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

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# 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®
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# 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 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.

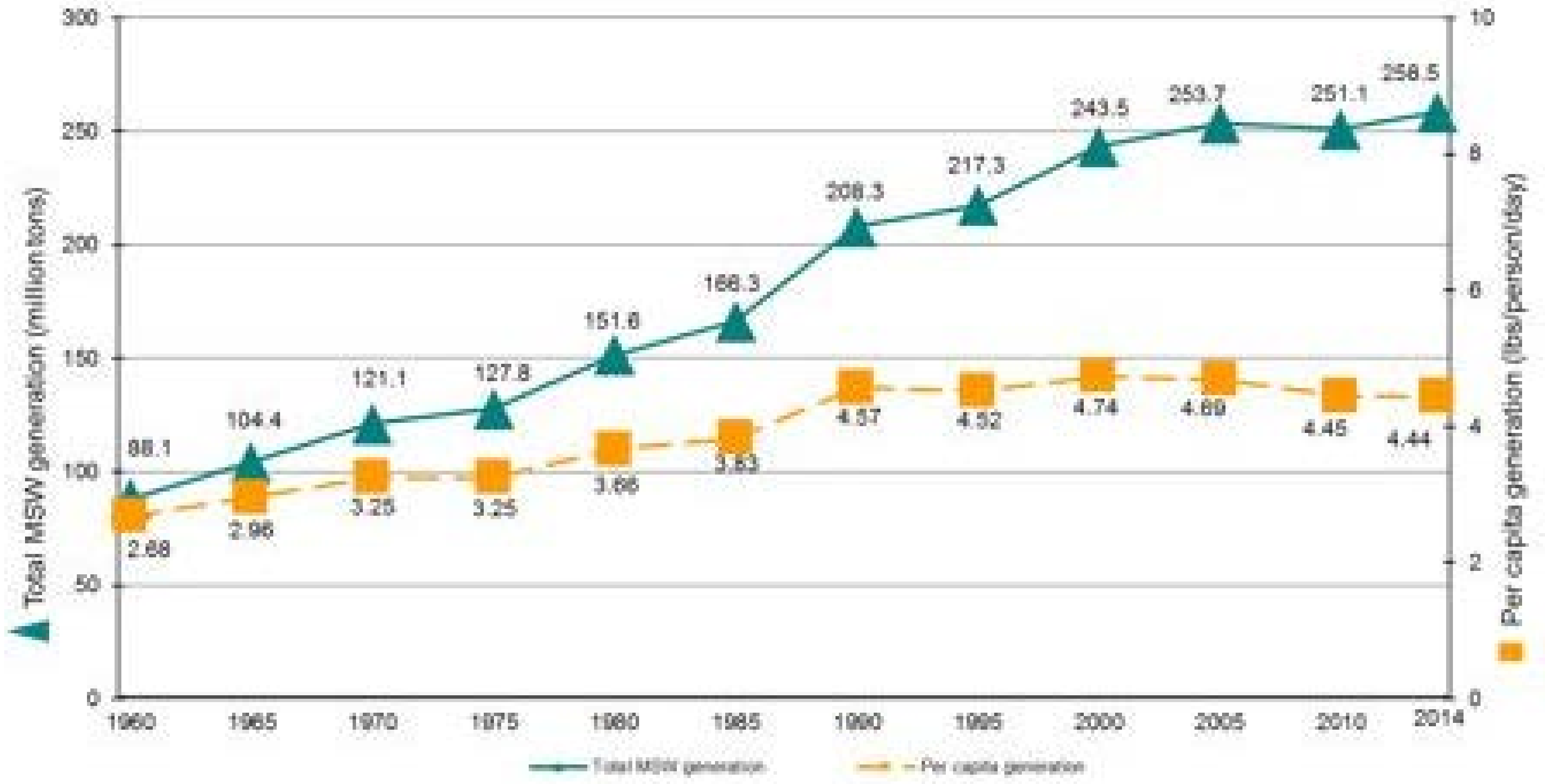
# Seeking the Truth in Refuse, New York Times, 1992

“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.”




# MSW Generation Rates 1960 to 2014

# Some solids waste facts….

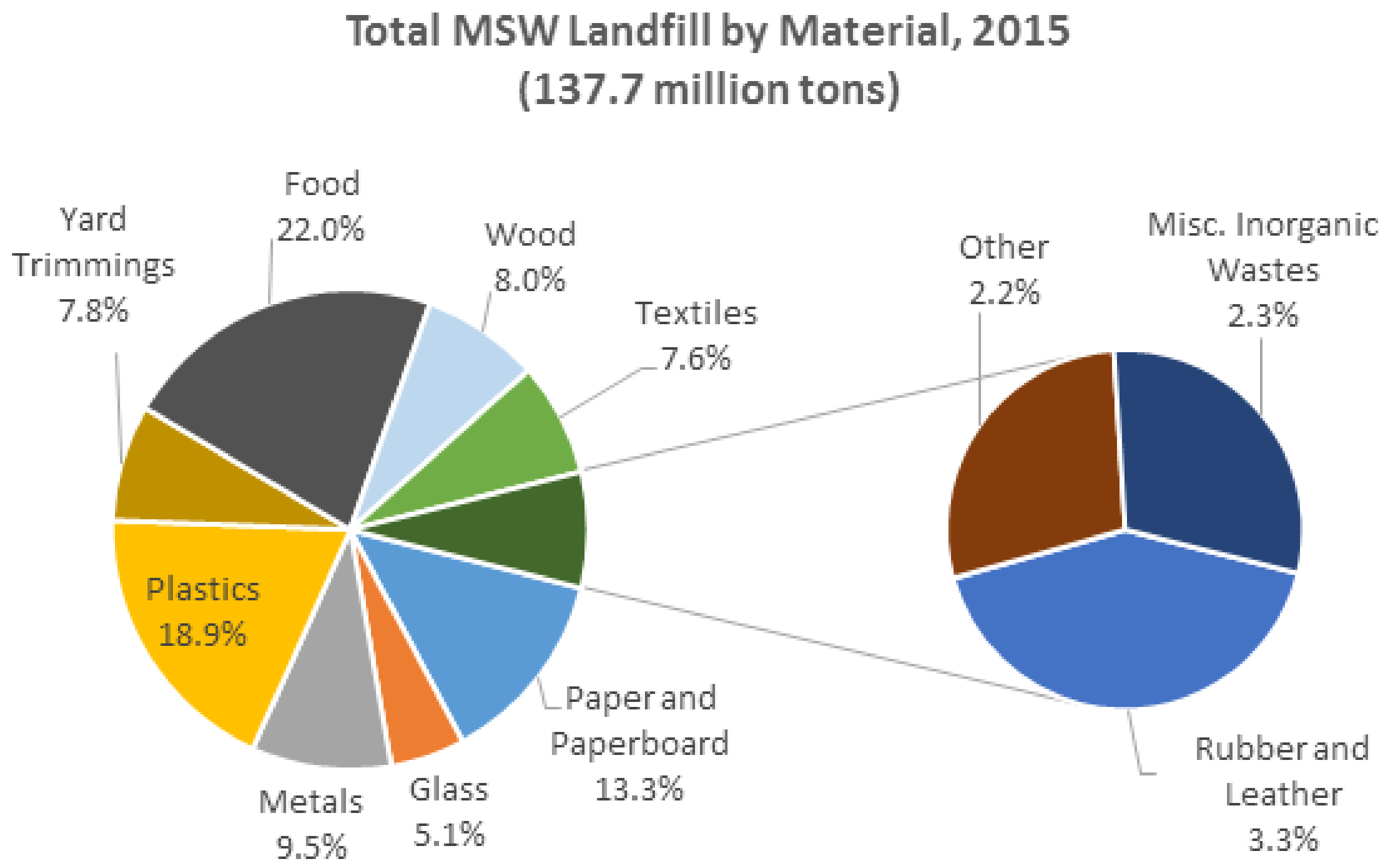
- Over the last few decades, the generation, recycling and disposal of MSW has changed substantially. Generation of MSW increased (except in recession years) from 88.1 million tons in 1960 to 262.4 million tons in 2015. Generation decreased 1 percent between 2005 and 2010, followed by a rise in generation of 5 percent from 2010 to 2015.

- 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.

# What goes to the landfill



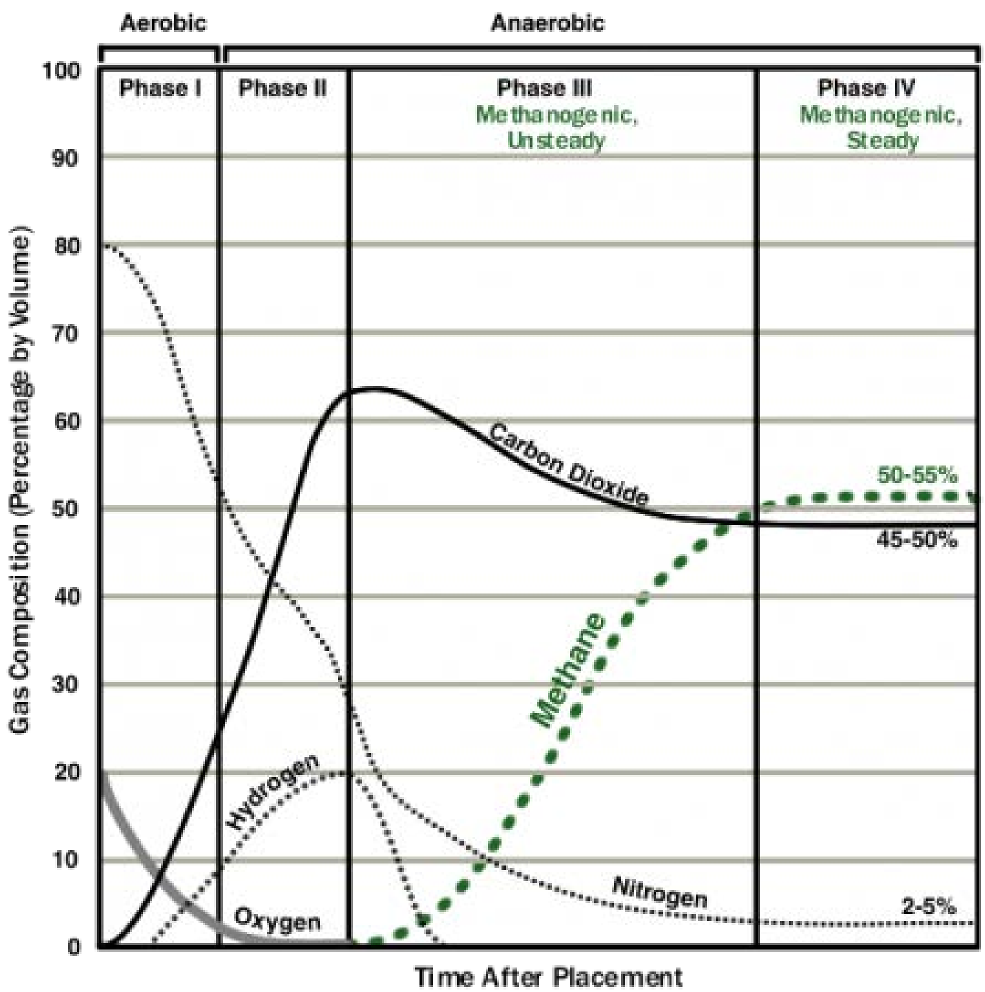

- About 36.39 million tons on food waste is buried in U.S. landfill each year
  - With limited oxygen, water, sunlight, and organisms food waste decomposes very slowly
- The older landfill are not set up to capture methane

https://www.epa.gov/sites/production/files/2018-07/image5.png

# 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.

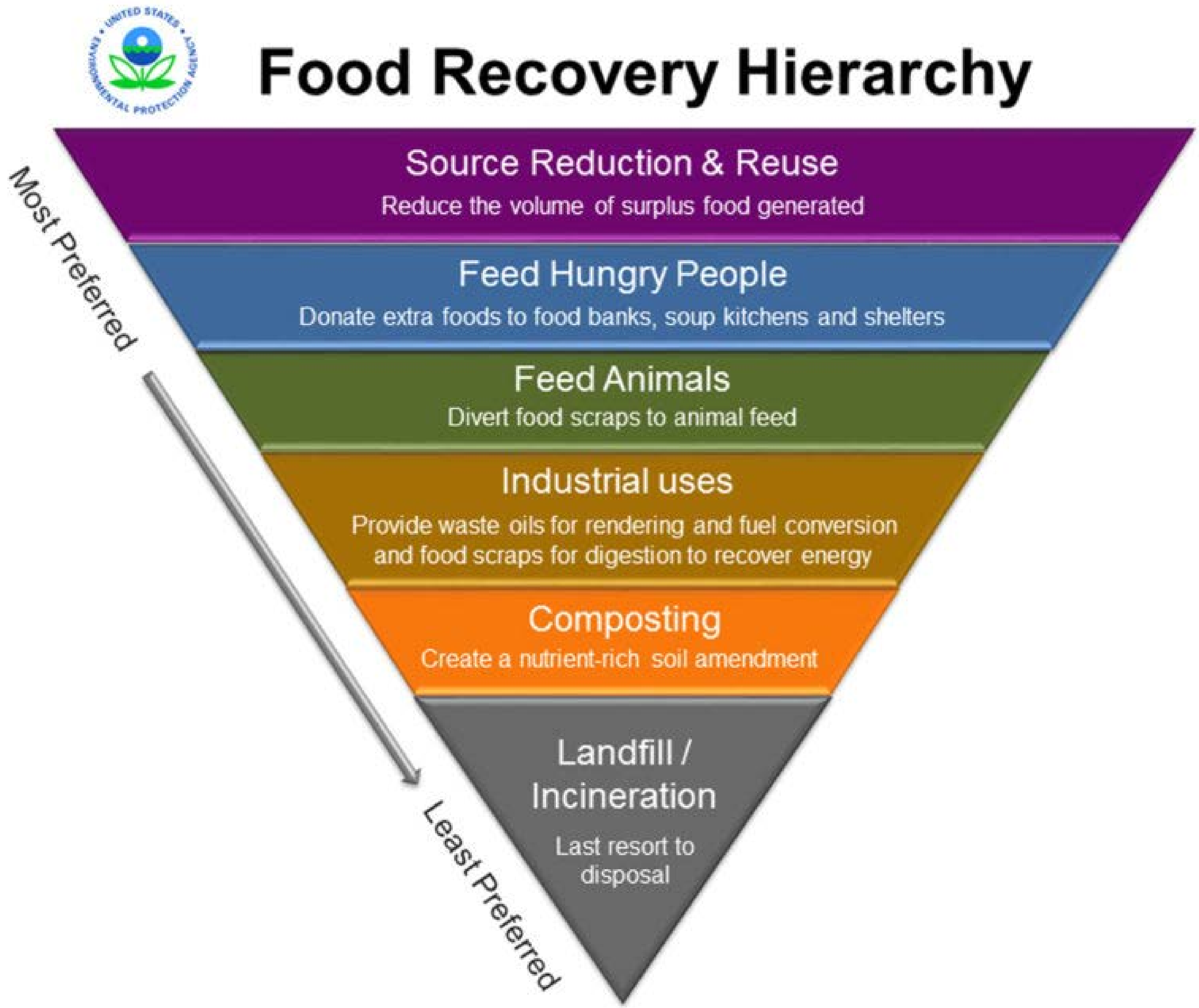


According to U.S. EPA Municipal solid waste (MSW) landfills are the third-largest source of human-related methane emissions in the United States, accounting for approximately 15.4 percent of these emissions in 2015.

# 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!

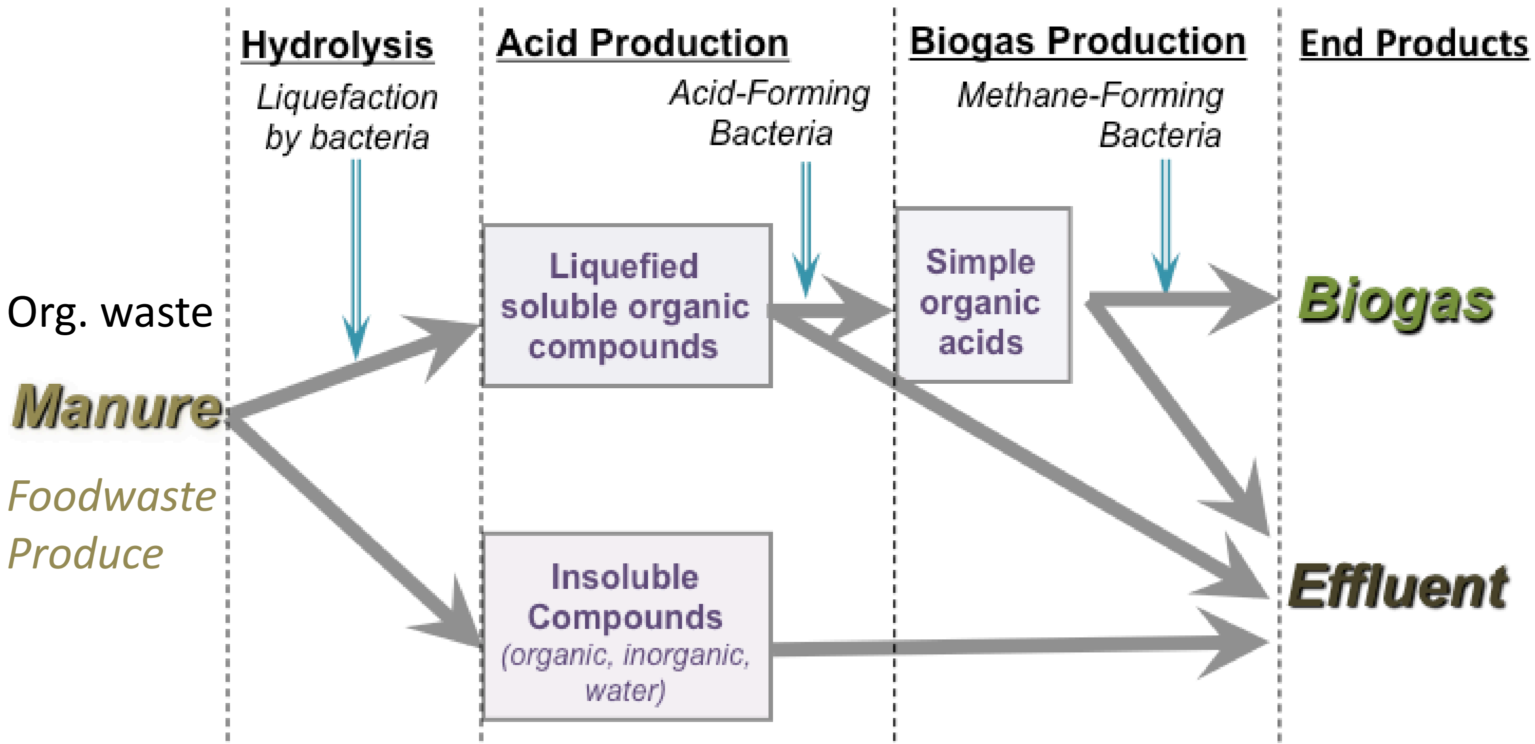
So what should we do with food waste?


Food Recovery Hierarchy
Most Preferred
Source Reduction & Reuse
Reduce the volume of surplus food generated
Feed Hungry People
Donate extra foods to food banks, soup kitchens and shelters
Feed Animals
Divert food scraps to animal feed
Industrial uses
Provide waste oils for rendering and fuel conversion and food scraps for digestion to recover energy
Composting
Create a nutrient-rich soil amendment
Landfill / Incineration
Last resort to disposal
Least Preferred

*Introduction to Anaerobic Digestion*

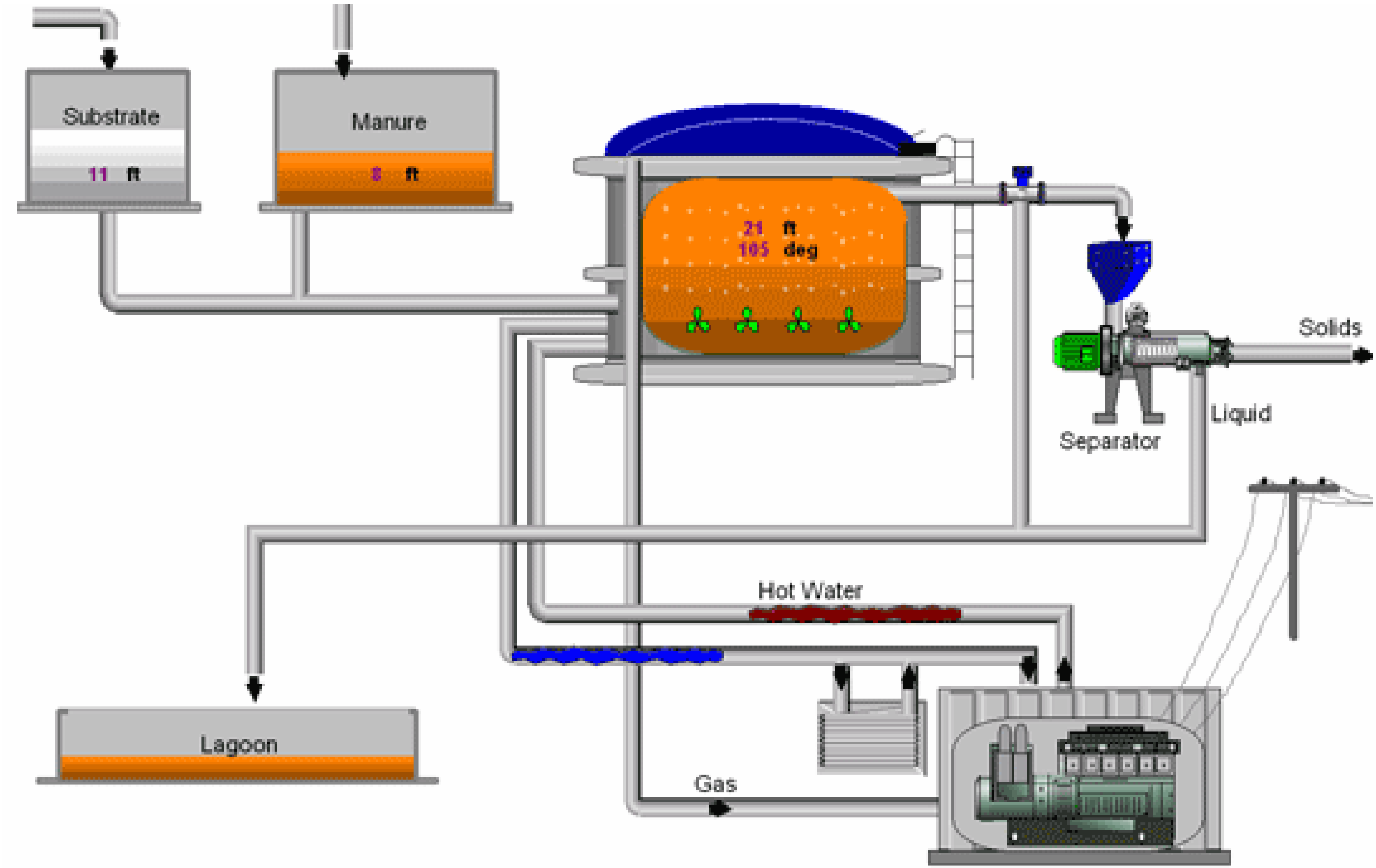
# Process Description

- 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 $ft^3$ 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/$ft^3$
- Average fuel value of propane = 2500 BTU/$ft^3$
  - Propane produces 2.5 times more energy per unit of volume

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

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

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

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

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

# Small Digesters

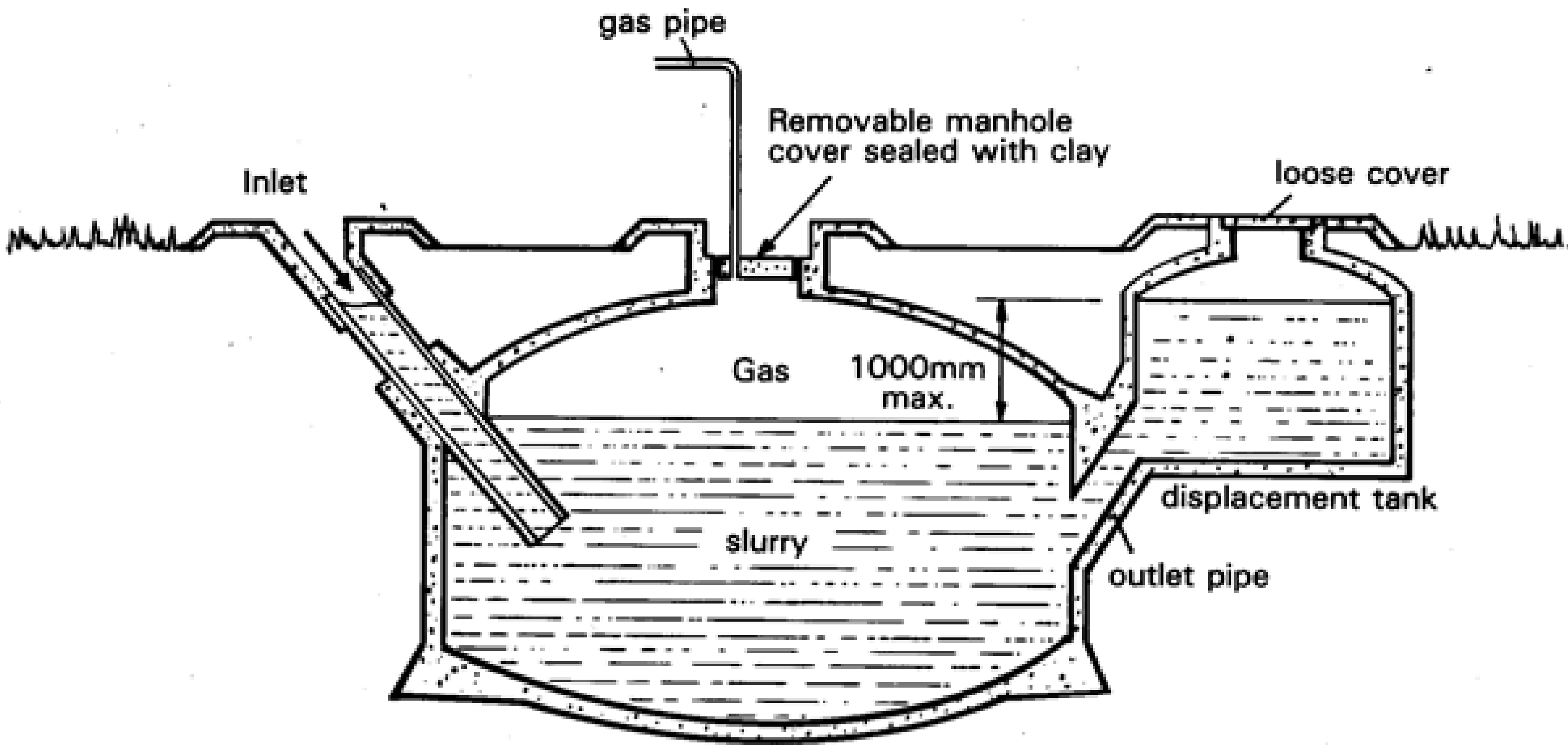
Capacity: 6 liters/day of food waste or 36 liters/day of animal manure.

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

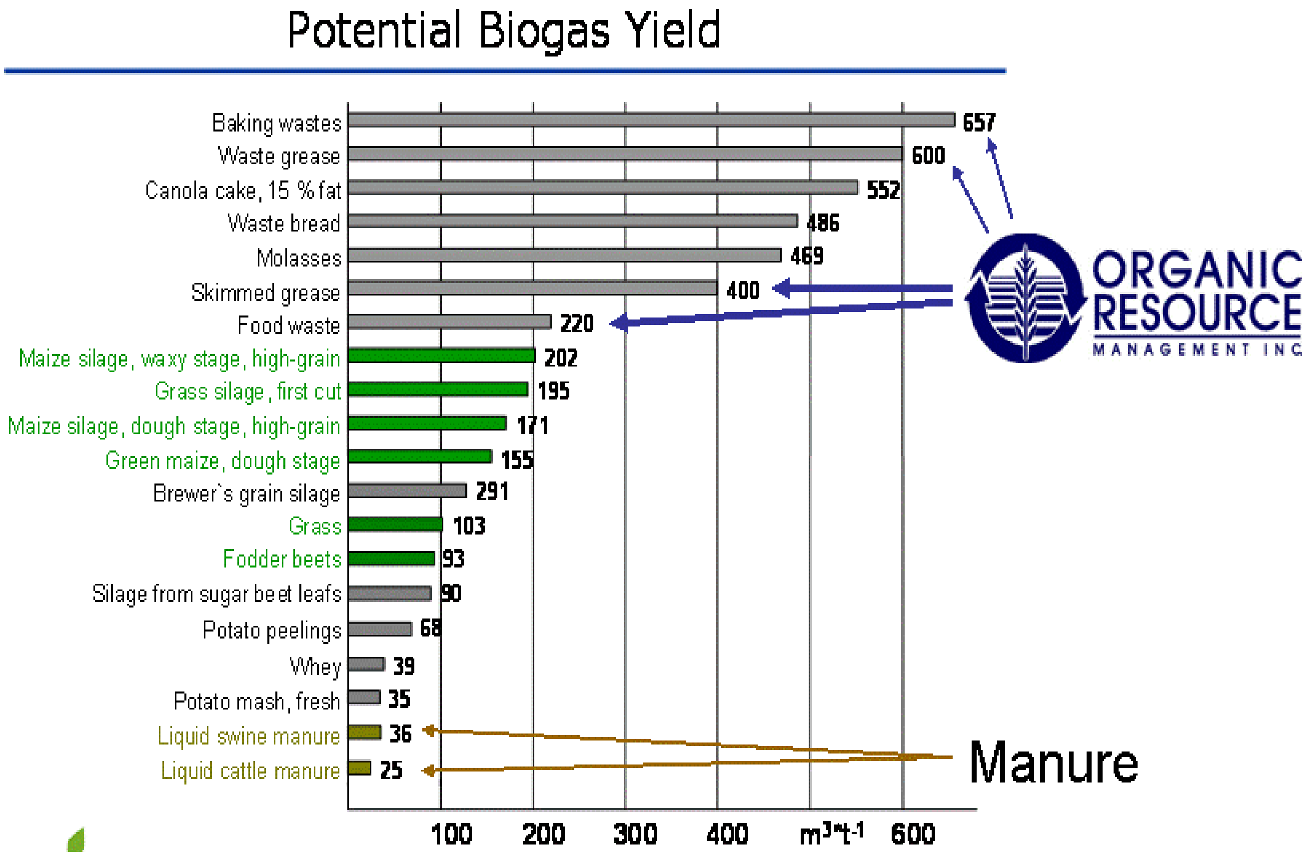
Add this waste to digesters

- ***Wastes that do not***
  - Fiber rich waste such as wood, leaves, etc.
  - Plastics or other refractory organics
  - Inorganic materials (salts, metals, sand, etc.)

Don’t add this waste to digesters

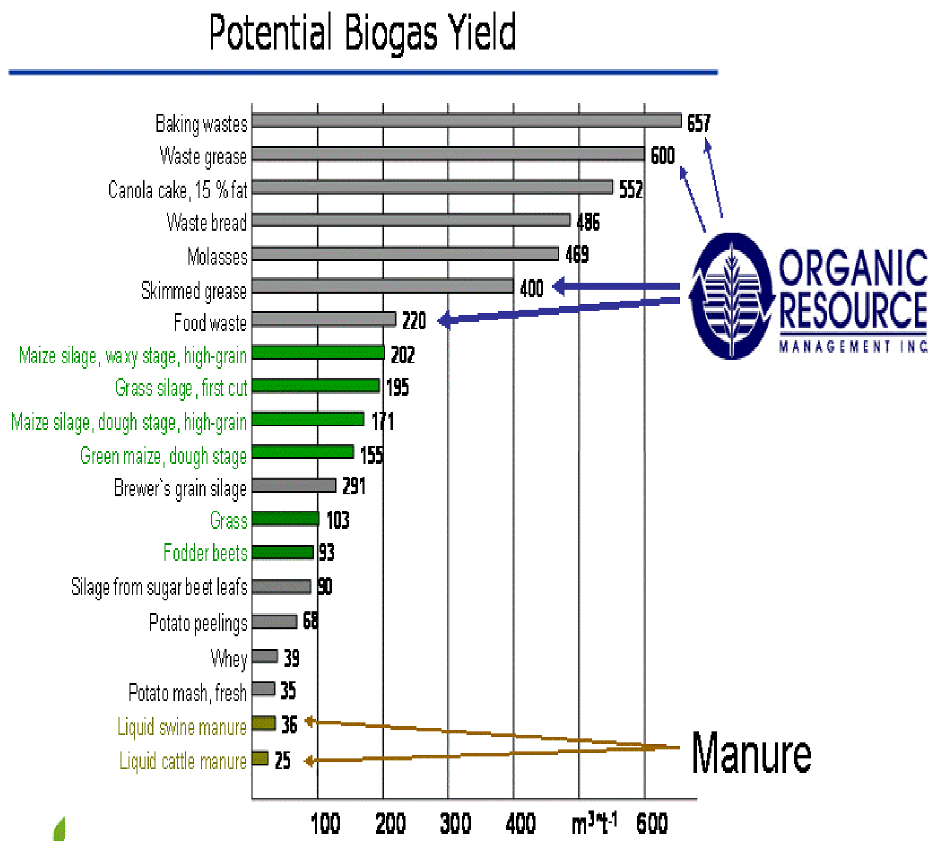
# Food Waste Potential

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



# Biogas Potential Depends on

- Biodgradability
  - 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:

$$0.25\ CH_2O \rightarrow 0.125\ CO_2 + 0.125\ CH_4$$

$$\frac{0.125\ CH_4}{(0.125\ CO_2 + 0.125\ CH_4)} = 0.50$$

50% $CH_4$ content in biogas

Protein degradation in digester:

$$0.015\ C_{16}H_{24}O_5N_4 + 0.159\ H_2O + 0.06\ H^+ \rightarrow 0.117\ CO_2 + 0.125\ CH_4 + 0.06\ NH_4^+$$

$$\frac{0.125\ CH_4}{(0.117\ CO_2 + 0.125\ CH_4)} = 0.52$$

52% $CH_4$ content in biogas

# Stoichiometry Examples

Grease degradation in digester:

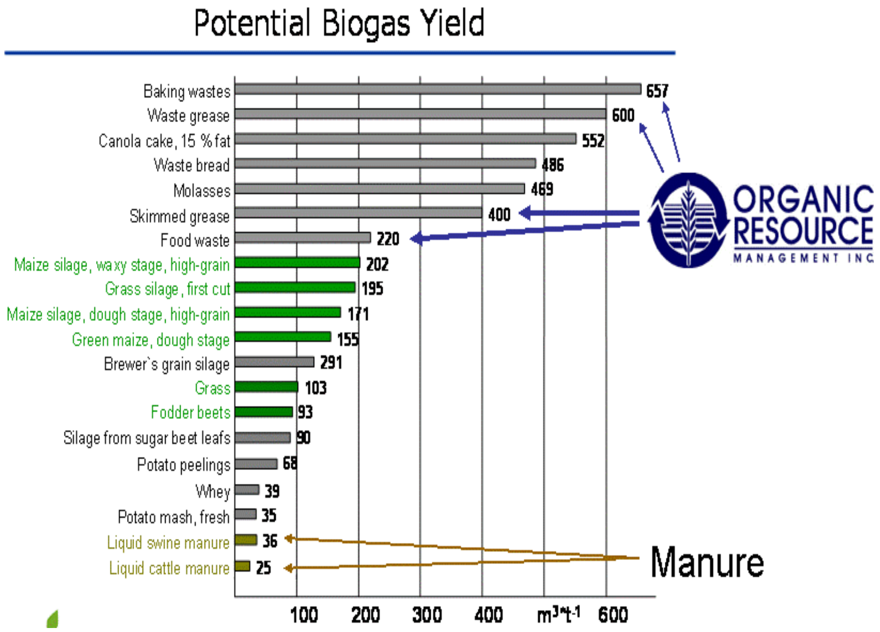
$$0.022\ C_8H_{16}O + 0.076\ H_2O \rightarrow 0.049\ CO_2 + 0.125\ CH_4$$

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

72% $CH_4$ content in biogas

# Food Waste Summary

- Food waste has higher biogas potential then other sources like agriculture and wastewater sludge.
- Carbohydrate waste generates biogas of 50% $CH_4$
- Protein waste generates biogas of 52% $CH_4$
- Grease/Fat waste generates biogas of 72% $CH_4$



# Resource Recovery and Anaerobic Digestion

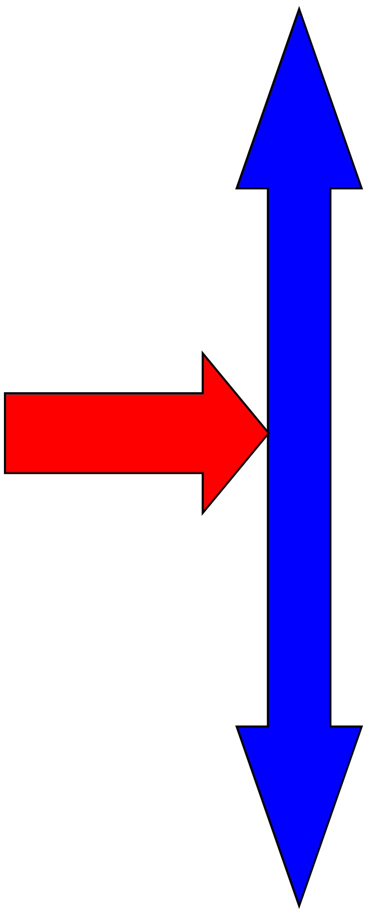
WHY TEACH about it? and

HOW does this topic fit into an EDUCATIONAL CURRICULUM?

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

# 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

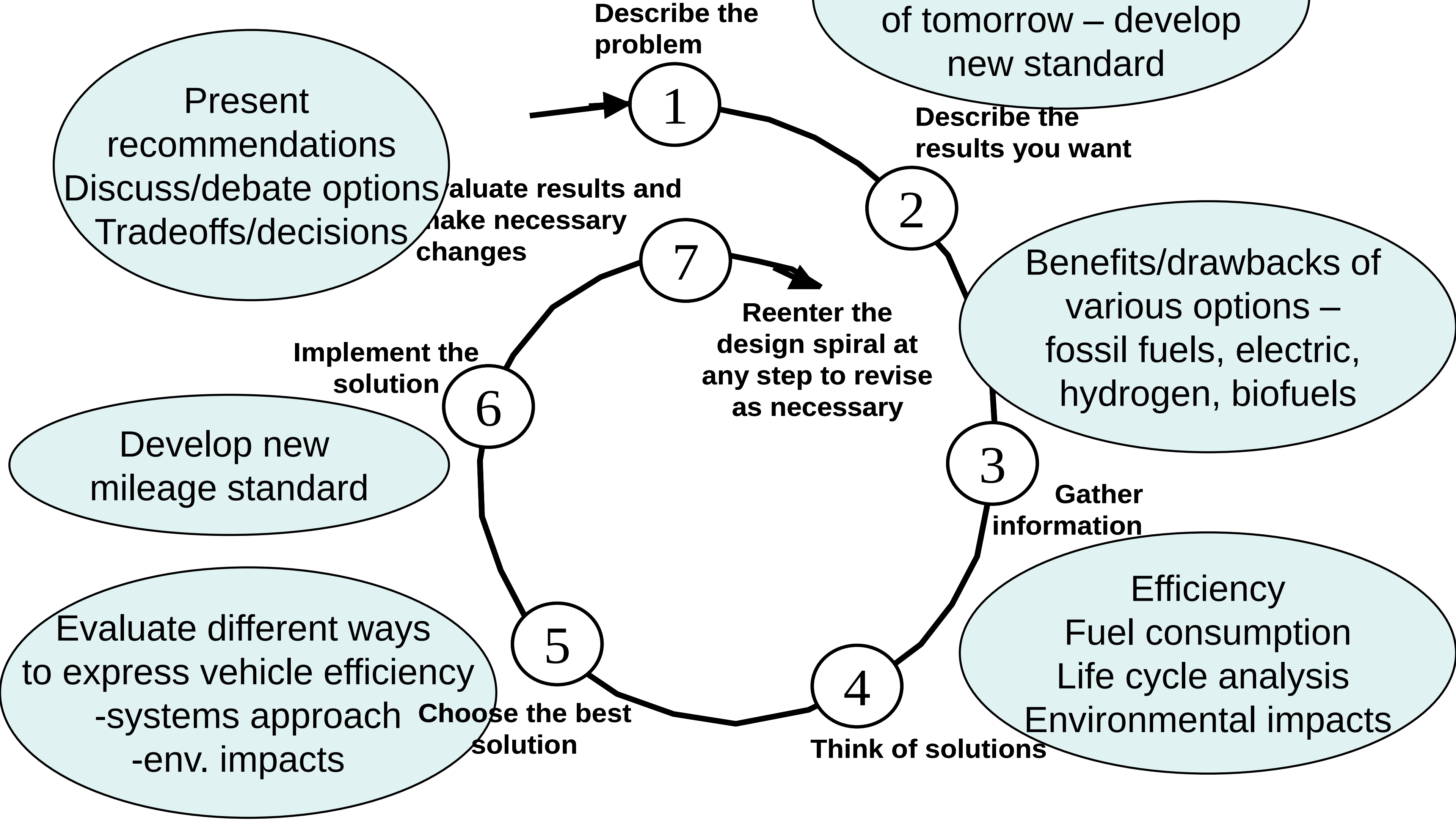
Teacher – Coaches students through ill-posed problem
Students – Active, investigates and solves the problem

## Problem-Based Learning

Torp and Sage, Problems as Possibilities, 2002

# Sample Project-Based Module

## Variation on a theme: Vehicular Transportation

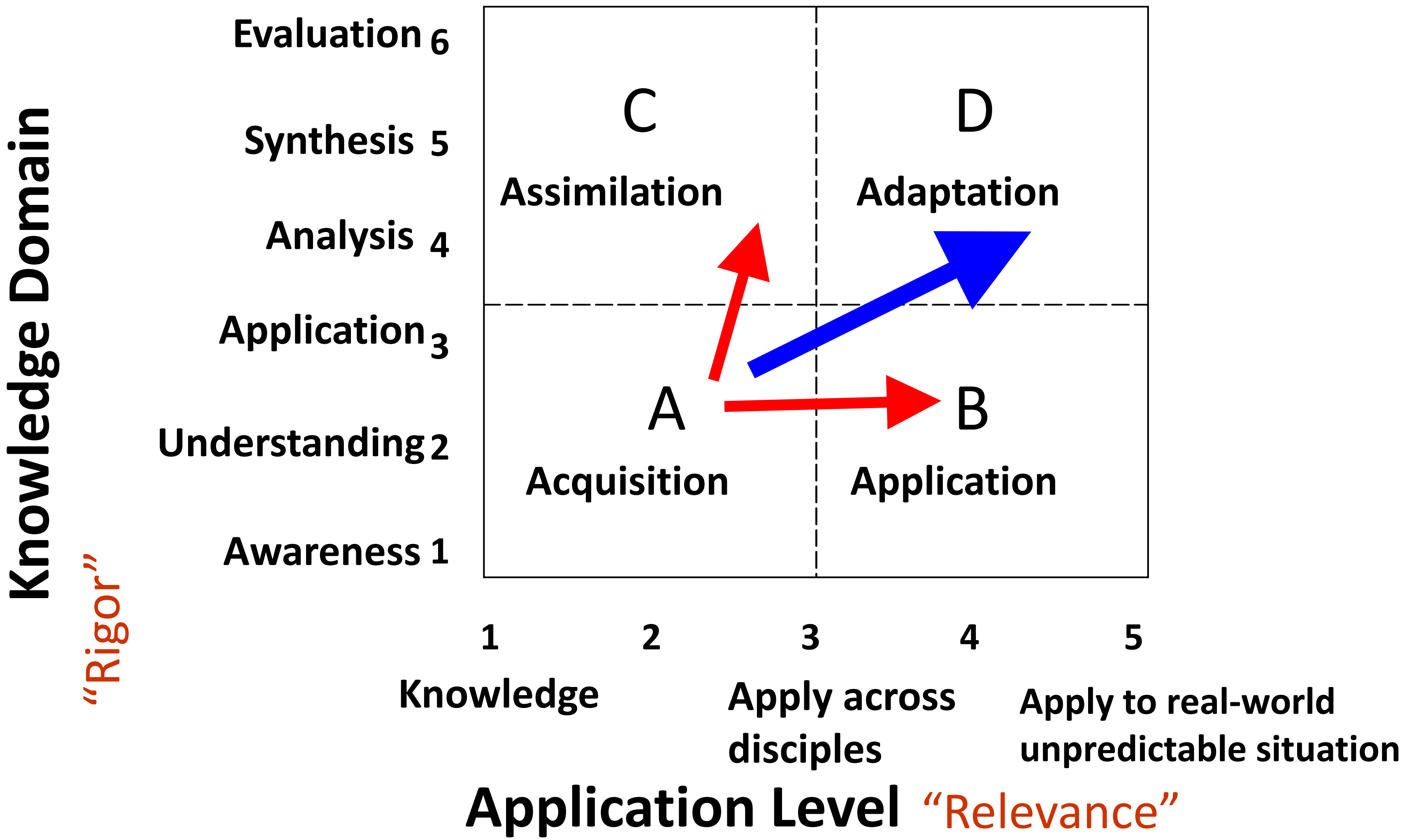


# Project-based Curricula

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

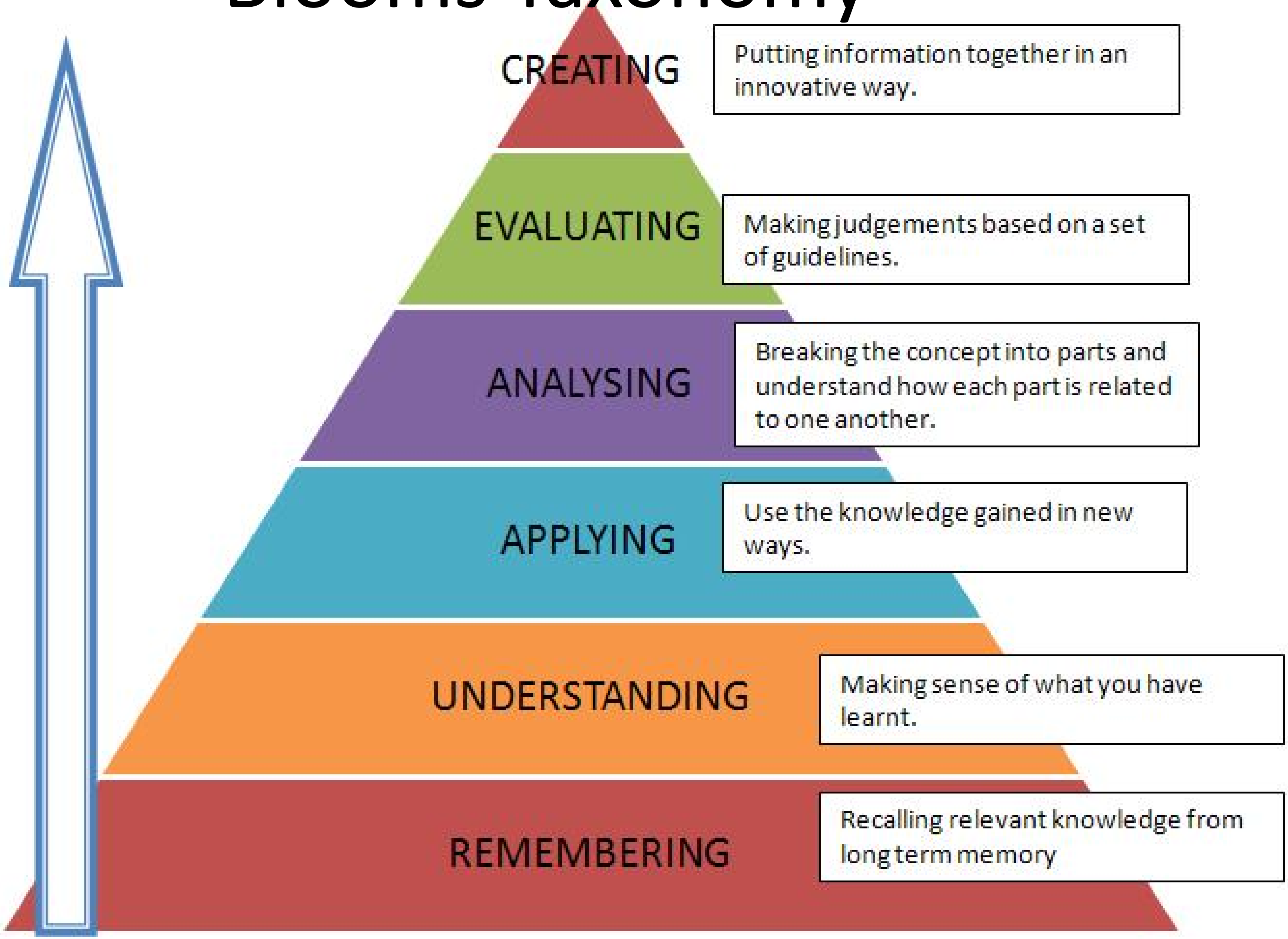
- Engages students in active learning
- Effectively integrates knowledge and skills from other disciplines
- Demonstrates relevance of what students are learning to their lives outside of school

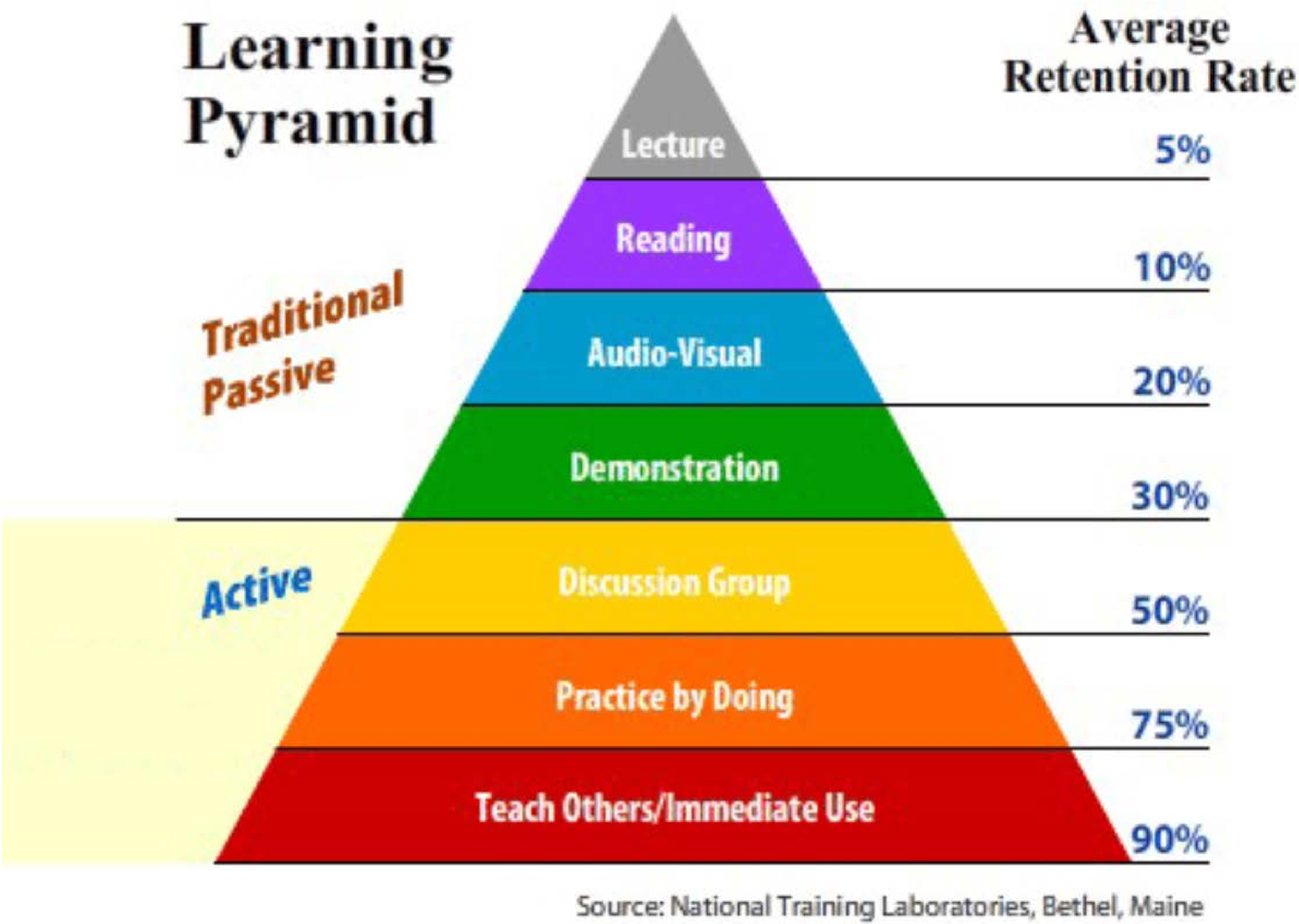
# Rigor/Relevance Framework




Daggett: International Center for Leadership in Education, 2001

# Blooms Taxonomy





Learning Pyramid
Average Retention Rate
Lecture
5%
Reading
10%
Audio-Visual
20%
Demonstration
30%
Traditional Passive
Discussion Group
50%
Active
Practice by Doing
75%
Teach Others/Immediate Use
90%
Source: National Training Laboratories, Bethel, Maine

# 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

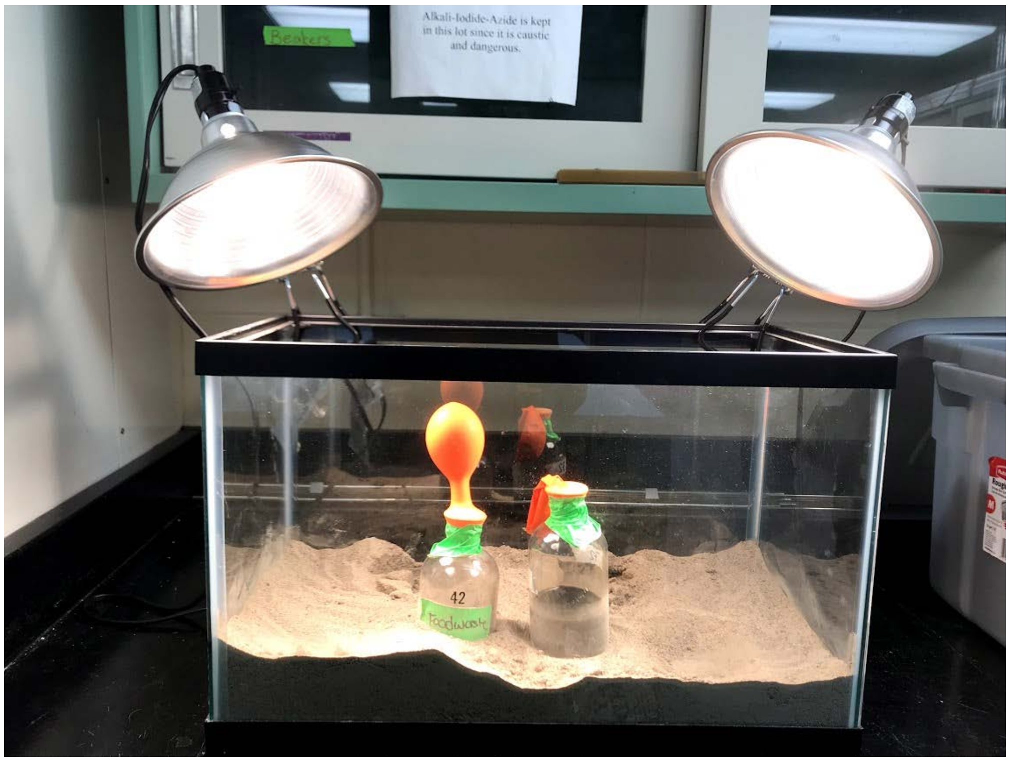
Constellation. An Exelon Company | CANTON CENTRAL SCHOOL DISTRICT | Cornell University Cooperative Extension St. Lawrence County | Clarkson University defy convention

# 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

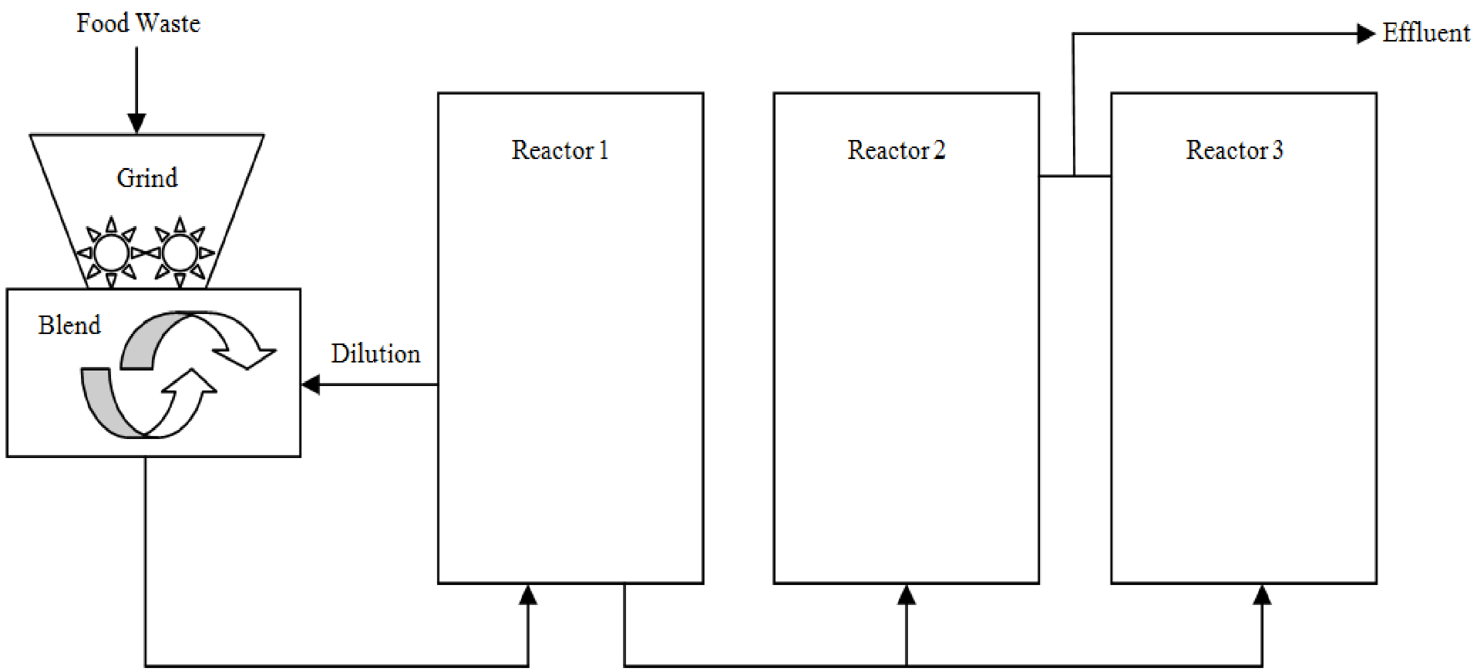
Cornell Cooperative Extension Digester

# Clarkson’s Mixed Food Waste

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

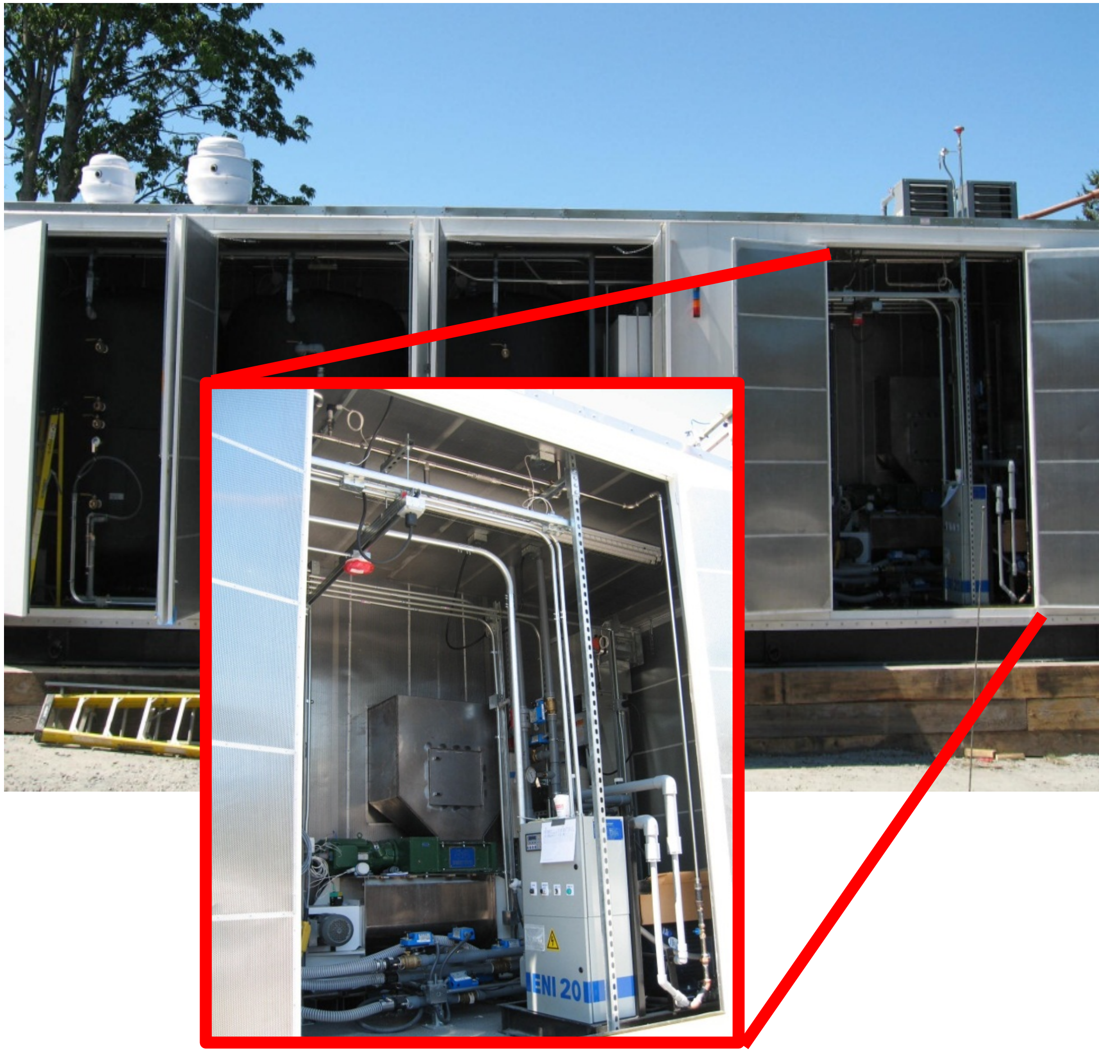
# Clarkson's Digester Operation

- Separate mixing cycles for each stage.



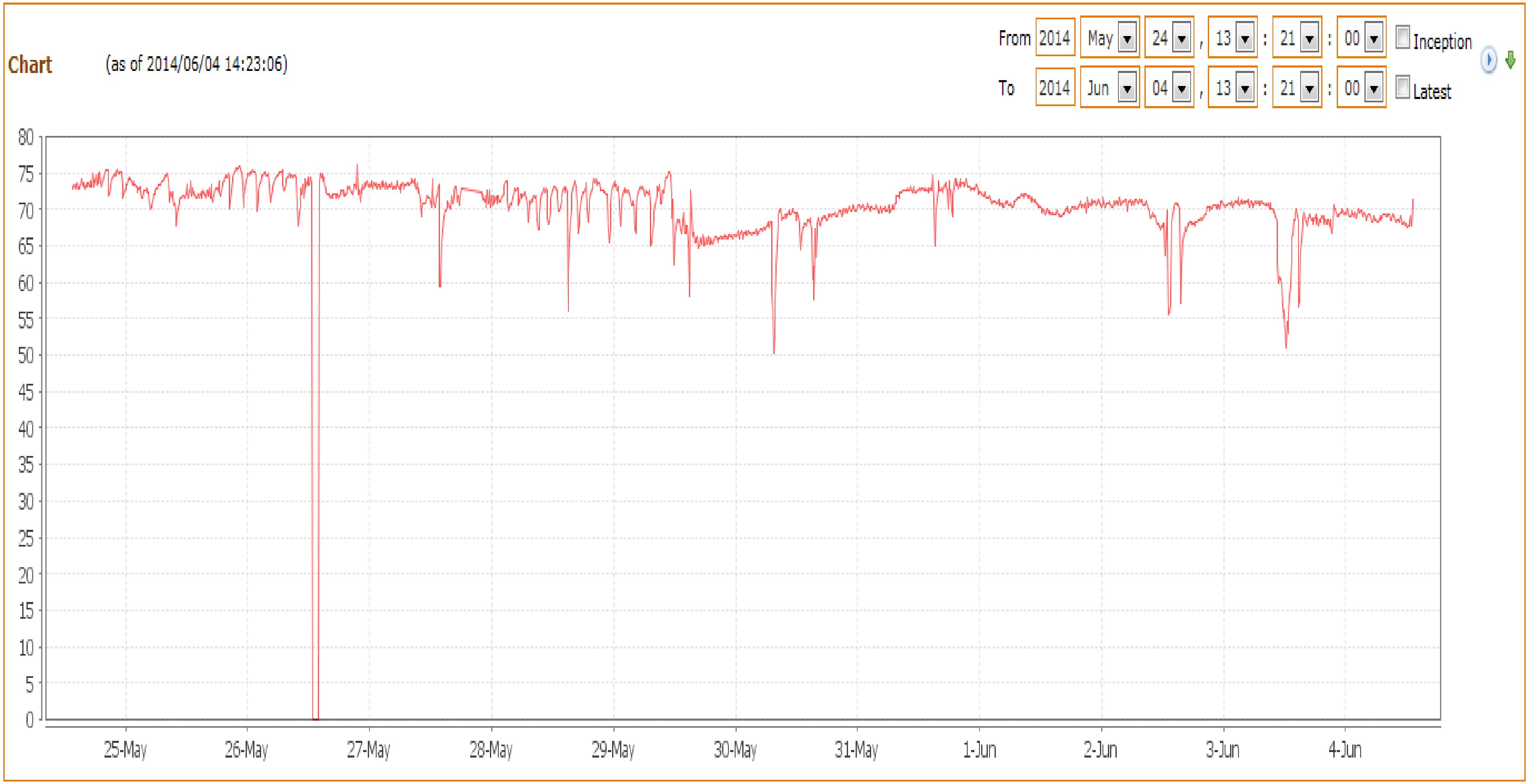
# Anaerobic Digester

- 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



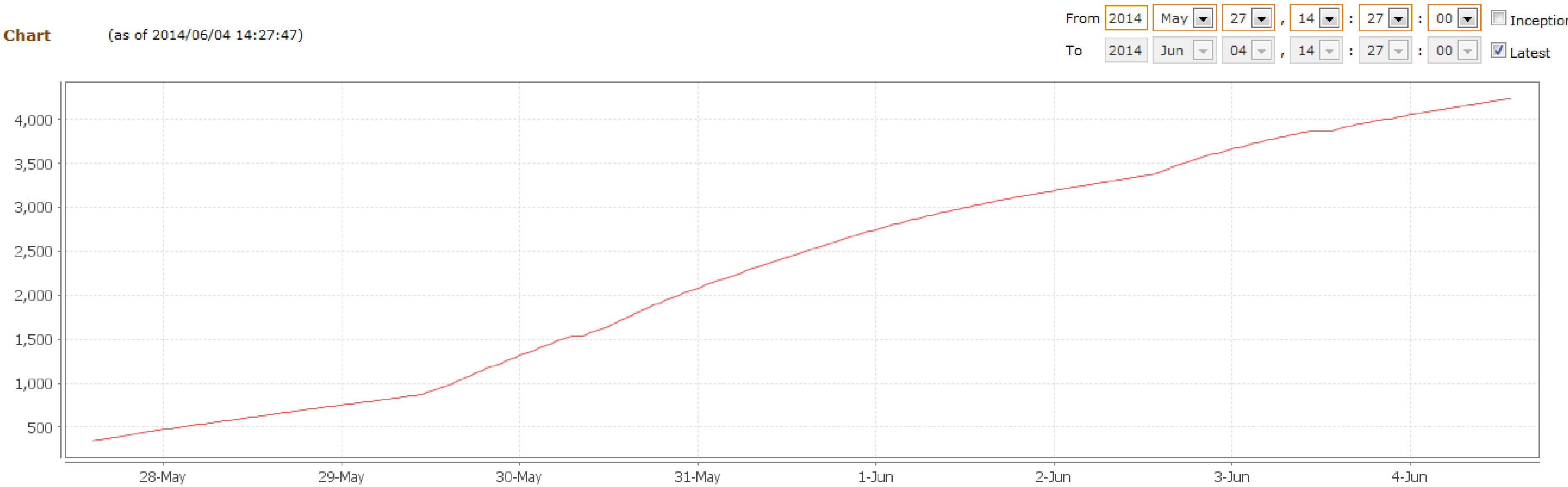
Anaerobic digester
Up to 300 kg food waste/day
Transformed into biogas
Savings: $200/ton food waste diverted from landfill

# Methane Content




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

# Biogas Production




Approximately 500 $ft^3/d$ feeding an average of 113 lbs/d at 12±8 % VS

Approximately 1,362±544 L $CH_4$/kg VS added

Or 272 $m^3$ 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

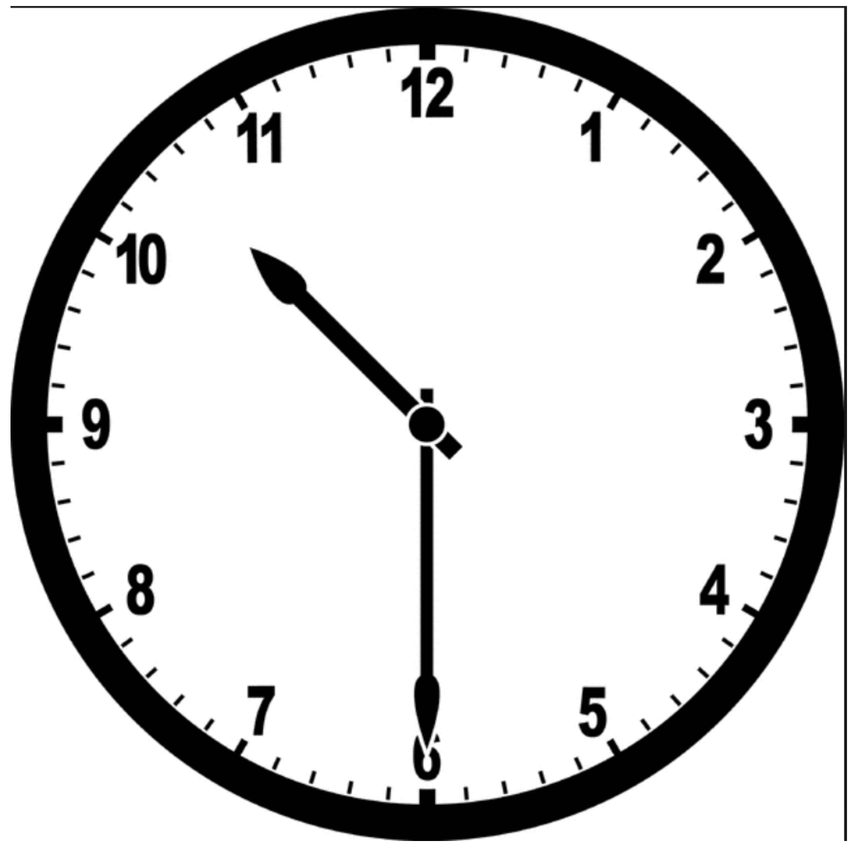
1.2 Mgal Digester, feed by 2,500 cows
400 kW Power generation +
Bedding recovery
Low odor effluent spread on fields

And on the smaller scale

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

# Your Own Field Trip

… and break …




Let’s reconvene at 10:30

# Today's AGENDA

**10:30-12:00**

3 classroom activities:

- What's in your Trash?
- My Bacteria Has Gas! (2 in parallel)


Balloon Bottle

Gas Sampling Bottle

**12:00 LUNCH**

# Today's AGENDA

**12:45-2:00**

Group/Independent break-out

*Time to work on assimilating what you have experienced in the activities and adapting it to your own classroom*.

Ask yourself:

→What can my students do in the space that I have?

→What learning objectives would I like to accomplish with this activity?

*Examples include hypothesis formation/testing; data collection, analysis and interpretation; and/or objectives related specifically to your discipline – biology, chemistry, ecology, earth science, climate change, global systems, etc …*

**2:00 – 3:00**

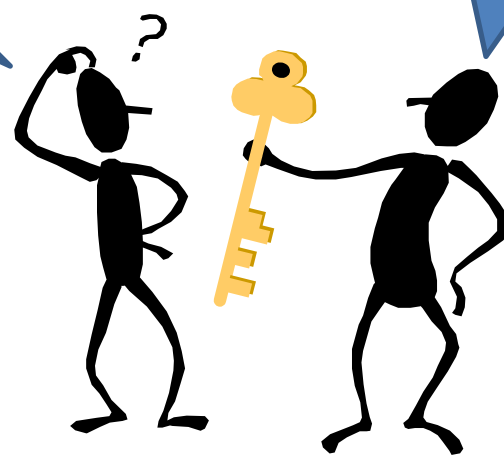
Sharing out

# Today's outcome

- Project staff and teachers sharing expertise; communication and networking today and in future
- ***Project-based*** activities developed for <u>your</u> classroom
  - academic ***rigor*** and ***relevance***
  - Integrate across STEM
- ***Finished curriculum modules/activities*** submitted to us will be shared through BOCES; eligible for stipend -- $100 for module; $100 for classroom application and followup

Where do we start?

Understanding the Problem!



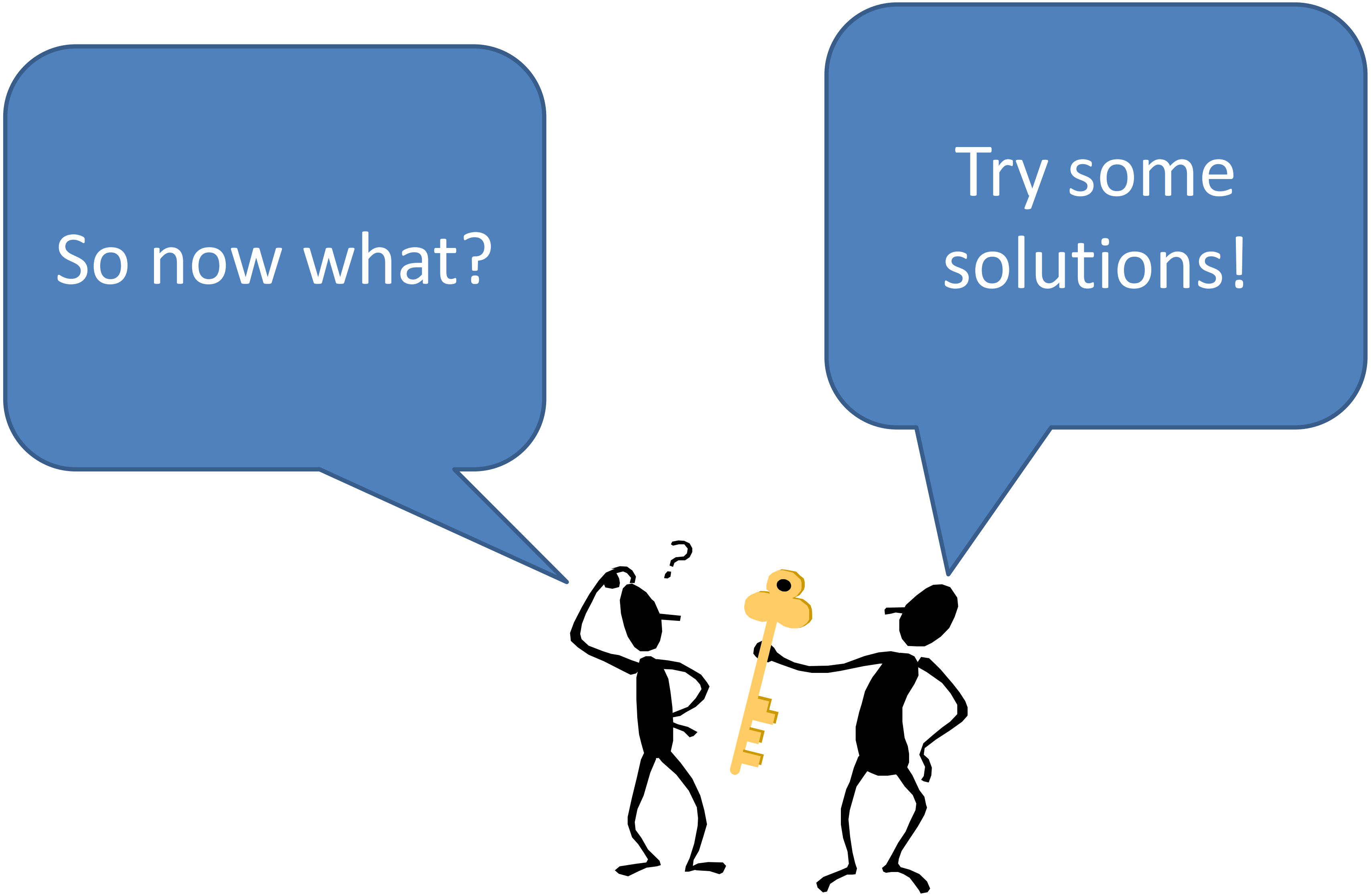
**LET'S GET STARTED!**

# Let’s get Started!

## Where Does the Trash Go?

[Landfill and Garbage video] (~4 min)

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




**AND THEN …**

# 2 parallel activities

My Bacteria has Gas!


# Wrap up

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

# Questions/Comments?

Contact us:

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