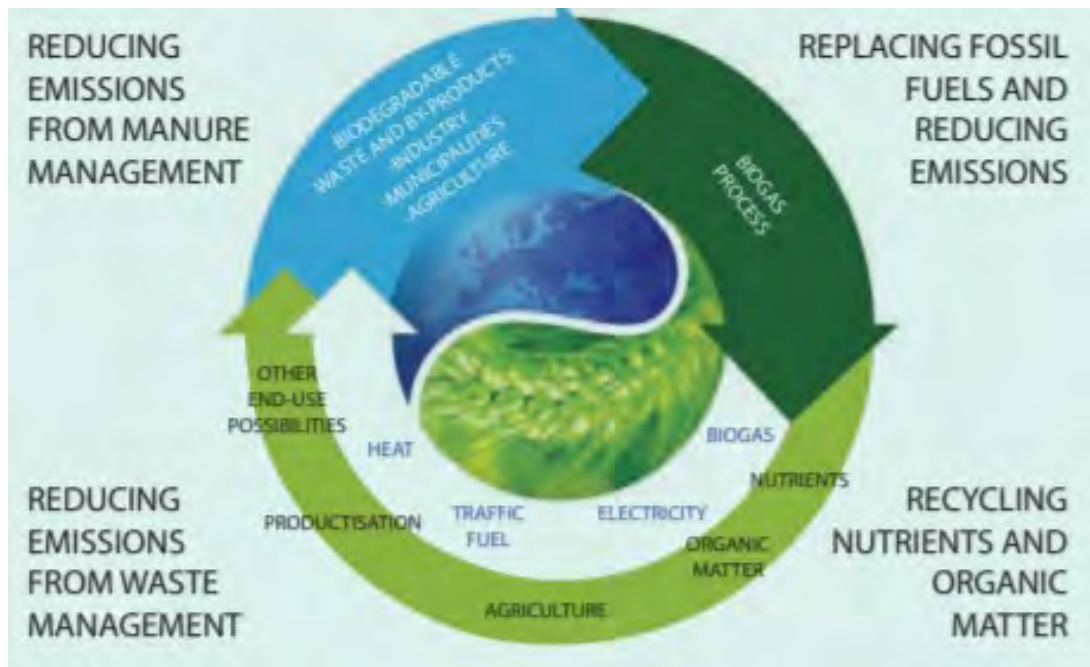


# Food Waste to Energy: How does that Work?

Jan DeWaters<sup>1</sup>, Stefan Grimberg<sup>2</sup>



<sup>1</sup>School of Engineering, Clarkson University

<sup>2</sup>Civil Environmental Engineering, Clarkson University



Clarkson™



# Food Waste to Energy: How does that Work?

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Clarkson™

# Part 1. Let's Talk Trash

Do you know how much the average American 'throws away' each day?

*According to the EPA, the average American person will produce about 5.91 pounds of trash, with about 1.51 pounds being recycled; **4.40 pounds is the rough average daily waste per person.** (epa.gov)*



# Part 1. Let's Talk Trash

*According to the EPA, the average American person will produce about 5.91 pounds of trash, with about 1.51 pounds being recycled; **4.40 pounds is the rough average daily waste per person.** (epa.gov)*

Do you know what happens to the things that you 'throw away'? (WHERE is AWAY?)



# Part 1. Let's Talk Trash

*According to the EPA, the average American person will produce about 5.91 pounds of trash, with about 1.51 pounds being recycled; **4.40 pounds is the rough average daily waste per person.** (epa.gov)*

*The solid waste generated in St. Lawrence County is brought to the DANC Solid Waste Management Facility (Landfill) in Rodman, NY*





## MSW Generation Rates 1960 to 2014

# Some solids waste facts....

- The generation rate in 1960 was just 2.68 pounds per person per day.  
The generation rate was 4.48 pounds per person per day in 2015, which was one of the lowest generation rates since 1980.
- Over time, **recycling rates have increased from just over 6 percent** of MSW generated in 1960 to about 10 percent in 1980, to 16 percent in 1990, to about 29 percent in 2000, and **to over 34 percent in 2015**.
- The **disposal of waste to landfills has decreased from 94 percent of the amount generated in 1960 to under 53 percent of the amount generated in 2015**.

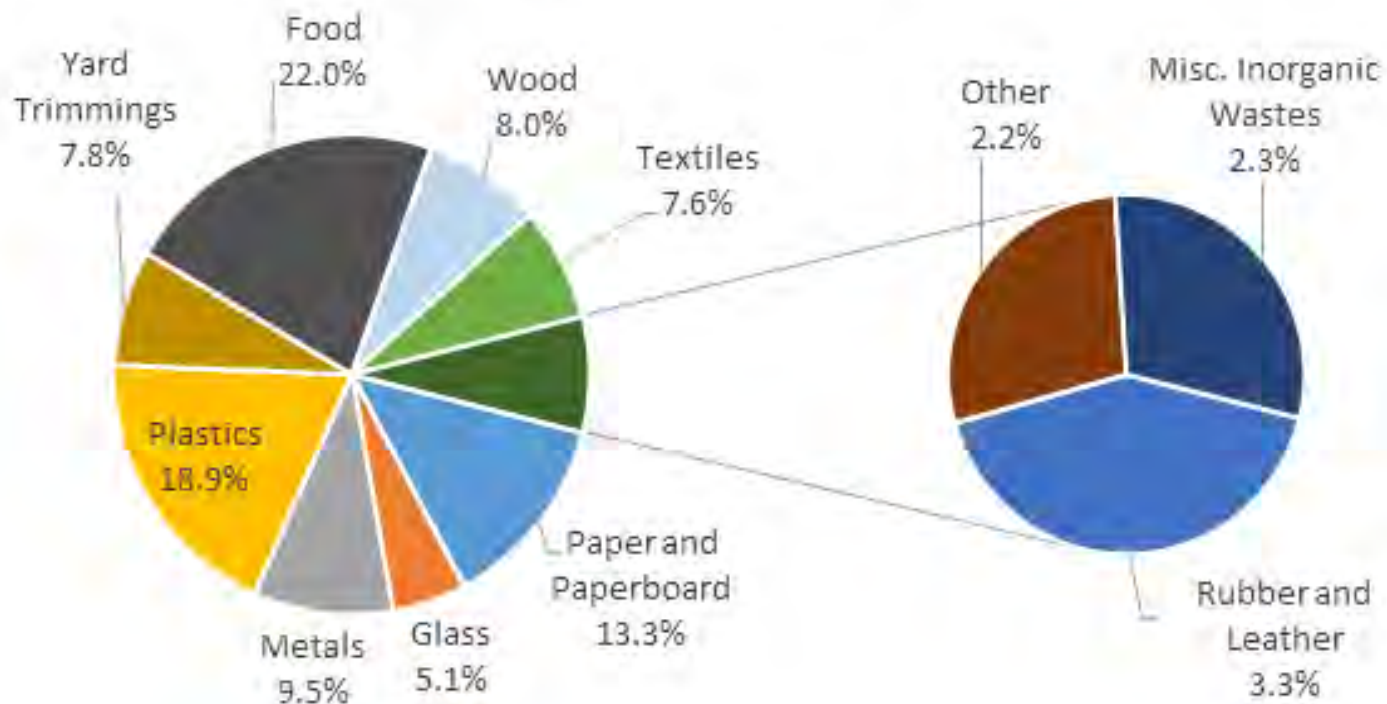
# Development Authority of the North Country (DANC) Solid Waste Management facility Rodman, NY





# What goes to the landfill

Total MSW Landfill by Material, 2015  
(137.7 million tons)



- About 36.39 million tons on food waste is buried in U.S. landfill each year
  - With limited oxygen, water, sunlight, and organisms food waste decomposes very slowly
- The older landfill are not set up to capture methane

# Trash vs. Recycling vs. ....? ....

Not all of our waste belongs in the landfill!

Let's look at some typical items and talk about where they should go when we are finished with them.

Trash vs. Recycling vs. ....? ....

# Where Does the Trash Go?

[Landfill and Garbage video](#) (~4 min)

[Large scale resource recovery operation video](#) (~5 min)



# Where Does the Trash Go?

## WASTE DISPOSAL CHART



| Item               | Which method(s) are feasible for this item? (C, AD, R, L, I) | Do any of these disposal methods use energy? | Do any of these methods create useful energy or by-products? | Do any of these methods create pollution or harmful by-products? |
|--------------------|--|--|--|--|
| Notebook paper     |  |  |  |  |
| Fruit or veg. peel |  |  |  |  |
| Leaf               |  |  |  |  |
| Plastic bottle     |  |  |  |  |
| Glass jar          |  |  |  |  |
| Wood scrap         |  |  |  |  |
| Rubber tubing      |  |  |  |  |
| Fabric scrap       |  |  |  |  |
| Empty steel can    |  |  |  |  |
| Aluminum foil      |  |  |  |  |
| Foam cup           |  |  |  |  |
| Battery            |  |  |  |  |

C = Composting  
R = Recycling  
L = Landfilling

AD = Anaerobic Digestion  
I = Incineration



# North Country Recycles

DEVELOPMENT AUTHORITY OF THE NORTH COUNTRY

Jefferson County

Lewis County

St. Lawrence County

Education & Outreach



<https://www.northcountryrecycles.org/>

## Upcoming Household Hazardous Waste Collection

August 28, 2019

The Development Authority of the North Country, in cooperation with its regional county partners and the New York State Department of Environmental Conservation, will be sponsoring three free household hazardous waste collection days this fall to help residents in Jefferson, St. Lawrence and Lewis c...

[More Info](#)



News



Recycling Map



Materials Memos



Learn More



Calendar



Contact Us

## How Do I Dispose Of...?

Below is a list of materials and directions on how to dispose of them properly.

If there are any questions or materials that are not answered or listed below, please [contact us!](#)



**Aerosol Cans**

**Ammunition and Explosives**

**Antifreeze**

**Asbestos Products**

**Batteries**

**Bulky Rigid Plastics**

**Cardboard Products**

**Cleaning Products**

**Clothing Hangers**

**Construction and Demolition Debris**

**Dishware**

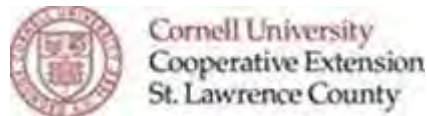
**Driveway Sealer**

**Egg Cartons**

# Part 2. Focus on FOOD

Material here were developed as part of a funded project

Converting Food to Energy: Recovering food waste  
and transforming it to a reusable product



# A Partnership between

- Canton public schools
  - Megan Smith, Tom van de Water
- Cornell Cooperative Extension
  - Nick Hamilton-Honey
- Clarkson University
  - Jan DeWaters, Stefan Grimberg

Financial support provided by



**Constellation**<sup>®</sup>

An Exelon Company



# Food Waste Trivia

Americans waste an unfathomable amount of food. In fact, according to [a \*Guardian\* report](#) , roughly 50 percent of all produce in the United States is thrown away—some 60 million tons (or \$160 billion) worth of produce annually, an amount constituting “one third of all foodstuffs.”



# How long does paper take to degrade in landfills?

Paper takes typically 2 weeks or as much as 5 months to degrade in a landfill. This may be true for most cases, but researchers have found newspapers that are dated back 40 years.

William L. Rathje, professor of archeology at the University of Arizona studies garbage as insight into human behavior. The only way to know who a people are is by what they throw away he says.



## Seeking the Truth in Refuse, New York Times, 1992

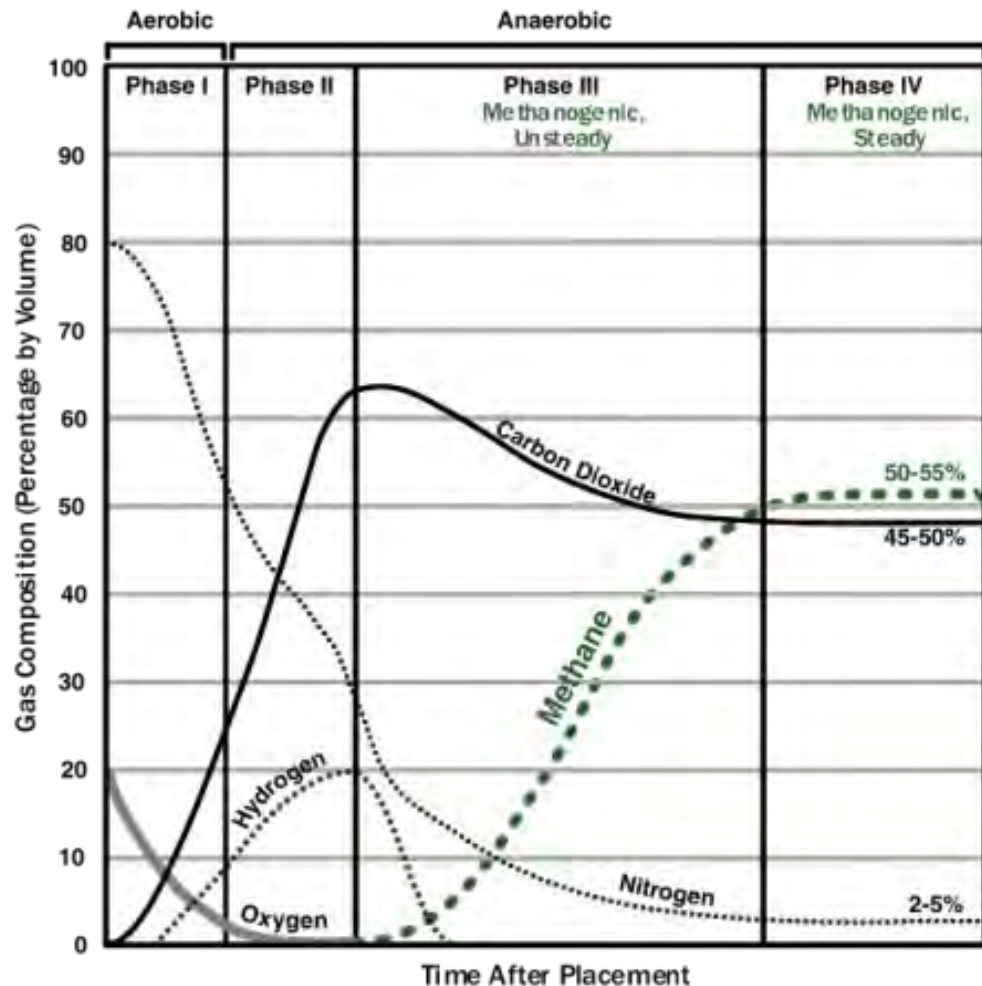
“After 20 years of sorting through garbage cans and landfills, the archaeologist William L. Rathje has accumulated precious memories. There are the 40-year-old hot dogs, perfectly preserved beneath dozens of strata of waste, and the head of lettuce still in pristine condition after 25 years.

But the hands-down winner, the one that still makes him shake his head in disbelief, is an order of guacamole he recently unearthed. Almost as good as new, it sat next to a newspaper apparently thrown out the same day. The date was 1967. The guacamole that would not die reinforces a point that Mr. Rathje and his co-author, Cullen Murphy, make in "Rubbish!" recently published by HarperCollins (\$23).

The garbage dumped in landfills tends not to biodegrade. It becomes mummified.”

# So what is the big deal with disposing organic waste in landfills?

- **ONE HEAD OF LETTUCE CAN TAKE 25 YEARS TO DECOMPOSE IN A LANDFILL**
- Methane gas is 23 times more powerful than carbon dioxide and it's one of the biggest contributing factors to global warming.



According to U.S. EPA Municipal solid waste (MSW) landfills are the **third-largest source of human-related methane emissions** in the United States, accounting for approximately 15.4 percent of these emissions in 2015.



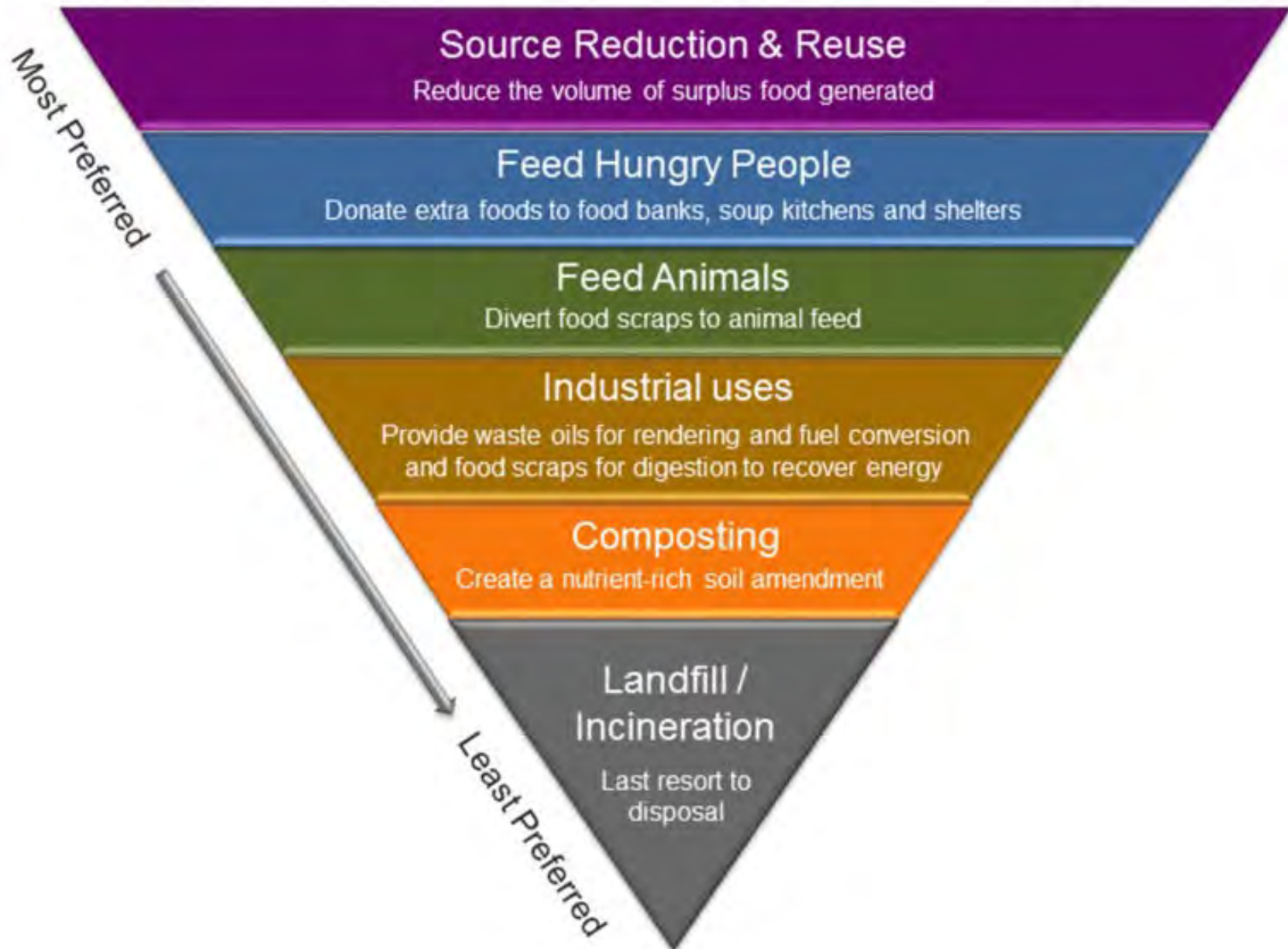
# So...

- While putting organic material into landfills is easy,
- it is not very smart
  - Because of global climate impacts and
  - Because it is a lost opportunity to recover resources!

So what should we do with food waste?



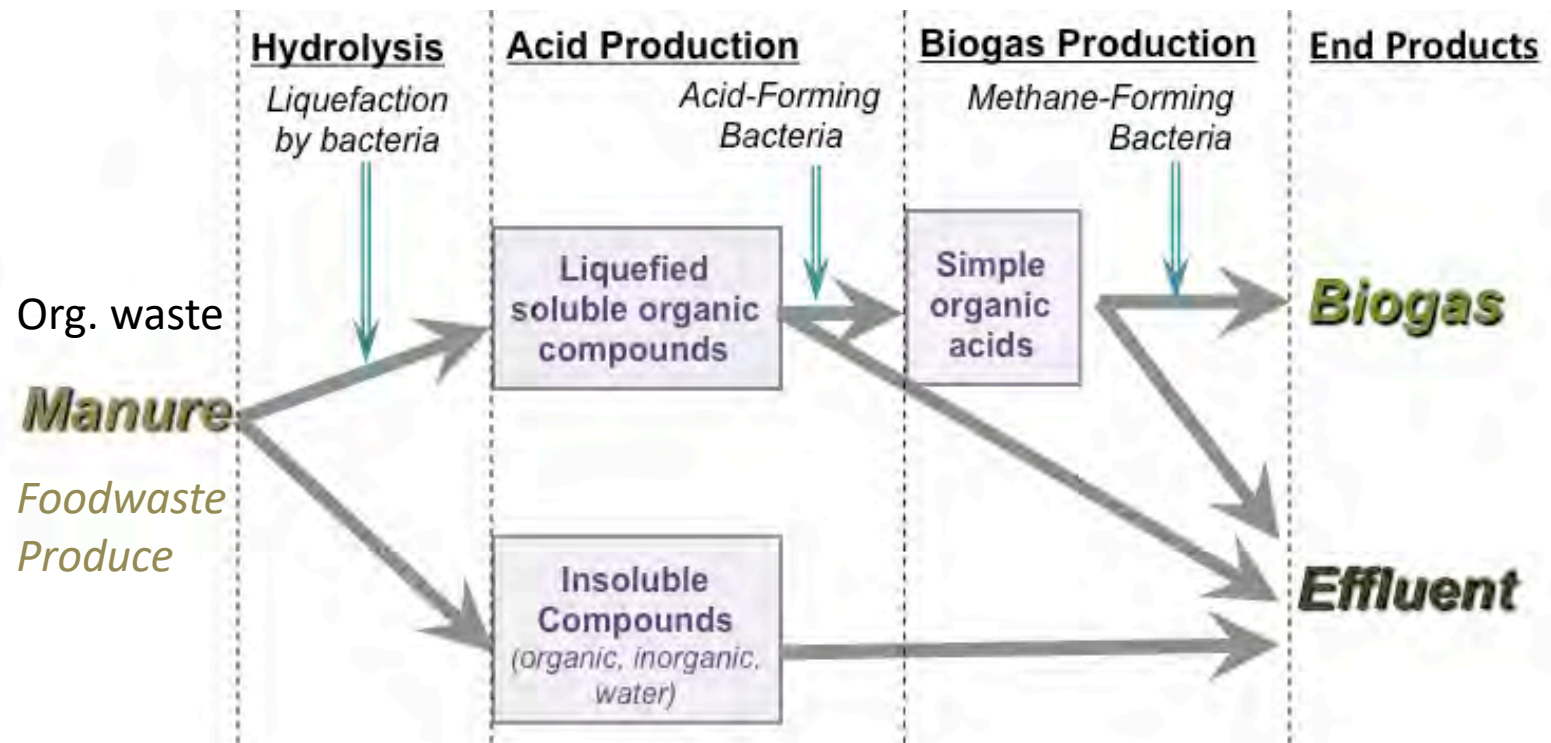
# Food Recovery Hierarchy



# Introduction to Anaerobic Digestion

## Process Description

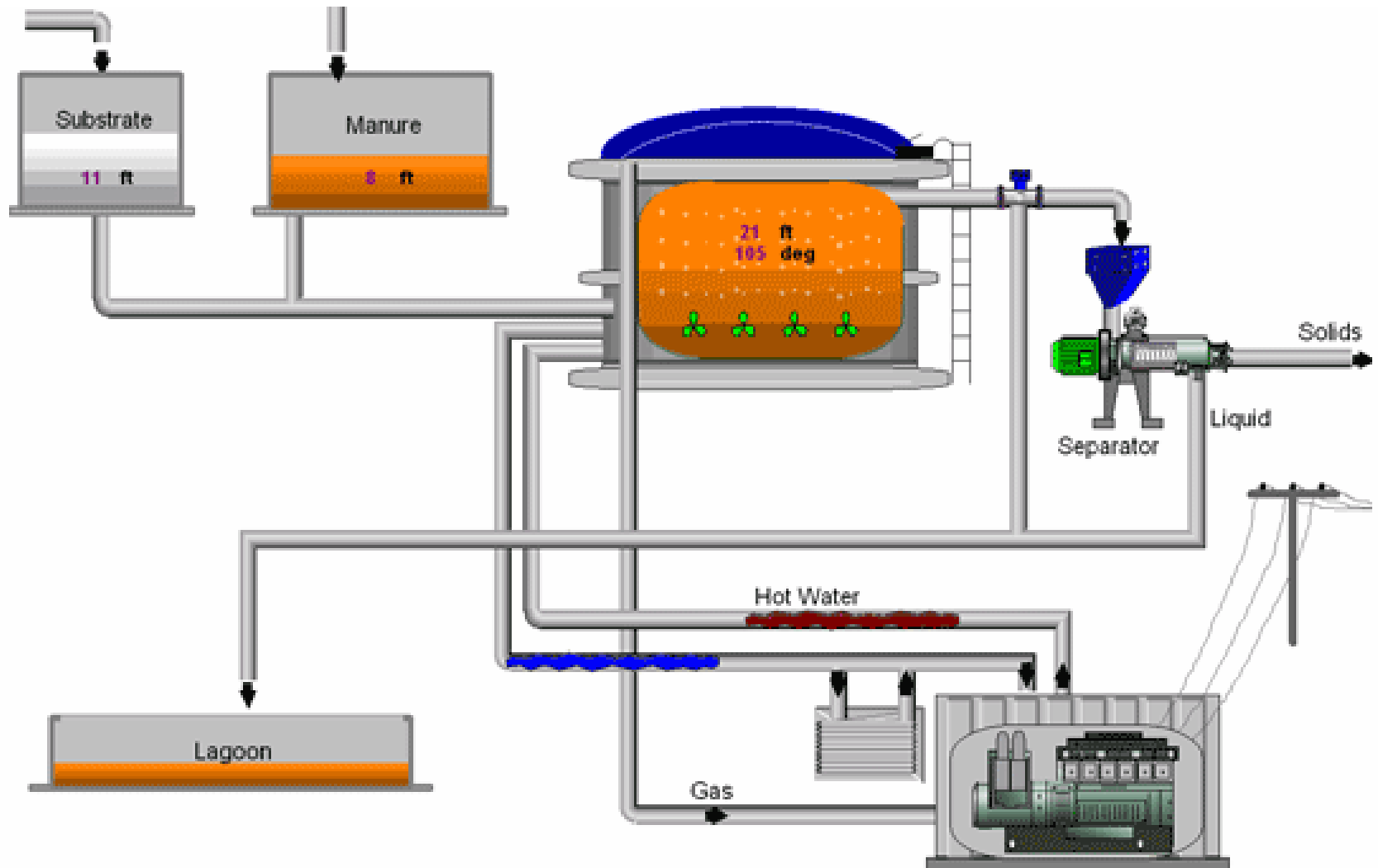
- **Anaerobic digestion:** Degradation of organic matter by microbes without oxygen





# Introduction to Anaerobic Digestion

## Process Description: Operation



## *Introduction to Anaerobic Digestion*

# Process Description: Operation

- Operating temperature:
  - Mesophilic* = 86 – 100°F
  - Thermophilic* = 120 – 135°F
- Biogas composition:
  - 50-70% methane
  - 30-50% carbon dioxide
  - Trace amounts of hydrogen, ammonia, and hydrogen sulfide
    - Remove hydrogen sulfide and water vapor to reduce corrosion issues
  - Production depends on waste feed, digester design, and operating temperature, but ~ 50-80 ft<sup>3</sup> per mature dairy cow (~40,000 Btu)\*
- Produce electricity in internal combustion engine or combined heat and power (CHP) system
- Use gas heating as a substitute for propane or natural gas

\* EPA figure – probably a little optimistic

# Process Description: Operation

## How much energy is in biogas?

- Average fuel value of methane = 1000 BTU/ft<sup>3</sup>
- Average fuel value of propane = 2500 BTU/ft<sup>3</sup>
  - Propane produces 2.5 times more energy per unit of volume

**Example:** We want 40 lbs of propane-equivalent

*----- assume 60% methane in biogas -----*

$$40 \text{ lbs. propane} \times \frac{1 \text{ gallon}}{4.2 \text{ lbs.}} \times \frac{35.97 \text{ ft}^3}{\text{gallon}} = 342.57 \text{ ft}^3 \quad \left( \times \frac{2500 \text{ BTU}}{\text{ft}^3} = 856,430 \text{ BTU} \right)$$

$$856,430 \text{ BTU} \times \frac{1 \text{ ft}^3 \text{ methane}}{1,000 \text{ BTU}} = 856 \text{ ft}^3 \text{ methane} \quad \left( \times \frac{0.041 \text{ lbs.}}{\text{ft}^3} = 35.1 \text{ lb methane} \right)$$

$$856 \text{ ft}^3 \text{ methane} \times \frac{1 \text{ ft}^3 \text{ biogas}}{0.6 \text{ ft}^3 \text{ methane}} = 1427 \text{ ft}^3 \text{ biogas}$$

# Small Digesters



Capacity: 6 liters (1.5 gal)/day of food waste or 20 liters (5 gal)/day of animal manure.

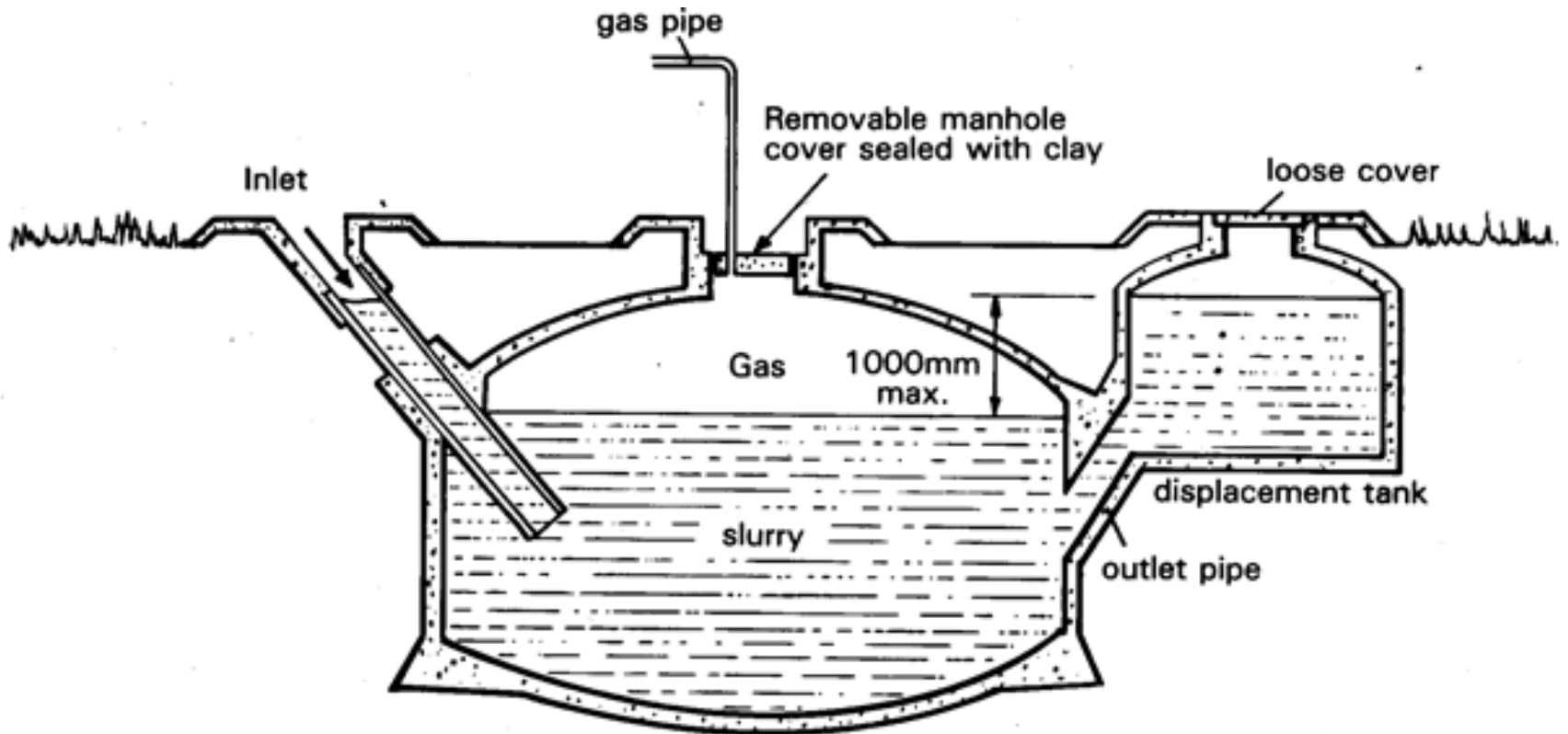
No heating (optimum at 20°C),  
no mixing



Every kilo of food waste recycled with HomeBiogas 2.0 produces about 200 liters of biogas, the amount needed for approximately one hour of cooking.

<https://homebiogas.com/>

# Digesters in Developing Countries



No heating, no mixing

# Digester in Cuba for Hog Manure Treatment



Manure of 4-6 pigs provides enough gas for cooking

Cardenas, Cuba



# Multifamily Digester

Cardenas, Cuba



Manure of 20+ pigs provides cooking gas for several households

## *Introduction to Anaerobic Digestion*

# Process Description: Compatible Wastes

- ***Wastes that yield biogas***

- Manure
- Waste grass, corn and silage
- Slaughterhouse waste
- Fats, oils and grease from restaurants
- Organic household waste such as food



Add this waste to digesters

- ***Wastes that do not***

- Fiber rich waste such as wood, leaves, etc.
- Plastics or other refractory organics
- Inorganic materials (salts, metals, sand, etc.)



Good for compost but not for anaerobic digester

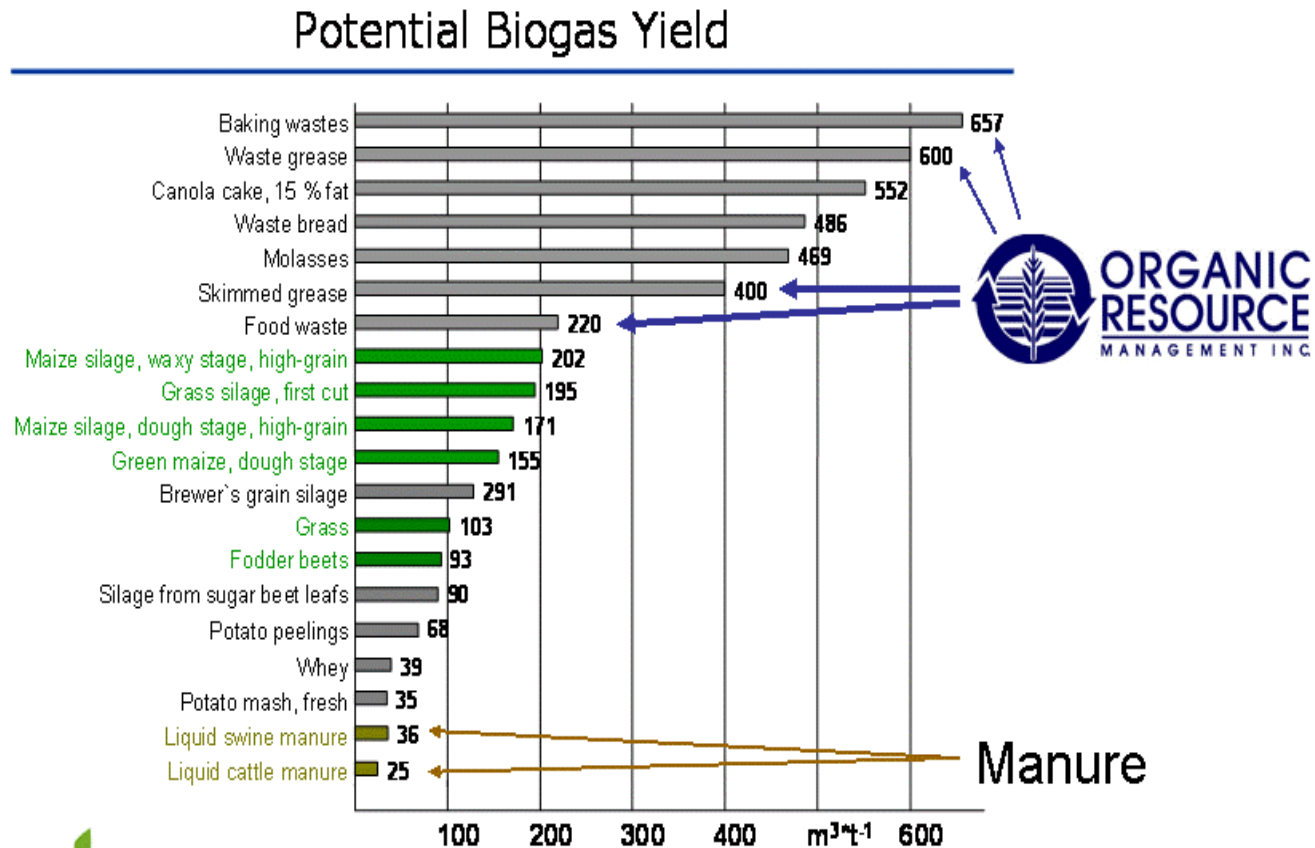


Don't add this waste to digesters



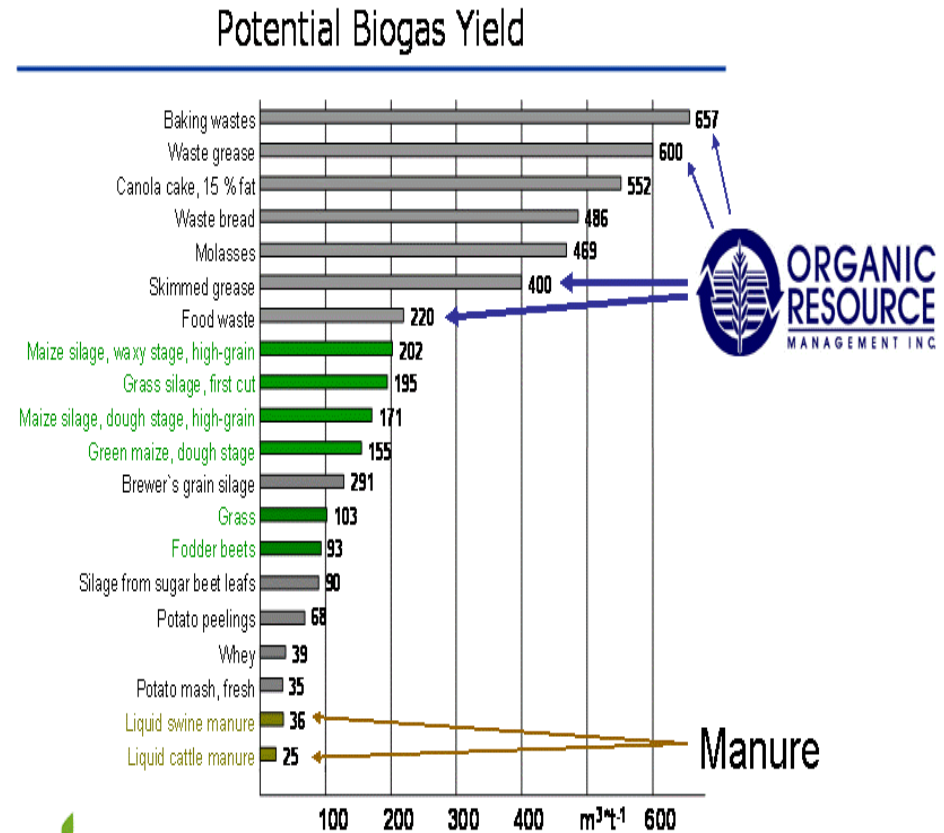
# Food Waste Potential

- Food waste has higher biogas potential than other sources like agriculture and wastewater sludge.



# Biogas Potential Depends on

- Biodegradability
  - Bigger more complex molecules may degrade slower
  - E.g. lignin is poorly biodegradable in AD vs. sugar is very biogradable
- Whether material dissolves in water
  - Oil has low solubility in water
  - Particles need to break down. Smaller particles have larger surface area; so may break down quicker.

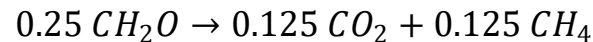


# So

- Different wastes produce different amounts of biogas and
- For different wastes the methane composition in the biogas will change.
  - Lets look as some chemical equations:

# Stoichiometry Examples

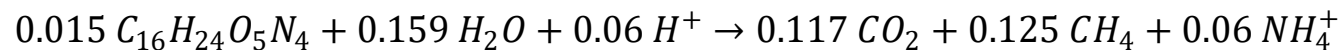
Carbohydrate degradation in digester:



$$\frac{0.125 \text{ CH}_4}{(0.125 \text{ CO}_2 + 0.125 \text{ CH}_4)} = 0.50$$

50% CH<sub>4</sub> content in biogas

Protein degradation in digester:

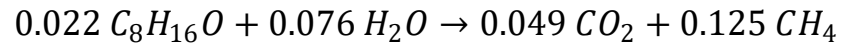


$$\frac{0.125 \text{ CH}_4}{(0.117 \text{ CO}_2 + 0.125 \text{ CH}_4)} = 0.52$$

52% CH<sub>4</sub> content in biogas

# Stoichiometry Examples

Grease degradation in digester:

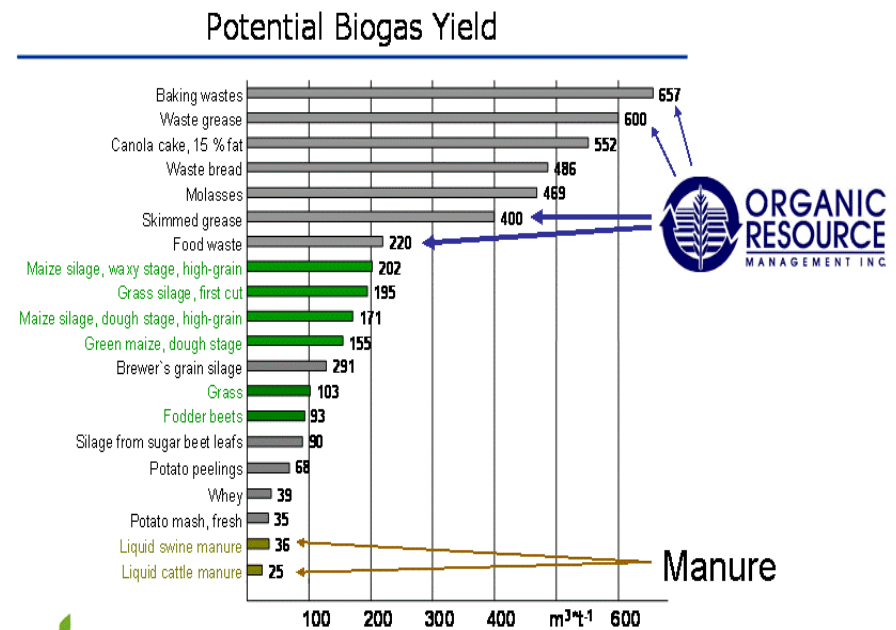


$$\frac{0.125 CH_4}{0.049 CO_2 + 0.125 CH_4} = 0.72$$

72% CH<sub>4</sub> content in biogas

# Food Waste Summary

- Food waste has higher biogas potential than other sources like agriculture and wastewater sludge.
- **Carbohydrate** waste generates biogas of **50% CH<sub>4</sub>**
- **Protein** waste generates biogas of **52% CH<sub>4</sub>**
- **Grease/Fat** waste generates biogas of **72% CH<sub>4</sub>**



# Resource Recovery and Anaerobic Digestion

WHY TEACH about it? and  
HOW does this topic fit into an EDUCATIONAL CURRICULUM?

It's more than just teaching students about how to minimize their waste!



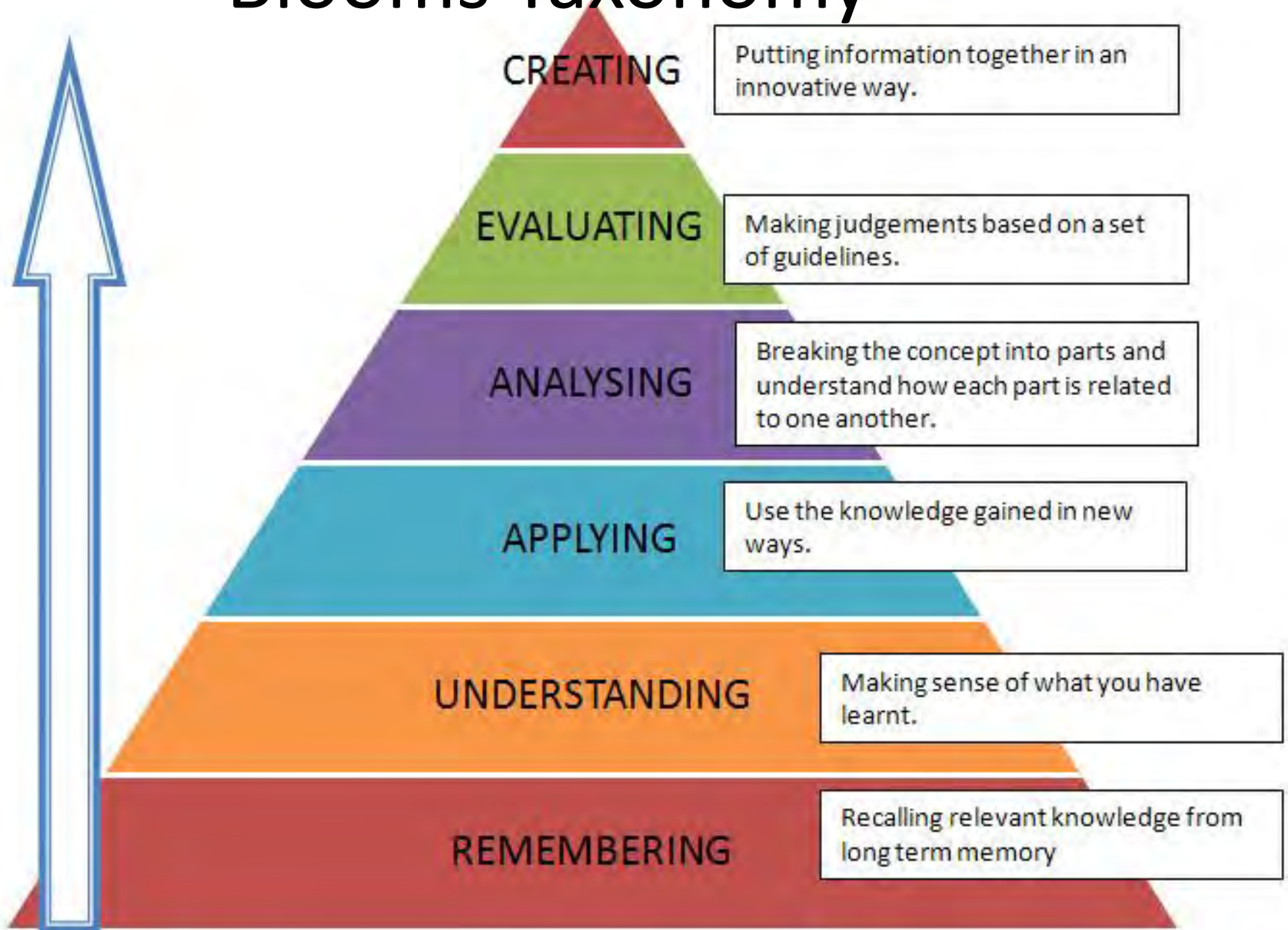
# Food-to-Energy: Cross-Fertilizing a K12/University Partnership to develop a Resource Recovery Program



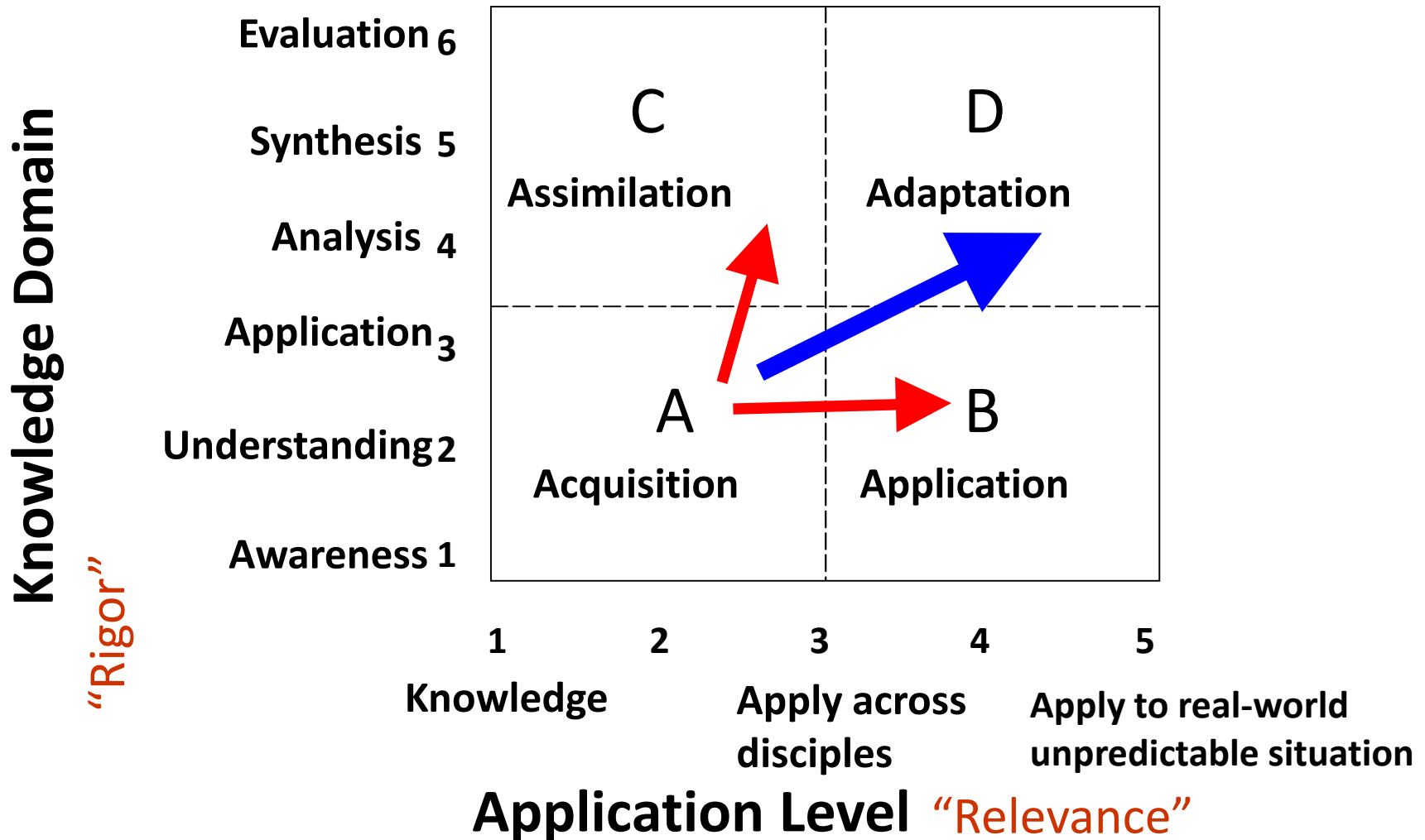
- (1) educates students about anaerobic digestion (AD) of organic solid waste
- (2) increases source separation behavior at Canton Central School District
- (3) can be replicated at other regional schools



# Blooms Taxonomy



# Rigor/Relevance Framework



# Problem- and Project-Based Learning

## Lecture

Teacher – Expert, deliverer of information  
Students – Inactive, receive knowledge, apply on test

## “Problem-Centered” Learning

Moderately structured problem - learning in relevant and connected ways

Teacher – translates problem to student’s world, explicitly teaches related content

Students – Active, evaluates resources, defines solutions

Teacher – Coaches students through ill-posed problem  
Students – Active, investigates and solves the problem

## Problem-Based Learning

# Project-based Curricula

Students are required to learn and use content and skills as they solve a problem or complete a project.

- Engages students in active learning
- Effectively integrates knowledge and skills from other disciplines
- Demonstrates relevance of what students are learning to their lives outside of school



Real-life projects make the learning more relevant

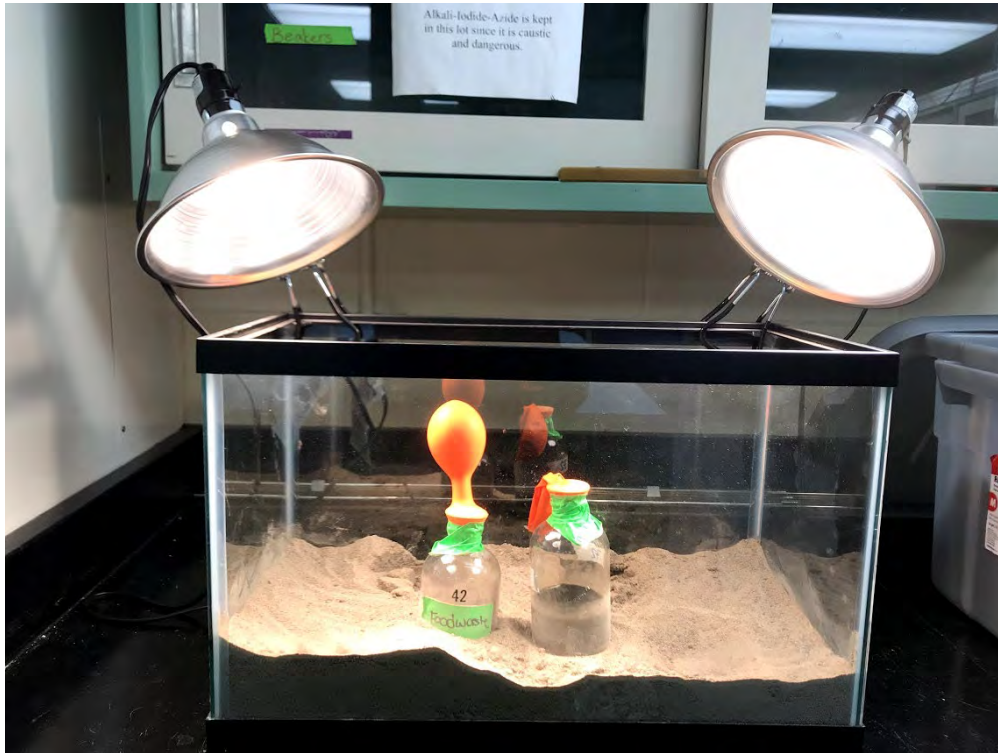
# Food-to-Energy: Cross-Fertilizing a K12/University Partnership to develop a Resource Recovery Program



Task 1:

Cafeteria food waste separation program

# Food-to-Energy: Cross-Fertilizing a K12/University Partnership to develop a Resource Recovery Program



Task 2:

Classroom Education  
(w/ curriculum development  
and teacher PD)

# Food-to-Energy: Cross-Fertilizing a K12/University Partnership to develop a Resource Recovery Program



Task 3:  
Field Trips

# Digester Field Trips

Clarkson Food Digester

Lisbon, Manure Digester

Cornell Cooperative Extension Digester



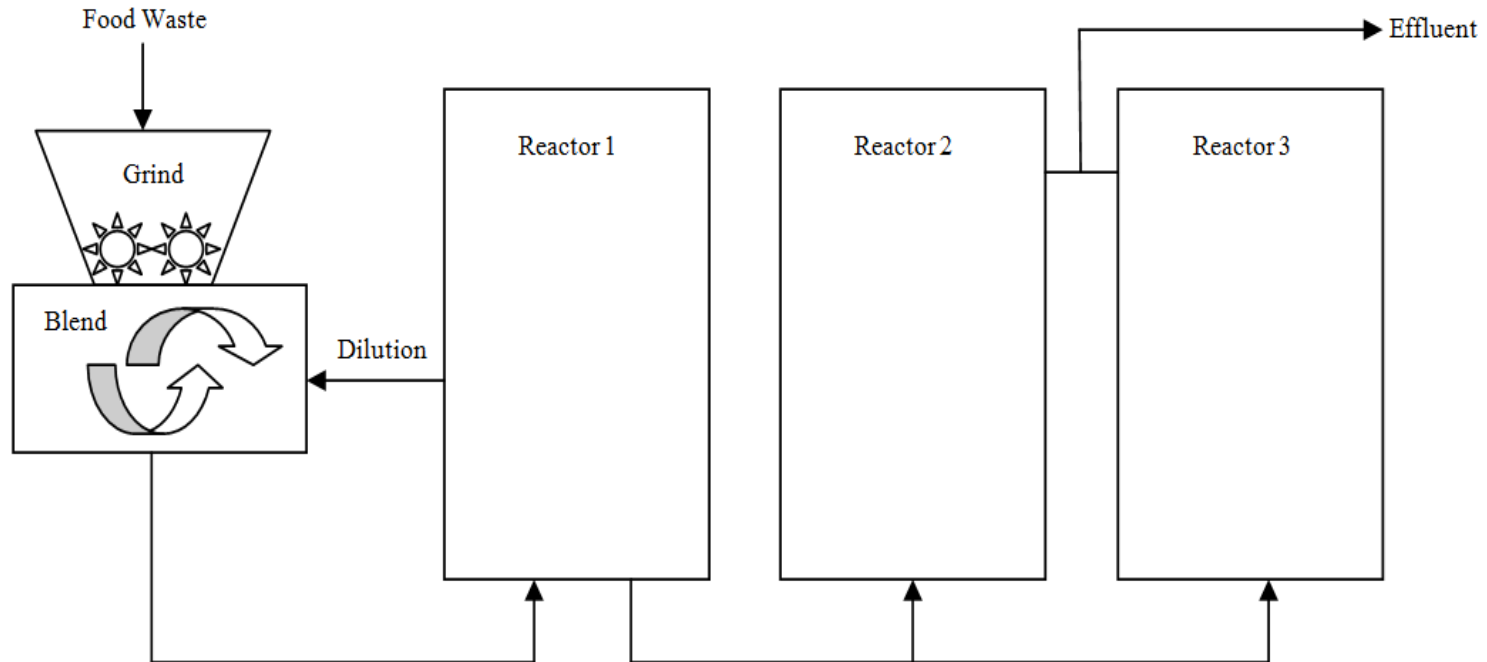
# Clarkson's Mixed Food Waste

- 100-300 lb/day preconsumer food waste is collected by students
- Chemical Oxygen Demand (COD) =  $268,264 \pm 181,549$  mg/L
- Total Solids (TS) =  $19.66 \pm 12.88\%$
- Volatile Solids (VS) =  $18.74 \pm 12.60\%$



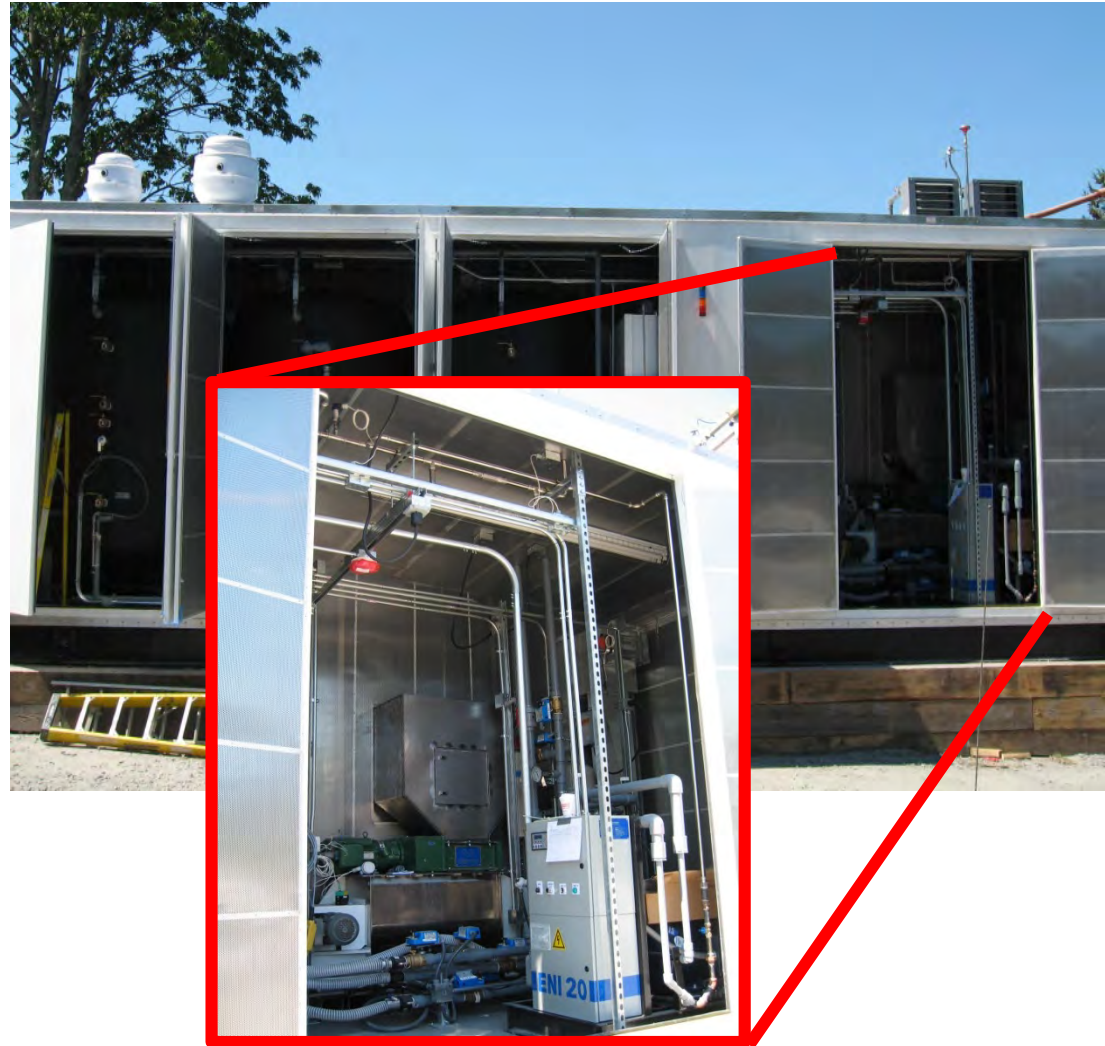
# Clarkson's Digester Operation

- Separate mixing cycles for each stage.



# Anaerobic Digester

- Material grinding and feeding system
- Three 1,400 gallon reactors operated as two-stage digester
- Biogas generated in the anaerobic environment
- ENI 20kW co-generation combustion engine → CHP
- Instrumentation for independent operation and remote control





Anaerobic digester  
Up to 300 kg food waste/day  
Transformed into biogas  
Savings: \$200/ton food waste  
diverted from landfill



# Methane Content



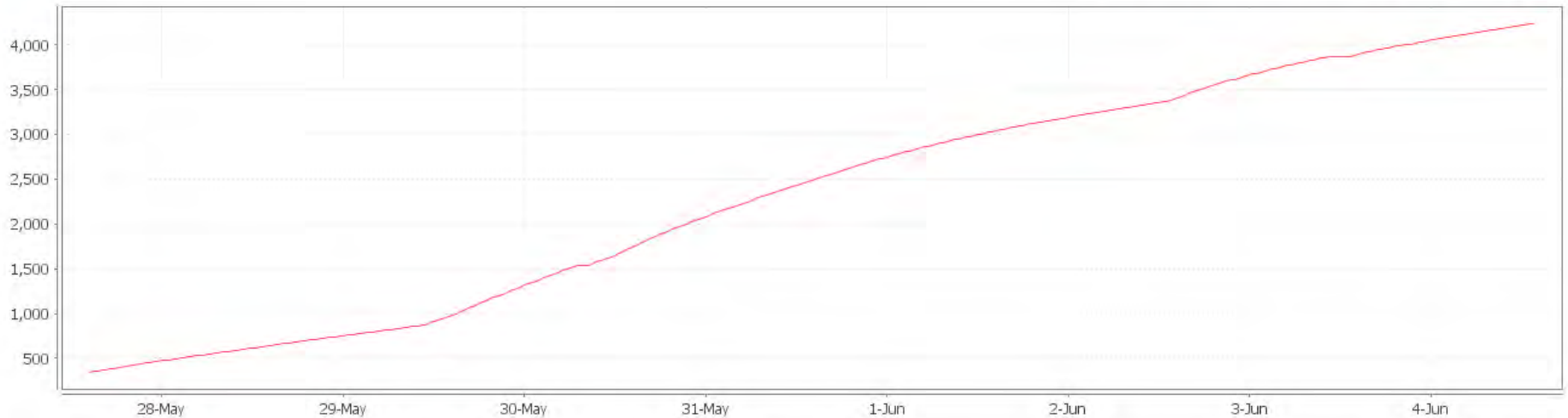
<http://greenhouse.wlan.clarkson.edu:8080/mango/login.htm>

# Biogas Production

Chart

(as of 2014/06/04 14:27:47)

From 2014 May 27 14 : 27 : 00  Inception  
To 2014 Jun 04 14 : 27 : 00  Latest



Approximately 500 ft<sup>3</sup>/d feeding an average of 113 lbs/d at 12±8 % VS

Approximately 1,362±544 L CH<sub>4</sub>/kg VS added

Or 272 m<sup>3</sup> biogas per ton of foodwaste or 21 kW per ton of FW



### **Current Digester Food:**

- Cheel kitchen (pre-consumer) ~100-300 lb/d
- Apartment collection ~100-150 lb/wk
- On-going – efforts to increase feeding rate → increase the biogas production
- The effluent of the digester is used as fertilizer for athletic fields on campus



# Lisbon Manure Digester



# Woodcrest Dairy



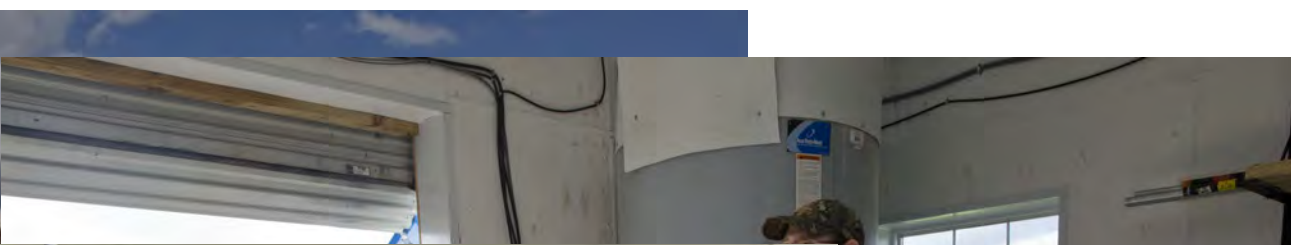
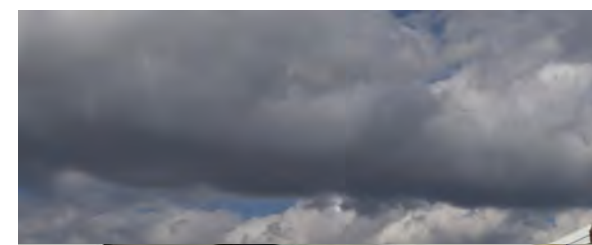
1.2 Mgal Digester, feed by 2,500 cows  
400 kW Power generation +  
Bedding recovery  
**Low odor effluent spread on fields**



And on the smaller scale

Bring your food waste to the digester at  
the Cornell Cooperative Extension Farm in Canton





# Your Own Field Trip

- Let's look at our digester

# Wrap up

- Questions?
- Notes for what's next?
- Please complete the informal feedback forms, thanks!

# Questions/Comments?

Contact us:

Stefan Grimberg, [grimberg@clarkson.edu](mailto:grimberg@clarkson.edu), 315-268-6490

Jan DeWaters, [dewaters@clarkson.edu](mailto:dewaters@clarkson.edu), 315-268-6577