U.S. Department of Energy
Energy Efficiency and Renewable Energy
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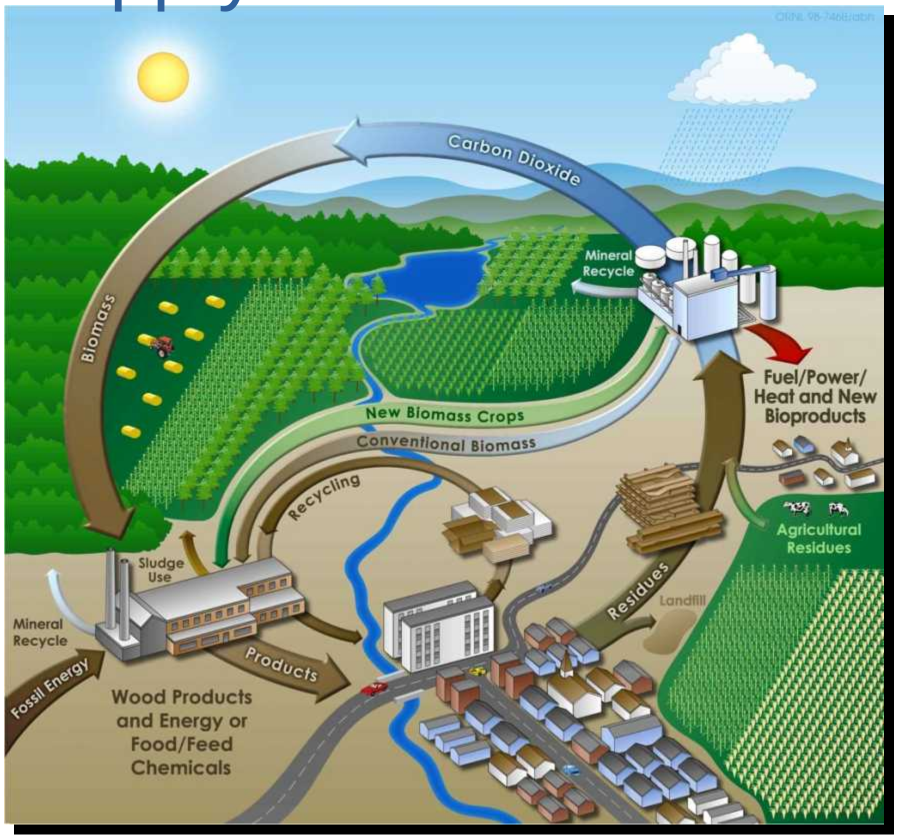
Biomass Program

# Cellulosic Ethanol: The Dynamics and Economics of Expanding the Fuel Supply Chain




Fuel Ethanol Workshop
St. Louis, MO
June 28, 2007


R. J. Wooley – NREL
Z. Haq – DOE
J. Sheehan – NREL
S. Peterson – The Peterson Group

# Presentation Outline

- Background of what DOE is trying to Understand and Influence
- Describe the Modeling Approach to help with that Understanding
- Illustrate how the model approaches two complex areas of the problem, Feedstock Supply and Capital Investment
- Describe a Scenario that Allows Cellulosic Ethanol to make a Significant Contribution to the President's 2017 Goal

# Background

- The DOE-Biomass Office has a need to better understand what impacts the ultimate deployment of billions of gallons of ethanol

- To that end, DOE is developing a dynamic model describing possible future scenarios of how biofuels will deploy in the marketplace

- Purpose of the model
  - Understand how DOE activities might influence the ultimate ethanol deployment
  - Explore what else (outside of DOE) might be needed to reach the desired deployment levels

# The Supply Chain

Goal: Estimate the penetration of Ethanol into the Fuels Market over time

Puzzle – What comes first?

Feedstock or Conversion Technology

Investment or Market Demand

Available Vehicles or Fuel

The list goes on ...


Biomass Feedstock Supply

Biomass Feedstock Transport

Biomass Conversion Technology

Fuel Market

Vehicle Market

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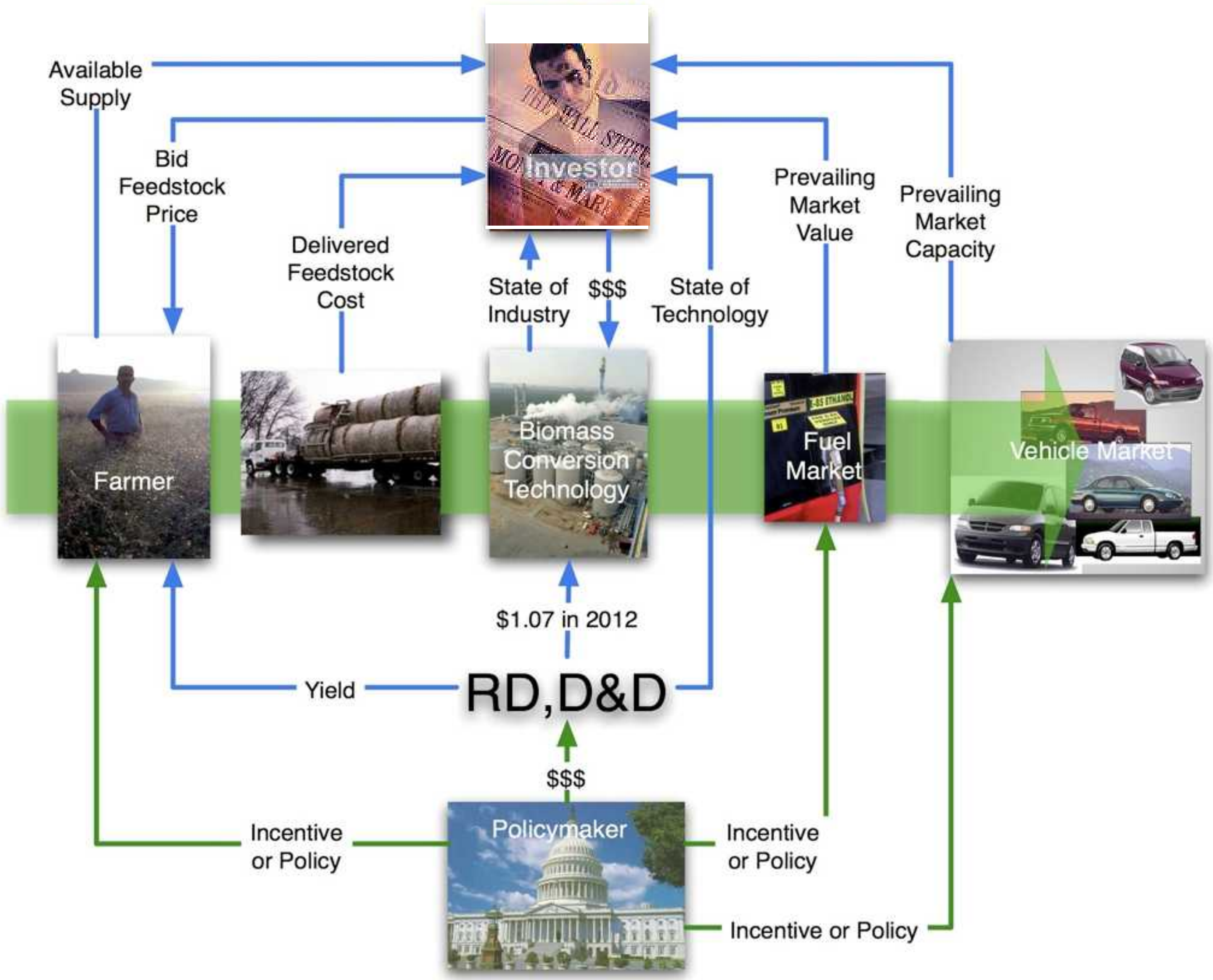
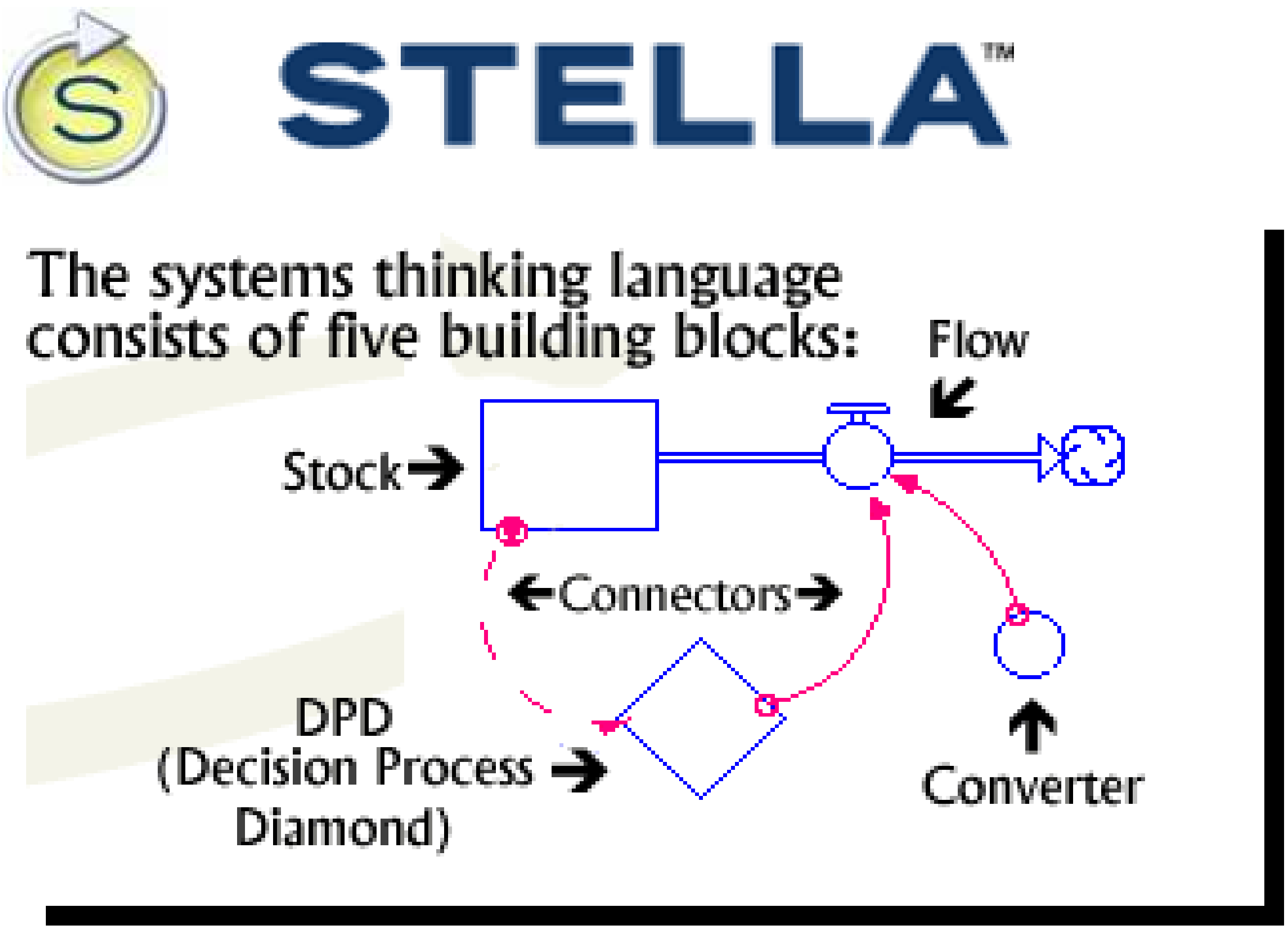
# The Players

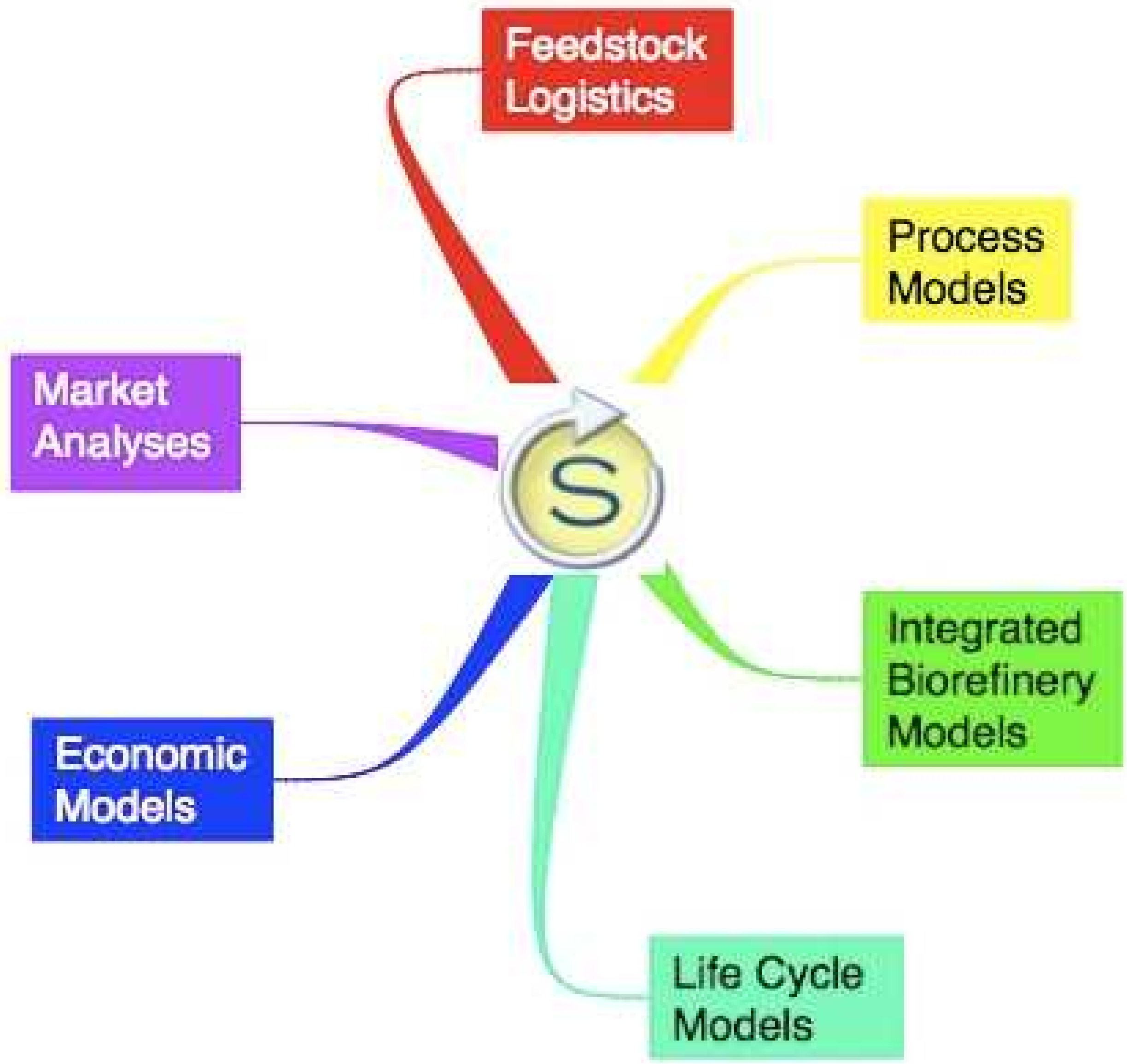
Farmers, Technology Developers, Investors and Operators, Government



# Telling the Story with System Dynamics



# Utilization of Supporting Data



# Dealing with Some of The Issues

- Getting the Feedstock Supply Going
  - How will producers respond to a new market & product
- Long term supply of large amounts of feedstock
- Developing New Technology
  - Harvesting, Conversion, Distribution, Vehicles
  - How much time will it take?
- Competing in the Fuels Marketplace
  - Production Costs
  - Cost of Competition
  - Consumer Acceptance
- Making Investments Happen
  - What is required to invest in the technology or change?
- What Government Policies and Incentives are Most Productive?

- There are More ...

# Model Structure Example: Feedstock Supply

## All Cropland

Land Excluded from Feedstock Analysis, e.g., specialty crop

Cropland Used for Crops

CRP Land

Cropland Used for Pasture

Economic Return Competition

### Cropland Allocation

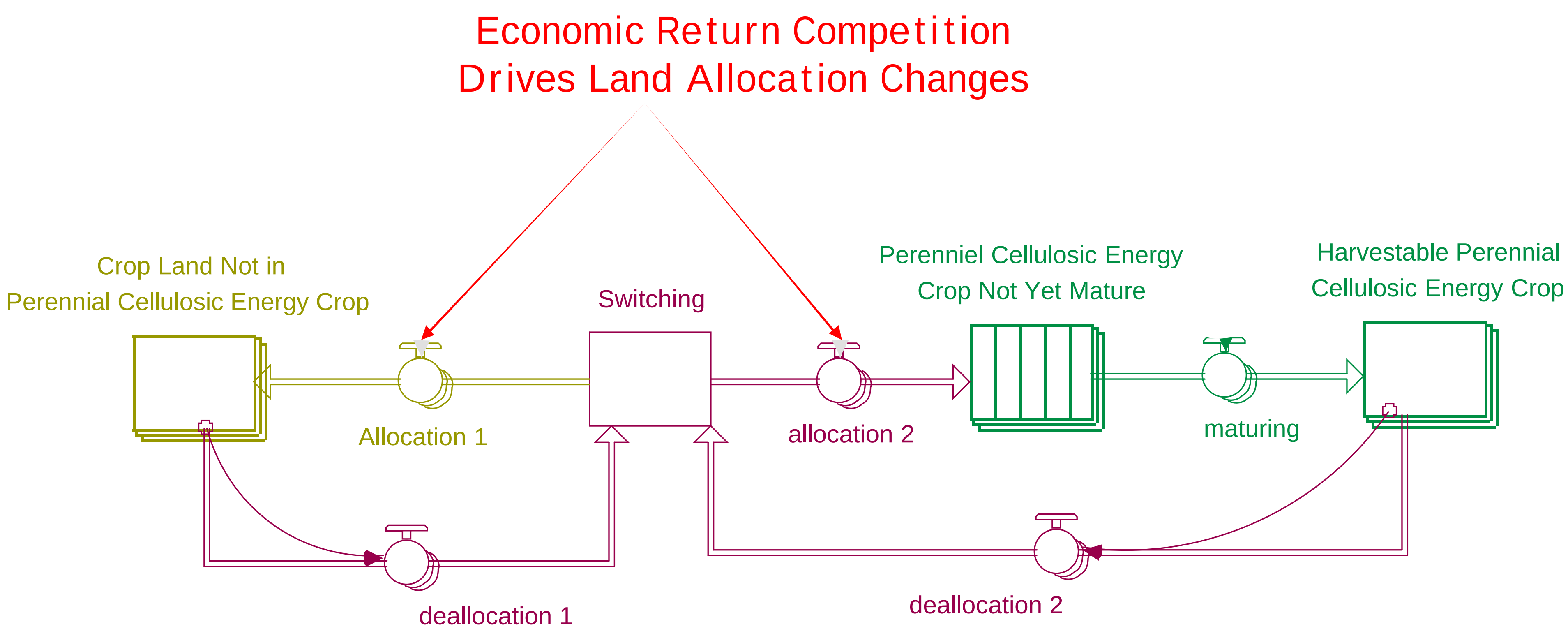
- Corn
- Soy
- Wheat
- Small grains (Sorghum, Oats, Barley)
- Cotton
- Hay

- Herbaceous Perennial Energy Crop
- Woody Perennial Energy Crop

### Pasture Allocation

- Pasture (used as pasture or harvested as energy crop)
- Herbaceous Perennial Energy Crop
- Woody Perennial Energy Crop

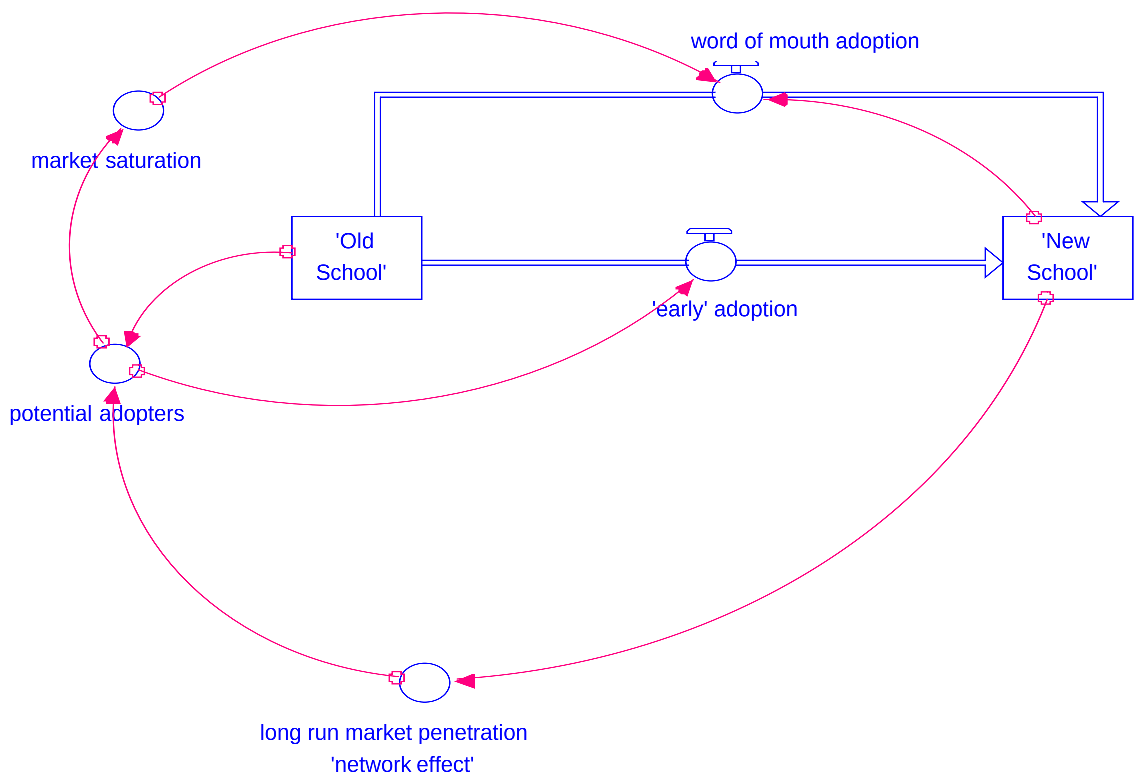
# Allocation logic drives Land-use Changes



# Uptake of New Agricultural Practices



- Key Chicken-and-Egg Dynamic related to diffusion/uptake of innovations & new practices
- Simple stock/flow structure handles transition from “old” to “new” farm practices
- In model, “new” practice farmers include residues, cellulosics as part of their choice set.



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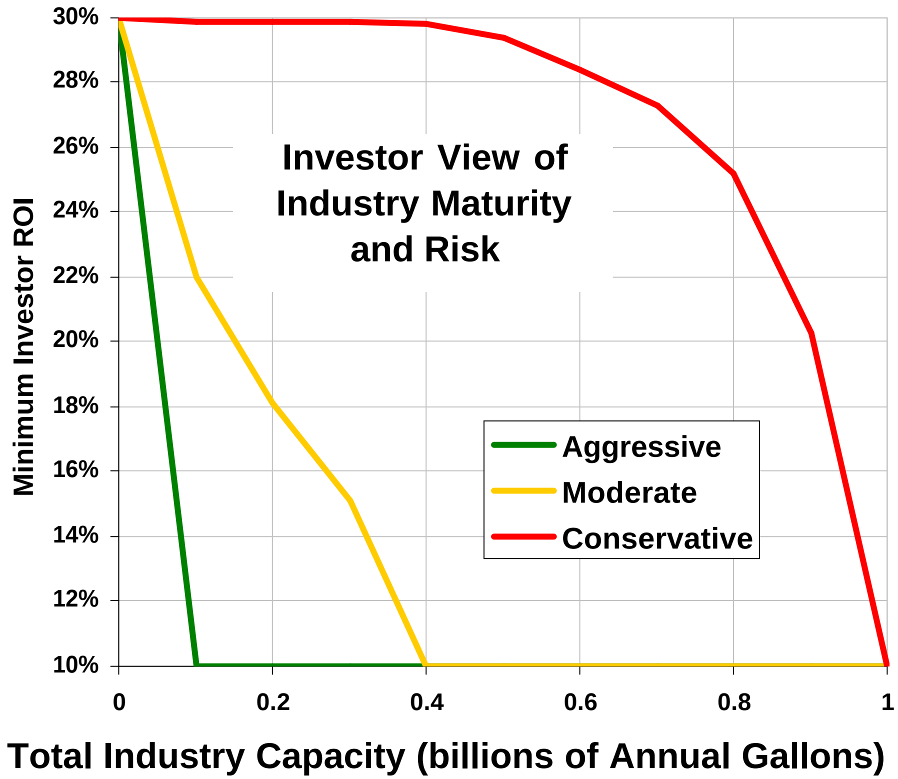
# Make the Investment Decision...

- The Conversion Plant Investor Looks at the Current Conditions for:
  - Vehicle Fleet Capacity for Ethanol – FF Vehicles in the Market
  - Current Ethanol Production
  - Feedstock Price and Availability
  - Cost of Conversion Technology
    - Extent of R&D
    - Level of Maturity – Demo Plants, Number of other Facilities
  - Government Policies in place – e.g., production or capital subsidies
  - Maximum selling price based on competing Oil Prices
- Calculate the Project ROI
- Build a new Facility if ...
  - Project ROI is Greater than the Minimum ROI Required by Investor
  - Fleet Demand Exceeds Production

# Model Structure Example: Investor Required ROI

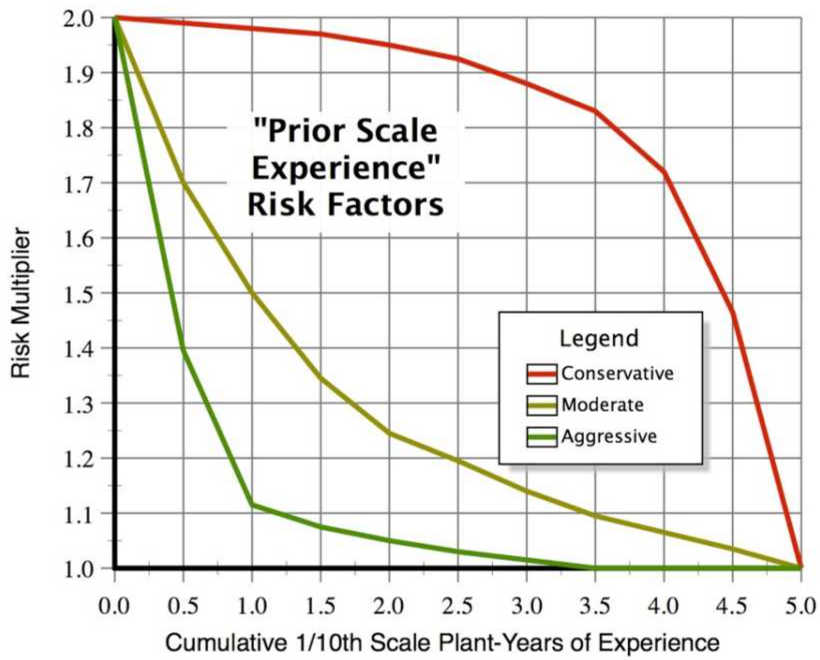
- The investor sets his required ROI, first based on the "experience in the industry", as measured by total industry capacity.

- The less overall experience, the more risk, the higher the required ROI.



# Model Structure Example: Investor Required ROI

- The investor then takes into account experience at a smaller scale.
- Required ROI = Industry Experience ROI
  x Risk Multiplier for Prior Scale Experience



# U.S. DOE Goal

- In The State Of The Union Address, The President Announced His "Twenty In Ten" Goal To Cut U.S. Gasoline Consumption By 20% Over The Next 10 Years.
  - By increasing the supply of alternative fuels and making motor vehicles more energy efficient
- 35 Billion Gallons Of Renewable And Other Alternative Fuels In 2017
  - This will displace 15% of projected annual gasoline use.
- 8.5 Billion Gallons due to Reforming CAFE Standards For New Vehicles
  - This will result in a further 5% reduction

## 2017 Cellulosic Ethanol
## What is possible?

# Key to Increasing 2017 Impact

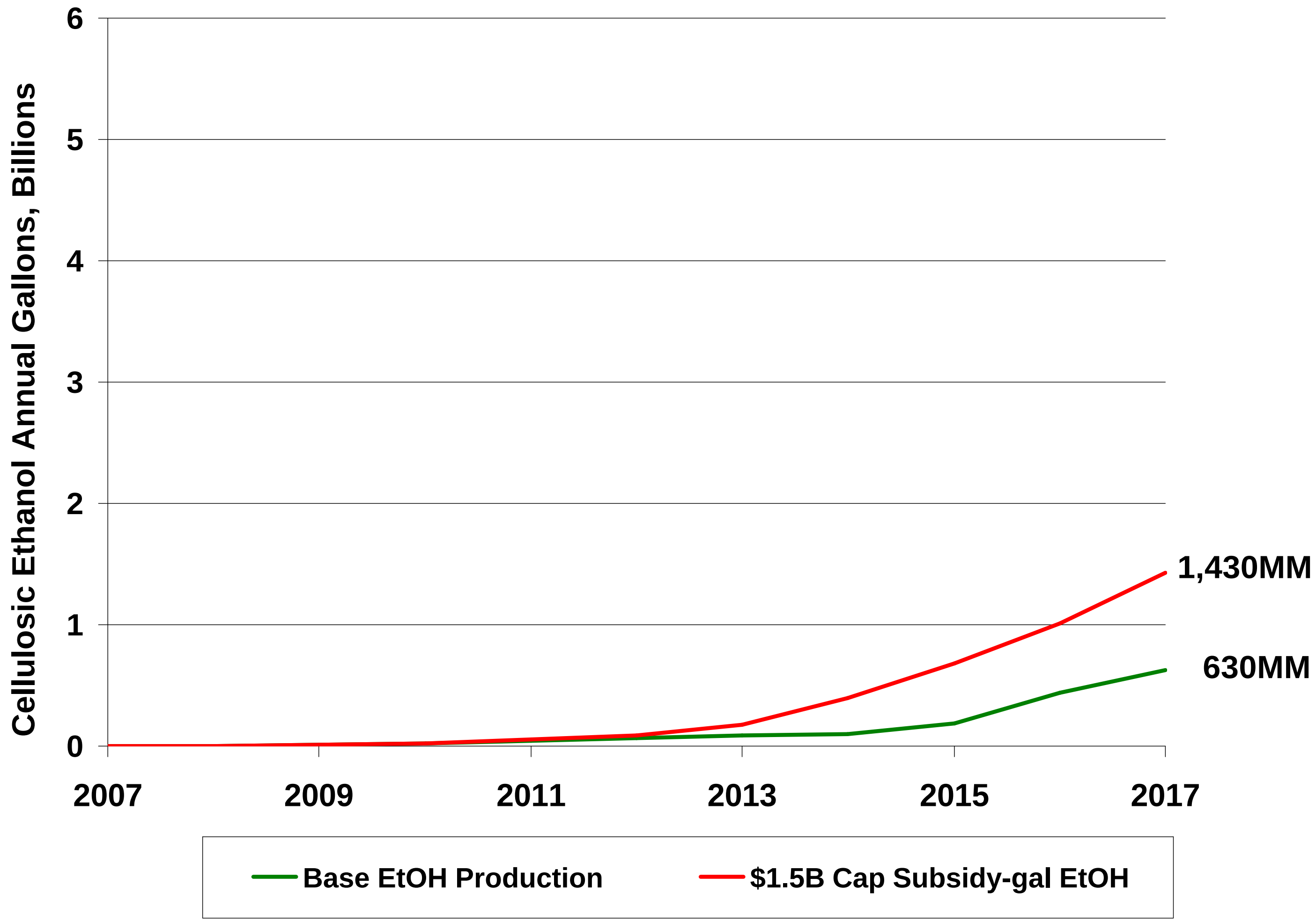
- Full Scale Plant Operations are Required
  - Feedstock & Vehicles should not be limiting for 2017
- Full Scale Plants are held back by:
  - First of a kind uncertainties
  - Expected Margins not high enough to Overcome Return on Investment required for "untried technology"
- Normal Progression
  - Develop Technology in Laboratory
  - Logical Scale-up
    - Pilot, Demonstration, Pioneer, Full Scale
    - Each step takes time
  - Learning Curve Improvements in Pioneer & Full Scale
  - Rapid Expansion of the Industry

# Modeling Results

- Key is for Government Involvement
  - to close the gap between Investor Required ROI and Project ROI
  - Until Industrial Experience Catches Up
- Handles
  - Lower the cost of production
    - Feedstock Incentives – Grower Payments
    - Ethanol Fuel subsidies
  - Raise the cost of the competition (Gasoline)
    - $CO_2$ Credits
  - Lower the Capital Investment
    - Capital Subsidies
- What has little impact on Cellulosic Ethanol
  - RFS with price limitations
  - Accelerating Core Research even More

# What's Possible – Lowering the Capital Cost

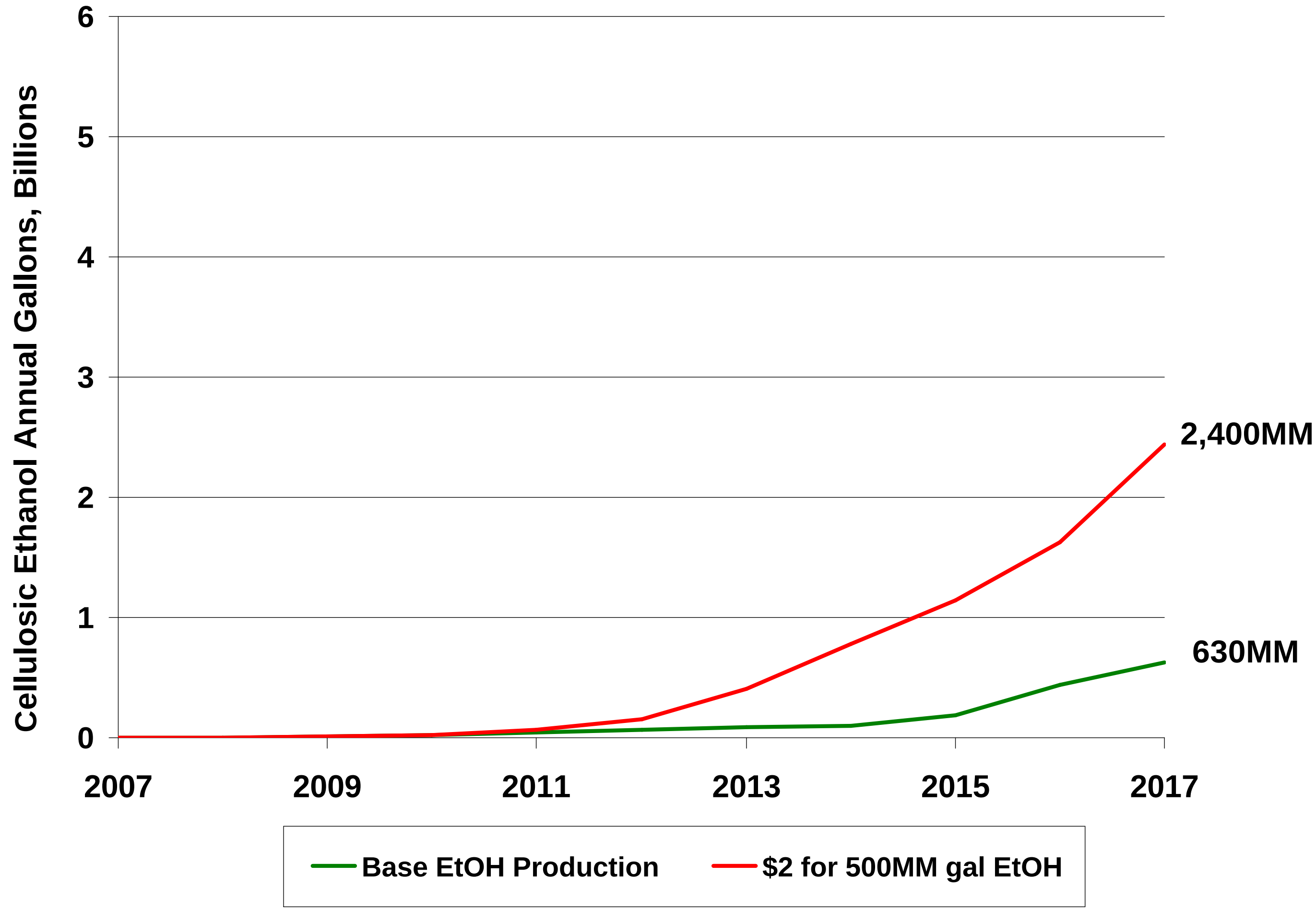
- Government Subsidies can be used to lower the Capital Cost




AEO High Oil

# What's Possible – Reducing Operating Costs

- Significant subsidy, $2/gal, on first 500 MM gallons of Cellulosic Ethanol

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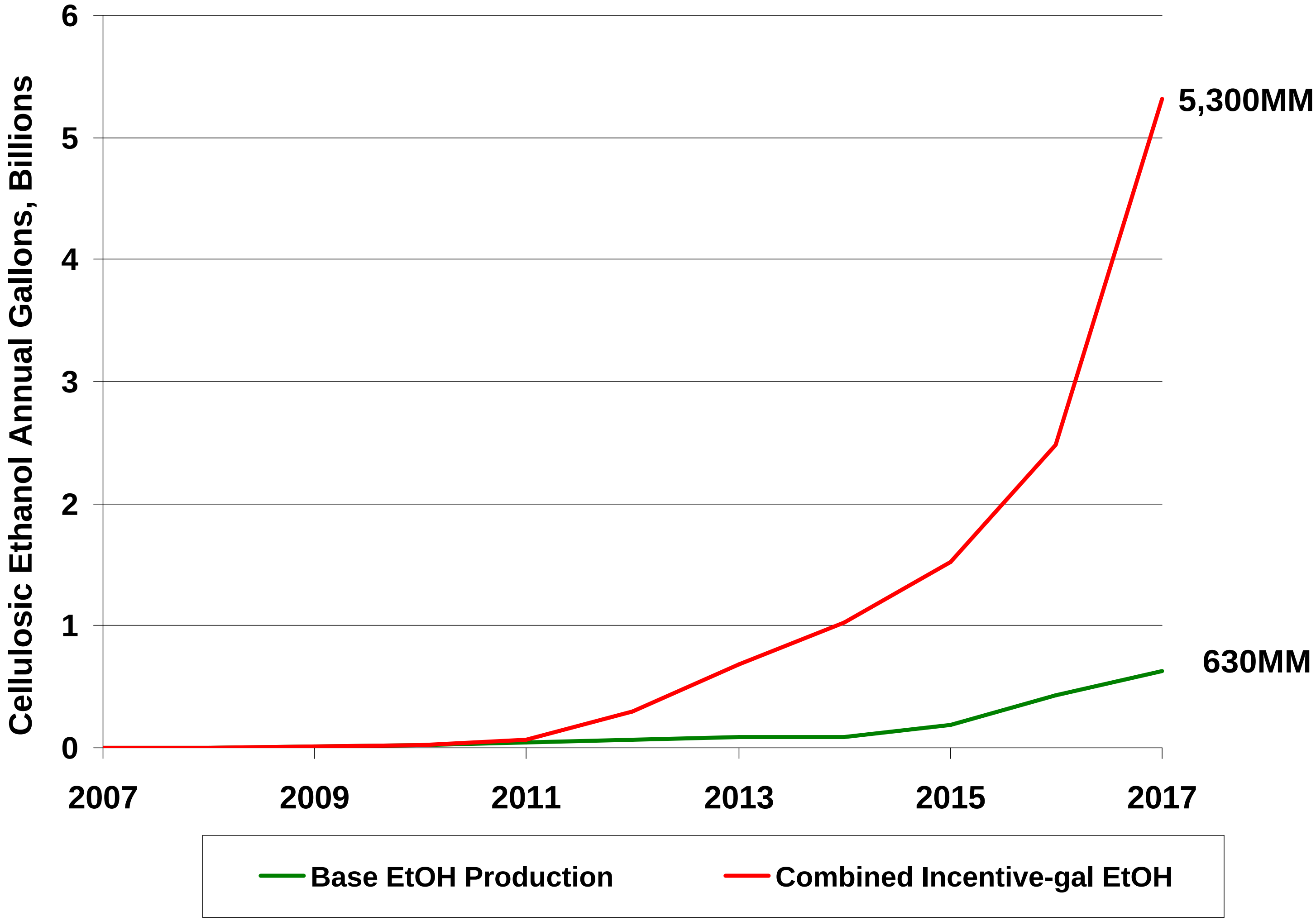
# Two Incentives are Synergistic

## Total Cost to Government $2.5 Billion

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# Summary of Enhancements Currently Underway

Enhancements Underway and Scheduled for Completion over the next year

| Investment | Conversion | Fuel Distribution | Petroleum Industry |
|---|---|---|---|
| • Conduct Investment Colloquy Meeting<br>• Understand Investment Community Attitudes about Deployment of New Technology for Cellulosic<br>• Capture Knowledge for inclusion in model from a Diverse Group of Investment Stakeholders | • 6 Potential Technologies; Multiple Products<br>•Starch Alone<br>•Starch + Fiber<br>•Starch + Biochemical<br>•Biochemical<br>•Thermochemical<br>•Combo | • 4 Distribution Modalities<br>• Greenfield vs retrofit of pipelines<br>• Regional depot/storage<br>• Refueling Stations<br>• Structure to capture evolution of system to connect ethanol production to fuel end use | • Simple global petroleum supply/demand dynamics<br>•Key oil stocks<br>•Refinery capacity<br>•Global petroleum demand scenarios |

# Acknowledgements

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- Additional Collaborators:
  - Bob Wallace - NREL