Economics of Lignocellulosic Conversion Processes: Options, Issues, Scale for Liquid Fuels

Francis Epplin
Department of Agricultural Economics
Oklahoma State University

RENEWABLE ENERGY
BIOMASS EDUCATION FIELD DAYS
November 16-18, 2010
Knoxville, Tenn.

Four Issues

1. U.S. Crude Oil Use

2. Cellulosic Biofuels Production Cost

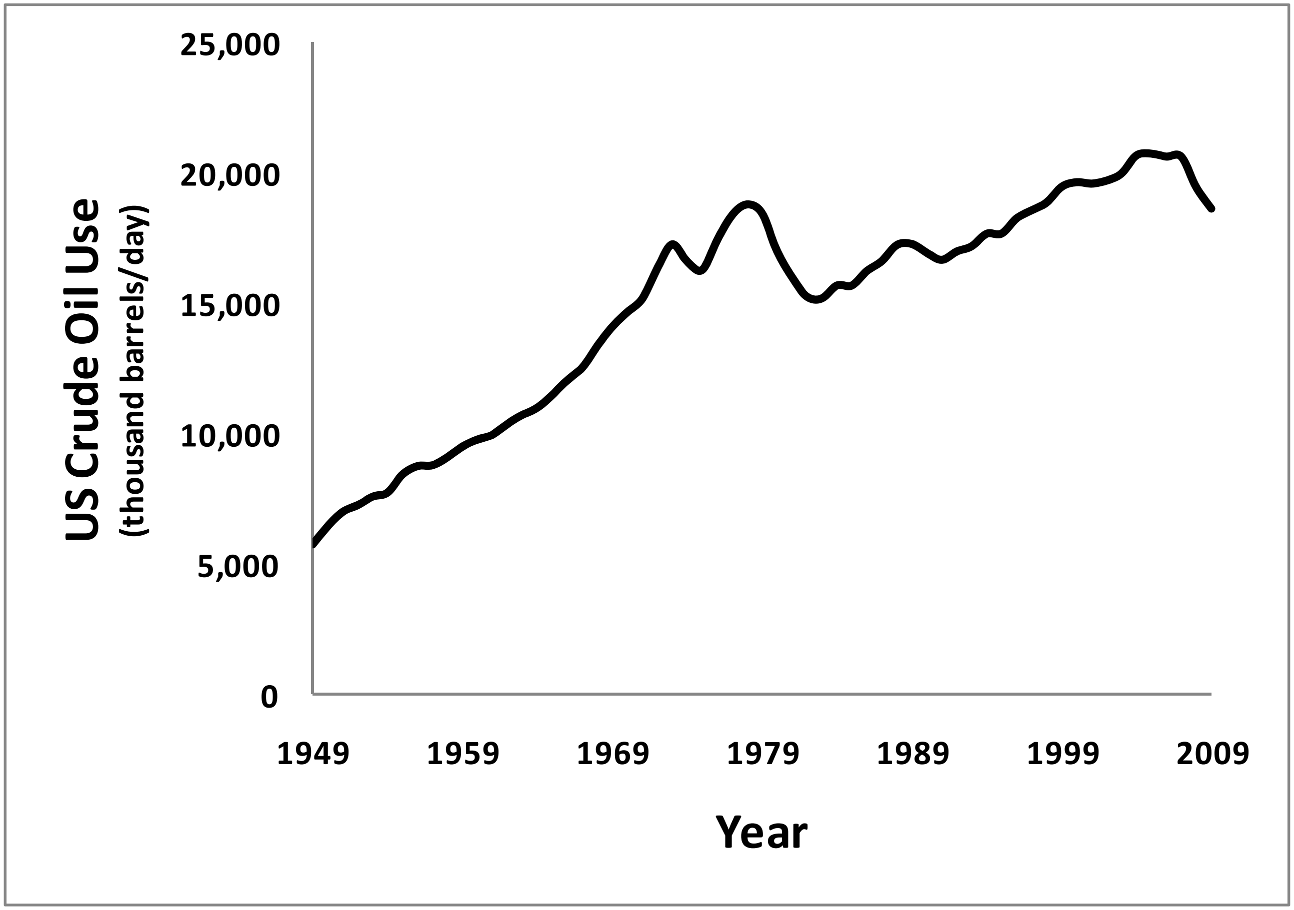
3. Cost-efficient Dedicated Energy Crop Production and Delivery

4. Potential Role for the USDA

OKLAHOMA STATE UNIVERSITY AGRICULTURE

U.S. Crude Oil Use

(thousands barrels per day)



How Much is 18.8 Million Barrels of Crude Oil ?

- Daily U.S. use (2009)

- Accounts for about 38% of U.S. Energy Use

BP Deepwater Horizon Macondo

- Spilled crude oil for 87 days
- April 20 – July 15, 2010
- Estimated 4.9 million barrels spilled
- How much was leaked
  relative to U.S. daily use?
- Equivalent to **6.3 hours**
  of U.S. use

Corn Ethanol

- 2009
  - 10.6 billion gallons of ethanol from grain
  - Contained energy equivalent to **7.4 days** of U.S. crude oil use

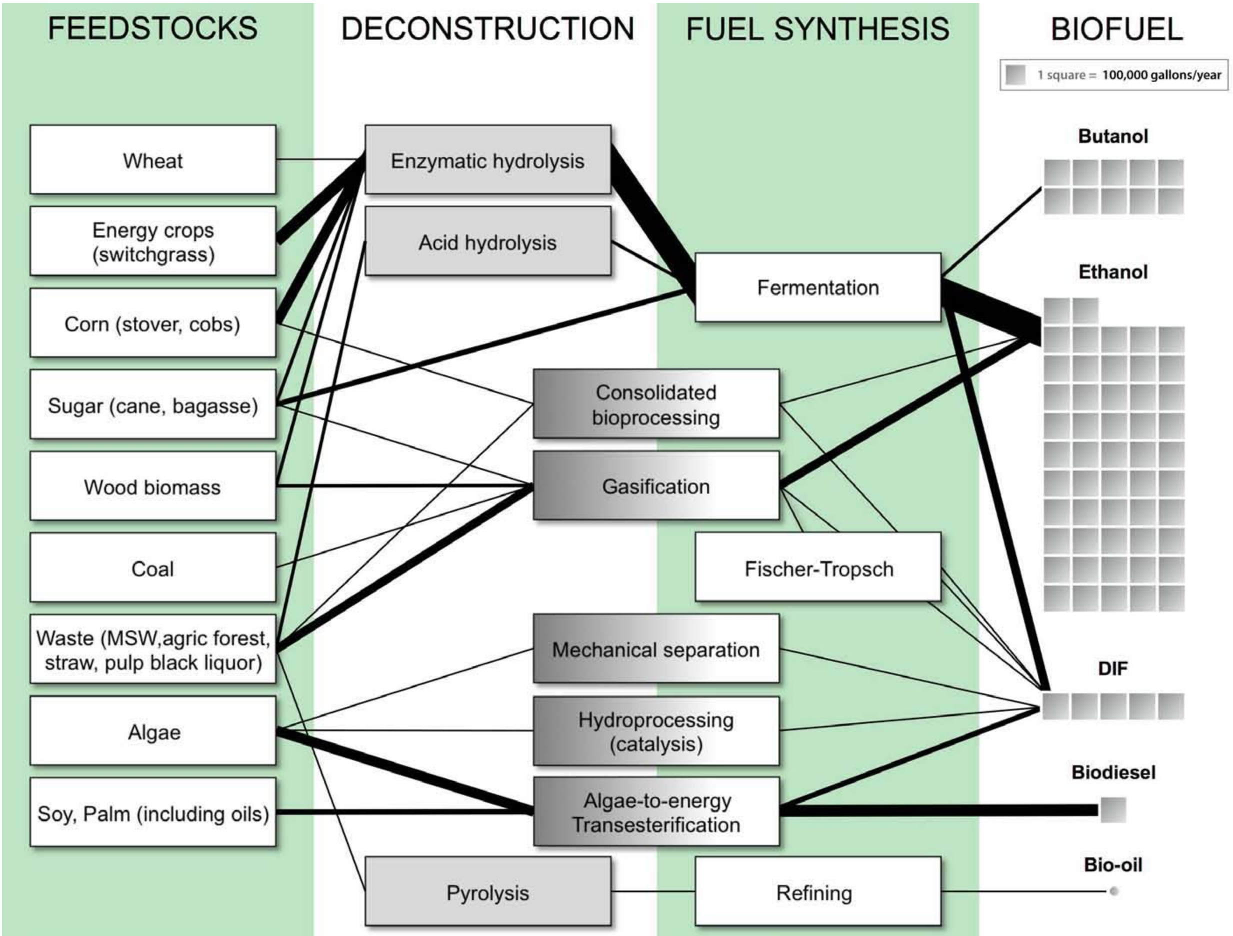
- 2010 corn crop
  - 12.66 billion bu
  - If every bu were converted to ethanol it would contain energy equivalent to **24.4 days** (6.7%) of U.S. crude oil use

Four Issues

1. U.S. Crude Oil Use
   – Spill - 6 hours
   – Corn - 7 days

2. Cellulosic Biofuels Production Cost

Biomass to Biofuel Technologies



Source: http://www.sandia.gov/news/publications/white-papers/BioFuels7-19V5.pdf

Figure 2: Today's Biofuels Sector. An overview of technologies used by the top 50 biofuel companies in 2009 in terms of feedstocks, conversion processes, and biofuels produced. Line thicknesses represent the relative number of these 50 companies using these processes in 2009. Quantities of biofuels produced are from 2009 company reports. Some companies produce fuels for markets outside of the United States. (DIF are drop-in fuels, mainly diesel type products.) Figure design from Nathan Hillson and Harry Beller, Berkeley Lab. Data from Jim Lane (ed.),Biofuels Digest: <biofuelsdigest.com>

Cellulosic Ethanol

- 1910 Standard Alcohol Company built a cellulosic ethanol plant in South Carolina to process waste wood from a lumber mill, sold to duPont who operated it until after WW I. (Source: Sherrard, E.C. and F. W. Kressman. 1945. "Review of Processes in the United States Prior to Wold War II." Industrial & Engineering Chemistry 37:5-8.)

- 1940s During WW II a cellulosic ethanol plant was funded by the Government as an insurance plant, in case of grain shortage.

- Economics was a secondary consideration during wartime

Cost Estimates (cellulosic ethanol)

	Conversion	Investment Cost	Gallons / Year	Investment Cost
	(gal / ton)	(million)	(million)	($ / gal yr cap)
DOE NREL/EPA	72 - 94	$245	60	$4.1
USDA (2010 roadmap)	70	$320	40	$8.0
Kazi et al. 2010	69	$376	53	$7.1
Coskata	100	$400	100	$4.0

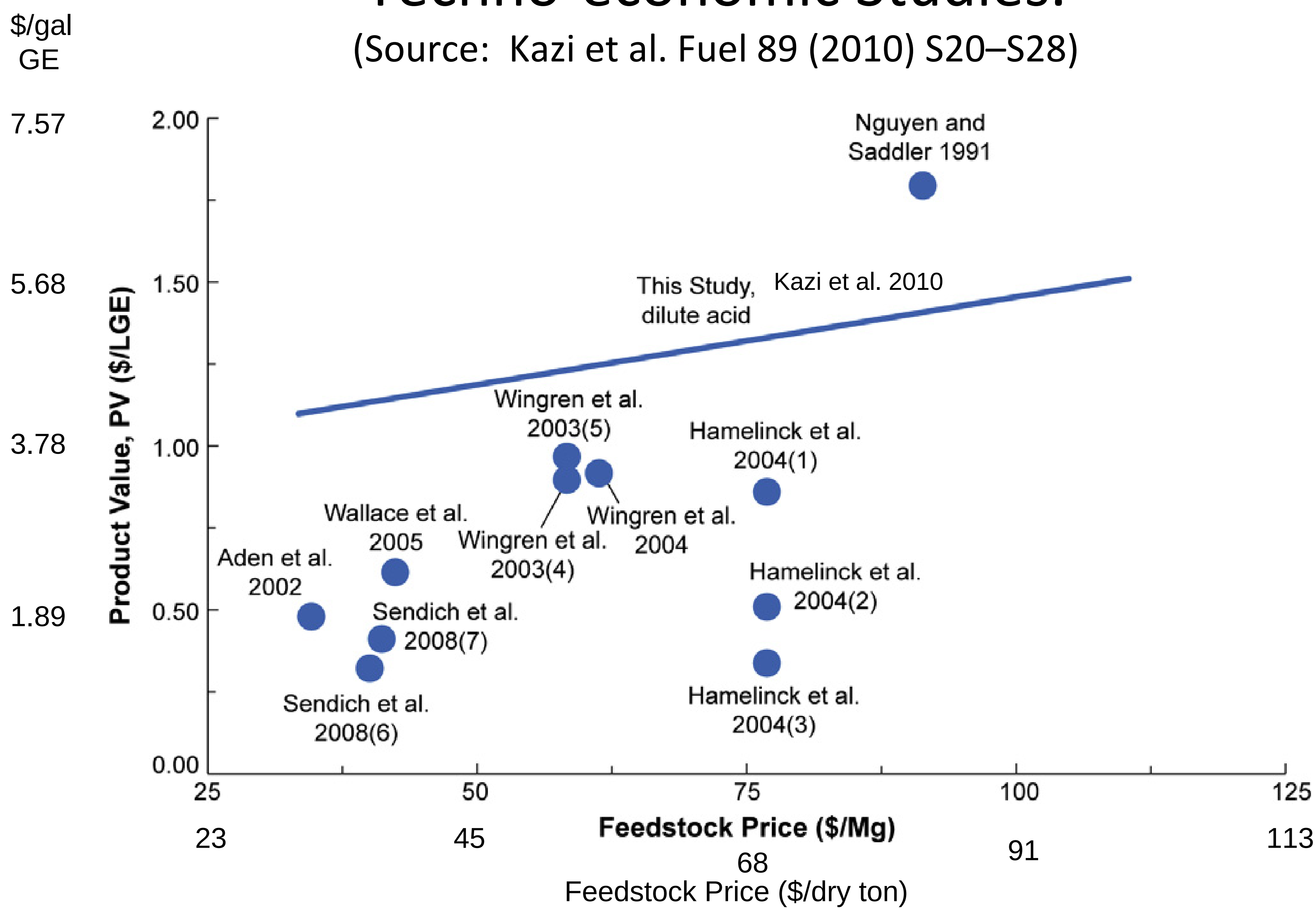
Kazi, Fortman, Anex (Iowa State); Hsu, Aden, Dutta (NREL); Kothandaraman (ConocoPhillips)

(*Kazi et al. Fuel 89 (2010) S20–S28*)

- Evaluated Eight Alternatives for Producing Ethanol from Corn Stover
- Lowest Cost Production System
  - $376 million investment cost
  - 53 million gal/year
  - 69 gal/ton
  - Feedstock cost $75/ton
  - Estimated Cost - $5.13 / gallon gasoline equivalent
    - $1.09 (21%) for feedstock + $4.04 / gallon

Cellulosic Ethanol Production Costs from Published Techno-economic Studies.

(Source: Kazi et al. Fuel 89 (2010) S20–S28)



OSU Field to Fuel

Switchgrass

$400 million investment cost

100 million gal/year

80 gal/ton

Feedstock cost $56/ton

Estimated Cost - $2.09 / gal ethanol

$0.70 (33% for feedstock)

Estimated Cost - $3.18 / gal gasoline equivalent ($121 / barrel crude oil)

OKLAHOMA STATE UNIVERSITY AGRICULTURE

If Externalities are Ignored, Difficult to Compete Economically with Crude Oil

1980 versus 2009

1980

"…By the mid 1980s, most authorities believe that cellulose conversion technologies will be commercially available to produce ethanol from crop residues, forage crops, wood, or municipal solid waste…" *(*Tyner. *Am. J. Agr. Econ. (1980) 62(5):961).*

2009

"… numbers (of flex-fuel vehicles) cannot grow fast enough to matter much in the next five years. …second generation ethanol … is **dead on arrival**. … Corn ethanol is cheaper and will completely fill the blend limit. That is one reason there is more talk about non-ethanol second generation biofuels…" *(*Tyner*. Ethanol Today.com October 2009)*

http://www.ethanoltoday.com/index.php?option=com_content&task=view&id=5&Itemid=6&fid=65

Four Issues

1. U.S. Crude Oil Use
   – Spill - 6 hours
   – Corn - 7 days

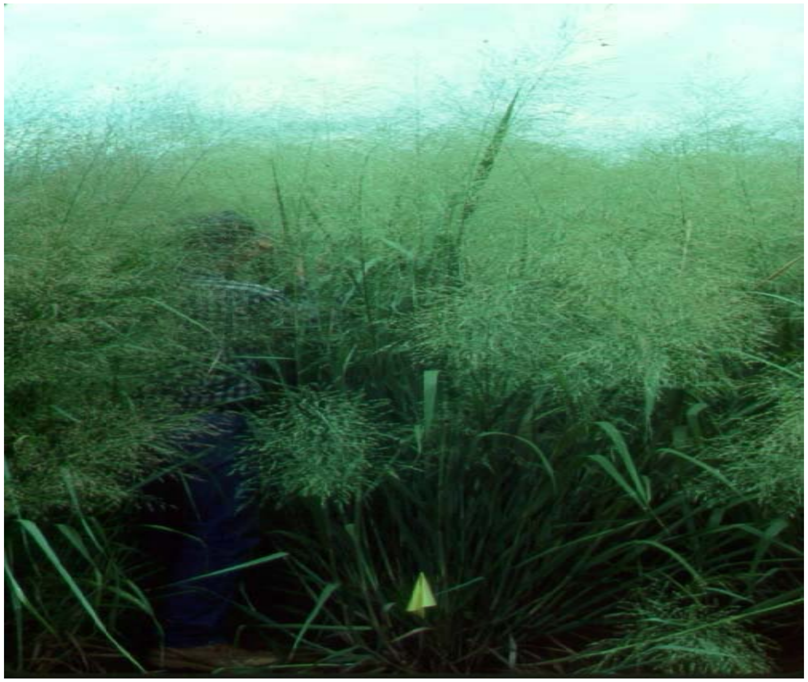
2. Cellulosic Biofuels Production Cost
   – If Externalities are Ignored, Difficult to Compete Economically with Crude Oil
   – Conversion Technologies Have Not Achieved the Projected Cost Targets

Four Issues

3. Cost-efficient Dedicated Energy Crop Production and Delivery

OSU Research

- Lignocellulosic Biomass Field to Fuels



Quantity of Feedstock Required for a 2,000 tons per day Biorefinery

- 350 days of operation per year
- 700,000 tons of biomass per year
- 17 dry tons per truck
- 118 trucks per day
- 24 hours per day
- 4.9 trucks per hour

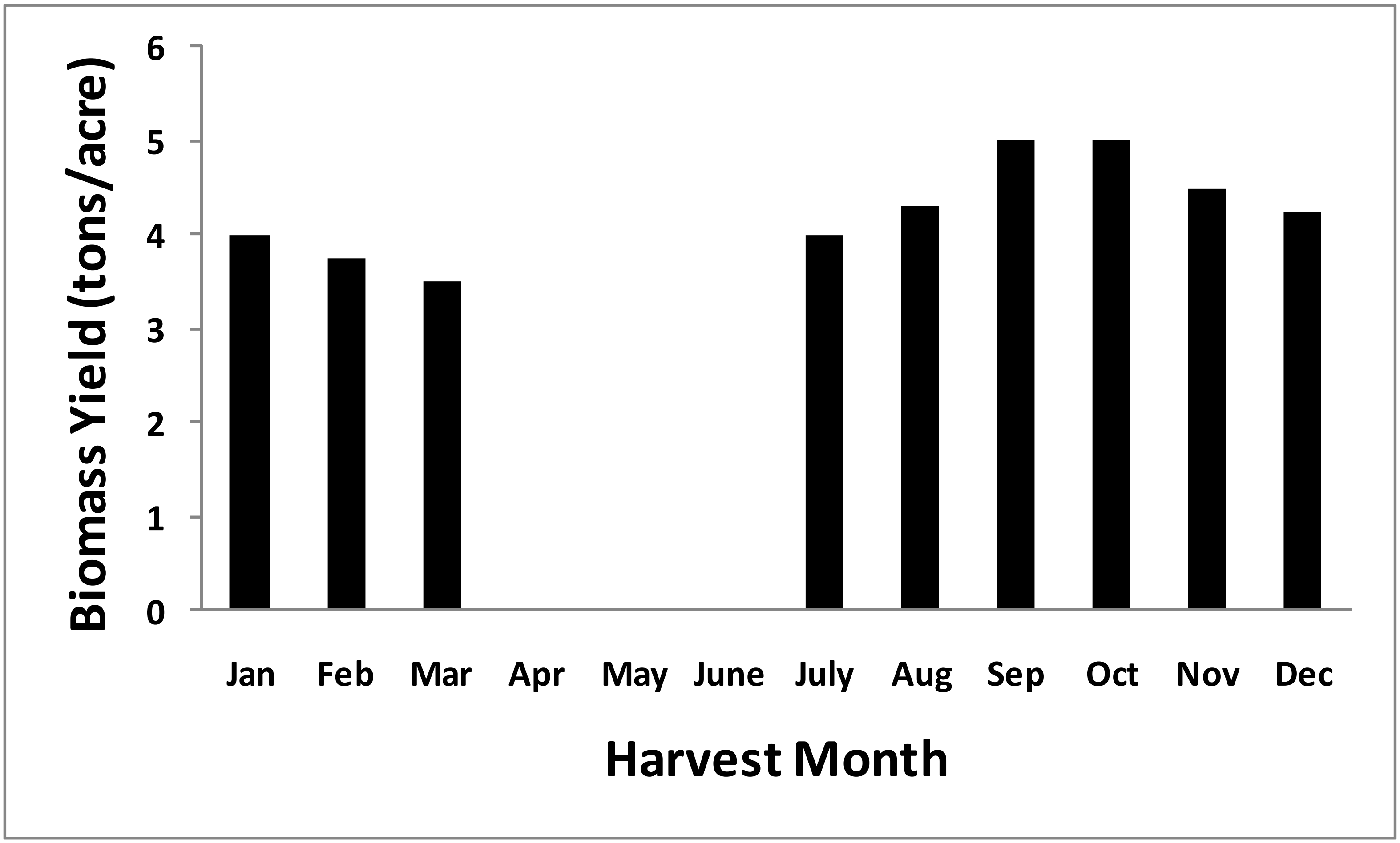
Perennial Grass Feedstock Production and Delivery

- Year-round delivery of feedstock
- Cost efficiency suggests
  - Highly coordinated production system
  - Coordinated harvest systems
  - Harvest season extended over as many months as possible (9 months in Oklahoma)

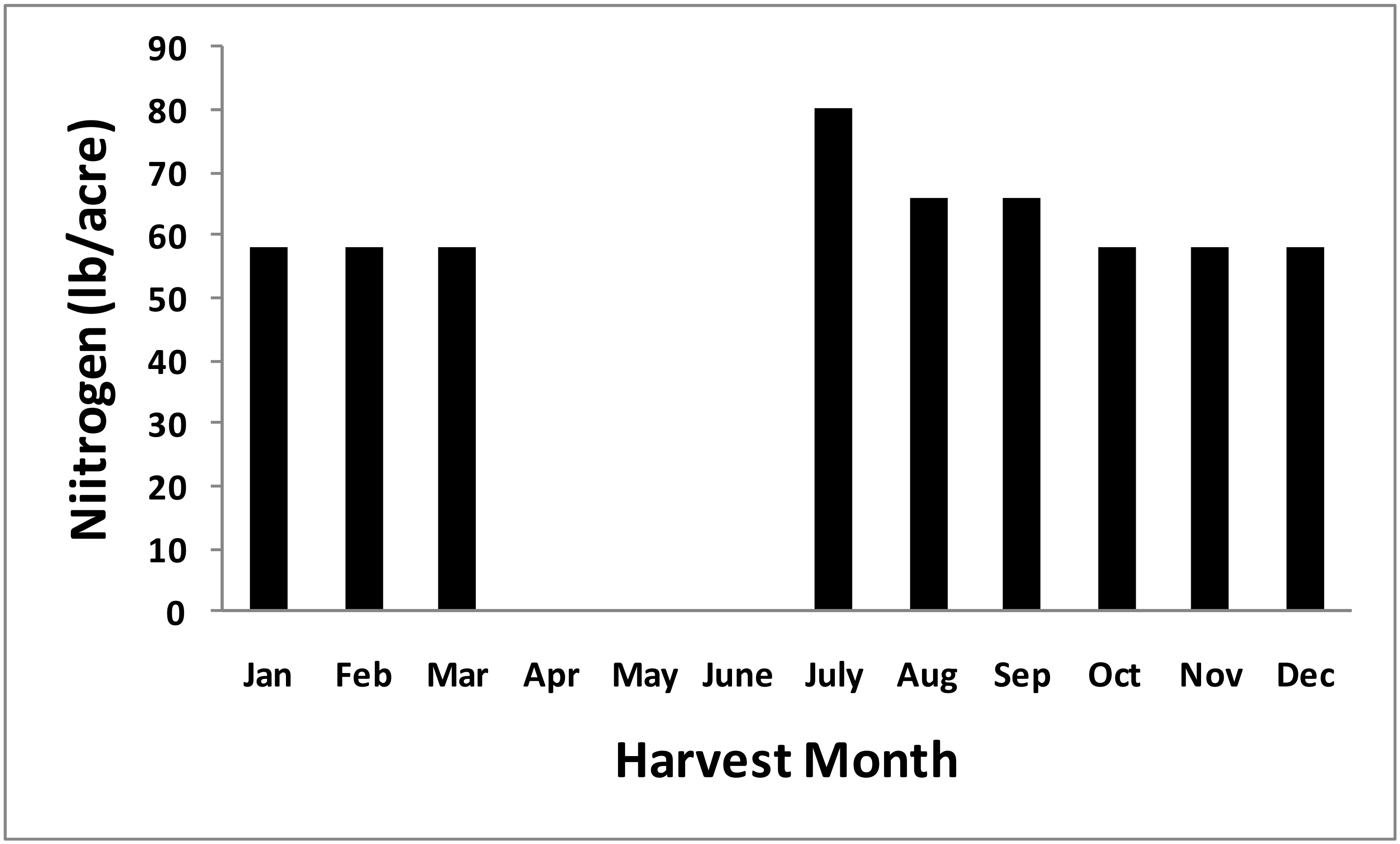
Length of Harvest Season

- Cost to harvest the quantity of feedstock required by a biorefinery depends on the number of required harvest machines which depends on throughput capacity and weather

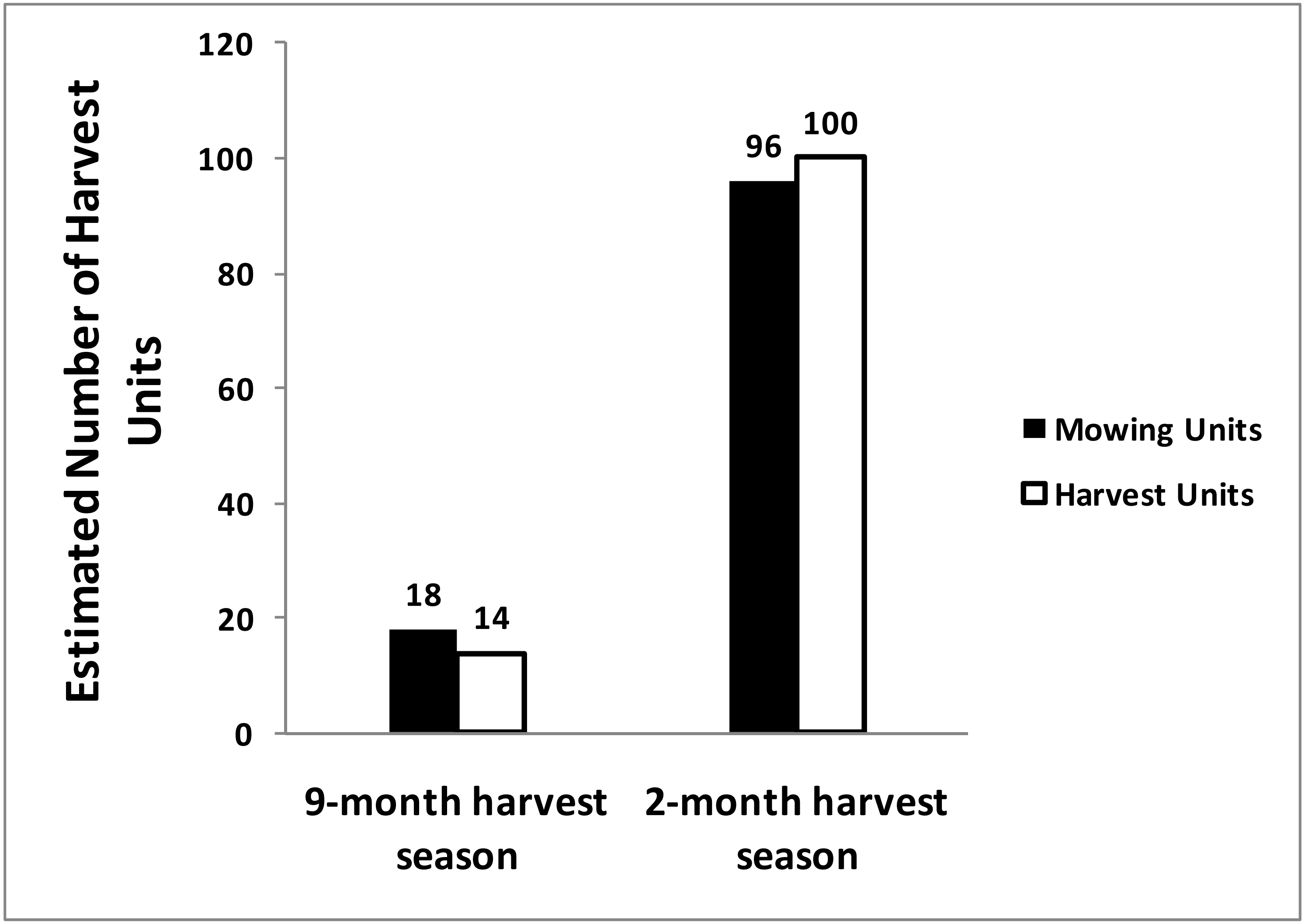
Switchgrass Biomass Yield by Harvest Month (one harvest per year)



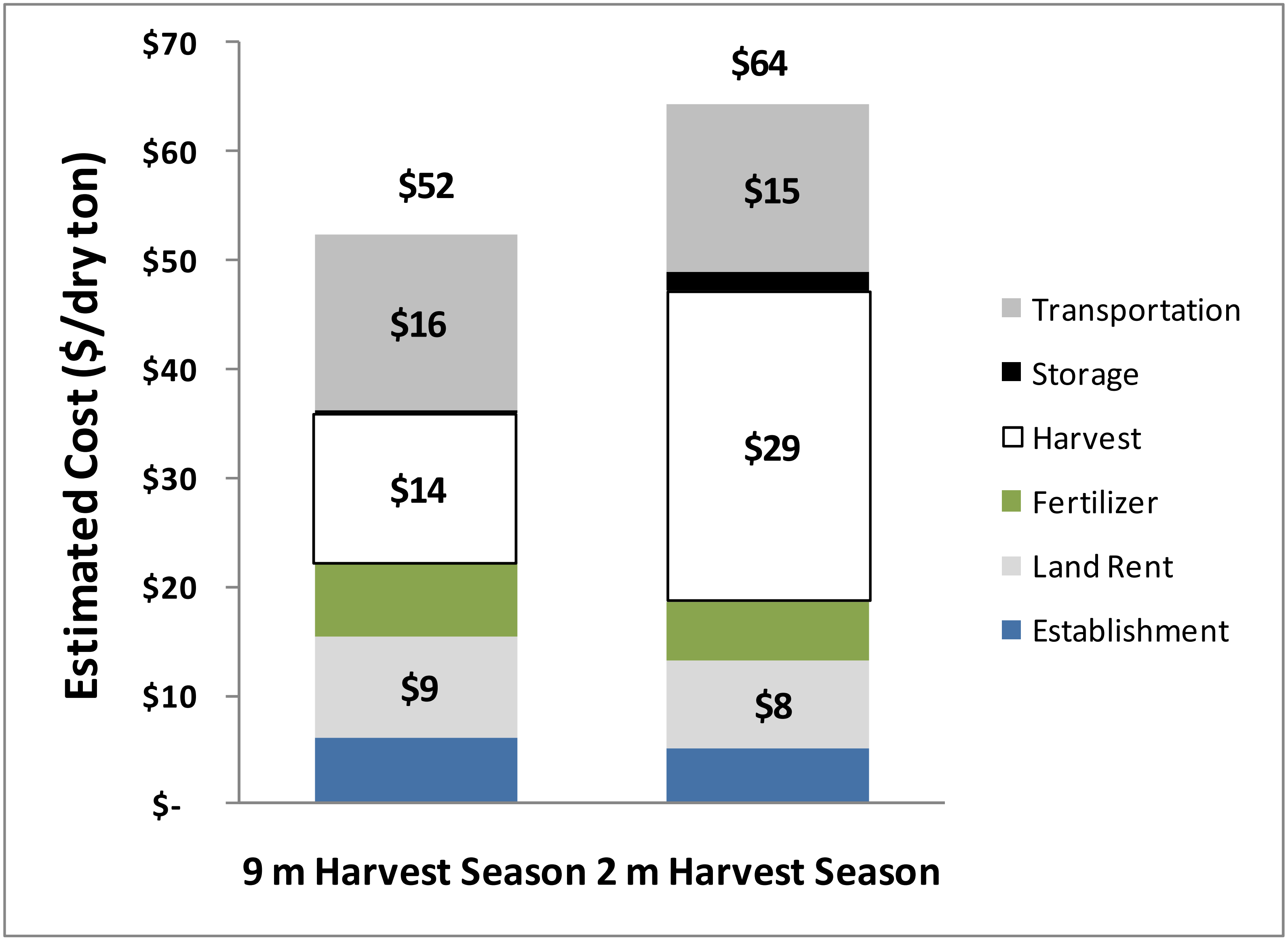
Plateau Level Nitrogen Requirements by Harvest Month



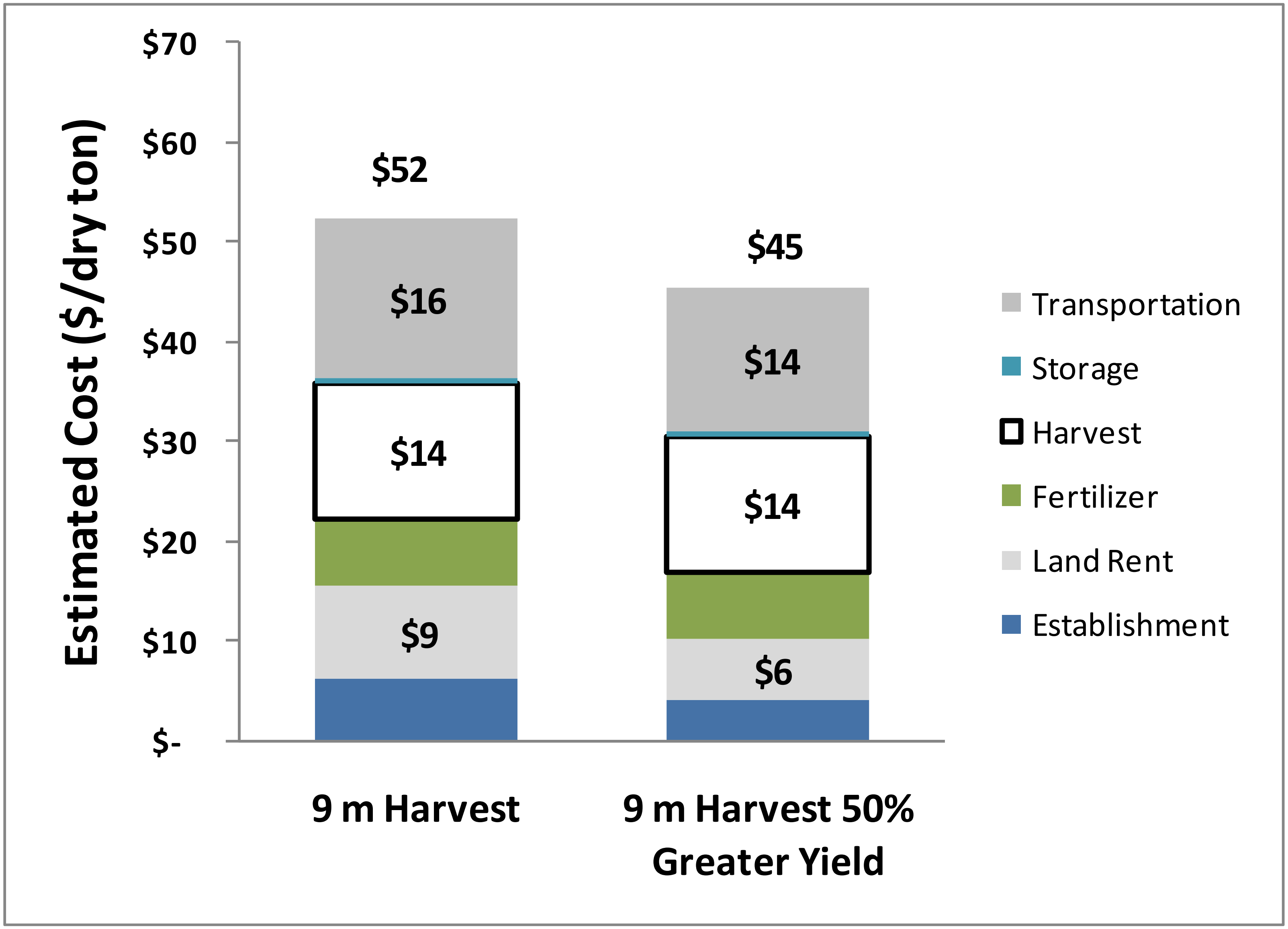
Estimated number of harvest machines for two- and nine-month harvest season to provide a flow of 2,000 t/day



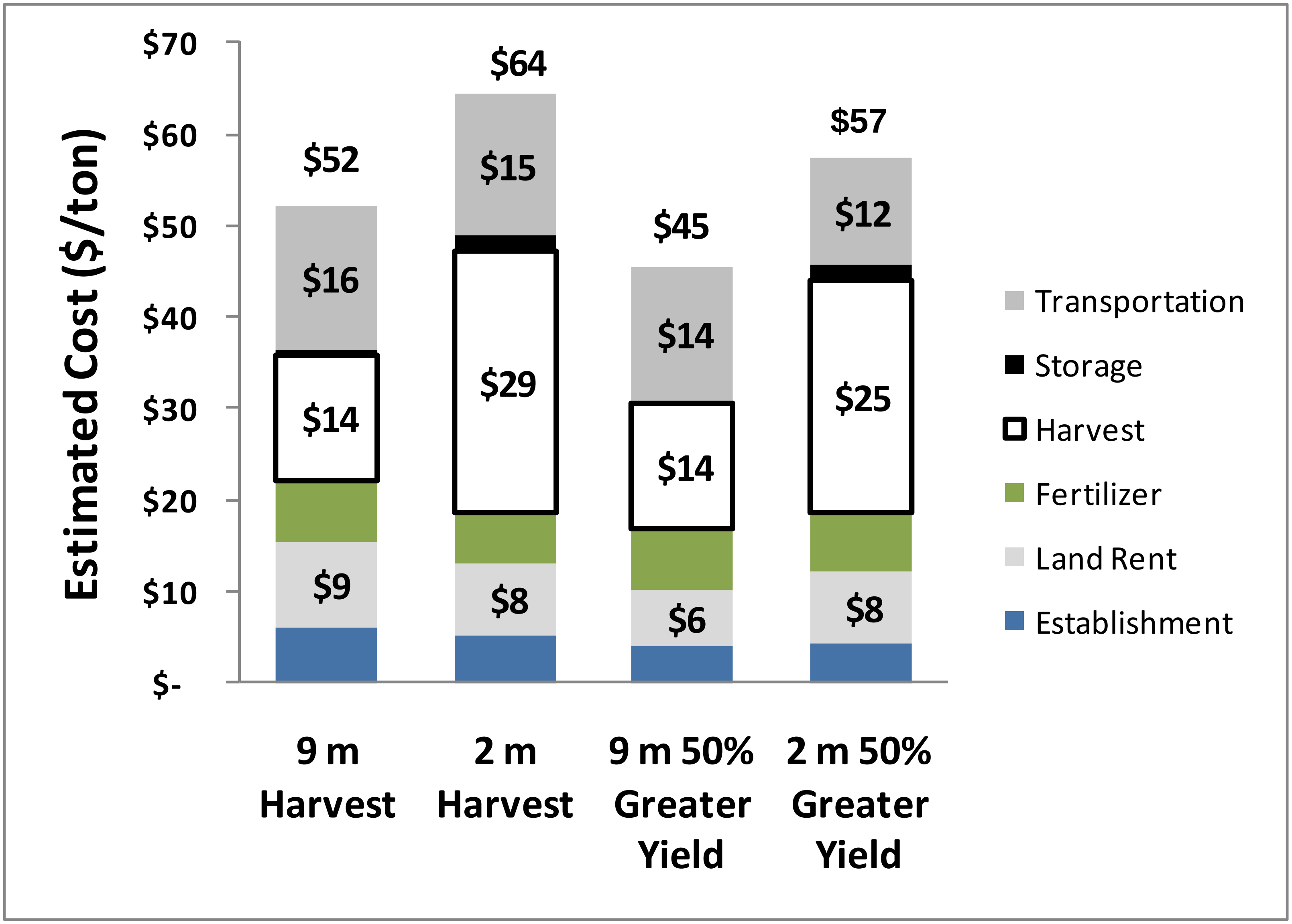
Estimated cost to deliver a flow of 2,000 t/day of switchgrass for both a two- and nine-month harvest season



Estimated cost to deliver a flow of 2,000 t/day of switchgrass for both a two- and nine-month harvest season



Estimated cost to deliver a flow of 2,000 t/day of switchgrass for both a two- and nine-month harvest season



Findings

Increasing harvest window from 2 to 9 months

- Decreases average yield per harvested acre
- Requires more land
- Requires more fertilizer
- Reduces harvest cost from $29 to $14 / ton
- Reduces cost to deliver feedstock from $64 to $52 / ton
- Harvest cost percentage of delivered feedstock costs decreases from 45% to 27%

Findings

Increasing biomass yield by 50% / year with 9 month harvest window

- Does not change harvest cost
- Decreases land requirement and land cost from $9 to $6 /ton
- Reduces transportation cost from $16 to $14 / ton
- Reduces cost to deliver feedstock from $52 to $45 /ton

Four Issues

1. U.S. Crude Oil Use
   - Spill – 6 hours
   - Corn- 7 days

2. Cellulosic Biofuels Production Cost
   - If Externalities are Ignored, Difficult to Compete Economically with Crude Oil
   - Conversion Technologies Have Not Achieved the Projected Cost Targets

Four Issues

3. Cost-efficient Dedicated Energy Crop Production and Delivery
   – If the most economical feedstock is from perennial grass, a highly coordinated production, harvest, storage, and delivery system could be expected.

4. Potential Role for the USDA

Challenge

- Highly coordinated harvest system
- Transaction cost (between land owners and biorefinery) of a system enabling wide harvest windows for perennial grasses when yield and fertilizer requirements vary across harvest month are likely to be lowest with a long term land lease system

Challenge

- What is the most efficient way for a biorefinery to lease thousands of acres?
- Would land owners be willing to engage in a long term lease that required them to invest in the establishment of perennial grass and restrict use?

USDA Experience

- CRP was established in 1985
- By July of 1987 more than 22 million acres were leased and most were seeded to perennial grasses
- Acquisition of land services and seeding to perennial grass should not be a major impediment to the development of lignocellulosic biorefineries

Potential Role for USDA Relative to Establishment of Perennial Crops

- Could use existing CRP land identification and leasing infrastructure to **facilitate contracting**

- FSA and NRCS have demonstrated that land owners are willing to enter into long term contracts and to establish perennial grass (22 million acres in 2 years)

- Biorefinery could **contract with government to purchase FSA and NRCS services** to assist the biorefinery in identifying and leasing acres from landowners.

Potential Role for USDA Relative to Establishment of Perennial Crops

- RMA could design lease insurance

Four Issues

1. U.S. Crude Oil Use
   – Spill - 6 hours
   – Corn - 7 days

2. Cellulosic Biofuels Production Cost
   – If Externalities are Ignored, Difficult to Compete Economically with Crude Oil
   – Conversion Technologies Have Not Achieved the Projected Cost Targets

Four Issues

3. Cost-efficient Dedicated Energy Crop Production and Delivery
   - If the most economical feedstock is from perennial grass, a highly coordinated production, harvest, storage, and delivery system could be expected.

4. Potential Role for the USDA

- Broker contracts between land owners and biorefineries
- Develop contract insurance system

Challenges to Cellulosic Biofuels

- Economically viable conversion system
- Profitable business model
- Energy is a commodity
  - The least-cost source will be used first
  - In the absence of policy incentives (subsidies, carbon taxes, mandates) extremely difficult to compete with fossil fuels on cost

Acknowledgements

- Oklahoma Agricultural Experiment Station
- USDA/NIFA
- USDA/NNF
- Oklahoma Bioenergy Center
- Sun Grant Initiative

OKLAHOMA STATE UNIVERSITY

AGRICULTURE