Going Beyond Corn-based Ethanol: Biorefinery Strategies for California Biomass

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CBOT Ethanol Crush Spread

[CBOT Nearby Ethanol - CBOT Nearby Corn]

In June of 2006, the sun was shining brightly on ethanol production from corn, at gross margins of >$9 per bushel

Crush Spread = (Ethanol Price x 2.80) - Corn Price
Estimated Gross Margin Per Bushel

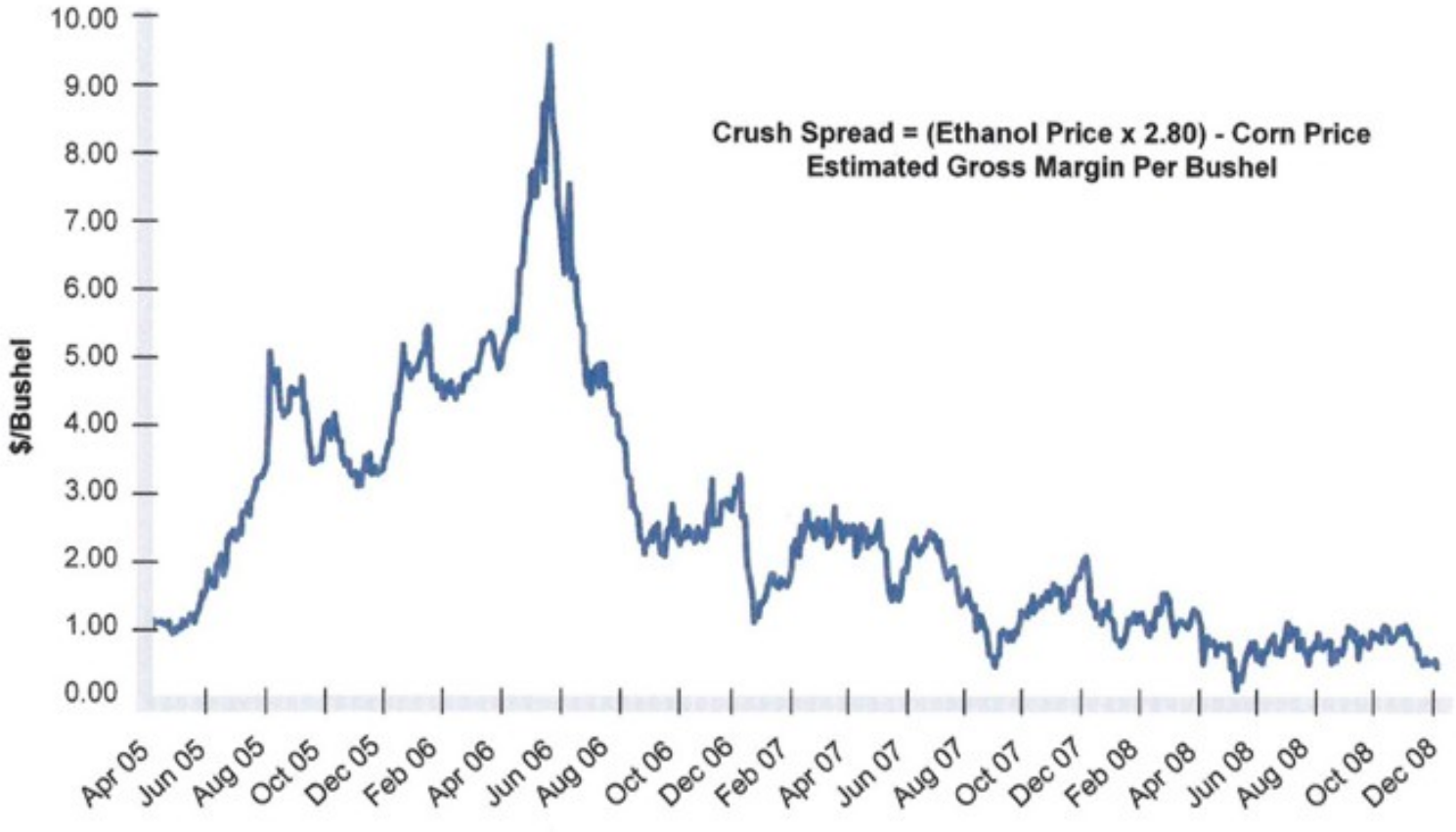
Source: Oil Price Information Service (OPIS) and The Chicago Board of Trade

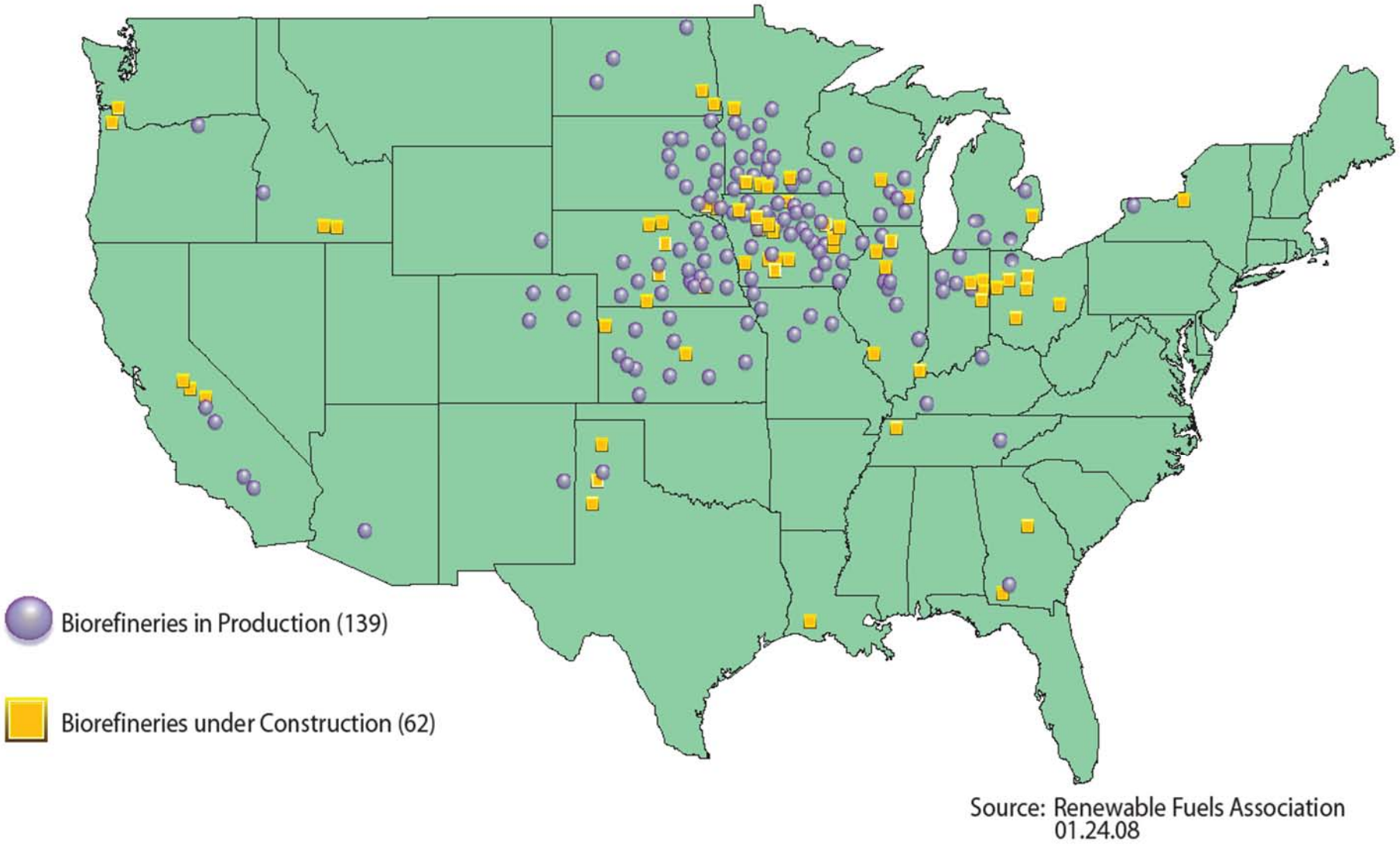
Carl Houtman, USDA Forest Products Lab

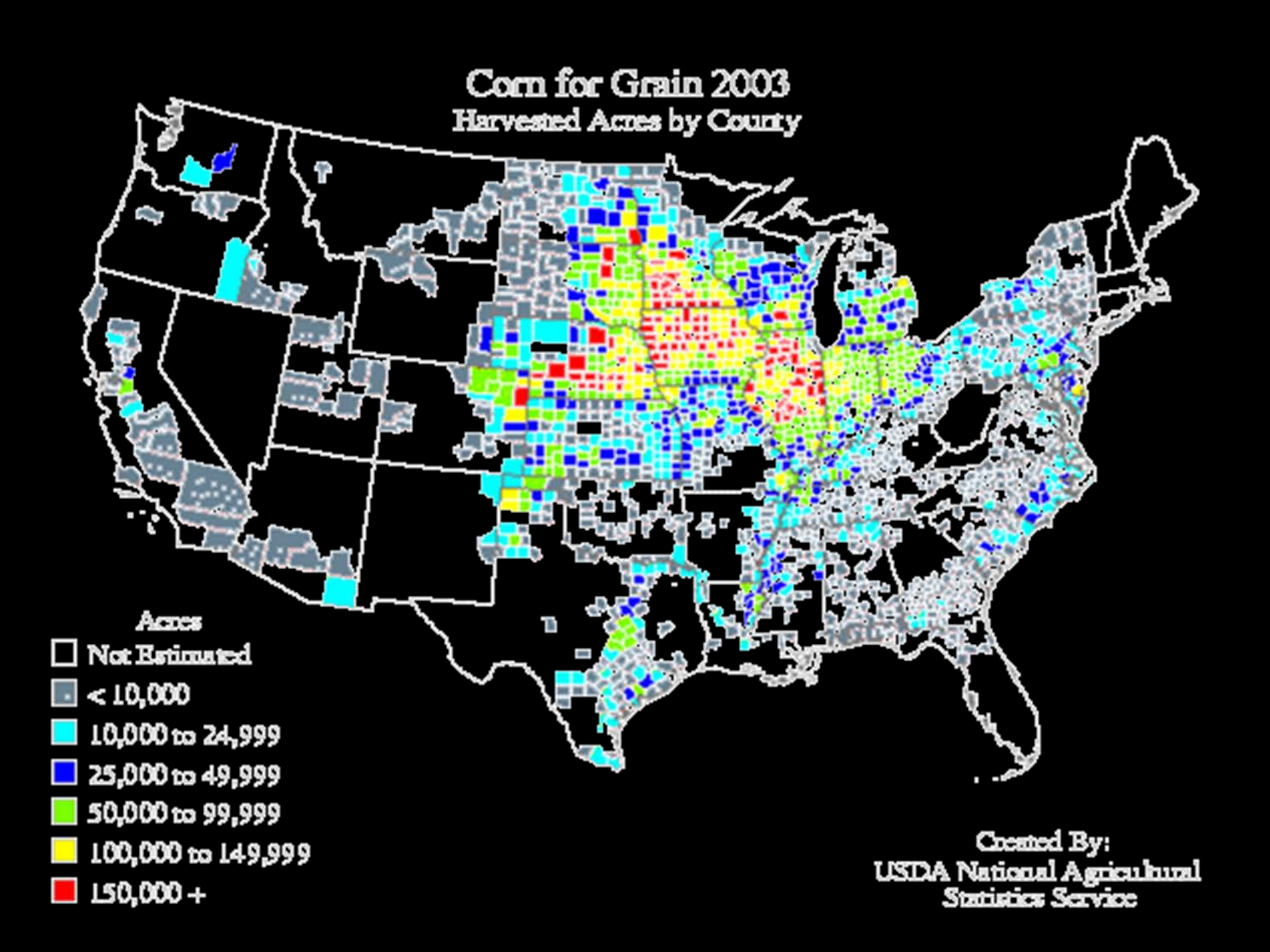
Ethanol Crush Spread

CHADBOURNE & PARKE

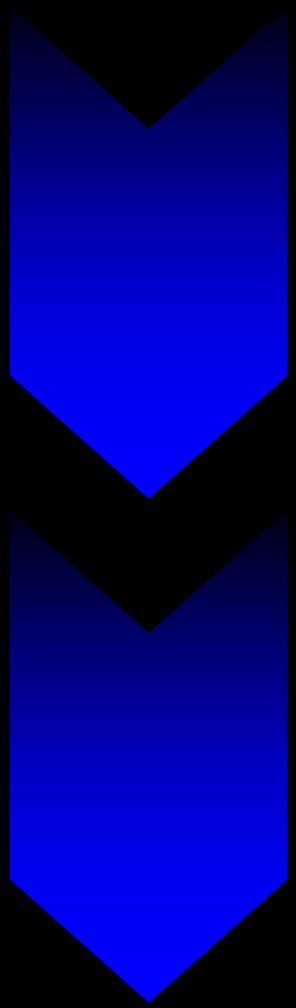
March 23, 2005 – December 2008
[2.80 * Nearby Ethanol Price – Nearby Corn Price]




Biorefineries in Production (139)
Biorefineries under Construction (62)
Source: Renewable Fuels Association
01.24.08


Corn for Grain 2003
Harvested Acres by County
Acres
Not Estimated
< 10,000
10,000 to 24,999
25,000 to 49,999
50,000 to 99,999
100,000 to 149,999
150,000 +
Created By:
USDA National Agricultural
Statistics Service

Corn-to-Ethanol: U.S trends



- Ethanol production capacity is >10 billion gals/yr
- >3% of transportation fuel
- Ethanol uses ~30% of US corn
- Most ethanol is not produced near refineries
- It is not widely produced in the most populated states.

Biofuels Trends

Generation 1: Food to Fuels

- Corn & soy as feedstocks

Generation 2: Cellulosics, etc

- Straw, wood, energy crops
- Sorghum ⇔ flexibility
- Municipal Solid Waste, MSW ??

We can invent our way toward energy flexibility.

There likely won't be a single answer!

IOGEN CORPORATION

Optimal Biorefinery:

= 100 MM gal/yr

= 4000 tons biomass/day

= 1000 acres wheat/day

= 365,000 acres/yr

= 570 sq. miles

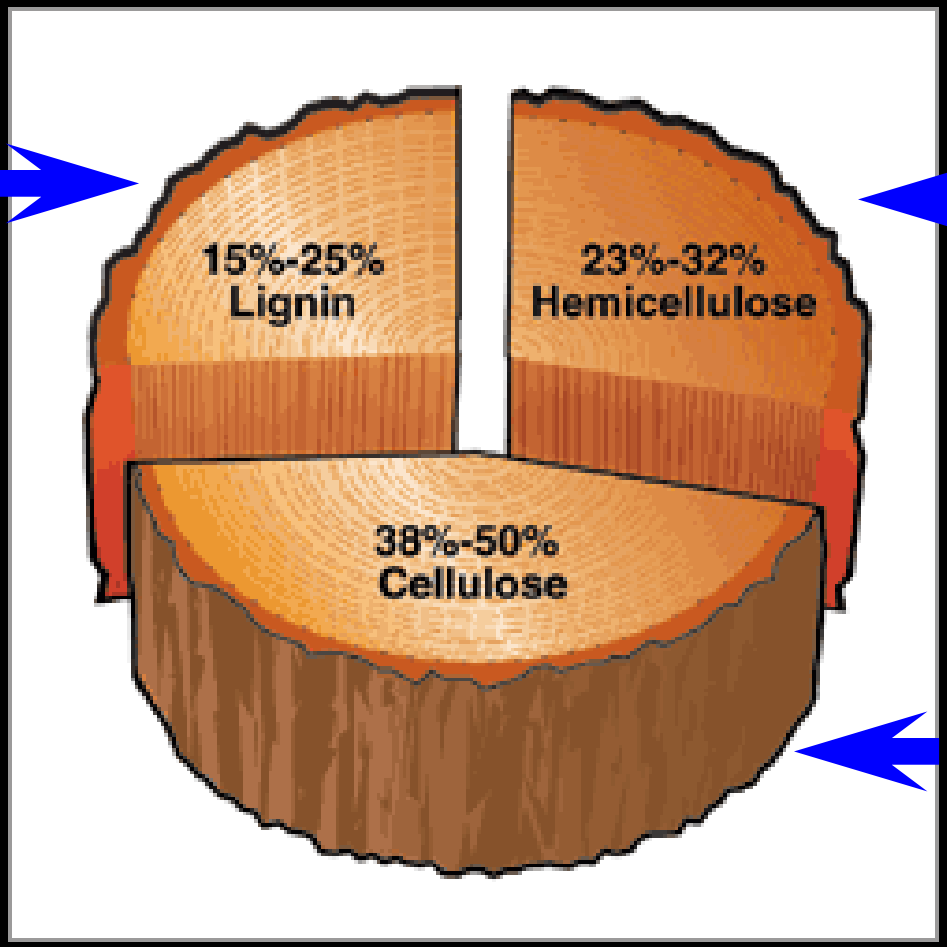
Chevron and Weyerhaeuser Create Biofuels Alliance

Letter of Intent Aimed at Development of Renewable Transportation Fuels Derived From Cellulose

SAN RAMON, Calif., and FEDERAL WAY, Wash., April 12, 2007 -- Chevron Corporation (NYSE: CVX) and Weyerhaeuser Company (NYSE: WY) today announced a letter of intent (LOI) to jointly assess the feasibility of commercializing the production of biofuels from cellulose-based sources.

Biomass Composition

complex phenolic



5-carbon sugar

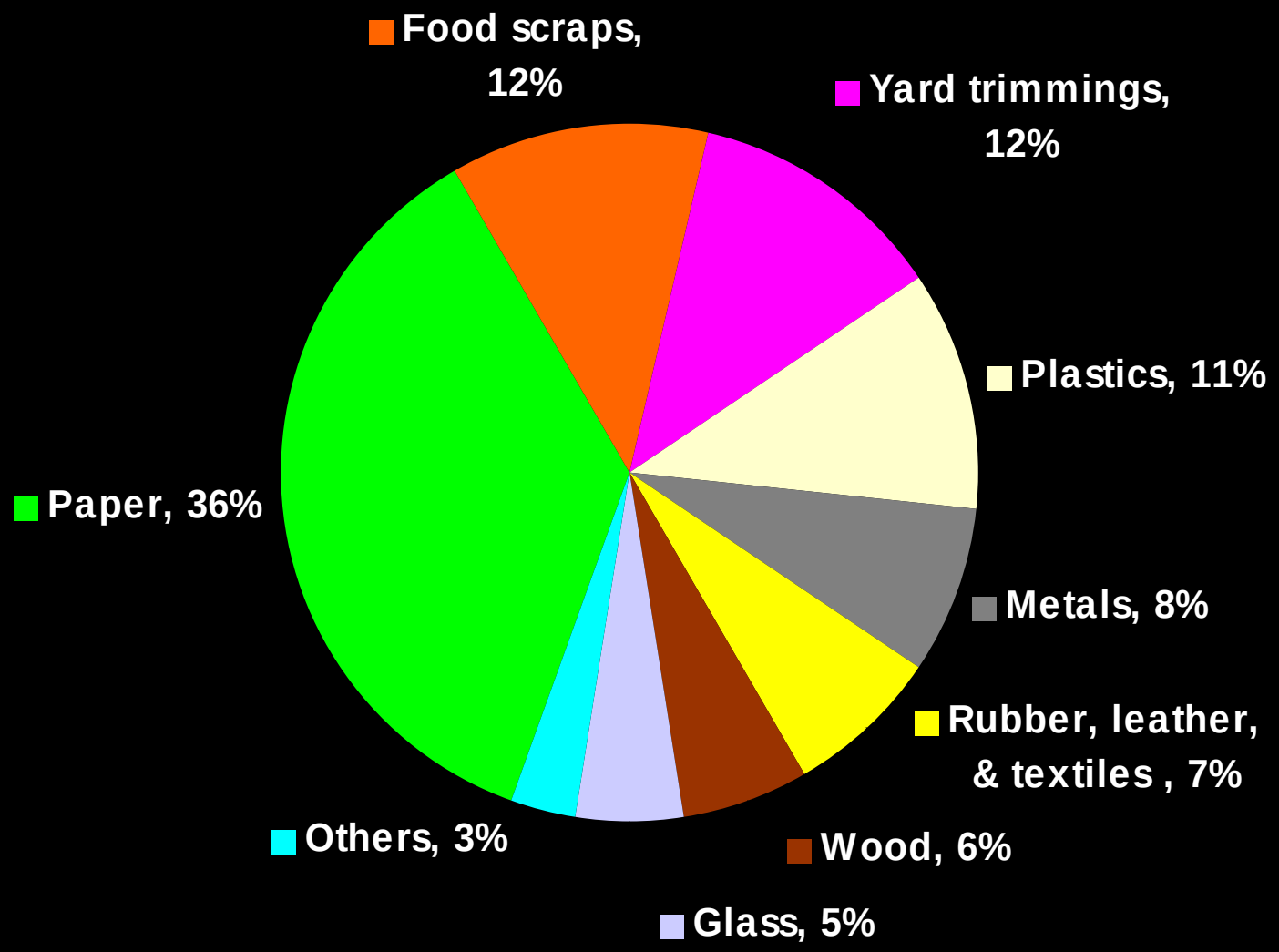
6-carbon sugar

Straw for cellulose-to-ethanol

ISSUES:

- **Straw varies with seasons**
- **Aging ⇔ harvest time is once per year**
- **Moisture and storage are challenging**
- **Transportation ⇔ Low density**
- **Supply is not near highest demand.**

Composition of MSW



425 million tons per year of unsorted MSW produced in U.S. alone (BioCycle, 2006).

CR^3 Autoclaves:

- Pressurized hot water treatment.
- Reduces volume.
- Isolates recyclables
- Fractionates components

Salinas Crazy Horse Landfill

Conveyor loading MSW to autoclave

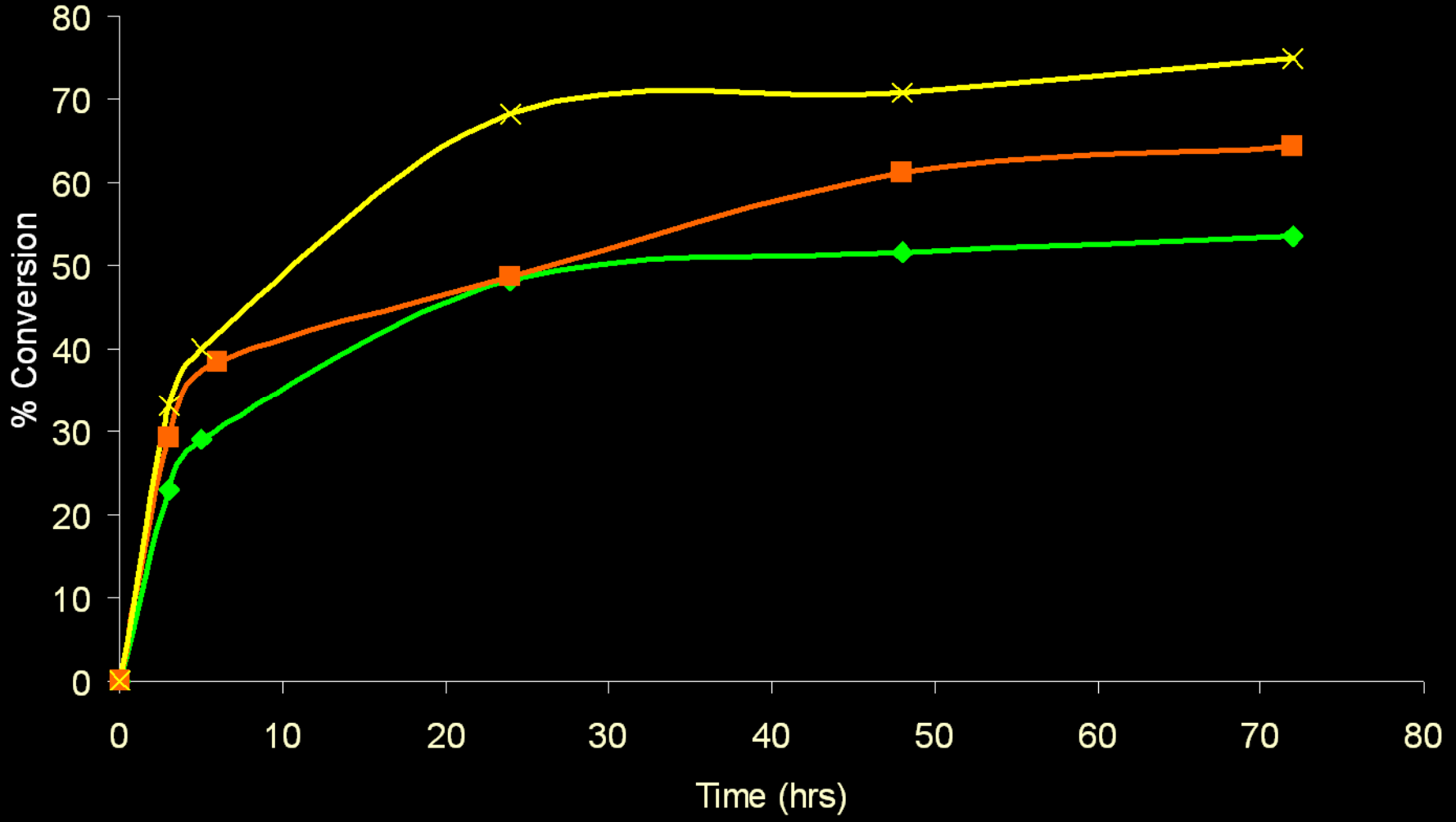
MSW inside the autoclave prior to steam treatment

MSW in the autoclave after steam treatment

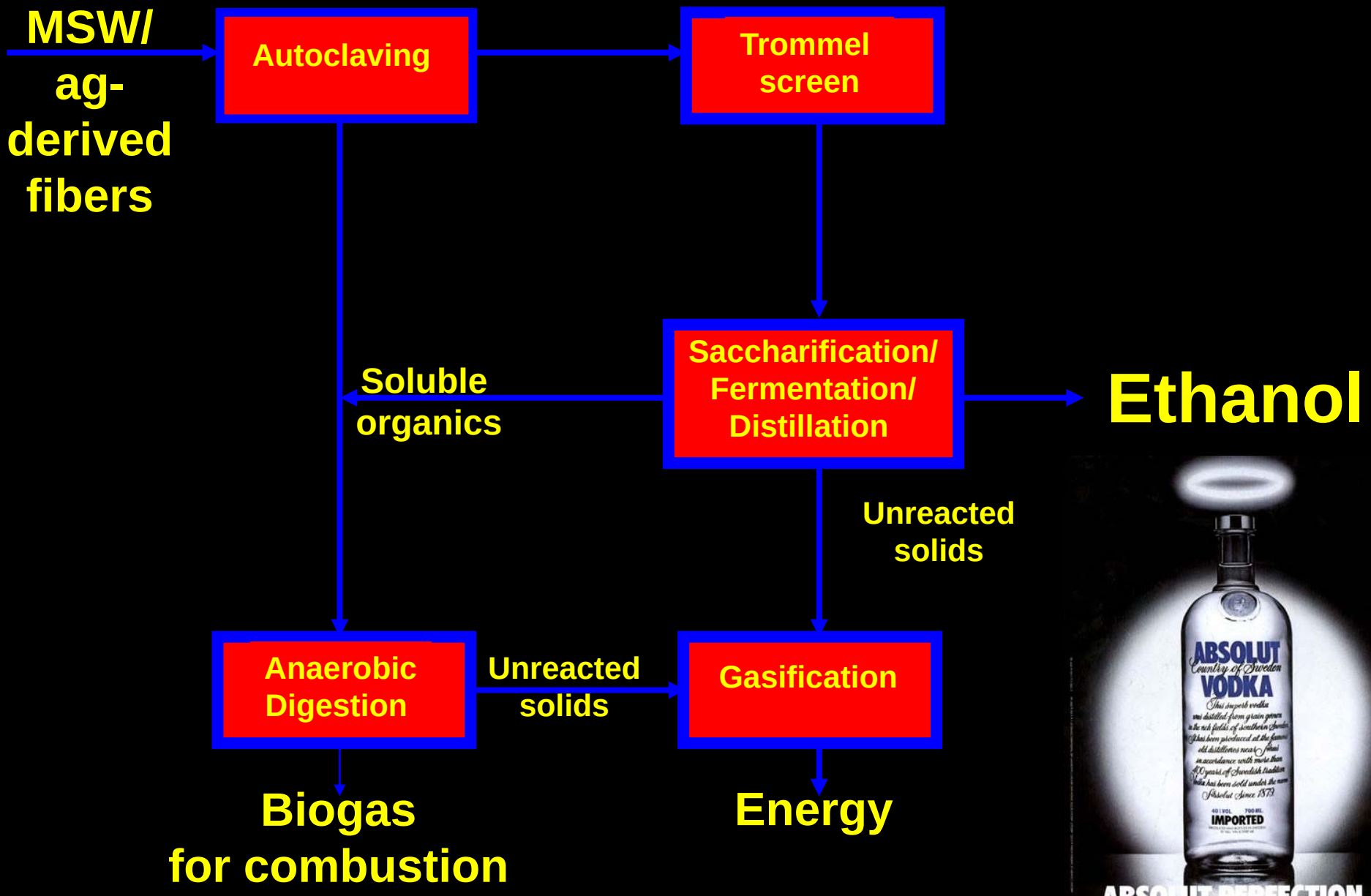
Treated MSW is Screened

Clean fiber from MSW after centrifugal cleaners

Enzymatic hydrolysis of MSW



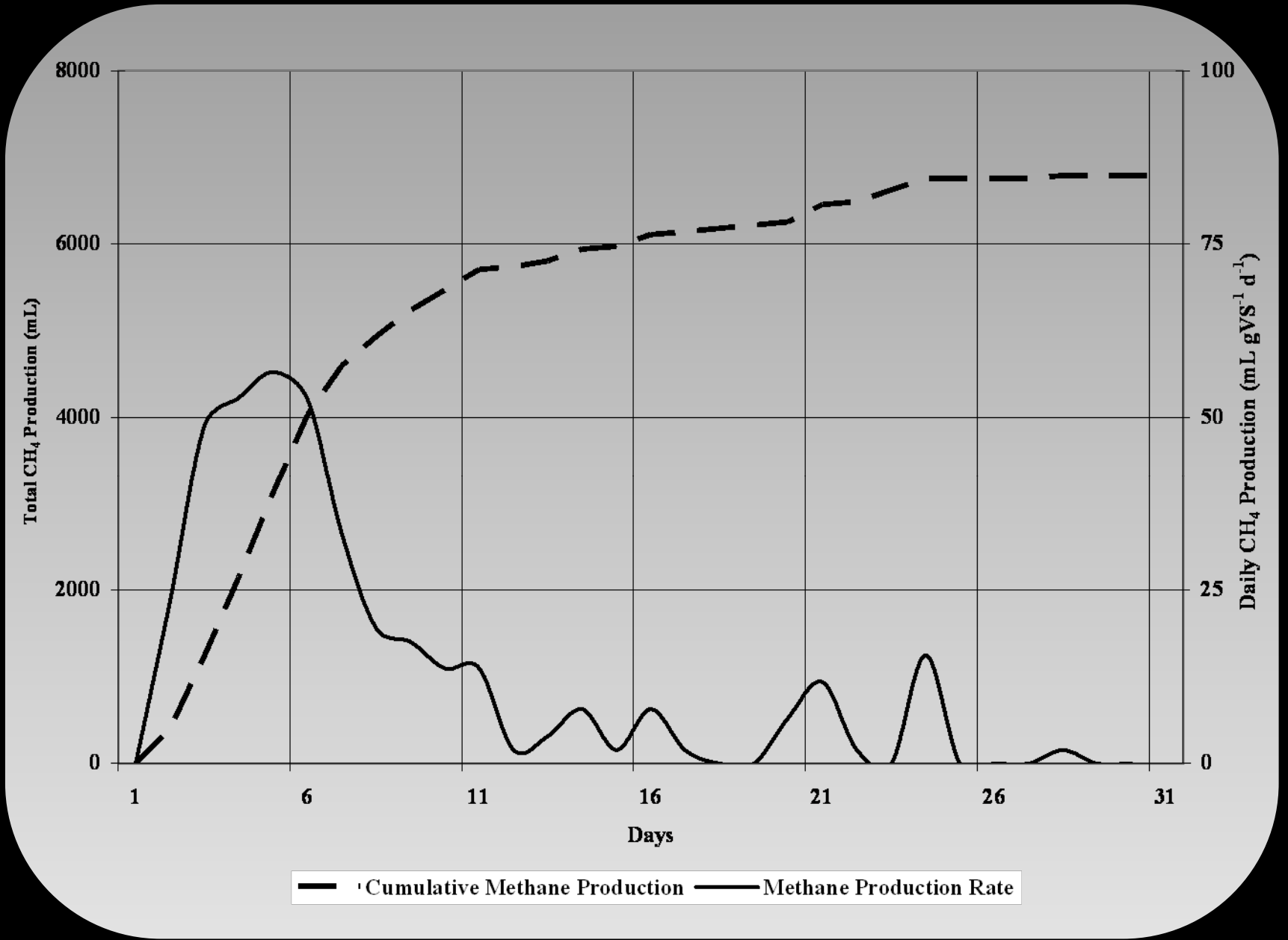
Flow scheme for flexible biorefinery



Component breakdown of incoming MSW and post trommel streams.

	Incoming MSW	3/8" Screen Accepts	1" Screen Accepts	Overs (> 1")
% pulp/paper	31.7	93.0	15.8	3.4
% woody material	6.5	1.7	8.6	1.2
% fines	4.5	1.9	1.4	0
% plastic	15.5	1.3	21.9	36.0
% glass	4.0	1.0	18.1	0
% metal	3.6	0	3.6	14.0
% C&D Waste	5.9	0.8	16.3	7.7
% solid food waste	10.2	0	1.8	0.8
% rubber/leather/textiles	17.4	0.4	12.5	36.9
% total	99.3	100	100	100

Gas production a slug feed of MSW pulp (20 g) in a 5 L CSTR with an SRT of 30 days.



Recycling: PET bottles were recovered and tested in recycle plastics

Ag-Derived biomass works about as well as MSW ⇔ Co-mingled waste….

Collaboration to produce bioenergy from MSW

USDA

WESTERN MILLING
QUALITY FEEDS

SALINAS VALLEY
SOLID WASTE AUTHORITY
Promoting the Environmental Health of the Salinas Valley
Reduce Recycle Reuse

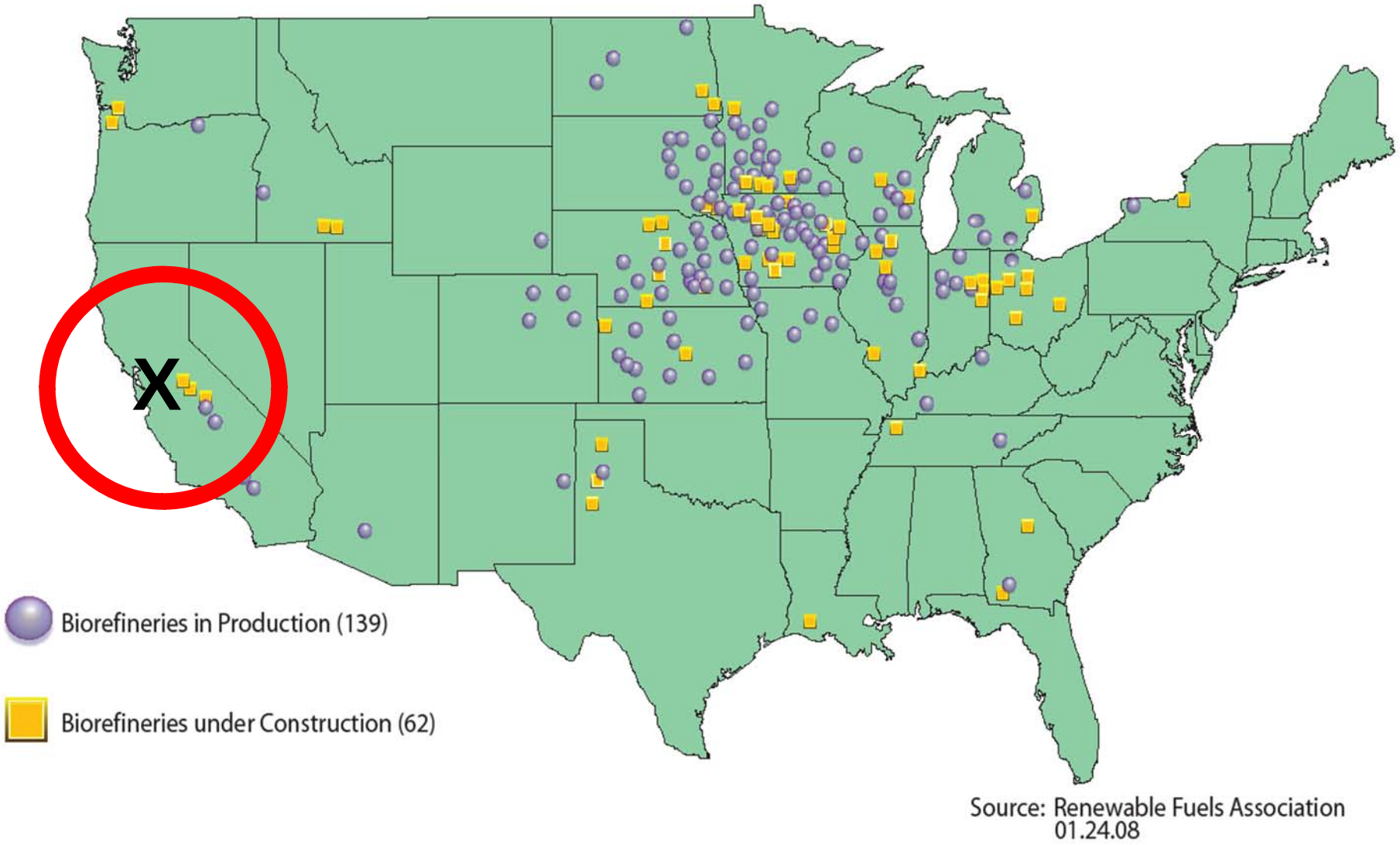
jbei
Joint BioEnergy Institute

Local-scale Straw-to-Energy Conversion

Gary Banowetz, et al. ARS – Corvallis, OR

- Novel two-phase gasifier
- On-farm energy
- Conversion of gas into liquid transportation fuels

Pilot gasification reactor
Western Research Institute
Laramie, WY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MSW as a Platform for Biomass-to-Ethanol Biorefinery

- 35 - 45% paper and paperboard products
- Will reduce landfill volume by >40%
- In MSW, paper is already fractionated
- Can produce other co-products
  - ⇔ Pulp
  - ⇔ Methane = ENERGY
- Ag-waste added when available

Integrated “Athletic” Biorefinery

Agricultural Research Service
ARS

- USDA's chief scientific research agency
- $1.1 Billion annual budget
- 2,100 PhD scientists
- 6,000 other employees

- 100+ research locations

Agricultural Research Service

Mission of ARS

To conduct research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination to……..

Means of Technology Transfer

- **Publications**
- **Seminars / Workshops**
- **Field Days**
- **Public Release of Plant Varieties**
- **CRADA's & Trusts**
- **Licensing of Intellectual Property Rights (IPR)**

The CRADA Exchange

The CRADA Partner must have internal research capacity and generally must provide at least one of the following to ARS:

***Funding *Equipment *Materials**
***Facility Access *Staff (i.e. Post-Doc)**

In Exchange, the CRADA Partner will receive:

***Access to ARS technology and expertise**
***Service from ARS Patent Advisors**
***Right to negotiate an exclusive patent license**

Partnerships: Industrial Cooperators

Chevron

CLOROX

Mantrose-Haeuser Co., Inc.

Cargill™

Sunkist

YULEX.

PENFORD
FOOD INGREDIENTS CO.

EKI

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