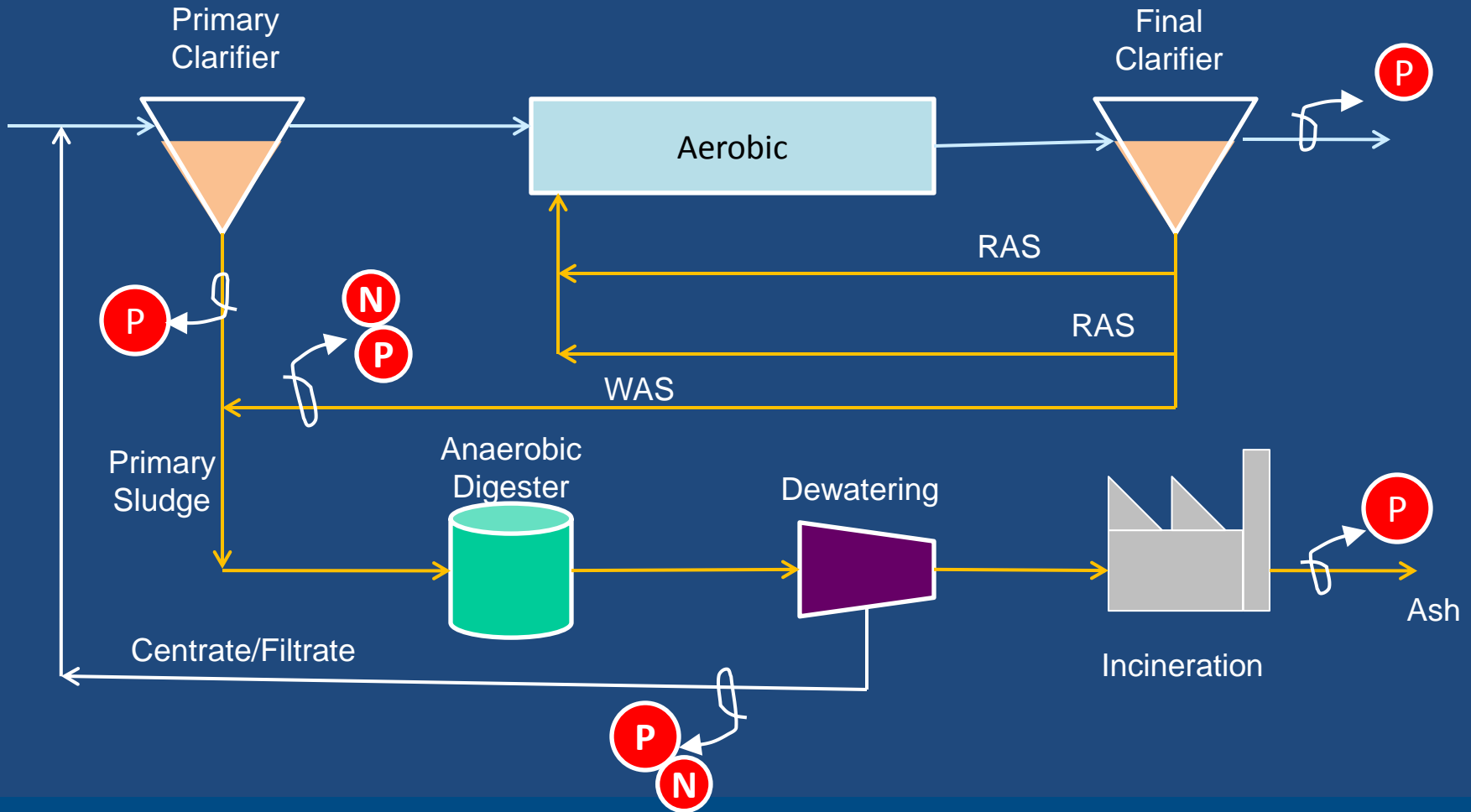
Adsorption

Sorption

Ion Exchange

Chemical desorption  
Magnetic separation

# Potential Locations for P Recovery

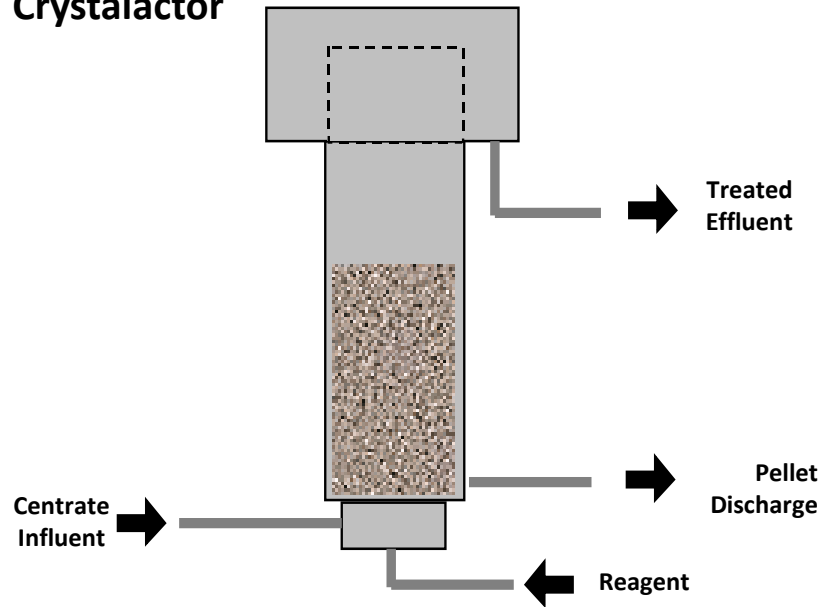


# Proven P Recovery Technologies

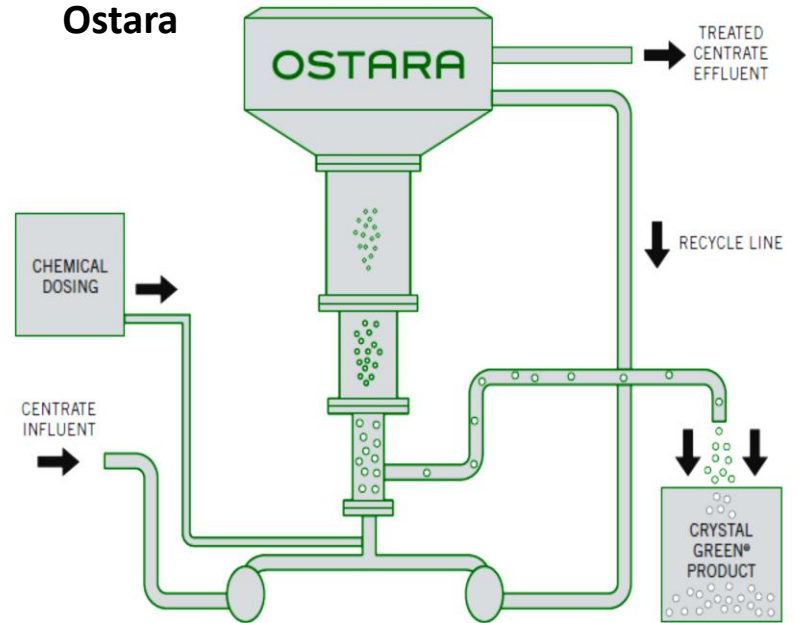
Technology	Feed Stream	Product	External Inputs
Crystalactor	RAS	CaPO <sub>4</sub>	Lime, sand
PhoStrip	RAS	CaPO <sub>4</sub>	Lime
Ostara	Centrate, filtrate	Struvite	MgCl, NaOH
Ostara	WAS	Struvite	MgCl, NaOH
Multiform Harvest	Centrate, filtrate	Struvite	MgCl, NaOH
Procorp	Centrate, Filtrate	Struvite	MgCl, NaOH

# Fluidized Bed Reactor

Crystalactor



Ostara



# 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

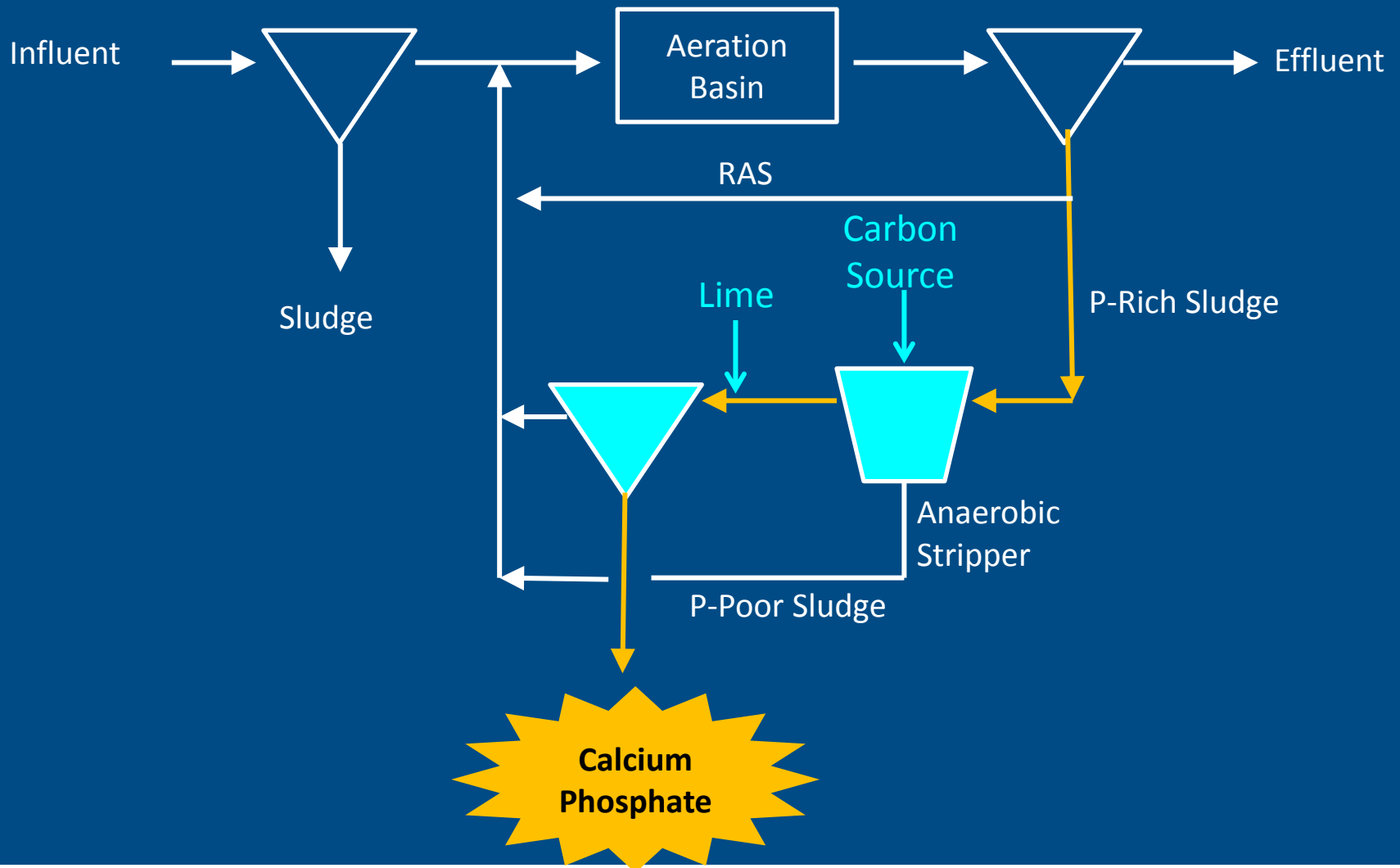
## Multiform Harvest

- Under Construction
  - Boise, ID

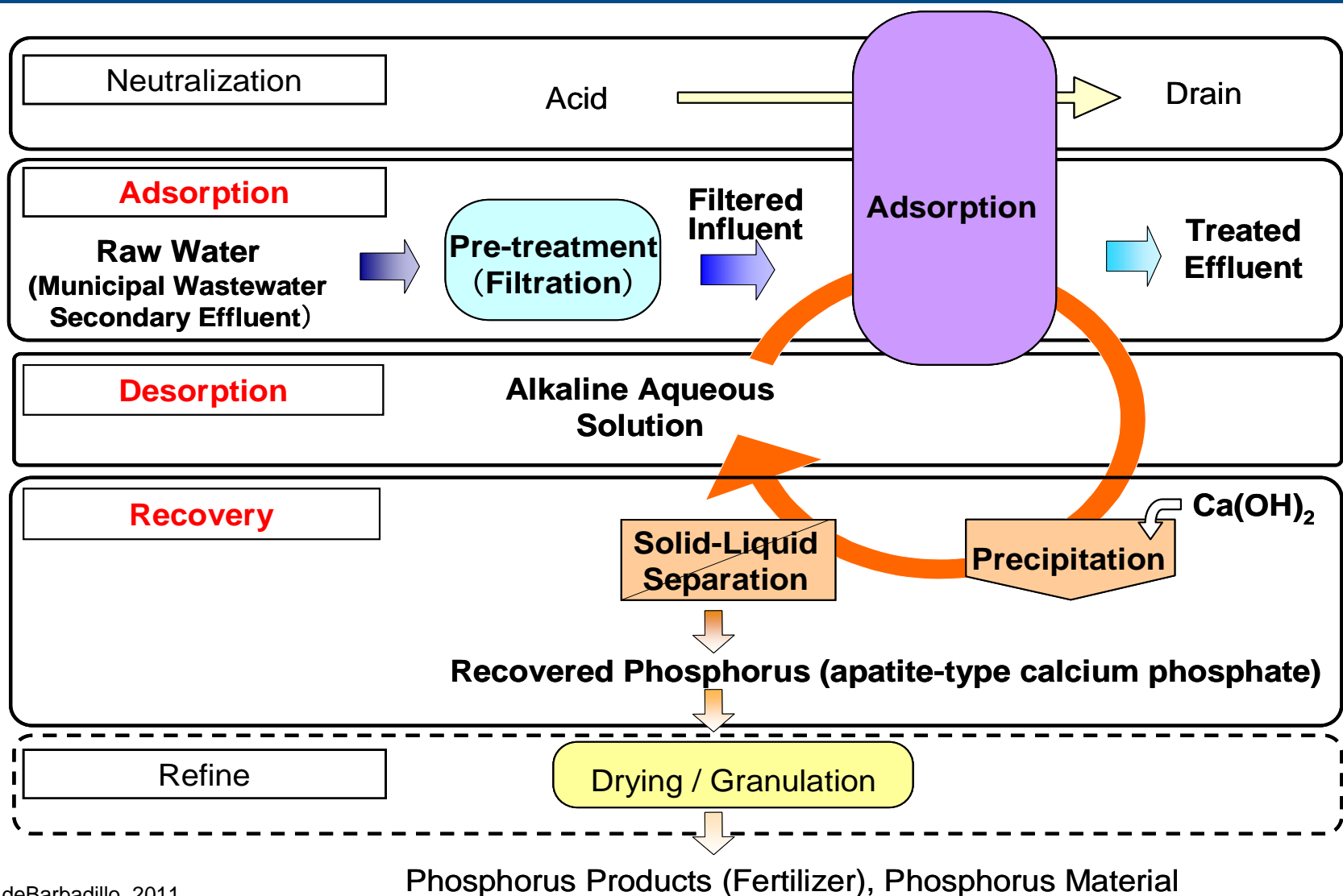
## Procorp

- Under design - 1

# PhoStrip



# Adsorption Technology



deBarbadillo, 2011

Phosphorus Products (Fertilizer), Phosphorus Material

# Other P Recovery Technologies

Technology	Origin	Feed Stream	Product	External Inputs
KREPO	Sweden	Primary sludge	Ferric Phosphate	Heat, pressure, H <sub>2</sub> SO <sub>4</sub> , NaOH
Seaborne	Germany	Digested sludge	Struvite	Heat, H <sub>2</sub> SO <sub>4</sub> , NaOH, Mg(OH) <sub>2</sub>
Kemicond	Sweden	Primary sludge	Ferric Phosphate	H <sub>2</sub> SO <sub>4</sub> , H <sub>2</sub> O <sub>2</sub> , polymer
BioCon	Denmark	Incinerator ash	H <sub>3</sub> PO <sub>4</sub>	H <sub>2</sub> SO <sub>4</sub> , ion-exchange
SEPHOS	Germany	Incinerator ash	AlPO <sub>4</sub> , Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub>	H <sub>2</sub> SO <sub>4</sub> , NaOH, Ca <sup>2+</sup>
Adsorption	Japan	Effluent	Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub>	Acid , NaOH, Ca <sup>2+</sup>

# Nitrogen Recovery Alternatives

Stripping

Adsorption

Precipitation

Air

Steam

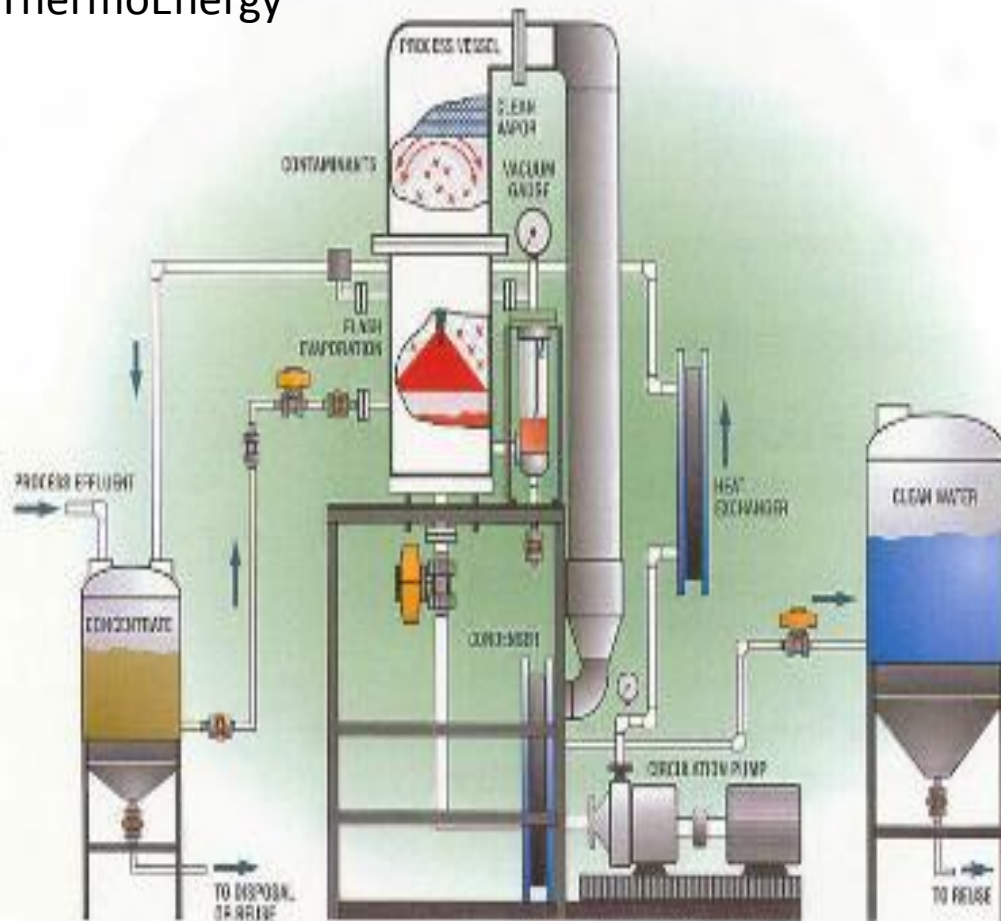
Sorption

Ion  
Exchange

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 21<sup>st</sup> 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

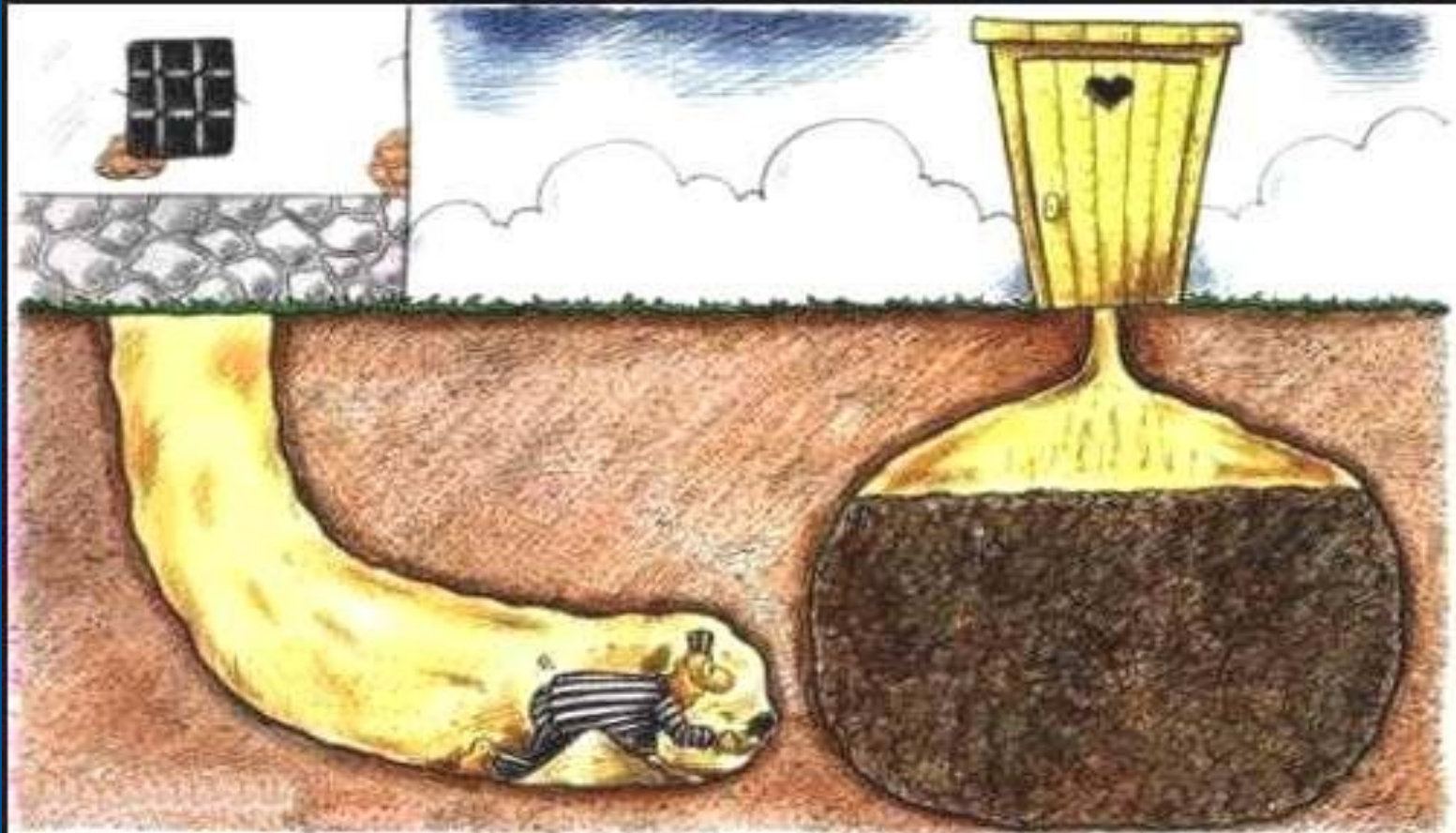
- ‘

# 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 Always Avoids Problems!*