# Biomass Feedstock-based Technology

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NYS SBDC/NYSERDA

The Directions of Renewable Energy

Shaping The Future of Business on Long Island

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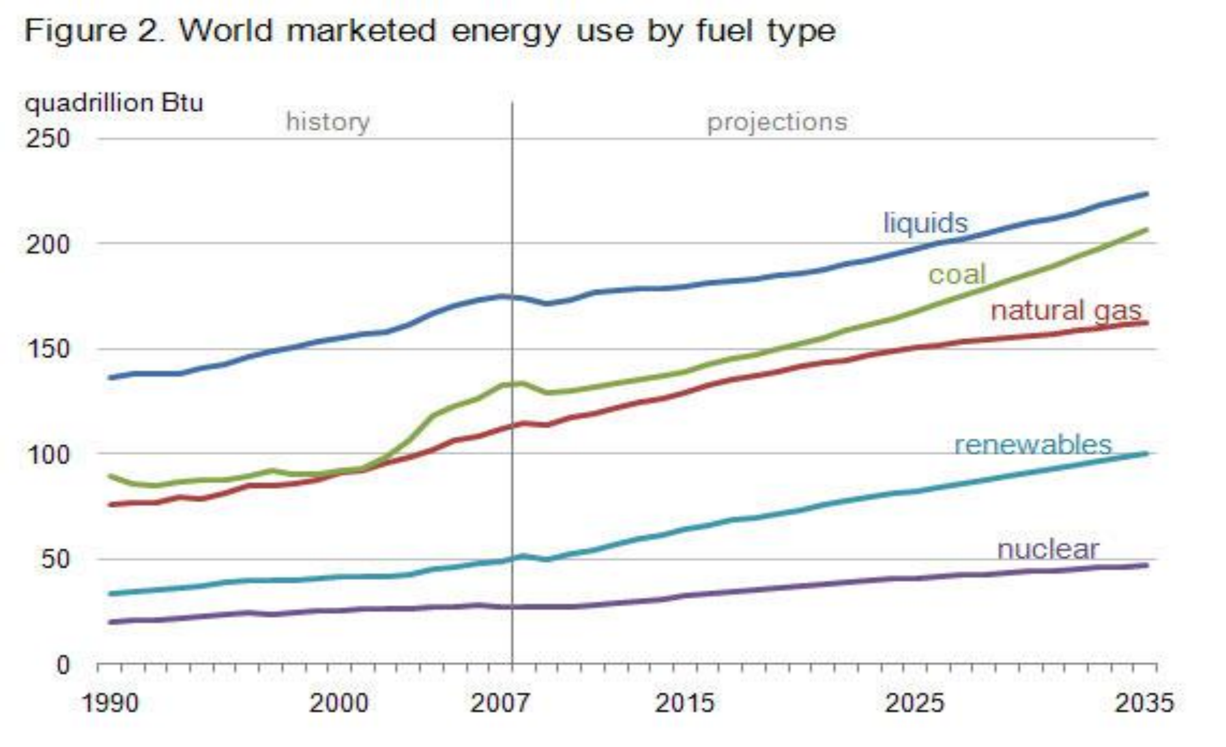
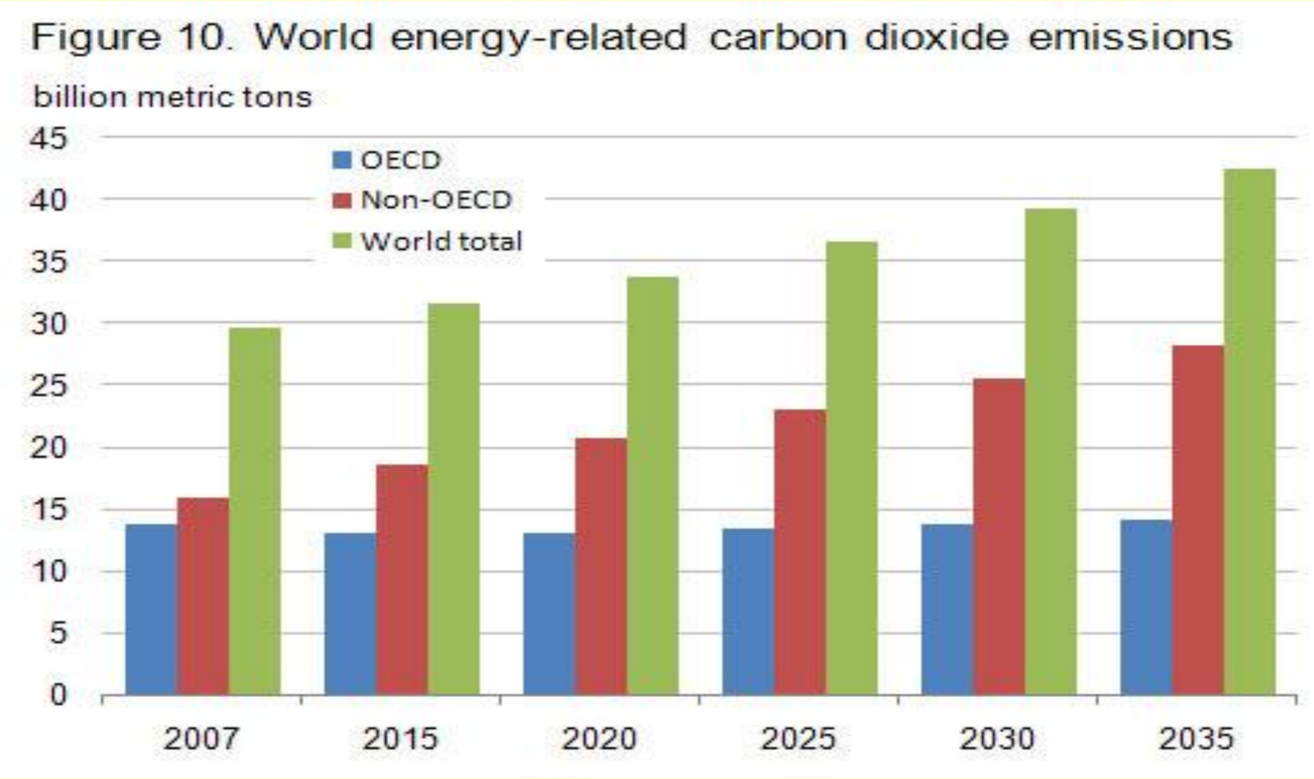
# World Energy Consumption- Projected




**Data source: US DOE- EIA (2010)**

# Worldwide $CO_2$ Emissions




**Data source: US DOE- EIA (2010)**

# Sectors that directly affect the public

**Direct**

- Cars: Gasoline, diesel
- Home heating: Natural gas or Oil
- Electricity

**Distributed**

- Jet fuel
- Diesel: Trucks, buses (transport food delivery, etc)

# Topics Covered

Topic1: Biofuels: definition and background
Topic 2: 1st Generation biofuels
Topic 3: 2nd Generation biofuels
Topic 4: New York State Initiatives
Topic 5: Relevance to Long Island Initiatives

# Topic 1

# Biofuels: Definition and Background

# Background

**Definition:**
**Fuels derived from $CO_2$-net neutral feedstocks.**

**Impact Sectors**
- **Transportation**
- **Utilities**
- **Manufacturing**

**Gasoline Consumption:**

| Year | Billion gallons |
|---|---|
| 2007 | 372 |
| 2009 | 346 |

**Goal: Replace 75% oil imports by 2025.**

# Topic 2

## 1st Generation Biofuels

- Bioethanol
- Biodiesel

# Biofuels

| Target Fuel | 2005 | 2012 | 2025 |
| --- | --- | --- | --- |
| | (billion gallons/year) | | |
| Bioethanol [U.S.]* | 5 | 7.5 | 60 |
| Biodiesel [U.S.]** | 0.6 | 1.3 (2008) | --- |
| Bioethanol [Brazil]** | 4.5 | | |

*Corn based
**Data from NBB
***Sugarcane based (45% of the world total).

# Topic 3

# 2nd Generation Biofuels

# Drivers

U.S. Energy Independence and Security Act of 2007:
136 billion L of renewable biofuels by 2022.
- corn-based ethanol: 57 billion L
- At least 61 billion L from cellulosic

**EPA Ruling- 01/21/2011**
- Vehicles 2001 or later: up to 15% ethanol

# Feedstocks

- Biogas
- Algae
- Cellulosic Materials

# Biogas:
# A Natural Source of Bio-methane

# Animal Waste

| Animal | Animal weight (lbs) | Total manure & urine (gal/day) | Biogas production* $ft^3$/head/day |
|---|---|---|---|
| Dairy Cow | 1400 | 12.5 | 46.4 |
| Beef Feeder | 800 | 6.1 | 27.6 |
| Market Hog | 135 | 1.35 | 3.9 |
| Poultry Layer | 4 | 0.032 | 0.29 |

Advantages

- Readily biodegradable organic matter content of manure.
- Reduction of odor by 50-98%.
- Reduction of pathogens by 90%.

Courtesy: M. Smith, USDA, 2009

# MSW

Composition

- 70-80% of MSW is "organic"
- Landfills: 55% US waste

  3 lbs $person^{-1}$ $day^{-1}$

  50% $CH_4$, 50% $CO_2$

  6.2-270 $m^3$ $tonne^{-1}$

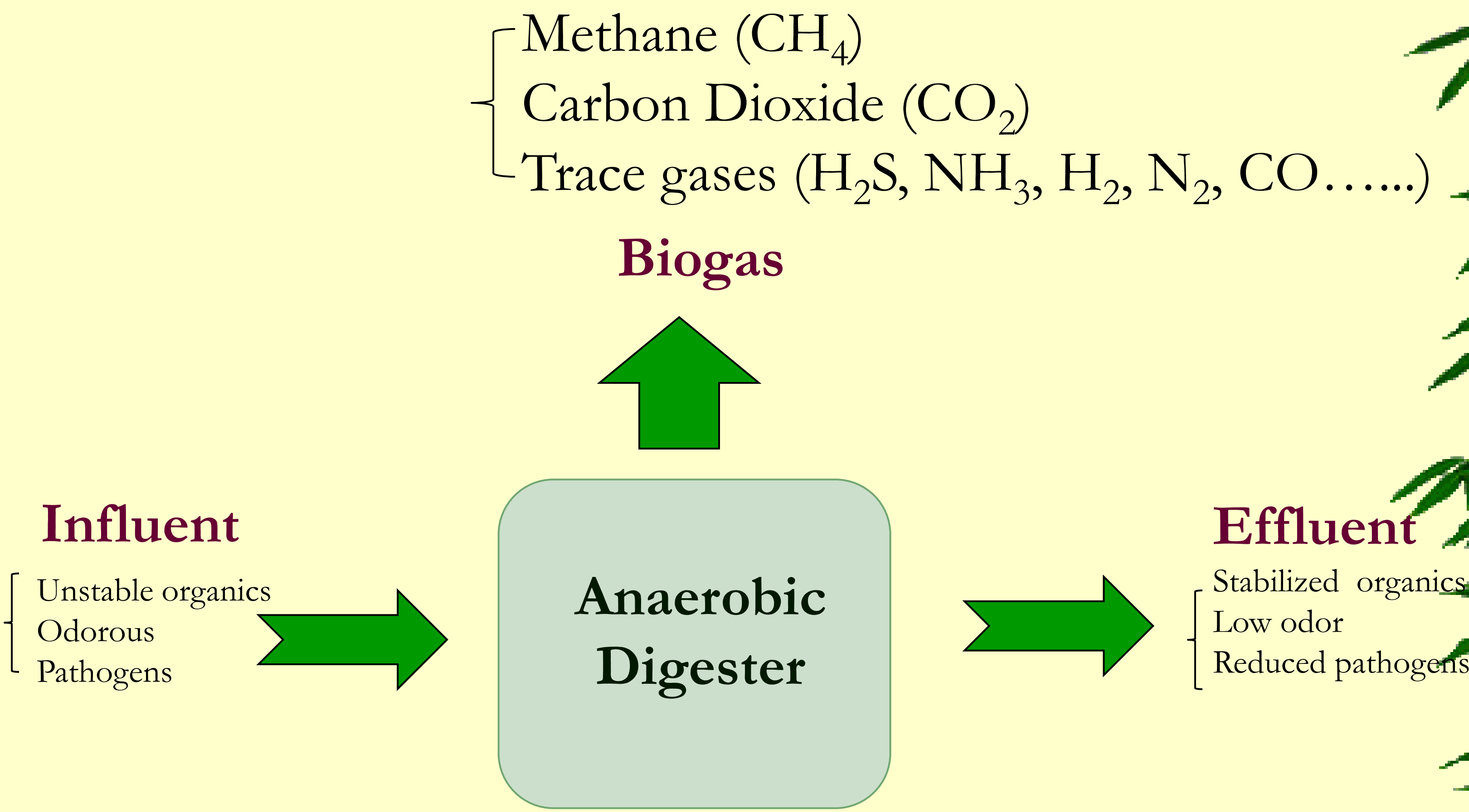
  (3.1-135 $m^3$ $person^{-1}$ $yr^{-1}$)
- Other processing feasible
- Source separation advantageous

Advantages

- For a landfill: reduces GHG impact, odor control
- Other processes: residues may have value

**Courtesy: USEPA 2008, USEPA LMOP**

# Anaerobic Digestion (ASD) Process




Courtesy: M. Smith, USDA, 2009

# Biogas Composition

| Component | Content |
|---|---|
| $CH_4$* | 55-70 % by vol. |
| $CO_2$* | 30-45% by vol. |
| $H_2S$* | 200-4000 ppm by vol. |
| $NH_3$** | 0-350ppm |
| Humidity*** | Saturated |
| Energy Content* | 20-25 $MJ/m_3$ |

*RISE-AT (Regional Information Service Center for South East Asia on Appropriate Technology), 1998. Review of current status of anaerobic digestion technology for treatment of municipal solid waste.
** Strik, D.P.B.T.B. et al., 2006. A pH-based control of ammonia in biogas during anaerobic digestion of artificial pig manure and maize silage. Process Biochemistry 41, 1235-1238
*** Rakičan, 2007. Biogas for farming, energy conversion and environment projection

Courtesy: M. Smith, USDA, 2009

# Biogas: Challenges

- Economical method to extract bio-methane from biogas.

# Algae- A natural source of Bio-oils

Ref.: Pienkos et al., IEEE Spectrum, November 2010

# What is Algae?

- Algae are microscopic organisms that are oil factories.
- Algae uses sunlight to make oils:

  $CO_2 \rightarrow$ Sugars $\rightarrow$ Oils

- Oil yields vary with algae strain (~30,000) but can be as high as 50%.

 - Soybean: 500 L oil/hectare/year

- Algae: 9,000 – 47,000 L oil/hectare/ year

- Oil is very similar to vegetable oils.
- Energy density: similar to gasoline whereas ethanol is lower.

# Algae- Advantages

- Algae can be grown using land and water unsuitable for plant or food production, unlike some other first- and second-generation biofuel feedstocks.
- Select species of algae produce bio-oils through the natural process of photosynthesis — requiring only sunlight, water and carbon dioxide.
- Algae have the potential to yield greater volumes

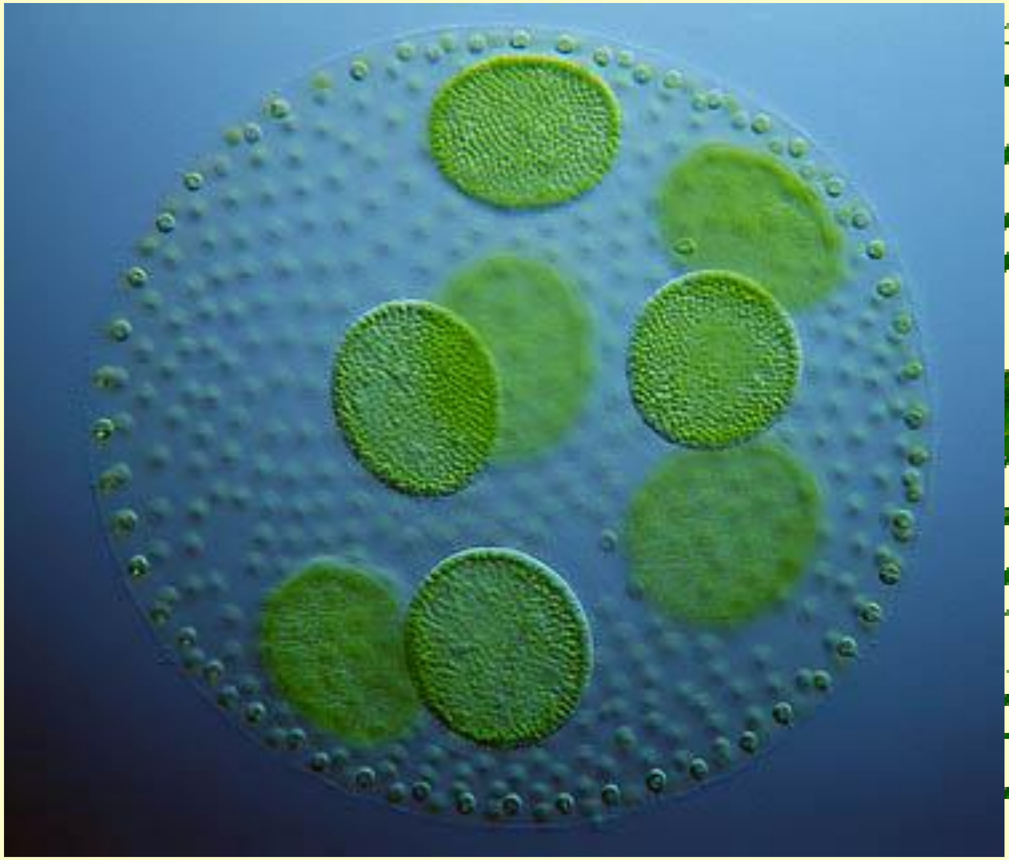
(2000 gallons) of biofuel per acre per year of production than other biofuel sources. Other sources yield lower.

- Palm: 650 gallons
- Sugar cane: 450 gallons
- Corn: 250 gallons
- Soy: 50 gallons

# Algae- Advantages

- Algae highly productive. Large quantities of algae can be grown quickly, and screened rapidly.
- Bio-oils from photosynthetic algae could be used to manufacture a full range of fuels: gasoline, diesel and jet fuel.
- Growing algae consume carbon dioxide; this provides greenhouse gas mitigation benefits.

# Algae Production-I: Open Shallow Ponds



# Algae Production-II: Photobioreactors

# Algae Production-III: Fermentors

- Can be grown in stainless steel tanks but not via photosynthesis.

- Add sugars, very similar to ethanol

*Not of interest*.

# Bio-Oil form Algae: Challenges

Present technology:
2010 $: 10 - 35 / gallon oil equivalent

- Screening for novel strains that can grow quickly and efficiently.
- Minimize water losses during growth (re.: open ponds)
- Minimize: 1) growth of useless competitors (weeds), 2) pathogens, and 3) predators.
- Dewatering after growth: 1 g algae/L water
- Product focus: diesel, gasoline and jet fuel

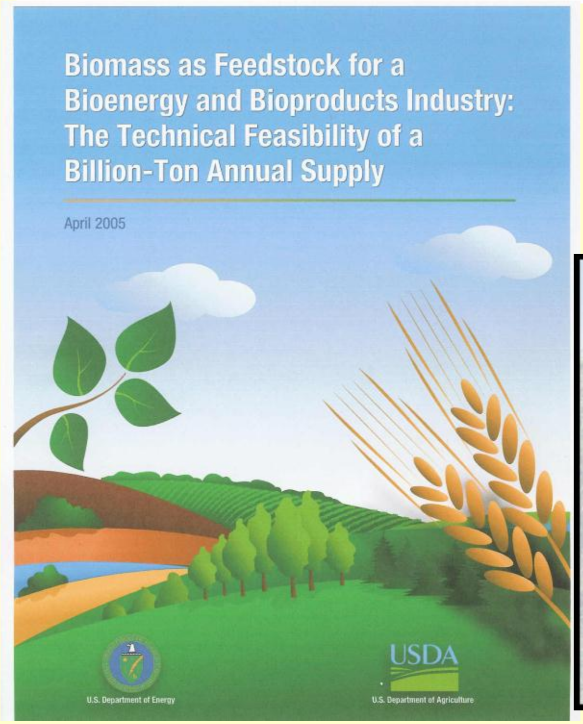
Projection (2020): $75 - $100 / barrel

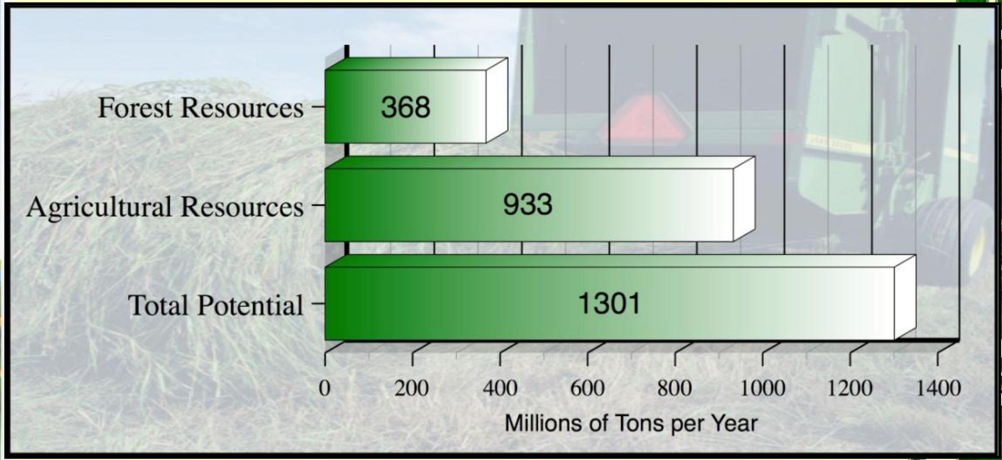
# Who is interested?

- Over 100 start-ups (~$150 million venture funds).
  - Algenol, Aurora Algae, Sapphire Energy, Solazyme, Solix Biofuels
- ConocoPhillips, Chevron, ExxonMobil, Royal Dutch Shell.
- Product focus: diesel, gasoline and jet fuel

# Cellulosic Materials

# Biomass Feedstock



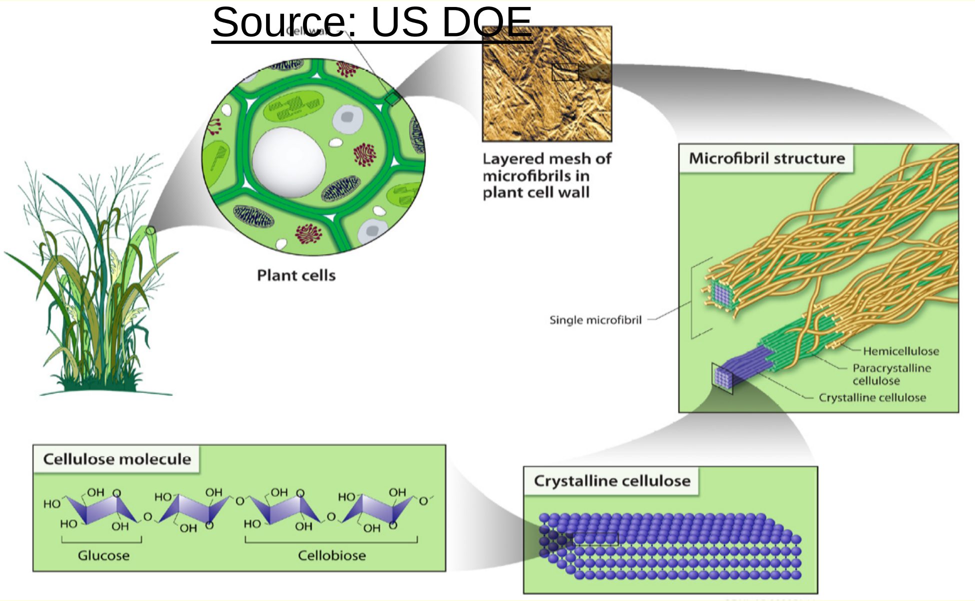



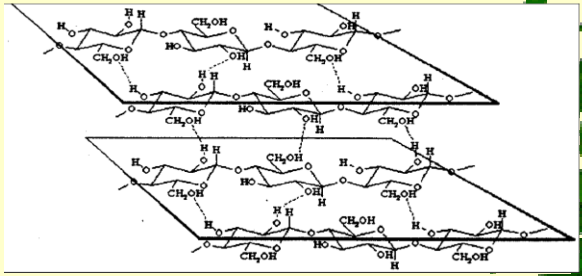

## "Billion ton" study (USDA/DOE)

- **Agriculture**: Corn stover, wheat straw, soybean residue, manure, switchgrass, other energy crops.
- **Forest**: Forest thinnings, fuelwoods, logging residues, wood processing and paper mill residues, urban wood wastes.

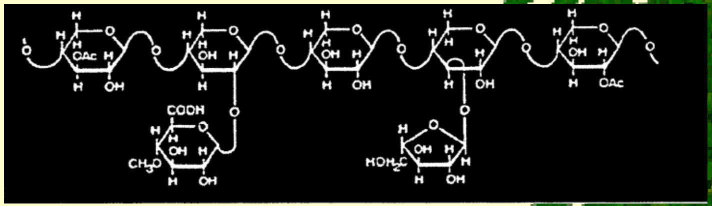
# Biomass: Structural Units

Source: US DOE

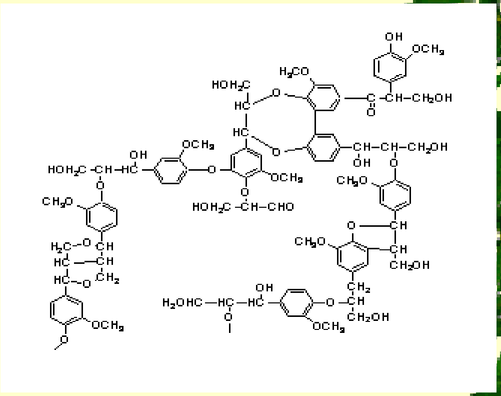


Cellulose: Polymer and cross-linkages among glucose units.



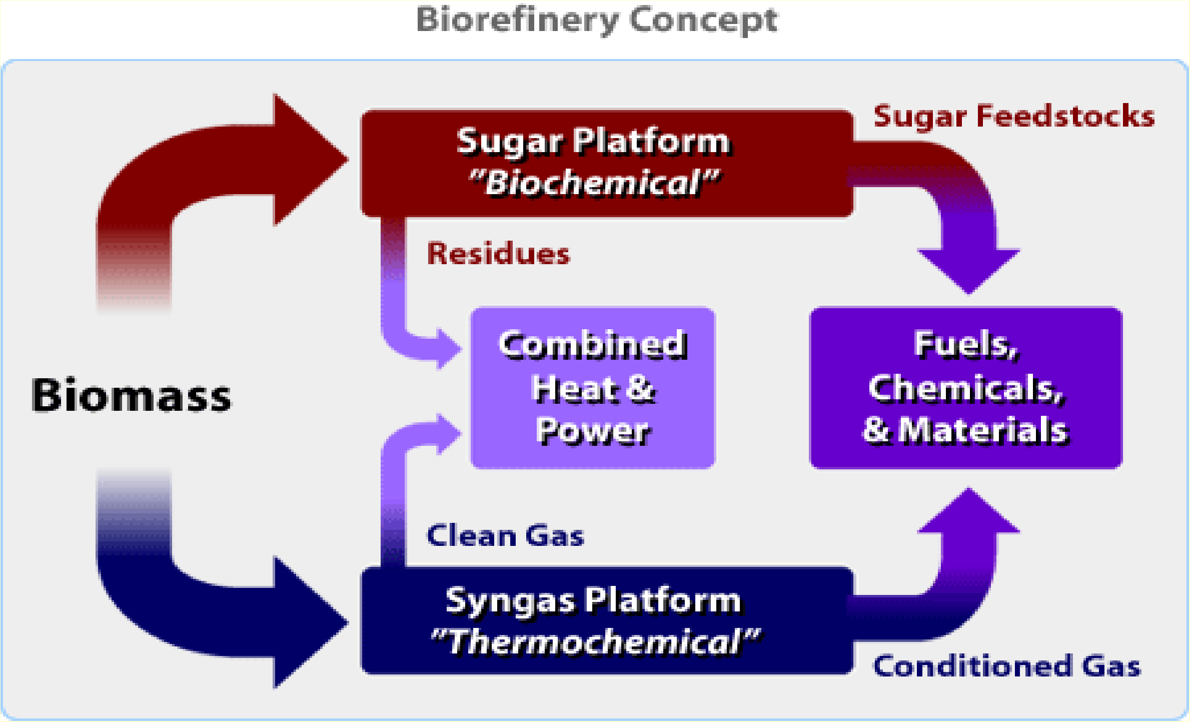
Hemicellulose: 5, 6 carbon sugars, sugar acids, acetyl esters- more complicated than cellulose.



Lignin: Phenolic polymers- impart strength to plants.

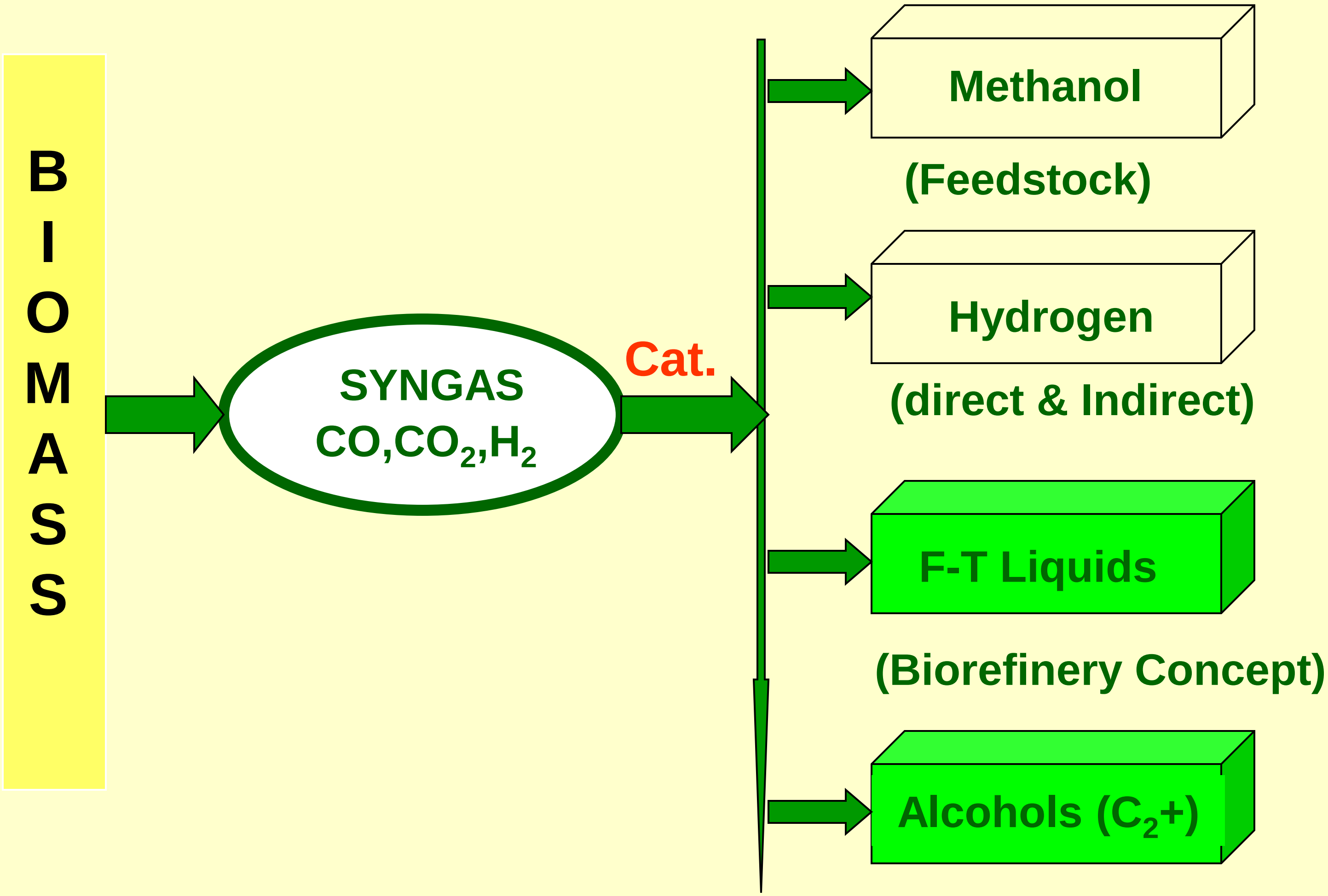
Typical composition
Carbohydrates/Sugars: 75%
Lignin: 25%

# “Biorefinery” Concept



# Biomass to Fuels

## Thermochemical Route: Syngas Platform



## Challenge

Total Carbon Utility with Product specificity

- Atom Economy .

## Approach

Combine new Process Engineering and Process Chemistry concepts.

**Process Chemistry**

Liquid Phase Low Temperature (LPLT) concept

- Single-site or Nano catalysis

**Process Engineering**

Heat management

- Microchannel Reactors

# Topic 4
# New York State Initiatives

Renewable Fuels Roadmap and Sustainable Biomass Fuels Supply

Released 2010

http://www.nyserda.org/publications/renewablefuelsroadmap/default.asp

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Released 2010

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- NYSERDA (NYS Energy Research and Development Authority)
- NYSDEC (NYS Dept. of Environmental Conservation)
- NYSDAM (NYS Dept. of Agriculture and Markets

# NYS Roadmap Highlights

- Assesses the prospects for the expansion of biofuel production in New York State, focusing on resource availability and economic and environmental impacts.
- Topics covered:
  - Biodiesel
  - Biofuels
  - Cellulosic ethanol
  - Competing uses
  - Conversion technology
  - Feedstock
  - Greenhouse gas emissions
  - Life cycle analysis
  - Renewable energy
  - Sustainability
  - Transportation fuels

# Key Issues Considered: 11

1. Stakeholder Input: Vision Document and Stakeholder Input Workshops.
2. Analysis of Sustainable Feedstock Production Potential in NYS
3. Feedstock Transportation and Logistics
4. Life Cycle Analysis and Public Health Assessment of Biofuel Production, Transportation, and Use in New York State
5. Technologies for Biofuels Production
6. Biofuel Industry Economic Impacts and Analysis.
7. Worker Training and Business Research Infrastructure for a Biofuel Industry in New York.
8. Sustainability Criteria.
9. Selected Future Production Pathways in New York.
10. Policy Analysis and Inventory of Existing Relevant State and Federal Policies.
11. Biofuels Markets in New York State & Integration in the Northeast Region and Competition for Biomass Resources.

# Expanding Biofuels in NYS

## Scenarios considered: 3

Scenario 1: "Big Step Forward"

- Focus on large (90 MGY) biofuel production plants.
- Rapid development of lignocellulosic feedstock resources is assumed on available rural lands.
- Total New York production of renewable gasoline substitutes would reach 508 MGY.
- Under this scenario, New York meets about 5.6% of its projected gasoline consumption with home grown biofuels.

# Expanding Biofuels in NYS

Scenario 2: "Giant Leap Forward"

- Some cropland is used for biofuel production.
- Assumes that 2nd generation lignocellulosic biorefineries (biochemical and thermochemical systems) are ready for commercial deployment.
- Large lignocellulosic biorefinery clusters (average capacity 354 MGY) exist in a centralized collection/distribution system.
- Total New York liquid biofuel production including grain derived ethanol would reach 1,449 MGY.
- New York could meet about 16% of its projected transportation gasoline consumption with home grown biofuels.

# Expanding Biofuels in NYS

Scenario 3: "Distributed Production"

- Same feedstock production and similar conversion technology as in Scenario 2.
- This scenario reflects a more decentralized fuel production industry with no individual biorefinery capacity exceeding 60 MGY, except for the existing grain ethanol biorefineries.
- Total New York liquid biofuel production including grain-derived ethanol would reach 1,449 MGY.
- New York could meet about 16% of its projected transportation gasoline consumption with home grown biofuels.

# Biomass Capacity

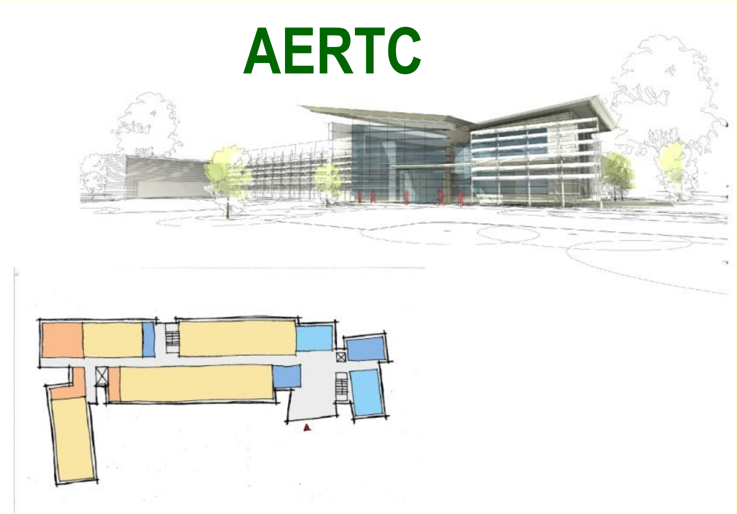
- Of the State's 18.5 million acres forest lands, nearly 15.8 million acres is producing or is capable of producing woody biomass.
- New York agricultural industry currently produces ~12 million dry tons biomass annually and produces another 9.5 Mdt/year of biomass from forests.
- The current forest products industry uses 2.5 Mdt/year. Corn provides the greatest amount of biomass from a single agricultural crop in the State (60%) and much of this is used by the New York dairy industry.

# Biofuel Production Technologies

- Fifteen current technologies were evaluated for converting solid biomass to liquid fuels.
- The Roadmap summarized process descriptions, current development status, and estimated economic and performance attributes for the year 2020.
- Only 3 are currently in commercial use.
- By 2020, the total capacity for lignocellulosic ethanol is estimated to be between 508 and 1,449 million gallons.

# Topic 5
# Long Island Initiatives

# Facilities

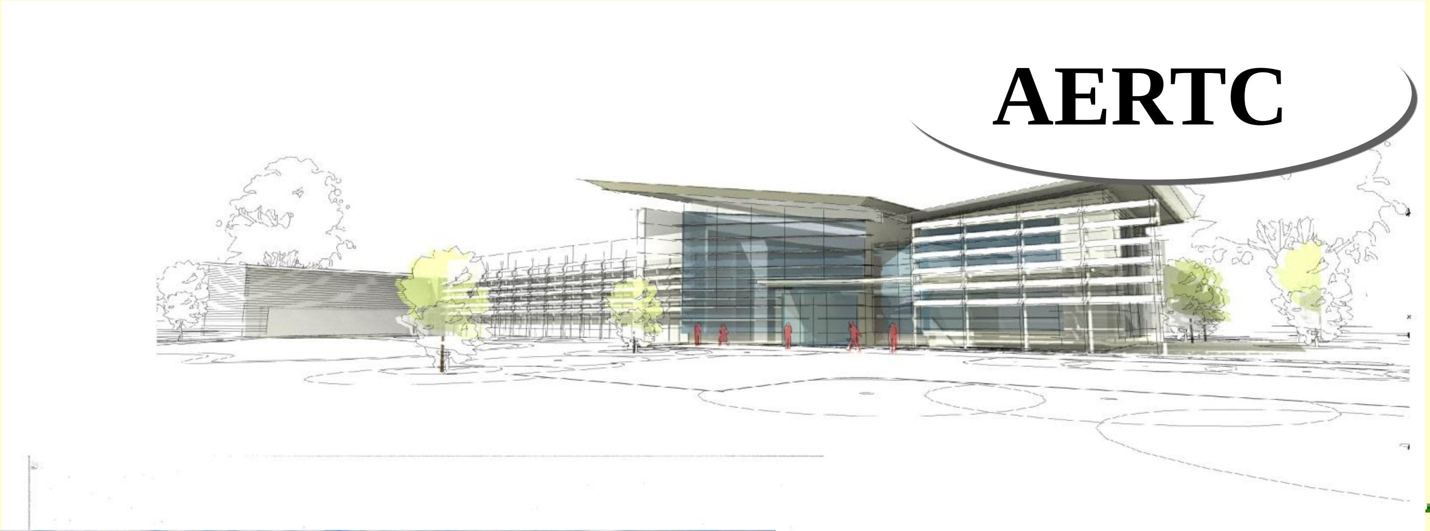


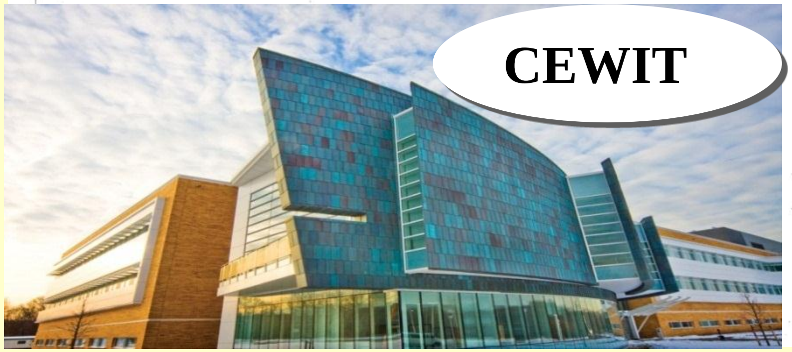


**<u>Research Facility</u>**
- New York State funded $45 million at SBU.
  - Build the Advanced Energy Research & Technology Center (AERTC)
- NSF C-BERD will be housed in this building.

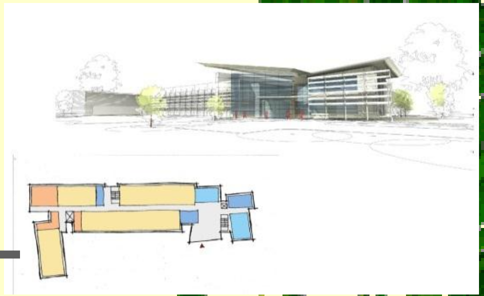
**<u>Characterization Facilities</u>**
- Center for Functional Nanomaterials **(CFN)**
  - A U.S. Department of Energy (US DOE) $85 million facility at BNL.

# Stony Brook University R&D Park



# AERTC:
# An Energy Efficient Building



**Leadership in Energy & Design (LEED) Certification**

**<u>Criteria</u>**

- Design
- Construction
- Operation

**<u>Levels (based on 100 points) in LEED 2009</u>**

- Platinum (80+)
- Gold (60-79)
- Silver (50-59)

# AERTC:
# An Energy Efficient Building

**LEED Features**

- Construction phase: Requires materials within 500 miles radius- provided jobs within local communities
- Operation:
  - Water system. Run rainwater is collected and used for non-drinking purposes.
  - Power savings. Sensors for lighting throughout.
  - Solar supplement. Shades to minimize AC usage.
  - AC. 4 Ice slabs at night for peak shaving and daytime use of AC. Chilled water for AC.
  - Parking Lot. 30kW solar panels to provide LED

- Provide charging station for 4 electric vehicles (A new US DOE grant).

# Renewable R&D at Stony Brook

**Green Buildings**

CEWIT

AERTC

**Electric Delivery Systems**

- Smart Grid

**Green Energy Projects**

- Solar
- Biomass to Biofuels
- Geothermal

**Carbon Capture Systems Coupled with Fossil Fuels**

- CCS

# Electric Delivery System: Smart Grid

<u>Key Elements</u>

- Security
- Reliability
- Renewable fuel choice and integration
  - Solar
  - Biofuels from biomass processing
  - Wind
- Sustainability

# Long Island's Smart Energy Corridor

A Collaborative Project

SBU PI:

Professor E. Feinberg, AMS Dept.

LIPA
Long Island Power Authority

STONY BROOK
STATE UNIVERSITY OF NEW YORK

Farmingdale State College
State University of New York

# Long Island's Smart Energy Corridor

# Renewable Fuels for Smart Grid- Liquids

| | |
|---|---|
| **Focus** | • Smart grid and renewable fuels integration<br>• Skid-mounted (small scale) renewable fuel plants |
| **Liquid Fuels** | • Focus: Transportation and power peak-shaving fuels<br>• Source: Biomass derived biofuels via pyrolysis and thermochemical routes.<br>- Gasoline, **diesel**, ethanol, methanol and butanol. |

CBERD

# Renewable Fuels for Smart Grid- Biogas

| | |
|---|---|
| **Why Biogas?** | • Biogas- a natural source of energy. Capturing fugitive methane has two advantages:<br>- Minimize methane release to the atmosphere.<br>Greenhouse factor: $CH_4$ (17); $CO_2$ (1)<br>- Simultaneously reduce imported natural gas |
| **Approach** | • Biogas assessment and potential on Long Island<br>- Regional and Global application<br>• Biogas upgrading to pipeline quality gas |

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# Biogas on Long Island: Existing & Potential Sources

# Biogas vs. Natural Gas

| Compound Name | Chemical Formula | Biogas (%) | Natural Gas (%) |
|---|---|---|---|
| **Methane** | $CH_4$ | 50-75 | 70-90 |
| **Carbon Dioxide** | $CO_2$ | 25-50 | 0-8 |
| **Nitrogen** | $N_2$ | 0-10 | 0-5 |
| **Hydrogen** | $H_2$ | 0-1 | Trace |
| **Hydrogen Sulfide** | $H_2S$ | 0-3 | 0-5 |
| **Oxygen** | $O_2$ | 0-2 | 0-0.2 |
| **Ethane** | $C_2H_6$ | Trace | 0-20% |
| **Propane** | $C_3H_8$ | | |
| **Butane** | $C_4H_{10}$ | | |

# Biogas Sources

- Landfills
  - MSW, C&D, and Yard Waste
- Wastewater Treatment Plants
  - Sewage sludge
- Agricultural Residues
  - Plant waste and animal manure

# Landfills

| Facility | Brookhaven | 110 Sand Company | Blydenburgh | Oceanside |
|---|---|---|---|---|
| Total Landfill Area (acres) | 150 | 116 | 30.5 | 190 |
| Area Used for Gas Collection (acres) | 120 | 116 | 30.5 | 160 |
| Number of Flares | 2 | 1 | 2 | - |
| Total Gas Collected ($ft^3$) | 601,940,000 | 624,320,000 | 306,400,000 | 110,440,000 |
| Energy Produced (MW-hrs) | 64 | - | - | 3,617 |

# Landfills

| Landfill Name | County | Waste in Place (tons) | Opening Year | Closing Year | Landfill Owner |
|---|---|---|---|---|---|
| **E. Hampton SLF** | Suffolk | 1,000,000 | 1942 | 1993 | Town of E. Hampton |
| **Holtsville SLF** | Suffolk | - | 1939 | 1974 | Town of Brookhaven |
| **North Sea LF** | Suffolk | 1,102,714 | 1963 | 1995 | Town of Southampton |
| **Port Washington LF** | Nassau | 2,161,000 | 1983 | 1991 | North Hempstead |

# MSW

- 3.5 million tons of waste produced annually
  - 1 million tons is recycled
  - 1.5 million tons is incinerated
  - 1 million tons is transported off island
- According to NYS, 65% of the waste stream is composed of degradable items in the form of paper and organics.

Source: Tonjes, D.J. Stony Brook University

# MSW

| Material | Dry Weight (ton) | Yield (ml of $CH_4$/dry g)† | Total $CH_4$ Yield (billion $ft^3$) |
|---|---|---|---|
| Coated Paper | 14,570 | 84.4 | 0.04 |
| Office Paper | 22,466 | 217.3 | 0.16 |
| Newspaper | 14,570 | 74.33 | 0.03 |
| Corrugated | 60,895 | 152.3 | 0.30 |
| Others | 181,326 | 74.33 | 0.43 |
| Food Scraps | 54,570 | 300.7 | 0.53 |
| Yard Trimming | 9,760 | 69.2 | 0.03 |
| Wood | 8,900 | 62.6 | 0.07 |
| Total | | | **1.29** |

† Eleazer, W.E. et al. Environmental Science & Technology 1997

# C&D

| Facility | Amount of Waste (tons) | $CH_4$ Yield (billion $ft^3$) |
|---|---|---|
| **Blydenburgh** | Wood – 34,612 | 0.07 |
| | Cardboard – 8,340 | 0.04 |
| **110 Sand Company** | Wood – 248,435 | 0.50 |
| | Cardboard – 59,865 | 0.29 |
| **Brookhaven** | Wood – 105,297 | 0.21 |
| | Cardboard – 25,493 | 0.12 |
| **Total** | | **1.23** |

# Yard Waste

- 365,000 tons of yard waste annually
  - Estimated 170 million $ft^3$ of $CH_4$ per year

| | AD vs. LF | AD vs. WC | WC vs. LF |
|---|---|---|---|
| **Energy Production (mmBTU/yr)** | +380,000 | +407,910 | -30,546 |
| **GHG Emissions (tons/yr $CO_2$ eq.)** | -134,379 | -93,470 | +42,075 |
| **$NO_x$ (tons/yr)** | -53.8 | -55.4 | +1.7 |
| **$SO_x$(tons/yr)** | -75.4 | 82.2 | +6.83 |
| **PM-10 (tons/yr)** | -64.4 | -56.0 | -8.4 |
| **VOC (tons/yr)** | -9.5 | -4.2 | -5.2 |
| **Lead (lbs/yr)** | -194.7 | -205.0 | +10.4 |

AD: Anaerobic digestion; LF: Landfilling without energy recovery; WC: Open window composting.

Source: Haight, M. Waste Science & Technology 2005.

# WWTPs

- 34 WWTPs located on Long Island
  - 12 in Nassua County; 22 in Suffolk County

| Facility Name | County | Authority Name | Actual Flow (mgd) | Potential Electric Capacity (kW) |
|---|---|---|---|---|
| **Long Beach WPC Plant** | Nassau | Long Beach DPW | 5 | 122 |
| **Bay Park STP & SD#2** | Nassau | Nassau County DPW | 53 | 1178 |
| **Cedar Creek STP & SD#3** | Nassau | Nassau County DPW | 57 | 1268 |

# WWTP

- On average a WWTP will process 450 L per day of wastewater per person served
- The total solids present in average sanitary wastewater is 800 mg/L
- An estimated 207,406 tons of sludge is processed yearly by WWTPs on Long Island

Source: Hammer, M. J *Waste and Wastewater Technology* 2001

# WWTP

- Assume volatile solids are 75%.
- Assume 50% reduction in volatile solids after digestion.
- Assume 16 cubic feet of gas produced per lb of volatile solids destroyed.

**Estimated gas production: 2.5 x $10^9$ ft$^3$**

Source: Hammer, M. J *Waste and Wastewater Technology* 2001

# Agricultural Residue

- 35,682 acres of farmland on Long Island
  - 75% is cultivated for crops
  - 25% used for pastures, woodland, and other usage.
- On farm composting is the most common method used for waste disposal.
- Assume 33,000 $ft^3$ $acre^{-1}$ $year^{-1}$ of $CH_4$

**883 x $10^6$ $ft^3$**

Source: Weiland, P. Applied Biochemistry and Biotechnology, 2003.

# Conclusion

- Total biogas potential

  = 7.7 billion cubic feet

  = 2.3 Twh of electricity

  = 12% of total electricity generated by LIPA from natural gas

# Conclusion

| Potential Source | Currently Exploited | Current/Potential $CH_4$ Yield (billion) | Optimal Use | Technology Barriers |
|---|---|---|---|---|
| **Sludge** | No | 2.49 $ft^3$ | Pipeline quality gas | ADs are needed |
| **LGRF** | Yes | 1.64 $ft^3$ | Electricity | Upgrading Technology |
| **MSW** | No | 1.29 $ft^3$ | Pipeline quality gas | AD; Upgrading technology |
| **C&D** | No | 1.23 $ft^3$ | Pipeline quality gas | Upgrading technology |
| **Agriculture Waste** | No | 0.88 $ft^3$ | On-site usage; Electricity | ADs are needed |
| **Yard Waste** | No | 0.17 $ft^3$ | On-site usage | ADs are needed |

# Center for Bioenergy Research and Development (CBERD)

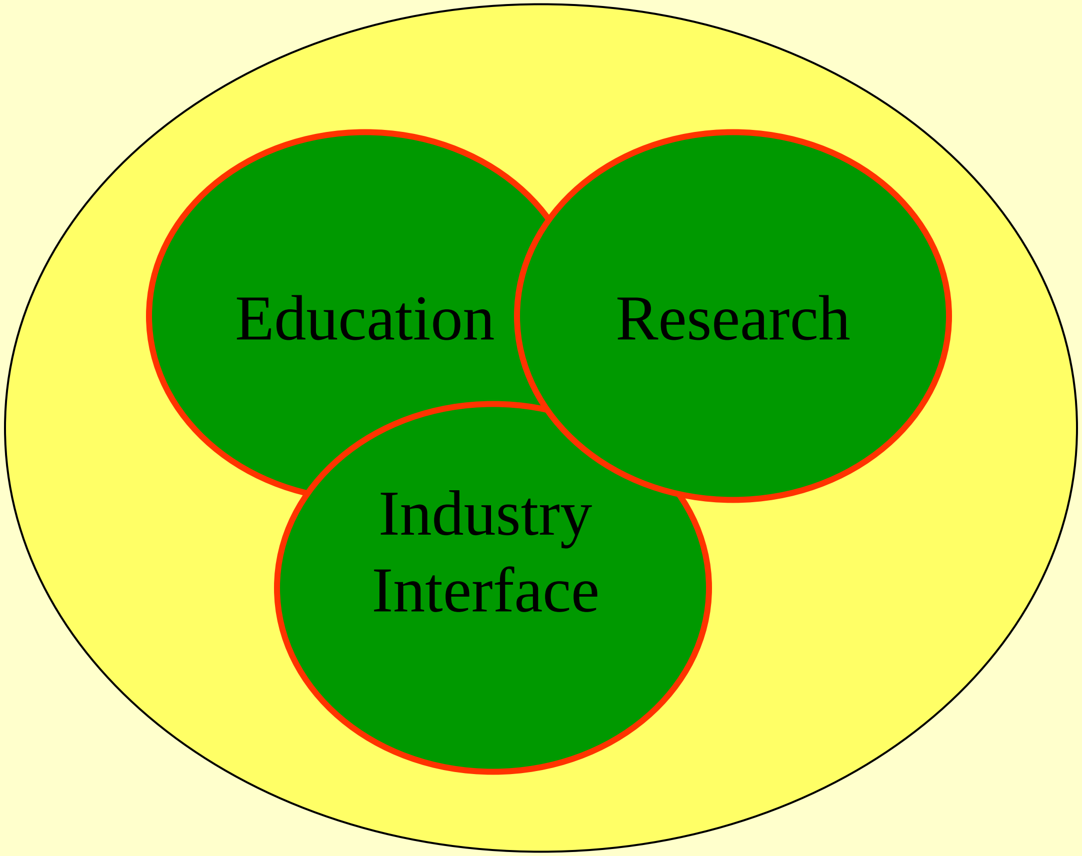
# C-BERD

**Founding Members**

Kansas State University (K-State)
North Carolina State University (NCSU)
South Dakota School of Mines and Technology (SDSMT)
Stony Brook University (SBU)
University of Hawaii (UH)

**Total industry membership: 25**

# CBERD Mission




**Mission**:
• To train students at all levels.
• Develop renewable energy technologies working with industry.

# CBERD Organization
# SBU Site

**Devinder Mahajan**
**Site Director**

Nay Htun,
Senior Advisor

## FACULTY

David Tonjes
Wendy Tang
Ben Hsiao
Ben Chu
Dilip Gersappe

Hazem Tawfik, Farmingdale

AJ Francis, BNL
CR Krishna, BNL

Kyoung Ro, USDA-ARS
Lijun Wang, NC A&T

## IAB Members

NATIONAL GRID
NYSERDA
TOWN OF BROOKHAVEN
US ARMY
BNL
AERTC

## THRUST AREAS

- Biogas upgrading
- Bio-oil Upgrading
- Syngas to fuels
- $H_2$ for fuel cells

## STUDENTS

Jeff Hung
Kristine Horvat
Saurabh Patel
Shangmin Xiong
Nan Wei
Tsung-Ming Yeh
Celest Okoli
Kurian Kuttiyiel

Kun tan
Matt Graham
Yun Ying
Daniel Santiago
Jake Dietz

# Question?