# Biomass Collection: A Challenge for Cellulosic Ethanol Production

2015 NSF FEW Nexus Workshop

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# Outline

## Introduction

- ADM Overview
- Biofuels
- Perspective on Feedstocks

## Cellulosic Ethanol

- Transportation Model
- Farmer Participation
- Scaling Function

## Corn Replacement Feed: A Stepping Stone

- Upgrading Crop Residue
- Feed Trials

## Final Remarks

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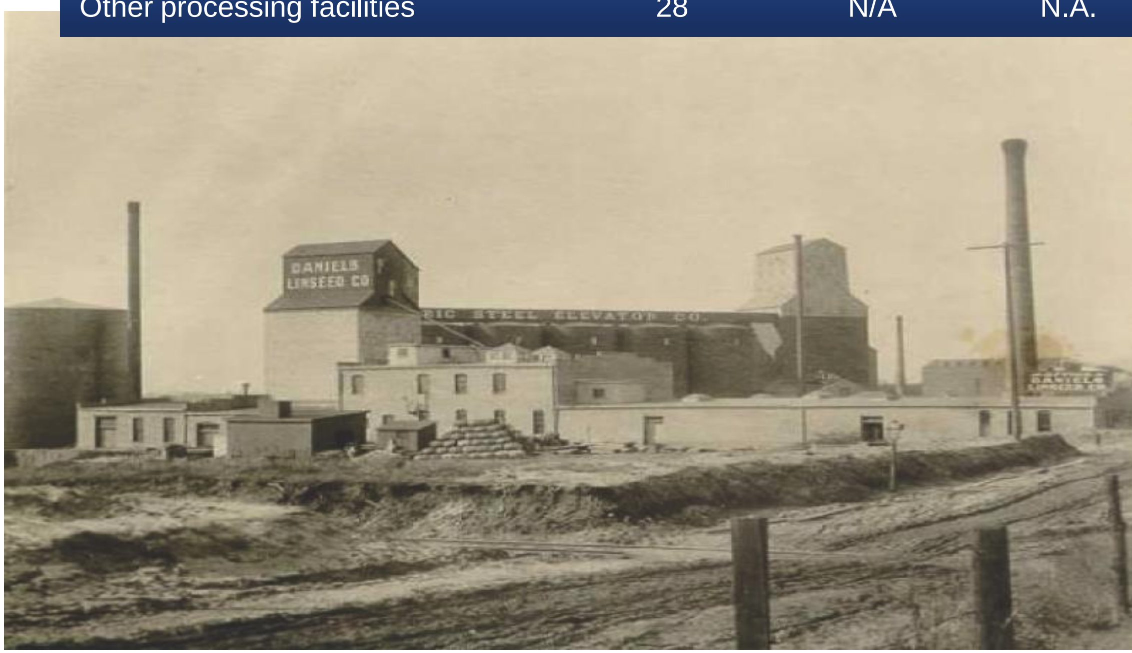
# ADM – A History of Biorefinery Innovation

- **•$81B in net sales FY14, 270 Processing facilities, 33k employees**
  - **•Global Headquarters in Chicago, IL**
  - **•Founded in 1902 as a linseed crushing operation**
- **•Stable earnings from a broad product portfolio**
  - **•Four traditional business platforms: Food, Feed, Fuel, Industrial Products**
- **•ADM Global Daily Processing Capacity**

| *Source: 2014 ADM 10-K* | Number | MT | Bushels |
|---|---|---|---|
| Oilseed processing facilities | 158 | 165,000 | 6.1 MM |
| Corn processing facilities | 18 | 76,000 | 3.0 MM |
| Ag Services processing facilities | 96 | 36,000 | 1.3 MM |
| Other processing facilities | 28 | N/A | N.A. |




Current

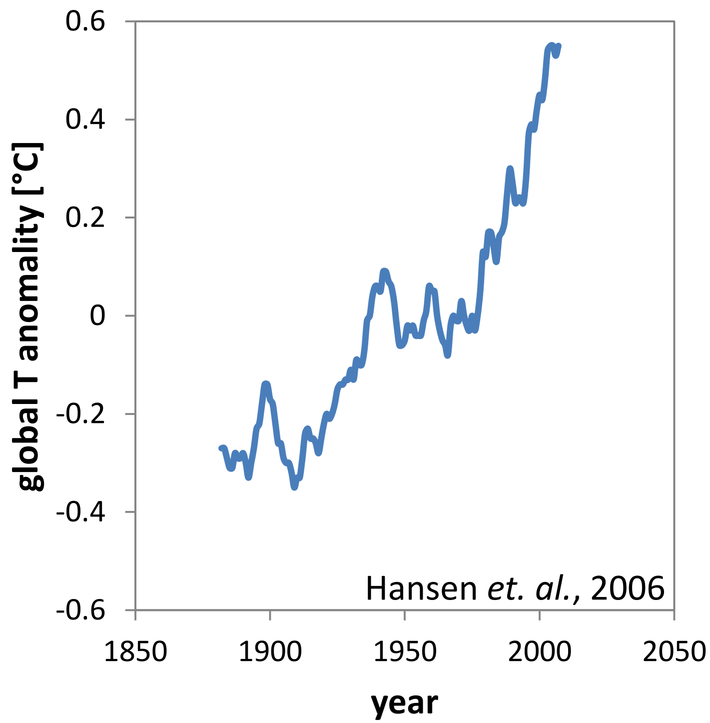
ADM
Supermarket to the world

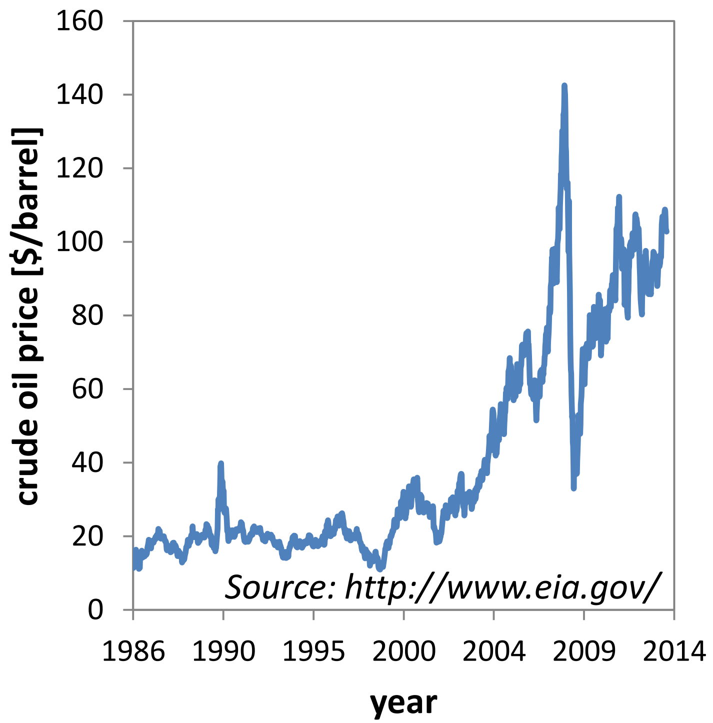
(1962 – 2001)

Archer-Daniels-Midland

Before 1962

# Interest in Biofuels




Environmental concerns of green house gases

Increasing costs of fossil fuels

Increase interest in biofuels

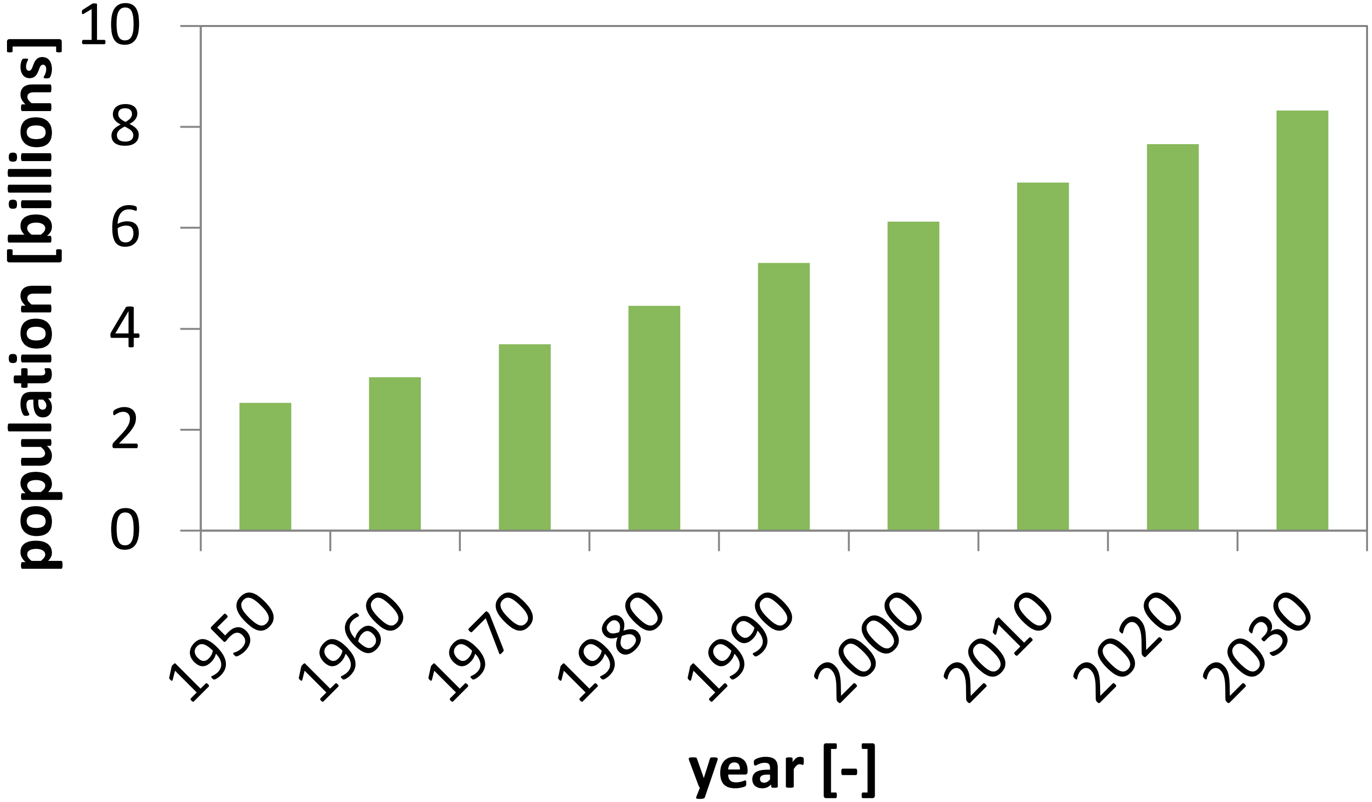
# Corn Stover as Feedstock for Biofuels

First generation

Second generation

Corn stover plentiful sources of cellulosic feedstock estimated 100 million Mg per year (Graham *et. al.*, 2007)

# Perspective on Agricultural Feedstocks



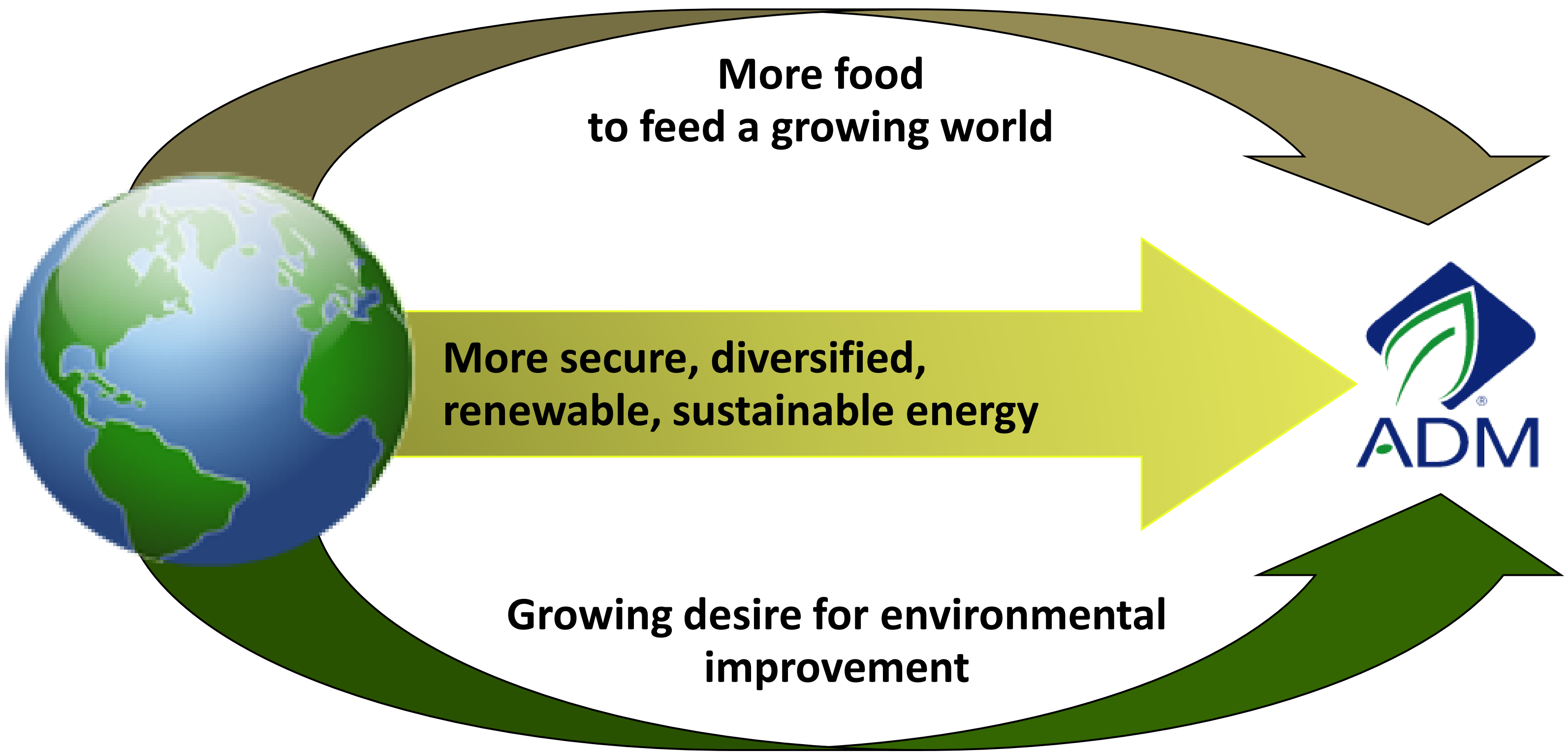

Increase in population ➡ Increase in agricultural products

*Source: http://esa.un.org/wpp/unpp/panel_population.htm*

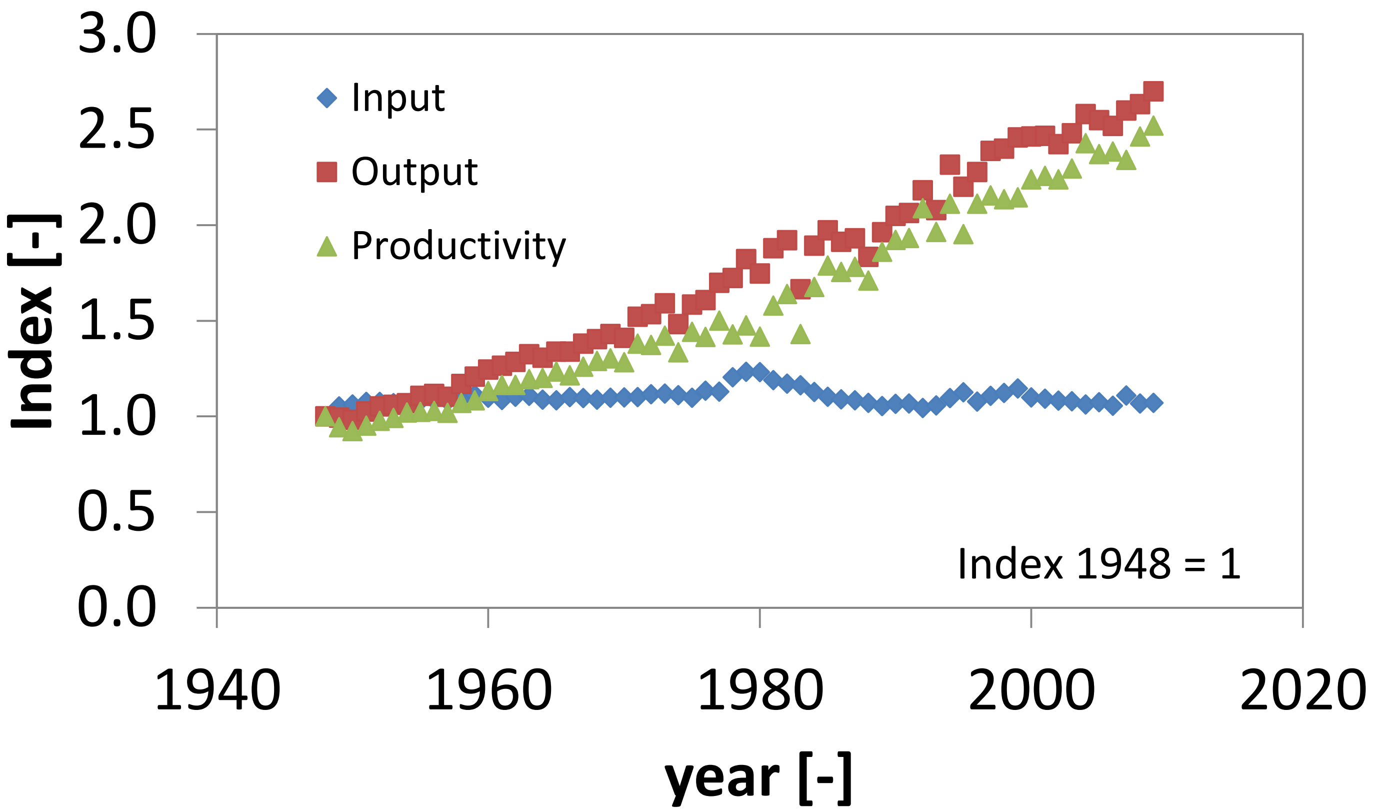
# World Trends

We see three trends shaping world demand

Agriculture will play a growing role in satisfying all three



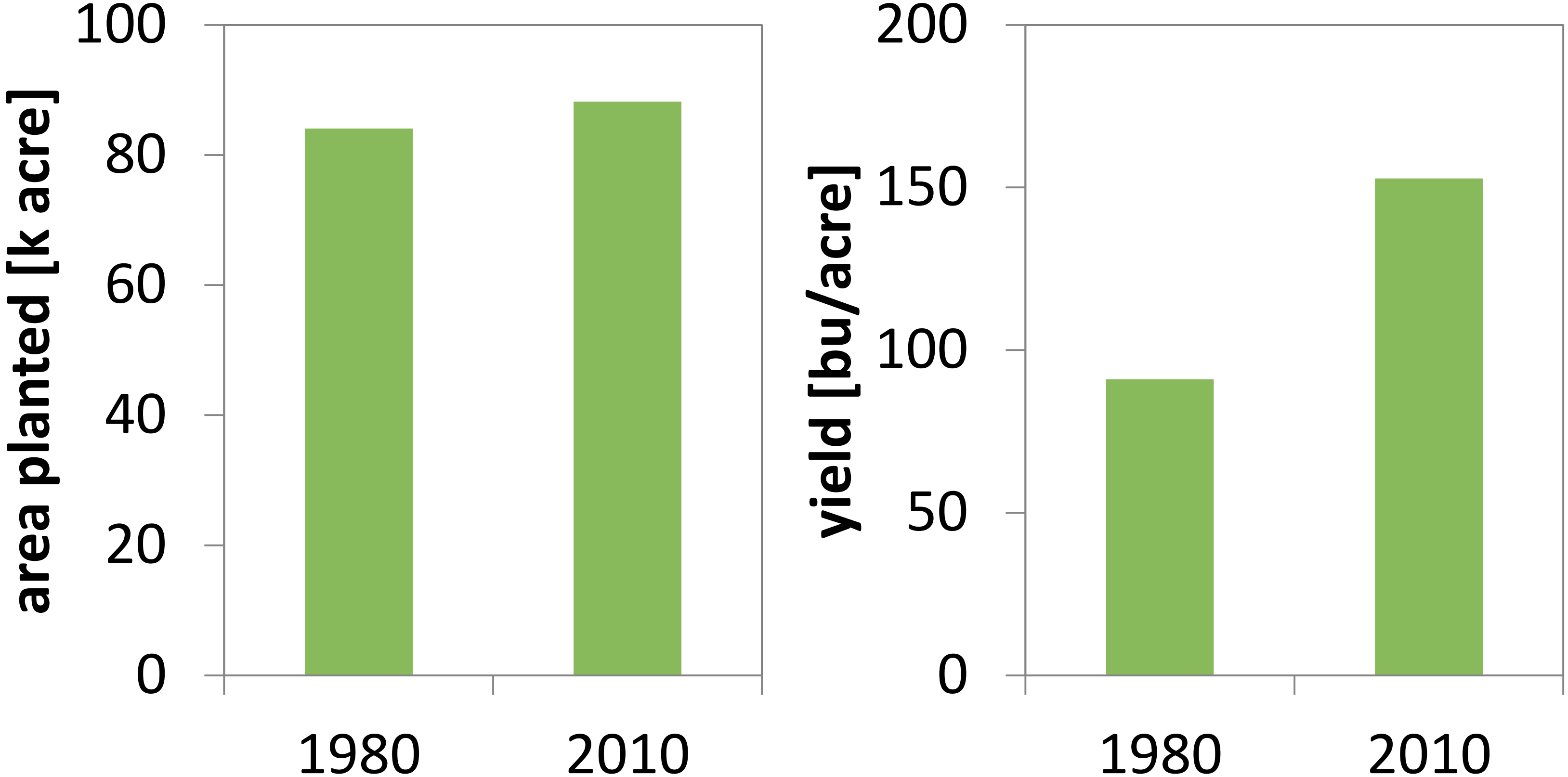
# Agricultural productivity is the key




2.5X production with same water, fertilizers, pesticides, labor, …

*Source: www.ers.usda.gov*

# Corn Agriculture




64,000 acres have bee “created”

*Source: http://www.nass.usda.gov/*

# Agricultural Residue

Increasing yield leads to increasing agricultural residue

Stalks, cobs and leaves are not widely used

- Fuel to generate energy
- Corn replacement feed
- Feedstock for chemicals

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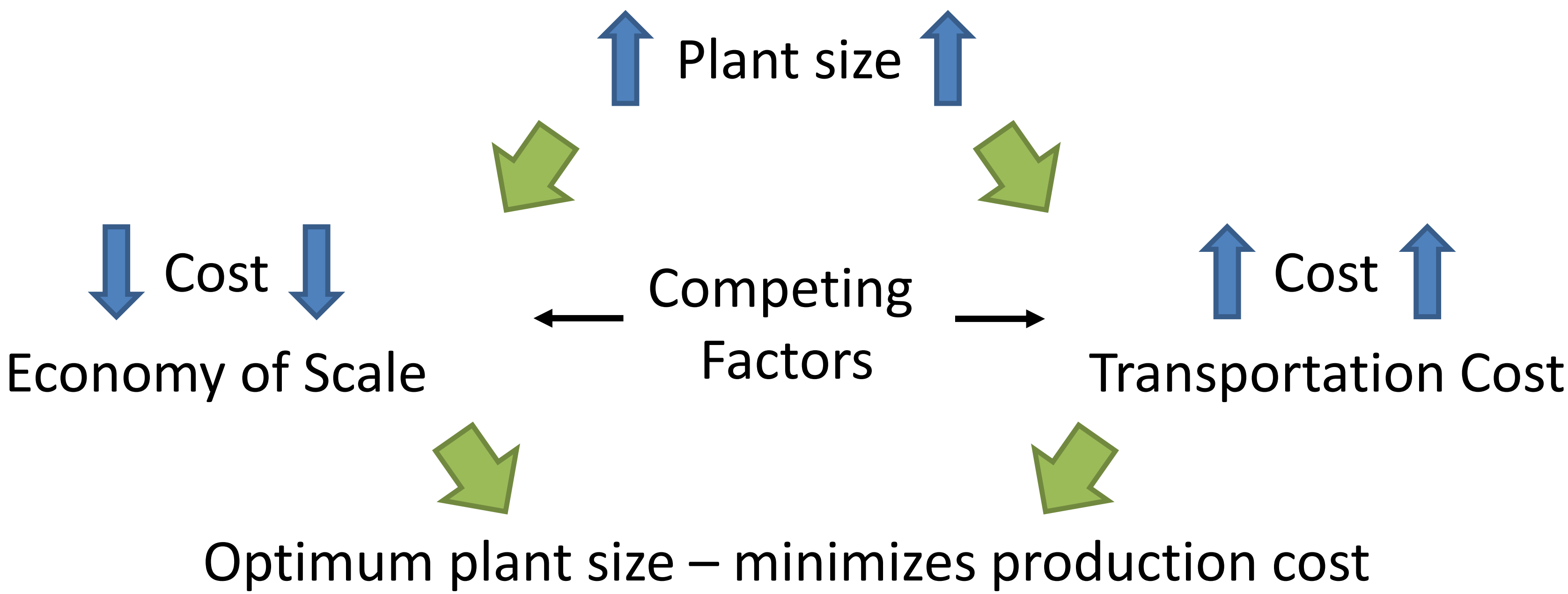
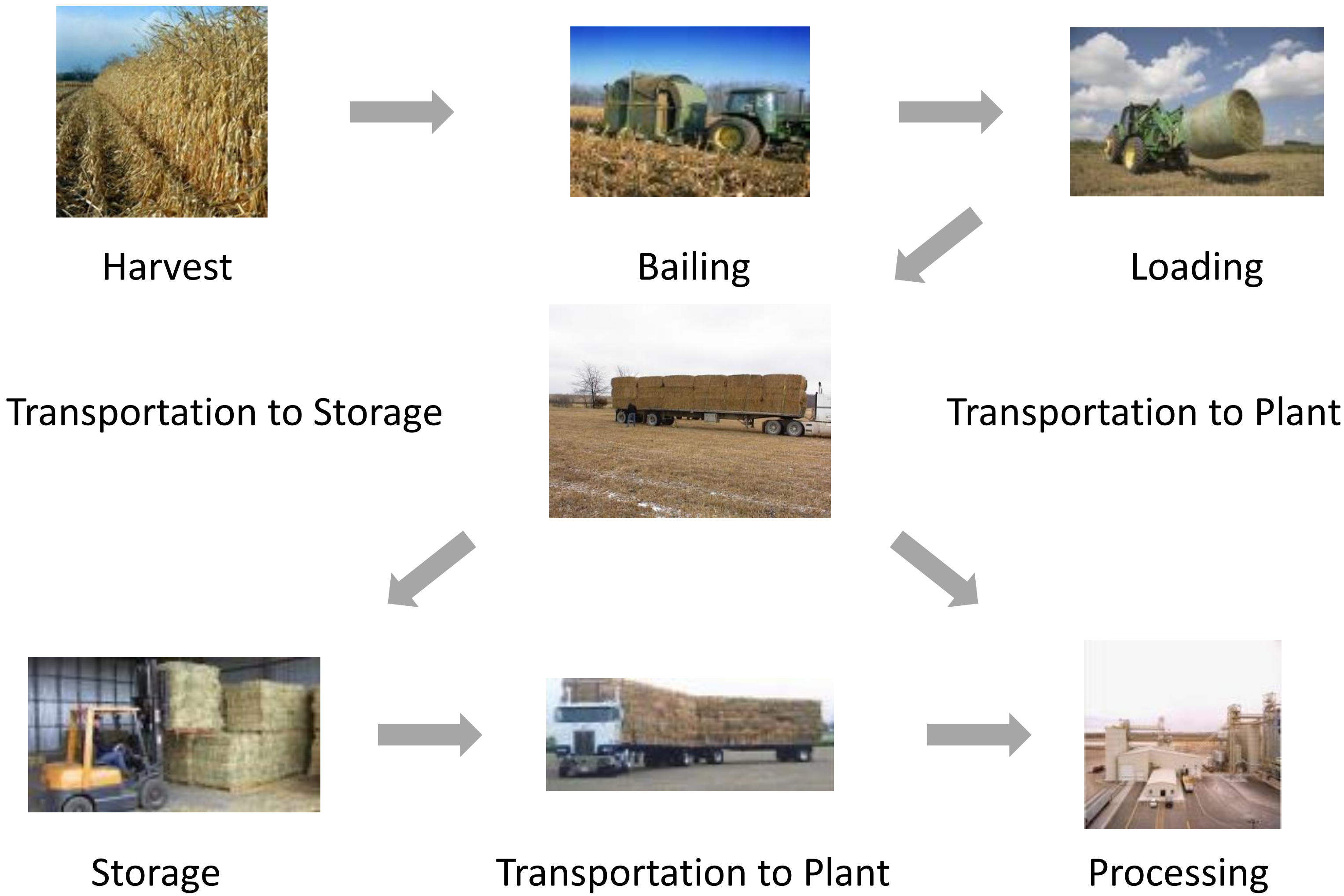
# Logistic Hurdles and Optimum Plant size

Characteristics leading to logistic hurdles

- Collection from many farms
- Collection is labor intensive
- Low energy density leads to expensive transportation



# Diagram of Transportation Model




Details of model: Leboreiro and Hilaly (2010,2013)

# Sustainable biomass harvest

Requires information on:

## Crop inputs

Rotation – Corn stover mass is much larger than soy stubble

Yield – Higher yields mean more plant residue

## Residue loss

Slope – more residue is needed to control erosion on steeper fields

Tillage – more tillage increases decay rate

Soil type – decay rates are faster in sandier soils

Latitude – decay rates are faster in warmer environments

Longitude – decay rates are faster in wetter environments

# Collection Area and Radius

$$A_c = \frac{D_s}{Y_s \cdot F_f \cdot F_c \cdot F_p \cdot F_a \cdot (1 - F_l)}$$

Collection Area ($A_c$)

Corn Stover Annual Demand ($D_s$)

Yield per Acre ($Y_s$)

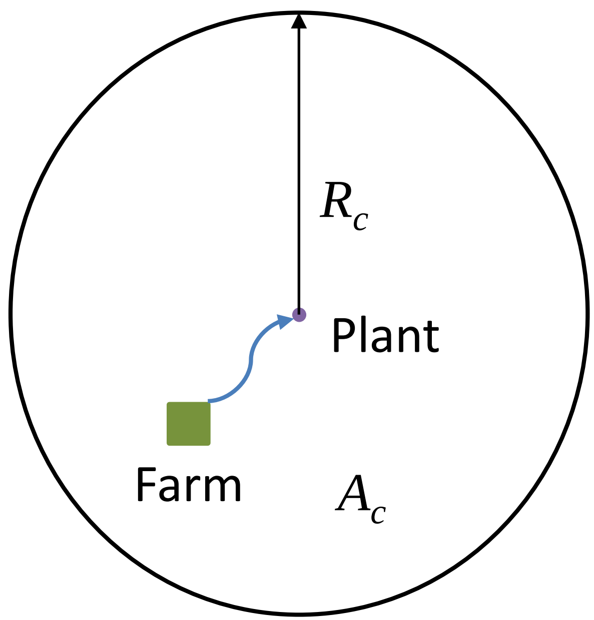
Fraction of Farmland ($F_f$)

Corn Fraction ($F_c$)

Farmers Participation ($F_p$)

Accessible Fraction ($F_a$)

Loss ($F_l$)



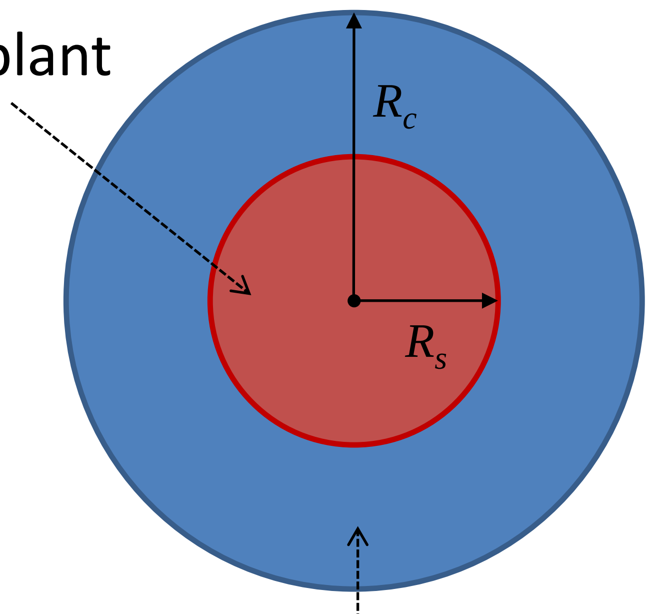
# Storage of Feedstock

Corn stover is left on field during harvesting ~ 3 months

Only 9 months of feedstock is sent to storage

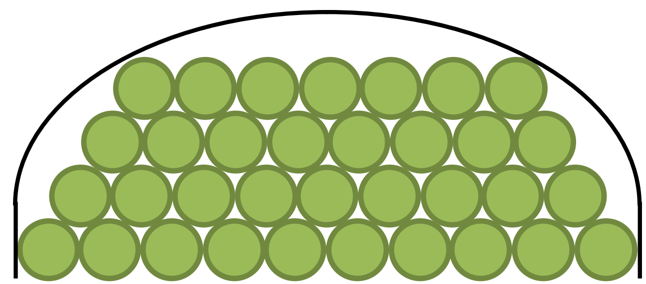
Avg. transportation distance to storage depot of 8 km

Corn stover direct to plant



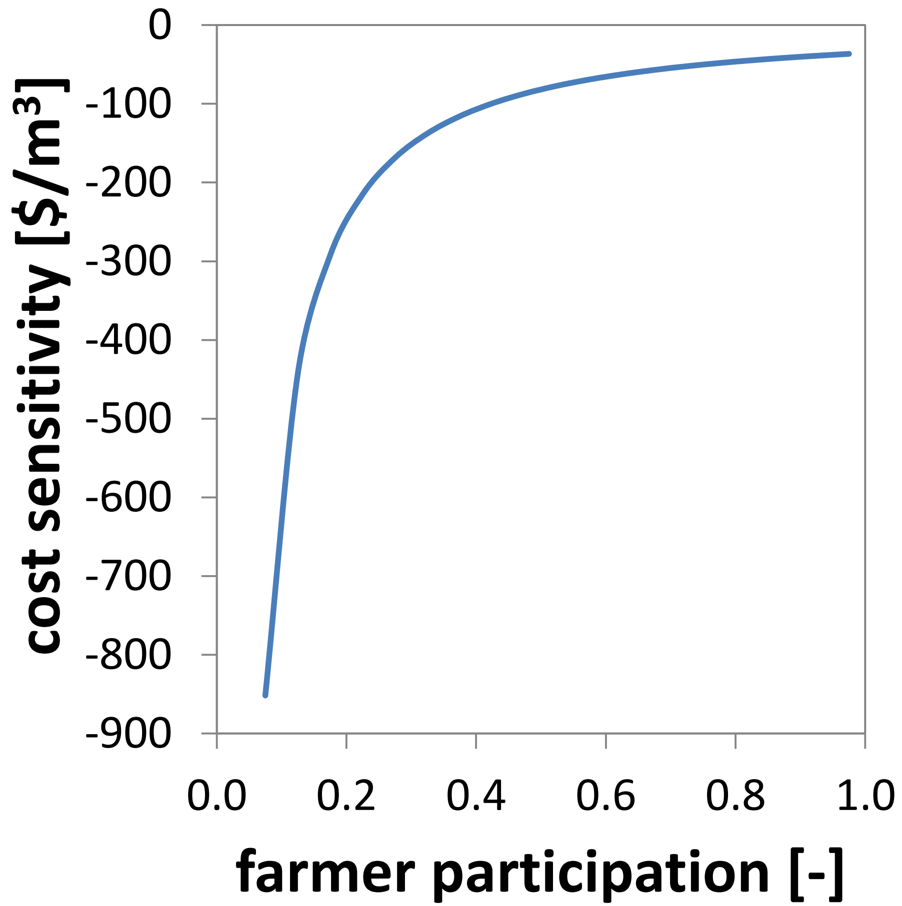

Corn Stover to storage

Tarp hoop structures



10–9–8–7 Bale Arrangement

# Sensitivity to Farmer Participation




Production cost highly sensitive to $F_p$ < 0.4

Biofuel producers should target $F_p$ = 0.5 (Leboreiro and Hilaly, 2010)

# Proposed Scaling Function

New scaling function for fermentation-based biorefineries

$$C_{\mathrm{TPEC}} = k \cdot P^{\alpha} + m \cdot P$$

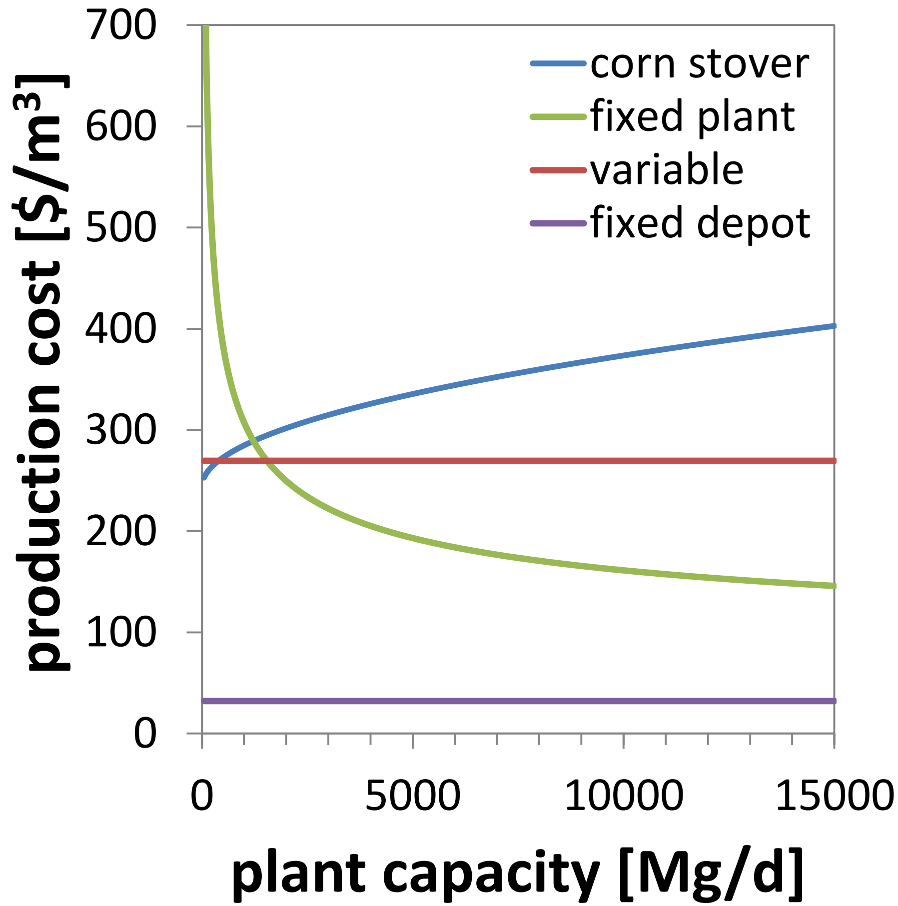
Purchase Equipment Cost

Other

Bio-reactors

Accounts for the linear scaling behavior of bio-reactors as well as the exponential nature of all other plant equipment

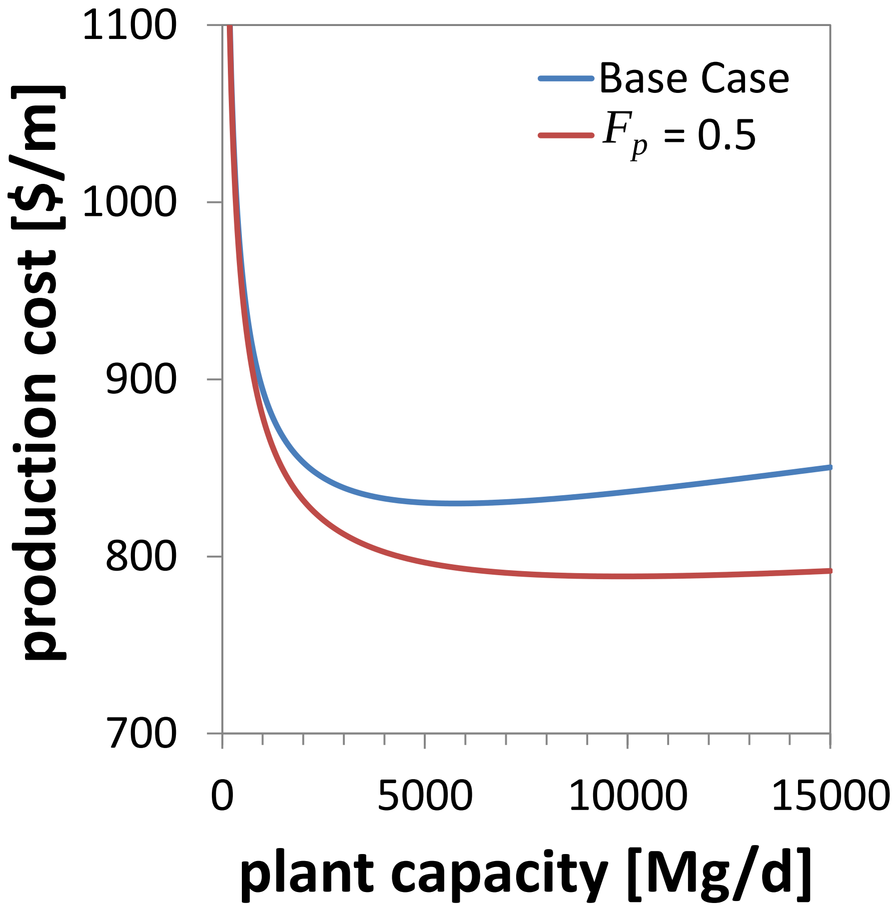
# Total Production Cost Breakdown




Competing factors are observed

Depots do not present economies of scale

# Impact of Farmer Participation




Minimum production cost: 789–830 $/m³ 2.98–3.14 $/gal

Optimum capacities: 5750–9850 Mg/d

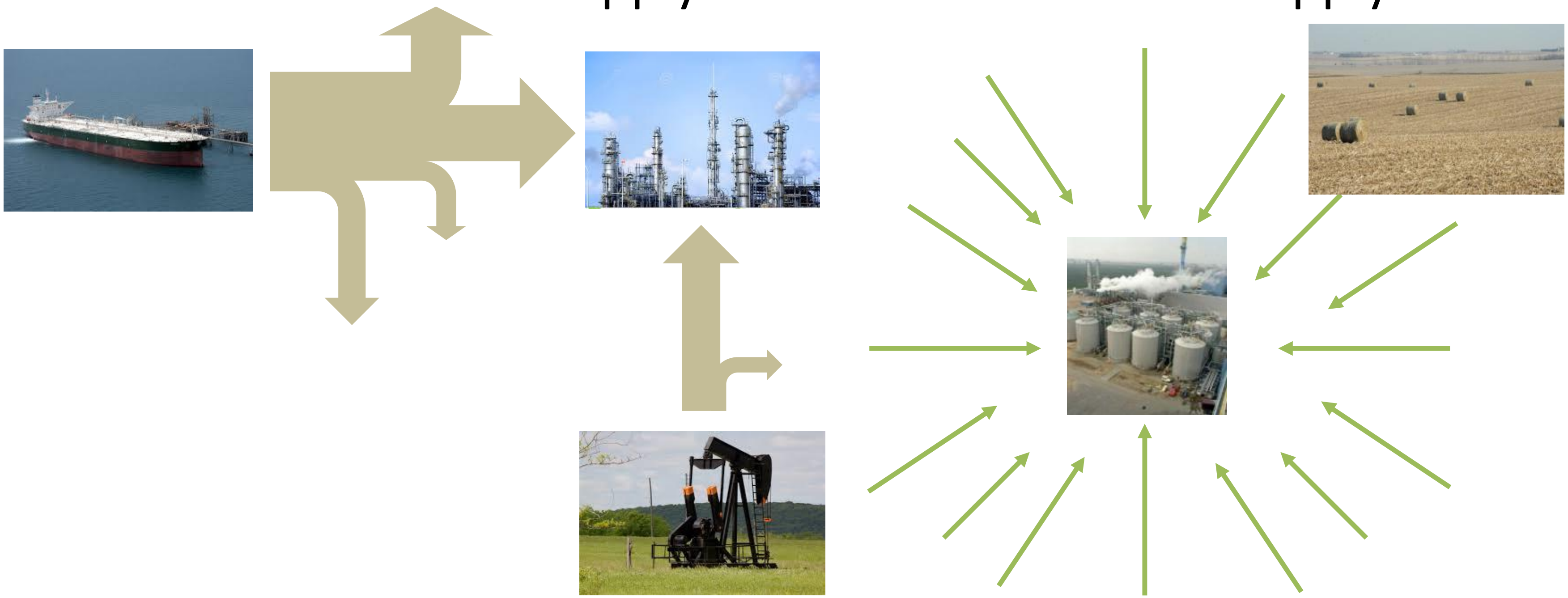
(Leboreiro and Hilaly, 2013)

# Challenge

Delivered corn stover cost ~ $80 per ton or $1.10 per gal

“Mine mouth” supply

Distributed supply



Economic viability of second generation biofuels from agricultural residues depends on resolving the logistic complexity of collection(Overend, 1982)

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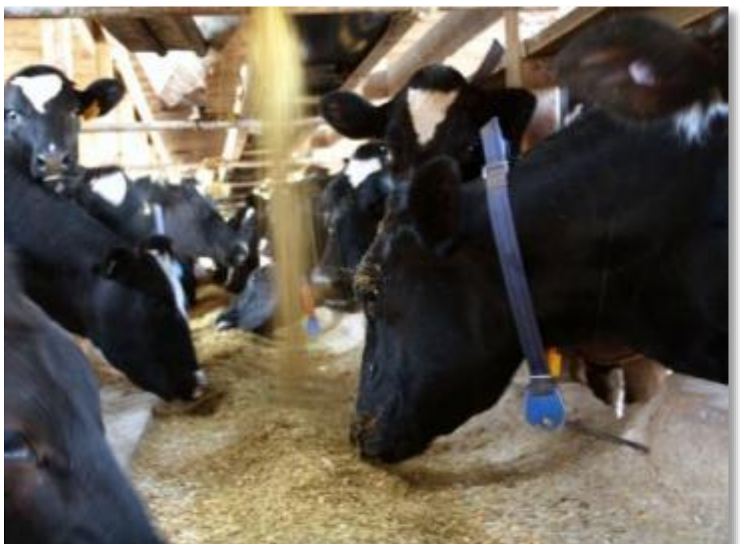
# Making more of today's crops

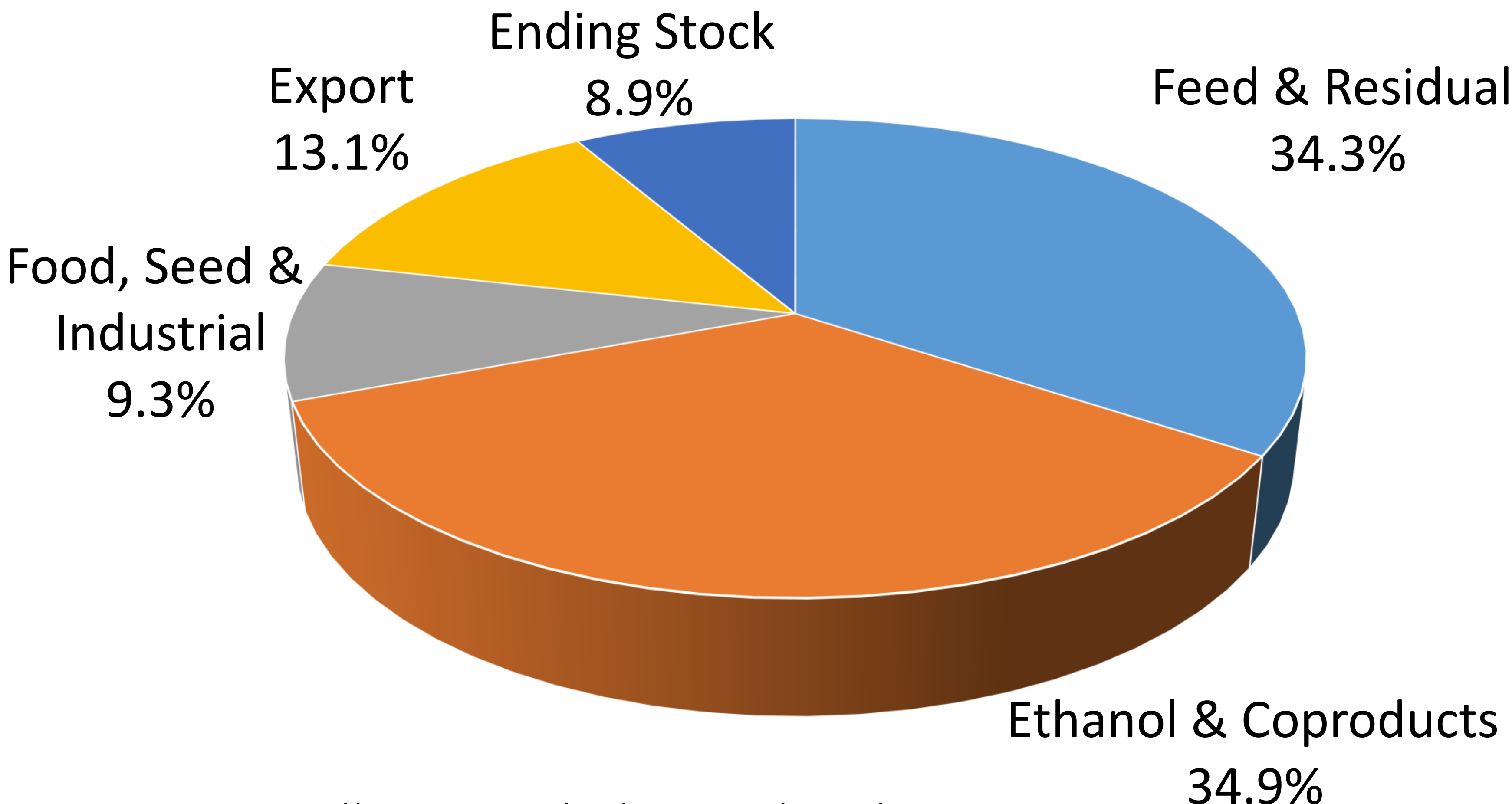
Can fibrous biomass replace some grain in cattle feed?



ADM has worked with major universities to treat crop residues with hydrolyzing agents to make them digestible for cattle This enables greater food and energy production from existing crop acres

# Corn Replacement Feed: A Stepping Stone

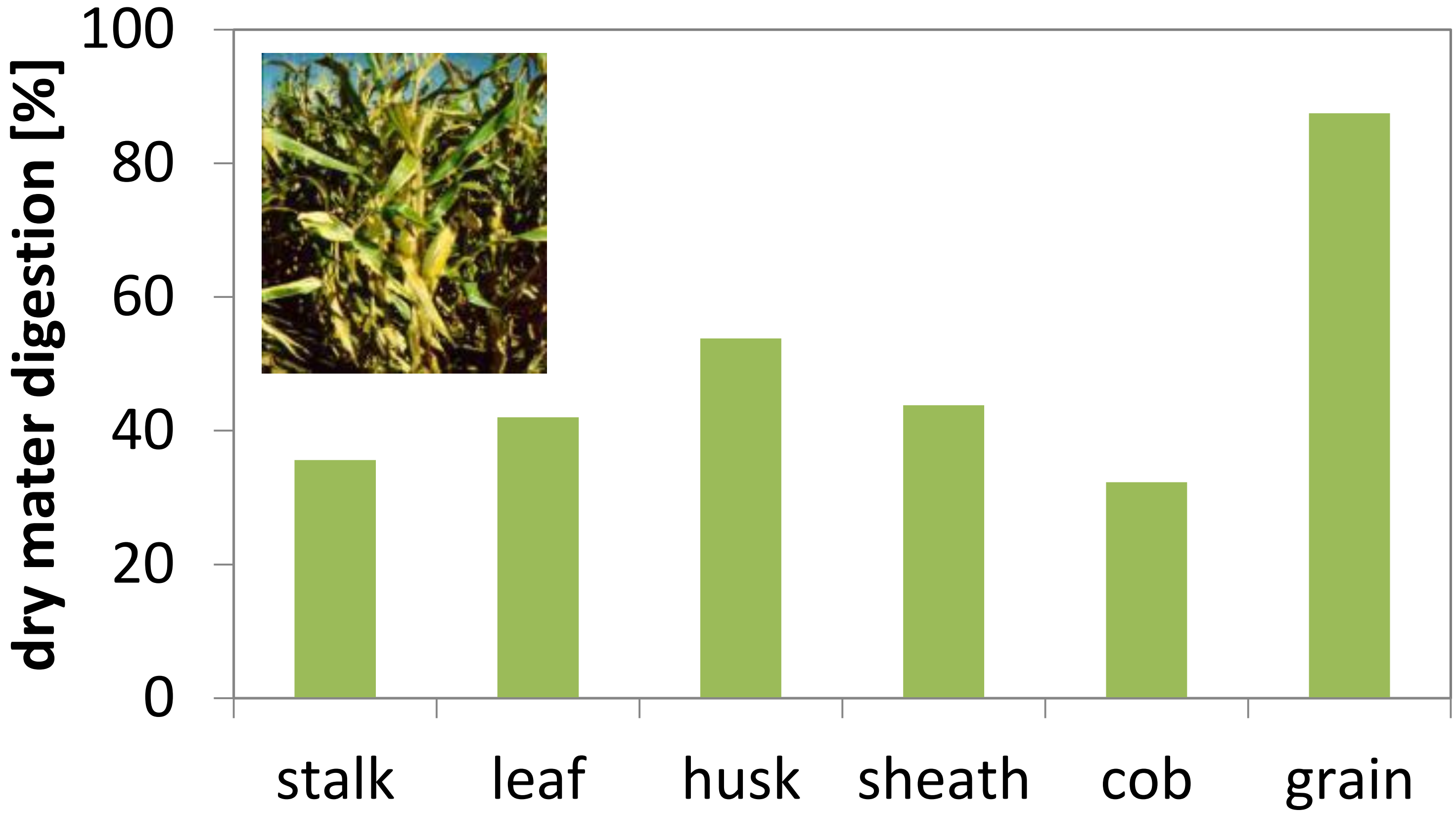
Total corn supply for the 2013/14 cycle 14,686 million bu




*Source: http://www.usda.gov/oce/commodity/wasde/*

# Digestibility

Fibrous biomass (stover) is less digestible than corn grain




Incubated 48 hours in buffered rumen fluid from beef cattle

Contained  fibrolytic and non-fibrolytic microbial species (bacteria, yeast, fungi)

*Source: Iowa State University*

# Integrated Approach

coproducts

pre-treatment

transportation

feed

pre-treatment

# Alkaline Treatment of Biomass

Alkali treatment processes:

- NaOH (caustic soda)
- NaOH + CaO or $Ca(OH)_2$ (lime)
- Ammonia

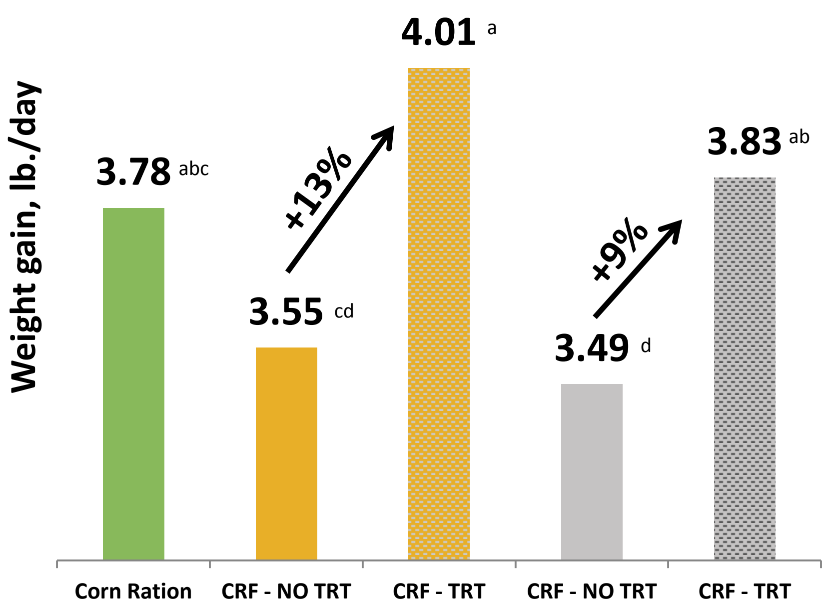
Advantages of lime treatment

- Handling & Safety
  - (less caustic than NaOH)
- Environmental
  - (Ca has less impact on soils than Na)


**Hydrate Lime product sold in USA specifically for treating crop residues (MS Lime Company)**

# Better Performance

Beef cattle fed distillers grains and alkaline treated biomass performed better than cattle fed high corn rations




| Ration | pounds of feed per pound of gain |
|---|---|
| **Corn ration** | 6.83 |
| **Corn replacement feed** | |
| Untreated straw | 7.12 |
| Treated straw | 6.44 |
| Untreated stover | 7.18 |
| Treated stover | 6.82 |

[abcd] Means with uncommon letters are different ($P < 0.05$)

Source: Chemical treatment of low quality forages to replace corn in cattle replacement cattle finishing diets, A. Shreck et al., University of Nebraska, Beef Day Report, 2012

# Large-scale Processing of Stover and Straw

## ADM trial (Oregon, June 2012) – price competitive to corn

**Bulk lime added to water**

**Lime pumped to grinder**

**Lime suspension applied**

**Treated stover pile**

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# Three Keys to Continue Progress

Innovation: new seed technology, new fertilizers to increase productivity, crop protection, increase in water utilization, new process technologies (e.g., catalyst, fermentation, separations)

Investments: in agricultural infrastructure, to enable the handling of larger crop volumes, as well as both food crops and biomass, R&D

Partnerships: public and private sector, civil society, academia, NGOs

# THANK YOU!

# QUESTIONS