# Recovering Resources, Transforming Water

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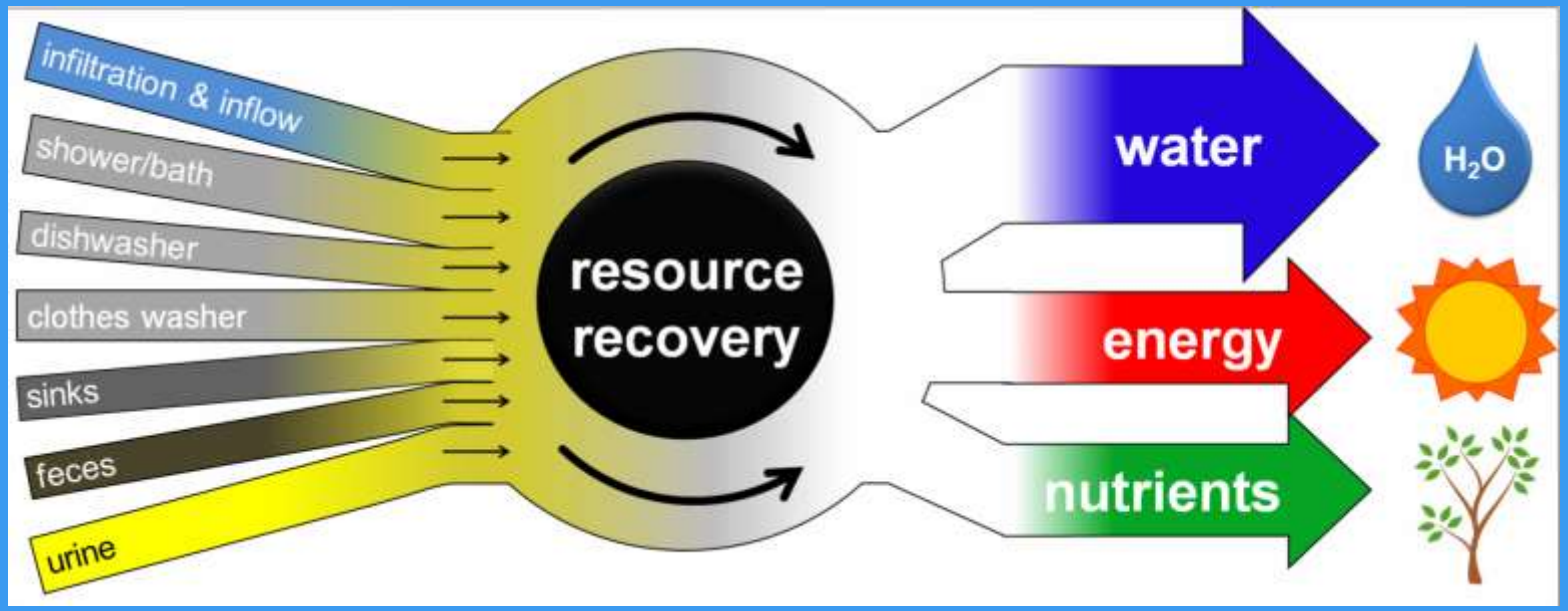
**Metropolitan Water Reclamation District of Greater Chicago**

# Resource Recovery Legislation

- Resource Recovery Bill signed into law in July 2014
- Grants the Metropolitan Water Reclamation District of Greater Chicago the authority to capture recovered resources and produce renewable energy resources.
- "The District has the opportunity and the ability to change the approach to wastewater treatment from that of a waste material to be disposed of to one of a collection of resources to be recovered, reused, and sold, with the opportunity to provide the District with additional sources of revenue and reduce operating costs."

# Wastewater as a renewable resource

A paradigm shift is underway!



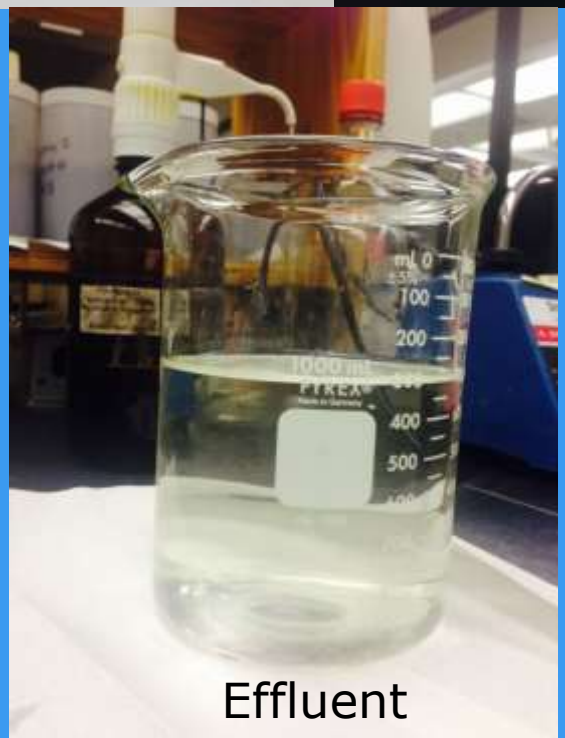
# MWRD's Resource Recovery Efforts

# WATER

DW Aurora

Raw Fox River

During Summer



Effluent

# Comparison of Drinking Water Regulatory Limits and Raw Intake for Aurora (Fox River) and Egan WRP Effluent

| Analyte | Units | Drinking Water Regul. Limits | Fox River Raw | Egan WRP Effluent |
|---|---|---|---|---|
| Alkalinity | mg/L | | 266 | 254 |
| Aluminum | mg/L | 0.05-0.2 | 0.25 | |
| Arsenic | mg/L | 0.01 | 0 | <0.05 |
| Barium | mg/L | 2.0 | 0.10 | 0.016 |
| Beryllium | mg/L | 0.004 | 0 | <0.001 |
| Boron | mg/L | 0.6/1.0 | 0.22 | |
| Cadmium | mg/L | 0.005 | 0 | <0.001 |
| Chloride | mg/L | 250 | 116 | 171 |
| Chromium | mg/L | 0.10 | 0 | <0.005 |
| Copper | mg/L | 1.3 | 0.003 | <0.005 |
| Cyanide | mg/L | 0.2 | 0 | <0.006 |
| Fluoride | mg/L | 0.9-1.2 | 0 | 0.9 |
| Iron | mg/L | 0.3 | 30 | <0.1 |
| Lead | mg/L | 0.015 | 0 | <0.02 |
| Manganese | mg/L | 0.05 | 0.07 | 0.01 |
| Nickel | mg/L | 0.10 | 0.002 | <0.009 |

# Comparison of Drinking Water Regulatory Limits and Raw Intake for Aurora (Fox River) and Egan WRP Effluent

| Analyte | Units | Drinking Water Regul. Limits | Fox River Raw | Egan WRP Effluent |
|---|---|---|---|---|
| Nitrate | mg/L | 10 | 1.83 | 17.65 |
| Selenium | mg/L | 0.05 | 0 | <0.009 |
| Silver | mg/L | 0.10 | 0 | <0.001 |
| TDS | mg/L | 500 | 615 | |
| Sulfate | mg/L | 250 | 52 | 73 |
| Thallium | mg/L | 0.002 | 0 | |
| Turbidity | NTU | 0.3 | 9.78 | |
| Zinc | mg/L | 5 | 0.01 | <0.03 |
| TP | mg/L | | 0.05 to 0.44 | 3.2 |
| DO | mg/L | | 6.36 to 11.35 | 8 |
| TKN | mg/L | | 0.7 to 2.3 | 2 |
| BOD5 | mg/L | | < 2 to 7 | <3 |
| FC | #/100 mL | | 2 to >5000 | <29 |
| TSS | mg/L | | 2 to 64 | <3 |

# All Water is Used Water

"You Probably Never had a glass that did not go through 7 Native Americans, 12 settlers and 50 buffaloes before you got it"

John R. Sheaffer

# MWRD's Water Reuse Initiative

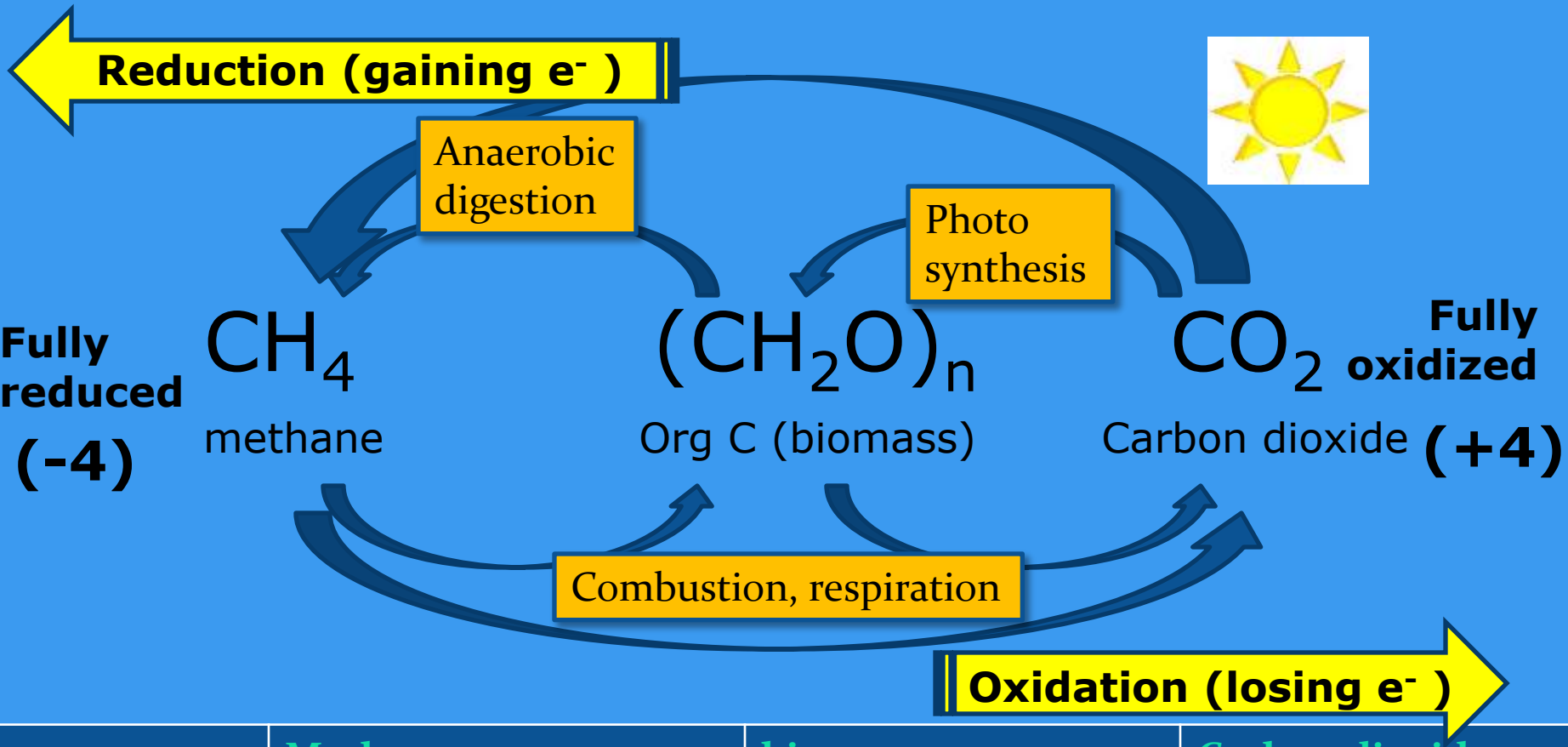
- MWRD's Calumet WRP Reclaims ~ 250 MGD
- MWRD Signed a Public/Private Partnership with Illinois American Water
- Illinois American Water to further polish effluent from Calumet WRP for ***Non-Drinking Water Needs*** of Large Industrial Customers
  - Fabricating
  - Processing
  - Washing
  - Diluting
  - Cooling
  - Transporting

# MWRD's Resource Recovery Efforts

# ENERGY

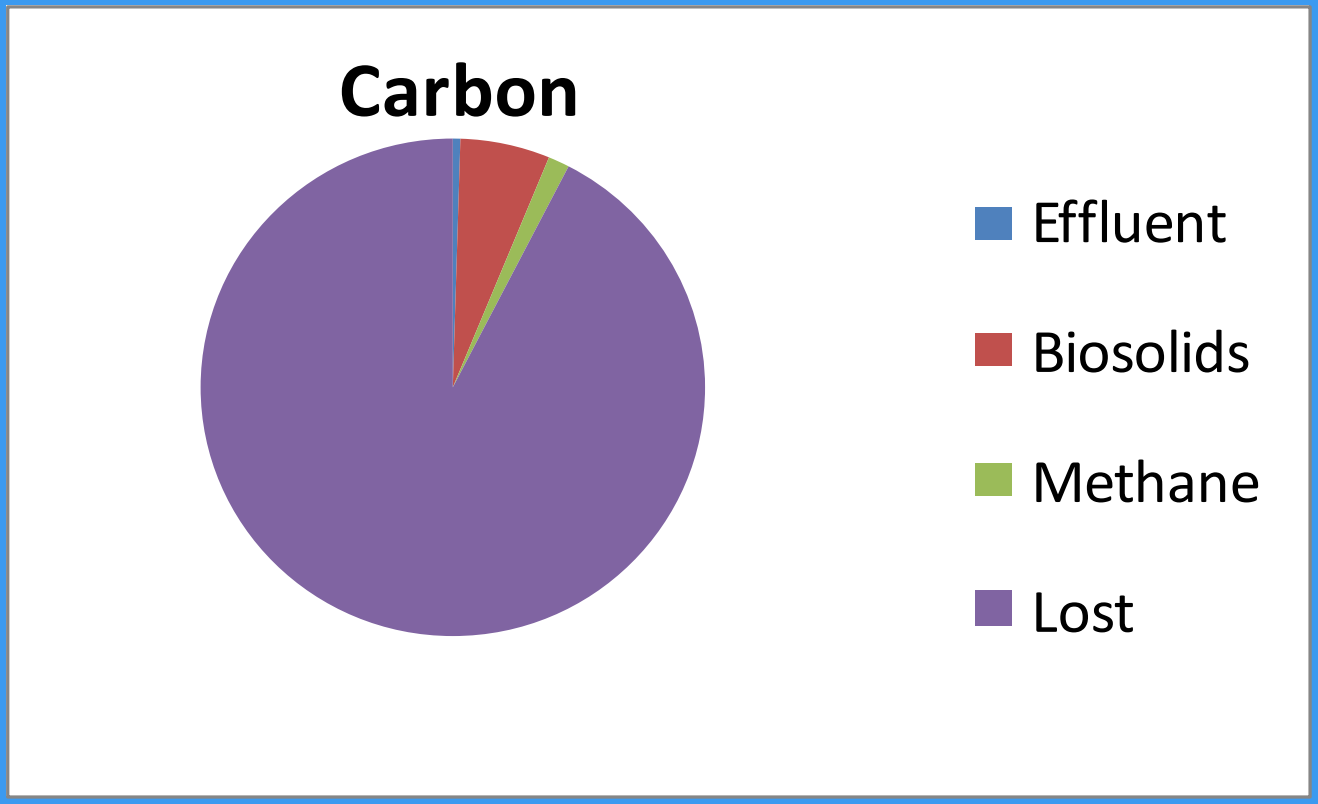
# Energy states of carbon

## all about **biorecycling**



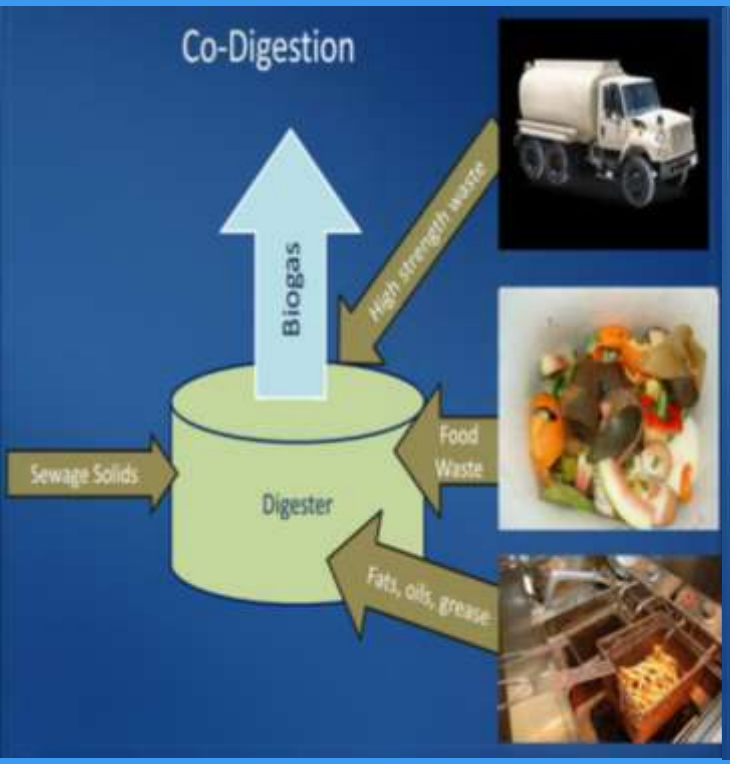

| | Methane | biomass | Carbon dioxide |
|---|---|---|---|
| **Energy** | rich | moderate | none |
| **Redox state** | -4 | In between | +4 |
| **COD (energy)** | 4 g OD/g (180.4 Wh /g) | Typically 1-3 g OD/g | zero |

# Mass Balance for 7 WRPs



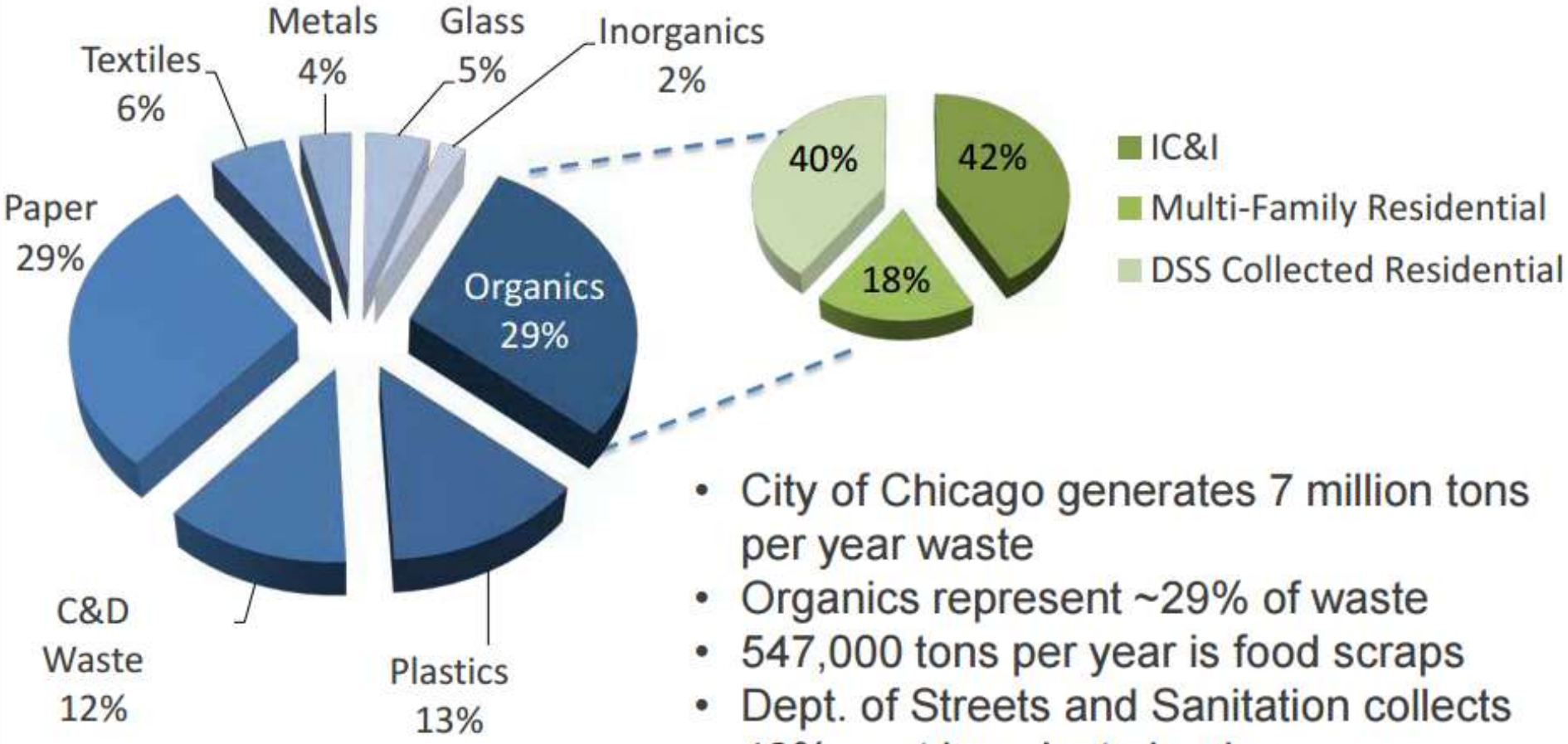

Influent 545,084 t/yr

# Anaerobic Digestion
# Feedstock Market Analysis & Challenges




| Organic Feedstock | Availability |
|---|---|
| FOG, Yellow Grease | Readily available in Chicago. But competitive uses. |
| Good quality industrial food waste | Available, often sold for animal feed |
| Source separated food wastes | Variable availability, cannot guarantee long-term supply, cannot control quality |
| Wet Commercial Waste/ Municipal Solid Waste | Available in large quantities, but organic material co-mingled with other debris |

# Chicago Waste Diversion and Waste Characterization Study (2007)*




- City of Chicago generates 7 million tons per year waste
- Organics represent ~29% of waste
- 547,000 tons per year is food scraps
- Dept. of Streets and Sanitation collects 40%, rest by private haulers

*City of Chicago Department of the Environment

# Calumet WRP Organic Waste Receiving Plan

| Feedstock Type | Quantity (ton/day) (approximate) | Biogas Generation (sfc/day) |
|---|---|---|
| Organic Fraction WCW | 285 | 1,617,093 |
| Liquid Waste | 120 | 107,930 |
| FOG | 35 | 126,976 |
| Total | 440 | 1,852,000 |

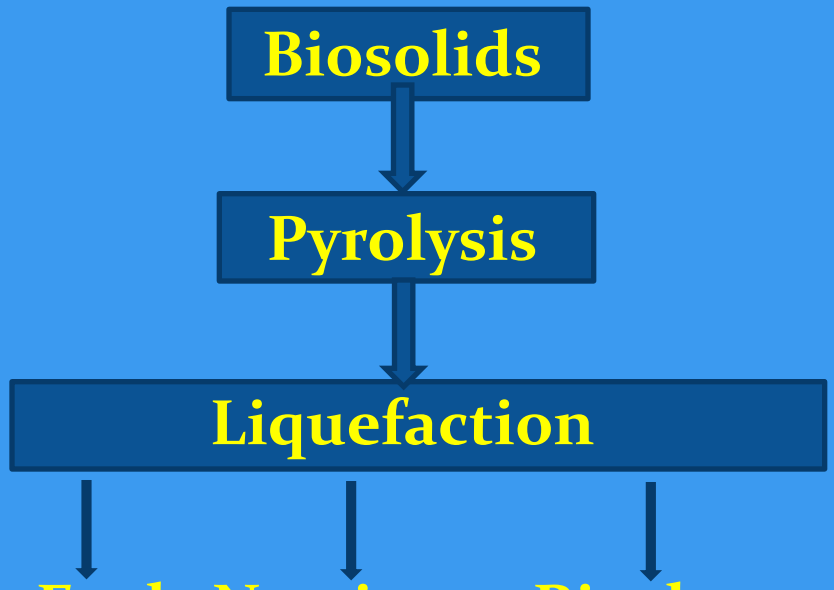
- Increase biogas production by 160%
- Total heating value: 1,770 mmBTU/day
- Equivalent to heating demand of 6,400 households
- Over $1 million/yr revenue from tipping fees

# Renewable Energy – Biomethane Production

- Clean biogas using Pressure Swing Absorption (PSA)
- Produce 1,500 mmBTU/day pipeline quality gas ("biomethane")
- Biomethane sold to natural gas pipeline
- Sale price of biomethane connected to market RIN value of biofuel under EPA's Renewable Fuel Standards program
- Potential revenue of $7 million/yr, assuming recent RIN market prices and natural gas prices

Photo courtesy of Ameresco Inc.

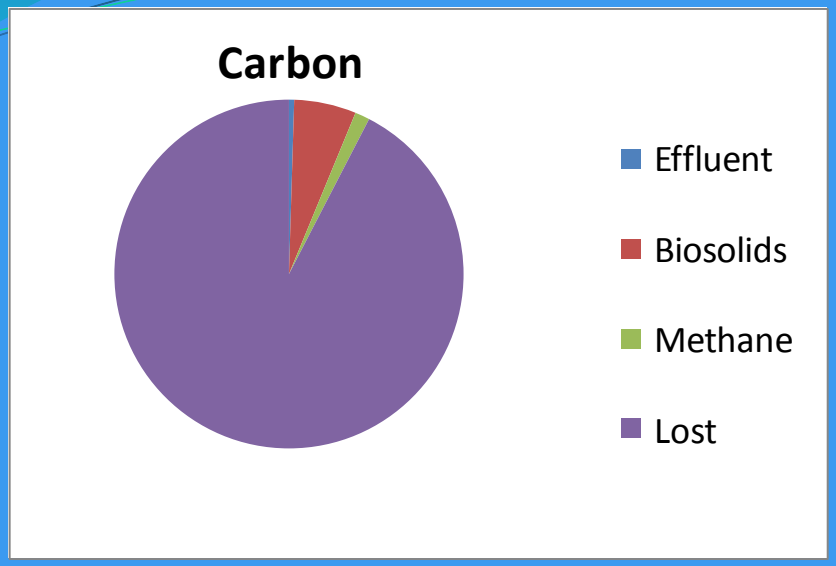
# New Technologies on Horizon



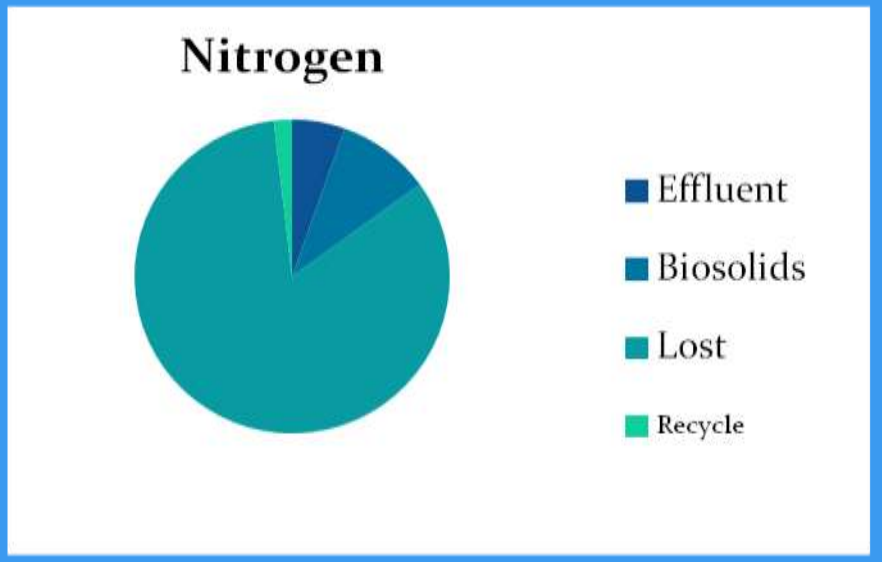

# MWRD's Resource Recovery Efforts

# NUTRIENTS – C,N,&P

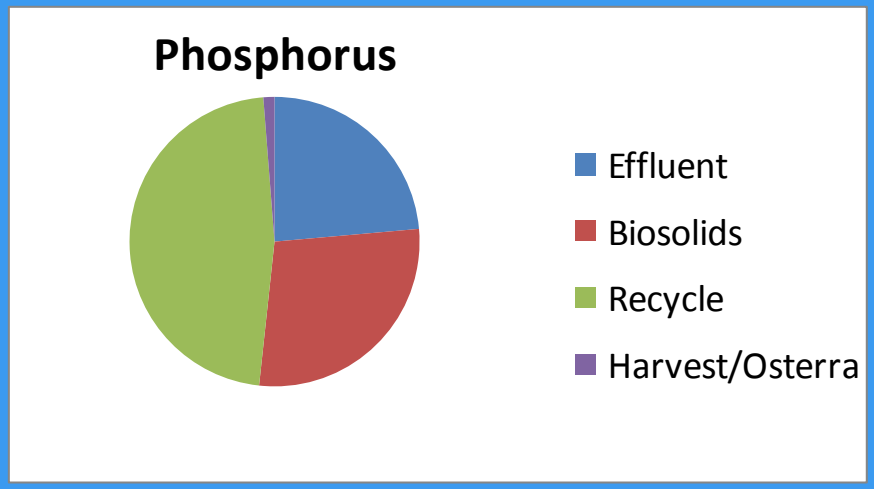
# Estimated Nutrient Balance for 7 WRPs




Influent 545,084 t/yr




Influent 54,187 t/yr

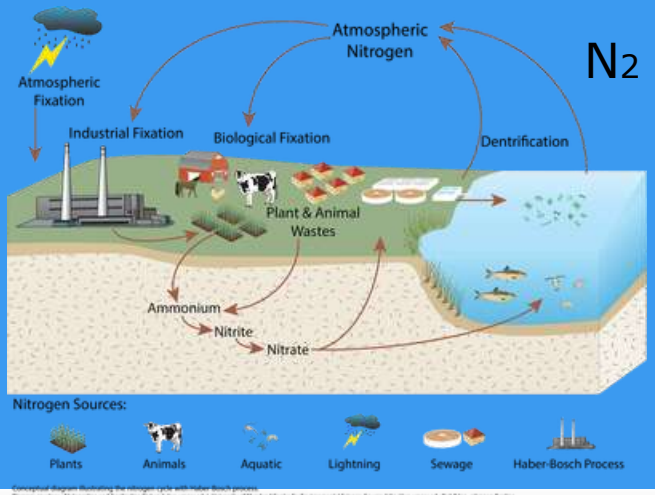



Influent 12,383 t/yr

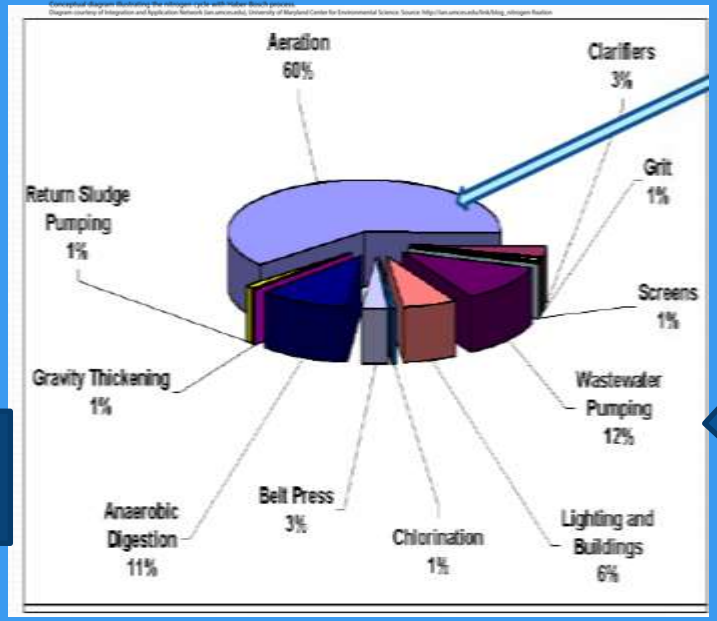
# Classic Example of Nitrogen

Energy Intensive Haber Bosch Process to Make Ammonia

$N_2$ to $NH_4$




$NH_4$ to $N_2$




WWTP Activated Sludge Process

# Phosphorus … "Emerging Issue"


From the June 2009 Scientific American Magazine | 29 comments

## Phosphorus Famine: The Threat to Our Food Supply

This underappreciated resource--a key component of fertilizers--is still decades from running out. But we must act now to conserve it, or future agriculture could collapse

By David A. Vaccari

From The Times

June 23, 2008

## Scientists warn of lack of vital phosphorus as biofuels raise demand

Leo Lewis, Asia Business Correspondent

NEWS SCAN

*Scientific American* – November 2009

Technology

## Sewage's Cash Crop

How flushing the toilet can lead to phosphorus for fertilizers BY KATHERINE TWEED

TUCKED AWAY IN OREGON'S WILLAMETTE VALLEY, THREE MASsive metal cones could help address the world's dwindling supply of phosphorus, the crucial ingredient of fertilizers that has made modern agriculture possible. The cones make consistently high-quality, slow-release fertilizer pellets from phosphorus recovered at the Durham Advance Wastewater Treatment Facility, less than 10 miles from downtown Portland. By generating about one ton

WASTEWATER WONDER: Ostara's Crystal Green, a slow-release fertilizer, incorporates phosphorus retrieved from sewage streams.


**Nature 461, October 2009**

**The Disappearing Nutrient**

Phosphate-based fertilizers have helped spur agricultural gains in the past century, but the world may soon run out of them. Natasha Gilbert investigates the potential phosphate crisis.

# Phosphorus Recovery – Stickney Centrate
## Black & Veatch/Ostara Selected

- Black and Veatch
  - To work in conjunction with District for the Design & Build of the P-recovery system
- Ostara
  - Pearl Process: Intentional manufacturing of struvite for fertilizer
  - Final product (Crystal Green®) marketed and sold by Ostara

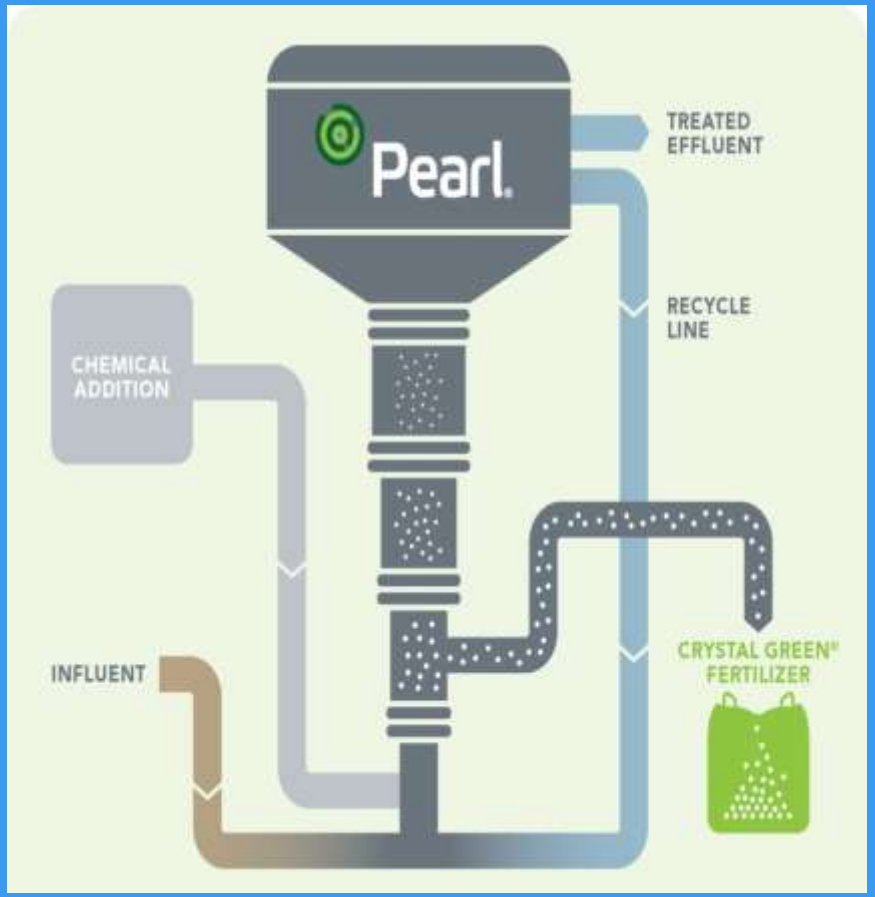
# What is Struvite?

$$Mg^{2+} + NH_4^{+} + PO_4^{3-} \rightarrow MgNH_4PO_4 \cdot 6H_2O$$

- Naturally occurring
- Exists in most wastewater plants
- Forms mostly in anaerobic digesters and post-digester operations
- Increases O & M costs
  - Digester cleaning
  - Chain knocking
  - Flush water
- Impacts plant reliability

# Principle of Technology

- Centrate flow pumped through the bottom of the reactor.
- Supersaturation conditions (driving force).
  - Inject NaOH to raise pH to ~ 7.7
  - Inject $MgCl_2$ at a molar ratio of 1.1 to 1 (Mg to P)
  - Spontaneous crystal nucleation occurs
- As chemical driving force reduces, deposition on surface of crystals occurs.
  - Thermodynamically favorable as surfaces reduce chemical energy needed for precipitation



# Finished Product

Crystal Green®

High Purity (99.5% Struvite)
5-28-0 +10% - Slow Release Fertilizer
Nitrogen | Phosphorus | Potassium + Magnesium

OSTARA
Creating Value from Waste

# Complete Ostara System


Crystal Green Storage & Bagging

Dewatering Screen & Dryer

Pearl Reactors

Chemical Storage & Feed

# Market for Struvite

- Struvite from Ostara systems marketed as

Crystal Green® - 5-28-0 +10%Mg

Nitrogen | Phosphorus |Potassium + Magnesium

- Premium Performance
- High Value
- Established distribution in US and Europe
- Strong partnerships with fertilizer blenders, distributors and dealers


# How Much P will be Harvested?

| Stickney WRP Centrate Data | | Proposed Pearl® Process Solution | |
|---|---|---|---|
| Flow (MGD) | ~ 2 | Ortho-P Removal | ~ 74-80% |
| Ortho-P Conc. (mg/L) | 81 | Mass of P Removed (lbs/d) | 923 |
| $NH_3$-N Conc. (mg/L) | 637 | Ammonia Removal (%) | 4 |
| Mg Conc. (mg/L) | 49 | Mass on $NH_3$-N Removed (lbs/d) | 417 |
| pH | 7.4 | | |
| Potential Crystal Green ® Production Rate (tons/yr) | | | 1300 |

Enough to Meet Corn Crop P requirement for ~ 10,000 Acres in Illinois

# HB1445 - Landmark Regulation Passed in Illinois in July 2015

- Amends the Environmental Protection Act. Provides that "pollution control waste", "sludge", and "waste" do not include exceptional quality biosolids.

# New Initiative - Composting at Calumet WRP ~ 250 MGD

- Produces ~30,000 t Biosolids/Year
- City of Chicago has to dispose wood chips due to ash borer
- District is going to produce ~ 40,000 tons of compost annually using Gore Cover Technology

Other Biosolids Products at MWRD

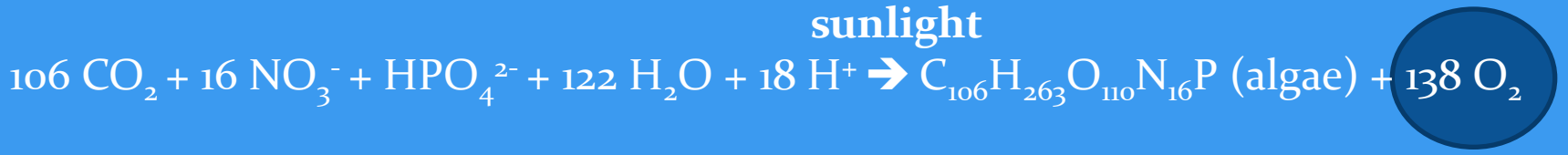
Class A Heat Dried ~ 55,000 tons

Class A Lagoon Aged and Air Dried ~ 15,000 tons

Centrifuge Cake for Farmland Program ~ 60,000 tons

# Nutrient Recovery - *Phycoremediation*

- Principle
  - Use of algae for nutrient uptake from wastewater




- Benefits
  - Can become a beneficial product
  - Energy positive→end use as biofuel or digester amendment
  - Less impact to biosolids→maintain optimal N:P ratio in biosolids
- Disadvantages
  - Large land area required – not practical for urban wastewater agencies
  - Lack of understanding of microalgae physiology in engineered processes
  - Unpredictability of mixed community dynamics in naturally-lit systems

From Cormier 2010

# Synergy of Algae and Wastewater

http://www.waterencyclopedia.com/images/wsci_04_img0570.jpg

Requires $O_2$

Produces $CO_2$

Contains Nutrients

Requires Energy

Produces $O_2$

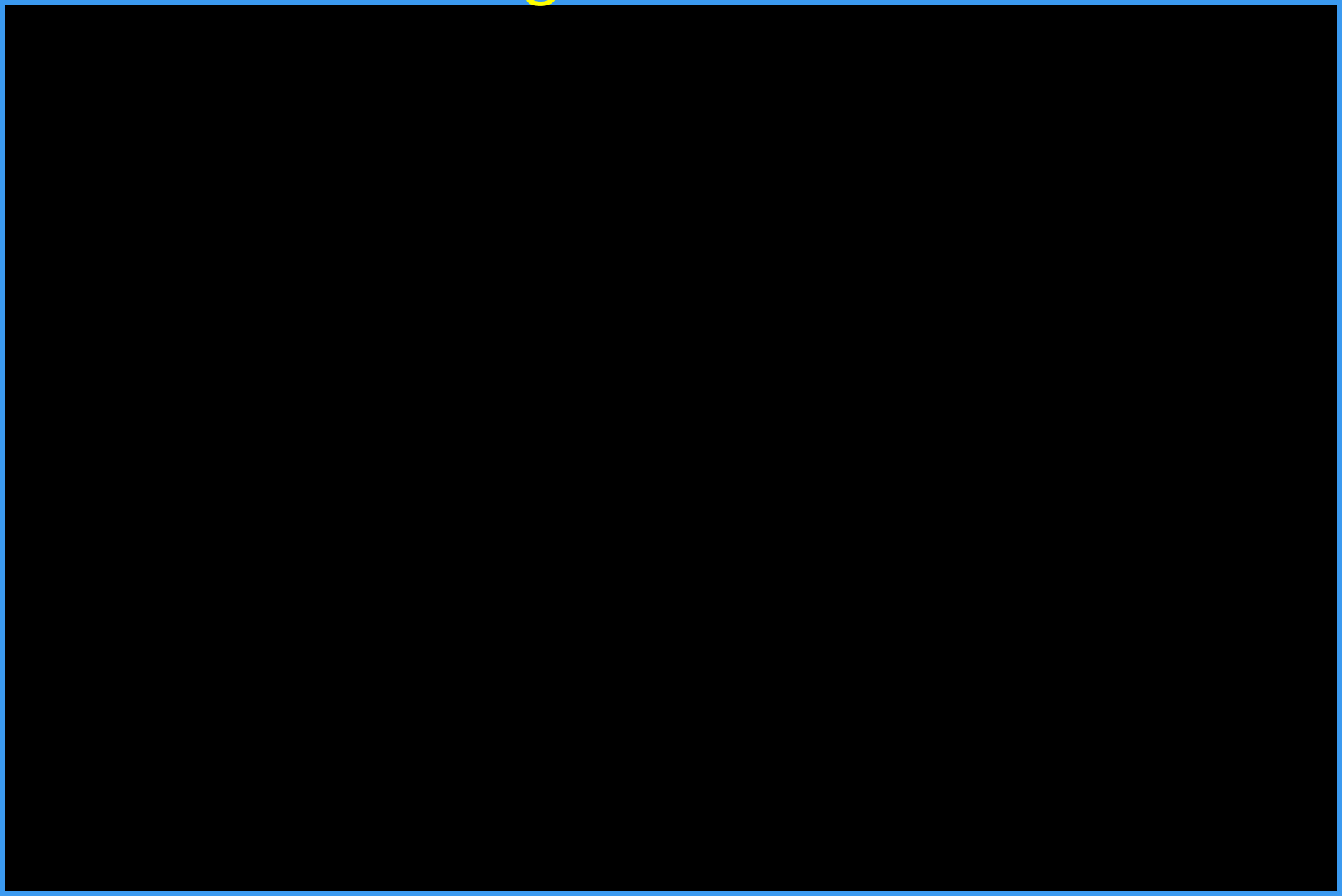
Requires $CO_2$

Requires Nutrients

Harnesses Energy

http://saferenvironment.files.wordpress.com/2008/10/alge.jpg

# O’Brien Revolving Film Bioreactors



# Estimated Benefits of Phycoremediation

| Waste Stream | Potential Algae Biomass t/yr | Carbon dioxide fixed t/yr | Fraction of MWRD C Footprint | Estimated Algae Value , m$/yr | | |
|---|---|---|---|---|---|---|
| | | | | Bio-fuel | Nutrients (N&P + C) | Bio-plastics |
| 7 WRPs Effluent | 270,648 | 487,166 | 0.96 | 81 | 32 + 4 | 271 |
| | | | | | | |
| 3 WRPs Side Streams | 50,918 | 91,652 | 0.18 | 15 | 6 + 1 | 51 |

1.8 kg Carbon dioxide fixed for 1 kg of algae biomass produced
1 ton algae produces ~ 3 barrels of oil @ $100/barrel = $300
~ $0.45/lb algae for bio-plastics
$0.75 /lb of N and $0.75/lb P from commercial fertilizers, C trading $30/t
4 year average District C footprint was(~506,000 MT $CO_2e$)

# High Value Products from Microalgae

- *Grow Haematococcus pluvialis* (MicroAlgae)in waste water to produce Astraxanthin, the red color dye while removing the nutrients from waste water.

# Conclusions

MWRD has Adopted the Paradigm of Resource Recovery under the Leadership of New Executive Director

Potential is Immense

…….

…….

…….AND Still a Long Road Ahead to Make a Difference …… BUT Most Importantly We are Moving in the Right Direction……