# Inflated Expectations, Unfulfilled Mandates, and Cost-Efficient Feedstock Systems for Cellulosic Biofuels


Francis Epplin

Department of Agricultural Economics

Oklahoma State University


AAEA Extension Section Webinar

11 am Central

April 20, 2011

# Issues

- Energy
- Corn Ethanol
- Cellulosic Ethanol
- Drop-In Fuels
- What is a farmer to do?

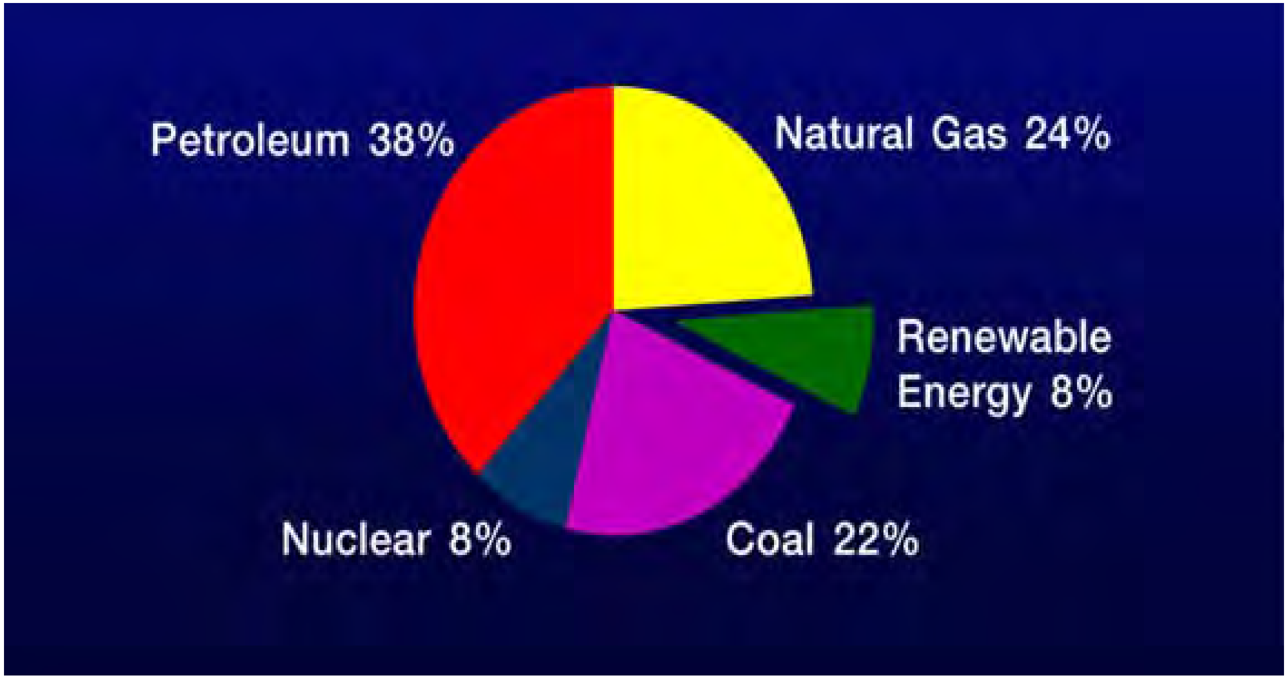
# Energy

- U.S. Crude Oil Use
- 19.1 million barrels per day in 2010

# How Much is 19.1 Million Barrels of Crude Oil ?

- Daily U.S. use (2010)

- 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. use?

- Equivalent to **6 hours** of U.S. use

# Issues

- Energy
  - 19.1 Million Barrels / day
  - 6 hours (2010 Gulf Oil Spill)

- **Corn Ethanol**

- Cellulosic Ethanol
- Drop-In Fuels
- What is a farmer to do?

# Why corn ethanol ?

Historical context ---

- To address the “excess capacity” problem in U.S. agriculture

# Corn Ethanol

- 2010
  - 13.2 billion gallons of ethanol from grain
  - Contained **gross** energy equivalent to **9 days** of U.S. crude oil use
    - Diesel tractors, combines, and trucks don't use ethanol blends

# Corn Ethanol

- 2010 corn crop
  - 12.66 billion bu
  - If every bu had been converted to ethanol it would contain **gross** energy equivalent to

  **24 days** (6.6%)

  of U.S. crude oil use

# Issues

- Energy
  - 19.1 Million Barrels / day
  - 6 hours (2010 Gulf Oil Spill)
- Corn Ethanol
  - 9 days (2010)
- **Cellulosic Ethanol**
- Drop-In Fuels
- What is a farmer to do?

# 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

OKLAHOMA STATE UNIVERSITY AGRICULTURE

# The Promise of Cellulosic Ethanol

- Convert “waste” to fuel
- Some early proponents projected feedstock cost to be close to zero.
- Some projected a “tipping” fee; expected that owners of “waste” would be willing to pay for someone to use it.

# The Promise of Cellulosic Ethanol

(one example)

*Science*

Lynd et al. (1991)

hypothesized that by the year **2000**,

technology would be developed enabling the production of **cellulosic ethanol** for a wholesale selling price of **$0.60 per gallon** (1985 $)

(**$1.22** in 2010 dollars).

# U.S. Energy Independence and Security Act of 2007 (EISA)

Renewable Fuel Standards 2

RFS2

- Mandated use of biofuels
  - these mandates are conditional on production or production capacity

# U.S. Energy Independence and Security Act of 2007 (EISA)

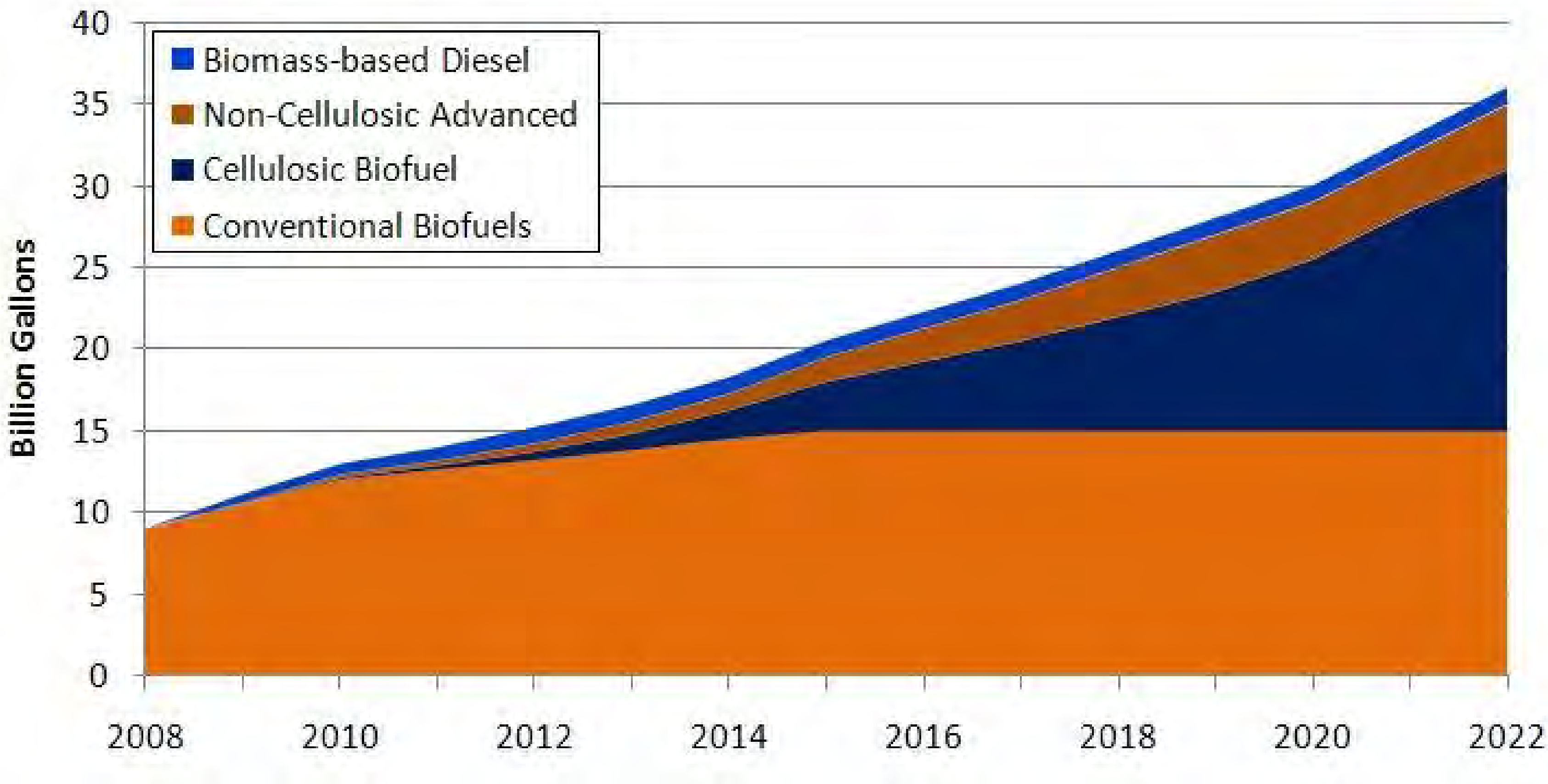
Why mandates?

- Experts proclaimed it was doable

- Means to ensure a market by requiring existing system to use biofuels if produced

- Guaranteed market was expected to facilitate investment in biorefineries

# EISA – 2007 - RFS2 Mandates




Source: http://www.pewclimate.org/federal/executive/renewable-fuel-standard

# U.S. Energy Independence and Security Act of 2007 (EISA)

Cellulosic ethanol mandates

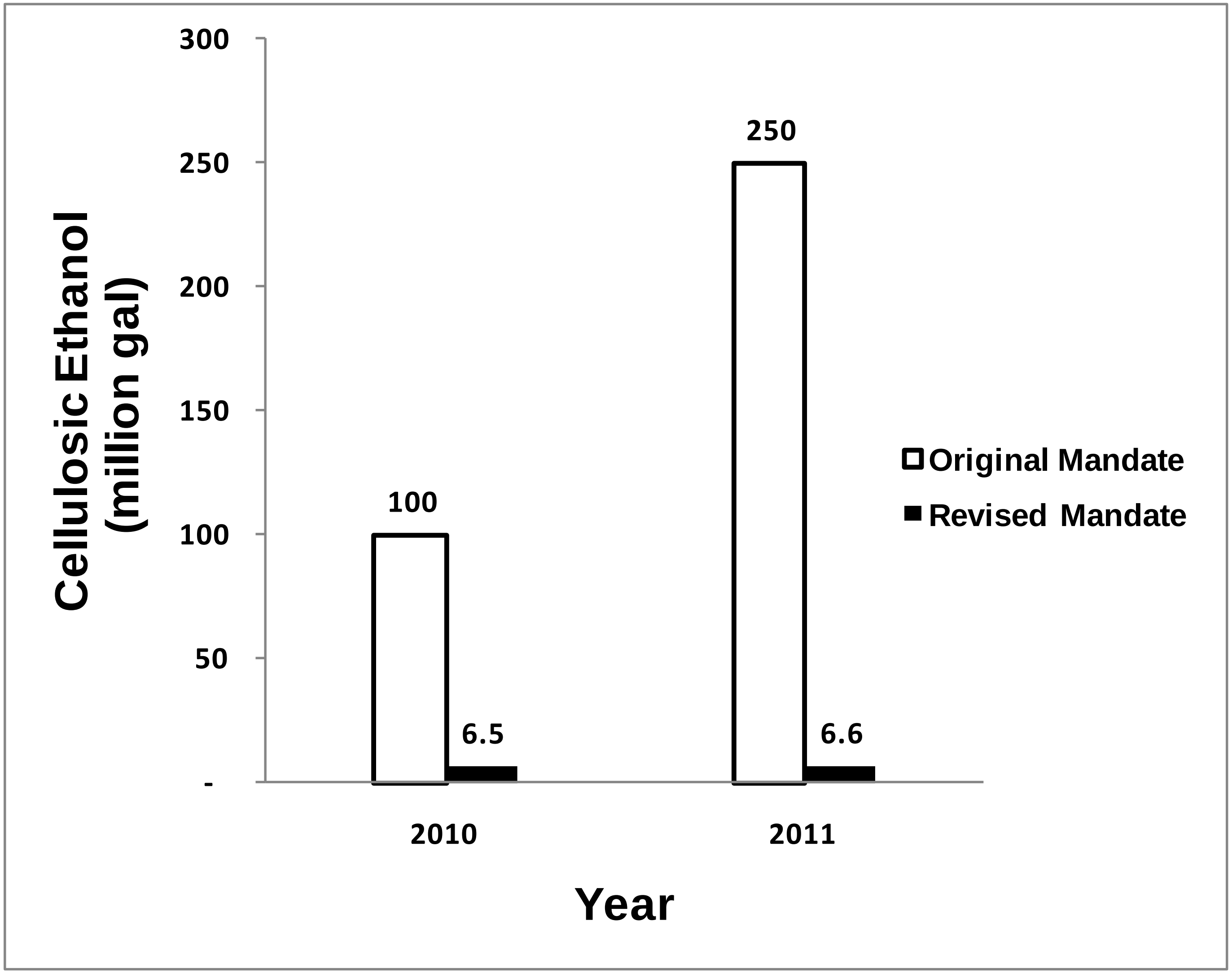
- 2010 100,000,000 gallons
- 2011 250,000,000 gallons

# Unfulfilled Mandate

Cellulosic Ethanol

- 2010 mandate 100,000,000 gallons
  - EPA reduced to 6,500,000 gallons
- 2011 mandate 250,000,000 gallons
  - EPA reduced to 6,600,000 gallons

# RFS2 Mandates for Cellulosic Ethanol



# Failure to Meet Cellulosic Ethanol Mandate

Why?

- Conversion cost targets were not achieved

- Best of several competing technologies for conversion remains to be determined

# Cost

Kazi et al. (2010) Evaluated Eight Alternatives for Producing Cellulosic Ethanol

- Lowest Cost Production System
  - Estimated Cost - $5.13 / gallon gasoline equivalent

  - Kazi, Fortman, Anex (Iowa State); Hsu, Aden, Dutta (NREL); Kothandaraman (ConocoPhillips) (Fuel 89 2010)

# Failure to Meet Cellulosic Ethanol Mandate

Why?

- More costly to produce than anticipated

- Blend wall

# Blend Wall

2010

- U.S. used 138.5 billion gallons of gasoline and blends that contained 13.2 billion gallons of ethanol

- When blends were limited to 10%, mandated levels of corn ethanol approached limit
  - flex fuel and 2001 and newer vehicles may use E15 if a source can be located

# Reasons to Move Beyond Ethanol

- Ethanol is not an ideal liquid fuel substitute in a country with infrastructure and vehicles designed to use gasoline, diesel, and jet fuel.
- Less energy dense
- Mixes with water
- Can't be moved practically through U.S. pipeline system
- Requires splash blending or blender pumps
- Has higher vapor pressure
- Cost?

# Reasons to Move Beyond Ethanol

- Other potential “drop-in” biofuels produced from cellulosic feedstock may be more economical

# Issues

- Energy
  - 19.1 Million Barrels / day
  - 6 hours (2010 Gulf Oil Spill)
- Corn Ethanol
  - 9 days (2010)
- Cellulosic Ethanol
  - Unfulfilled expectations
- **Drop-In Fuels**

- What is a farmer to do?

# Drop-In Biofuels

The ideal drop-in

- invisible to the operator
- meet fuel performance requirements of existing engines
- require no change to the current stock of engines
- could be mixed or alternated with petroleum fuels (wouldn't encounter a blend wall)
- require no change to the infrastructure
- be economically competitive

# Example Drop-In Biofuel

- fast pyrolysis of **cellulosic biomass** to bio-oil
- upgrading of the bio-oil to naphtha and diesel range fuels.
- Wright et al. (2010) estimate production cost of $2.11 per gallon of gasoline equivalent for the n$^{th}$ plant
  - (Of course this estimate may be as overly optimistic as the 1991 estimate of cellulosic ethanol production cost of $1.22.)

# Potential Feedstocks for Drop-In Biofuels

- Implications for agriculture if technology bypasses cellulosic ethanol?

- Crop residues and perennial grasses are also potential feedstocks for “drop-in” biofuels

# Potential Feedstocks

- Municipal solid waste
- Forest residue
- Sugarcane bagasse
- Crop residue (corn stover, wheat straw)
- Dedicated energy crops
  - Perennial grasses (switchgrass, miscanthus)
  - Energy sorghum
  - Energy cane

# Potential Feedstocks

- If the technology can use any of the feedstocks, expect entrepreneurs to locate plants near what they consider to be an inexpensive source of feedstock
  - The least-cost source will be used first

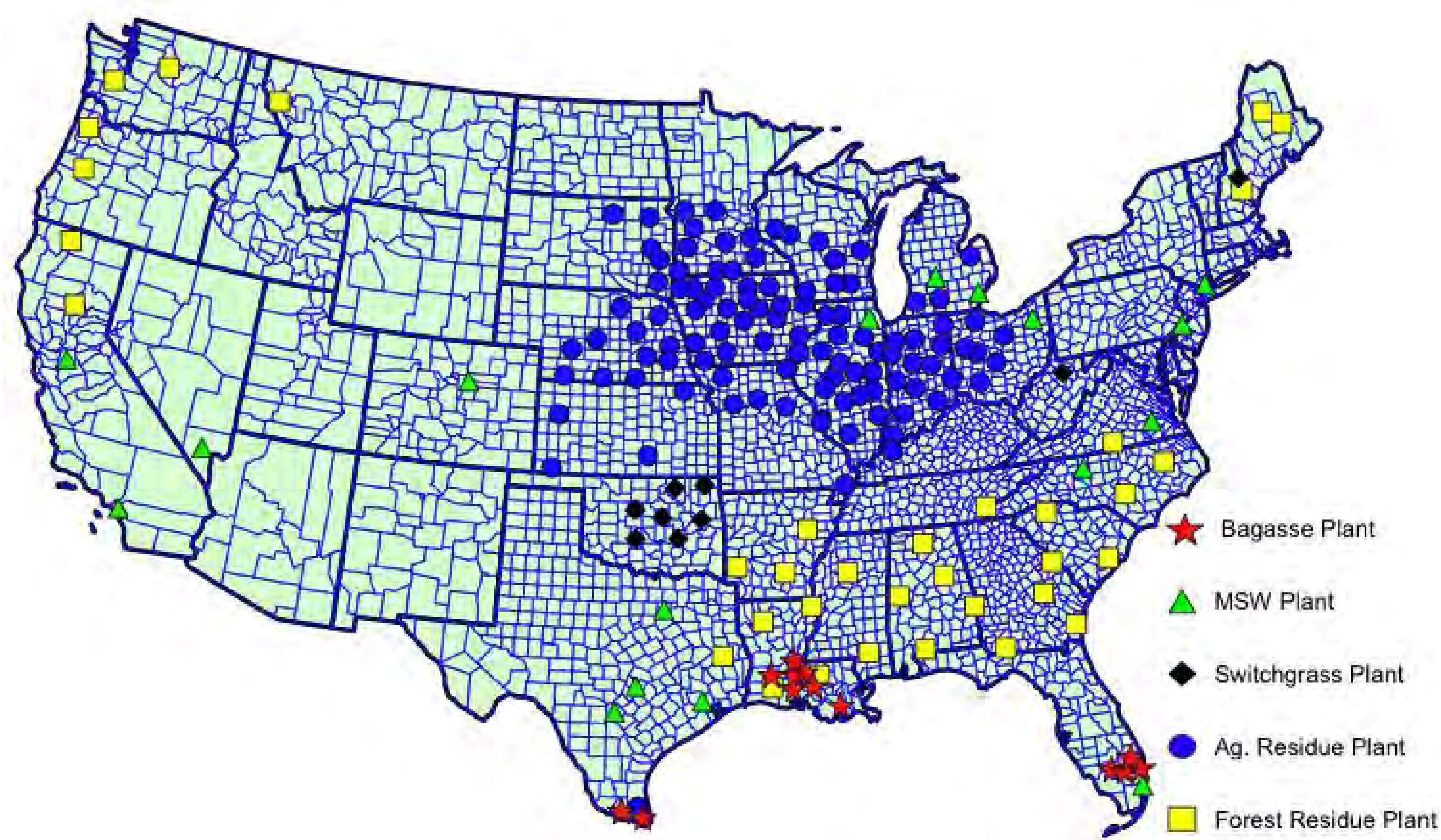
# Quantity of Feedstock Required for a 2,000 tons per day Biorefinery

- 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

# Biorefineries

- For 16 billion gallons per year
- 300 2000 tons/day plants
  5 trucks / hour each
- 150 4000 tons/day plants
  10 trucks / hour each

# EPA Projections of Cellulosic Biorefineries to Fulfill RFS2 Mandates




One projection

# Challenge for Biorefineries

- Highly coordinated harvest system
- Efficient system to provide a flow of biomass throughout the year from thousands of acres

# Feedstock Flow Management

## 5-10 trucks/hour/plant

- Harvest
- Storage
- Transportation

- Most efficient system may differ depending on feedstock
  - Crop residue
  - Perennial grass

# Contracts for Feedstock

- Most efficient contracting system may differ depending on feedstock
  - Crop residue
  - Perennial grass

# Issues

- Energy
  - 19.1 Million Barrels / day
  - 6 hours
- Corn Ethanol
  - 9 days
- Cellulosic Ethanol
  - Unfulfilled expectations
- Drop-In Fuels
  - Hope
- **What is a farmer to do?**

# What is a farmer to do?

- Wait until a contract is offered
- Evaluate alternatives
- Request assistance from local and state Cooperative Extension Service
- Prior to signing a contract, prior to investing in specialized equipment, and prior to establishing a perennial grass, consider the potential for biorefinery bankruptcy

# Issues

- Energy
  - 19.1 Million Barrels / day
  - 6 hours
- Corn Ethanol
  - 9 days
- Cellulosic Ethanol
  - Unfulfilled expectations
- Drop-In Fuels
  - Hope
- **What is a farmer to do?**
  - **Relax and farm**

# Challenges

- 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

# Summary

- Energy
  - 19.1 Million Barrels / day
  - 6 hours
- Corn Ethanol
  - 9 days
- Cellulosic Ethanol
  - Unfulfilled expectations
- Drop-In Fuels
  - Hope
- What is a farmer to do?
  - Relax and farm

# Acknowledgements

- Oklahoma Agricultural Experiment Station
- USDA/NIFA
- Oklahoma Bioenergy Center
- Sun Grant Initiative
- Biobased Products and Energy Center at Oklahoma State University