BioEnergy Bridge™ Partnership

The Pennsylvania State University

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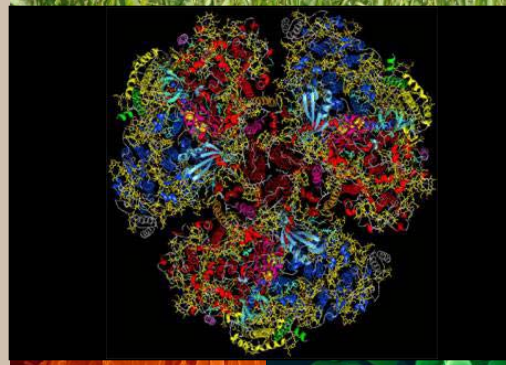
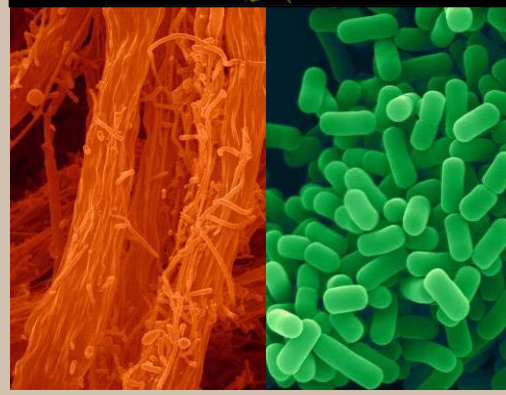




- *Penn State Institutes of Energy and the Environment*
- *Environment and Natural Resources Institute*
- *EMS Energy Institute*
- *Huck Institutes of the Life Sciences*
- *Materials Research Institute*
- *Larsen Transportation Institute*
- *USDA-ARS Pasture Systems and Watershed Management Unit*

Penn State Presents the BioEnergy Bridge™

A university-industry-public partnership to address the critical need for integrated research and technology in the area of biomass fuels and power research

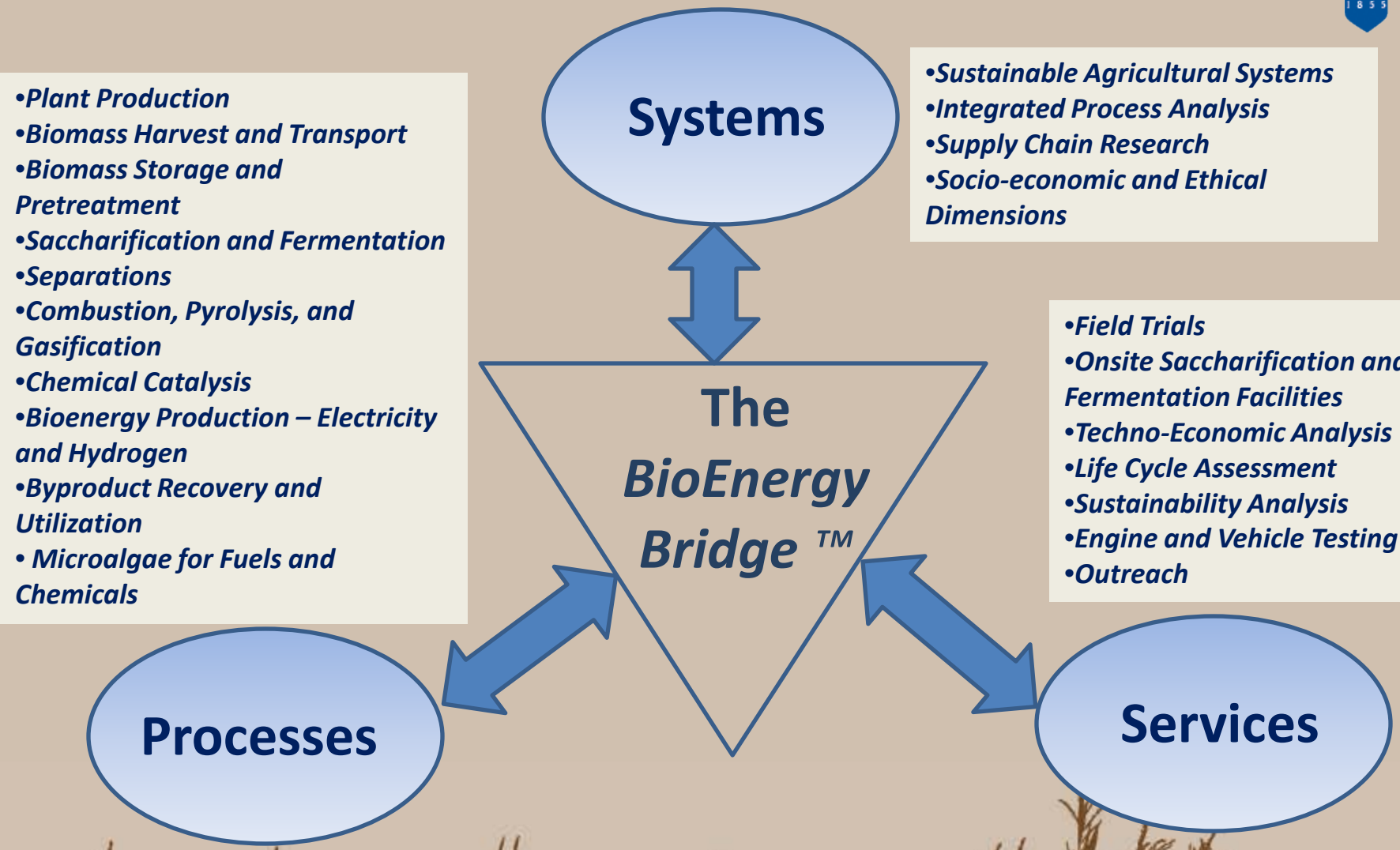
The *BioEnergy Bridge™* will address the full spectrum of challenges to our national priority of reducing dependence on foreign oil as well as decreasing environmental impact of fossil fuels

Penn State Presents the BioEnergy Bridge™

The *BioEnergy Bridge™* will build upon the University's well established R&D pillars throughout the biomass supply chain to address the larger, systems issues that are critical to successful bioindustry development.

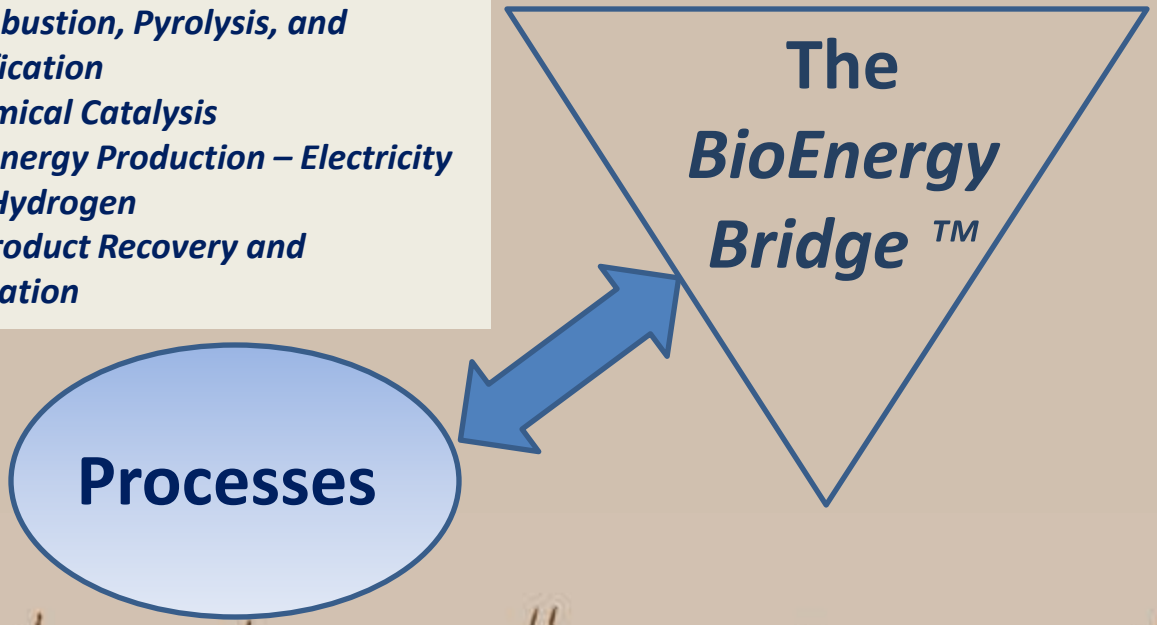
- Diverse Feedstock Assessment
- Feedstock Supply Chain and Delivery Infrastructure
- Technoeconomic Analysis
- Environmental Assessment
- Economic and Workforce Development
- Policy
- Community Outreach

Penn State: BioEnergy Bridge™



Penn State: BioEnergy Bridge™

- ***Plant Production***
- ***Biomass Harvest and Transport***
- ***Biomass Storage and Pretreatment***
- ***Saccharification and Fermentation***
- ***Separations***
- ***Combustion, Pyrolysis, and Gasification***
- ***Chemical Catalysis***
- ***Bioenergy Production – Electricity and Hydrogen***
- ***Byproduct Recovery and Utilization***



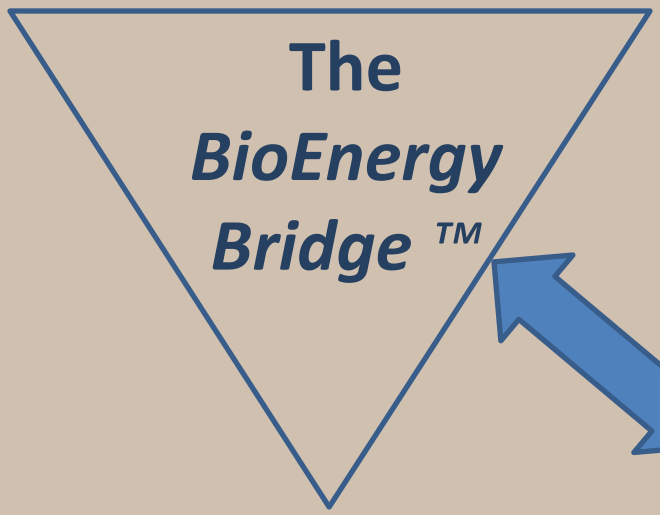
- Partnering to perform world class R&D at the bench and pilot scale
- Utilizing PSU's vast intellectual capabilities to solve the technical issues related to fuels, power and products from biomass

Penn State: BioEnergy Bridge™

PSU will provide scale-up capabilities to commercialize innovative technologies from both academic and industrial research

PSU will serve as a proving ground for companies that wish to test:

- Plant varieties
- Engineered organisms
- Biocatalysts
- Combustion and gasification technologies
- Fuels for car and truck engine testing



- ***Field Trials***
- ***Onsite Saccharification and Fermentation Facilities***
- ***Techno-Economic Analysis***
- ***Life Cycle Assessment***
- ***Sustainability Analysis***
- ***Engine and Vehicle Testing***
- ***Outreach***

Services

Penn State: BioEnergy Bridge™

PENNSTATE

Connecting the laboratory bench with industrial implementation in the areas of:

Systems

- ***Sustainable Agricultural Systems***
- ***Integrated Process Analysis***
- ***Supply Chain Research***
- ***Socio-economic and Ethical Dimensions***

The *BioEnergy Bridge ™*

- Diverse Feedstock Assessment
- Feedstock Supply Chain and Delivery Infrastructure
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Diversified Biomass Production Resources

Penn State has over 14,000 acres of land

- 3,000 + acres of crop land
- 10,000 + acres of forest land

Biomass Feedstock Production

- Feedstock Production
- Harvest and Storage Technologies
- Plant Biotechnology

Ecological Intensification of Agriculture

Integrating bioenergy crops in food crop rotations

Winter canola, camelina and soy biodiesel

- Canola: 115 gal/A @ 50 bu/A vs.
- Soybeans: 71 gal/A @ 50 bu/A

Winter barley for ethanol

- cover crop for soil protection
- summer ethanol feedstock

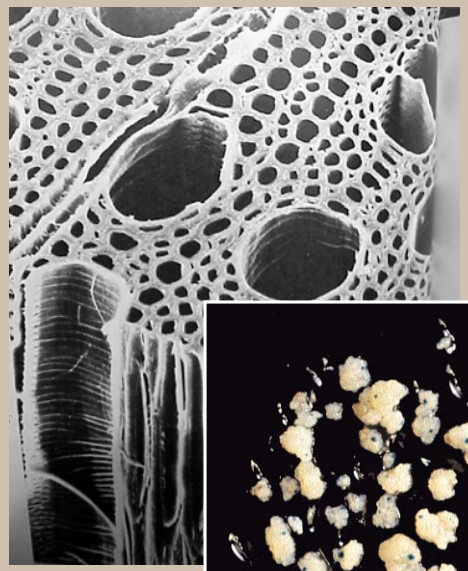
21st Century Forestry

- Forest thinning for timber and wildlife
- Harvest small diameter, low use wood
- Logging residue recovery and use

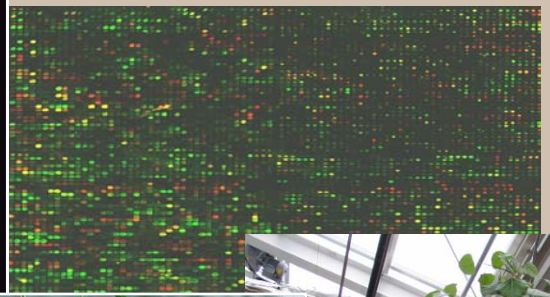
Biomass Harvest and Value-added Storage

- Minimize dry matter loss
- Facilitate densification and transport
- Reduce pretreatment severity, minimizing energy and chemical inputs and costs

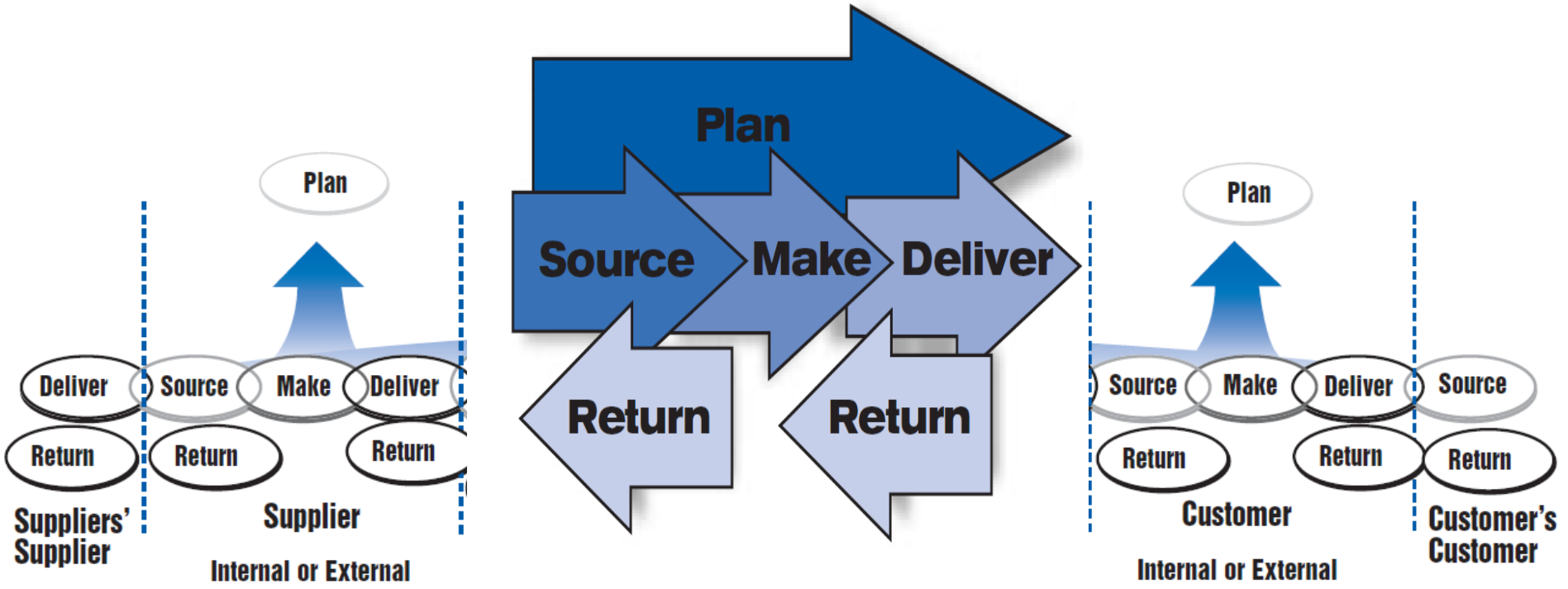
Plant Biotechnology



- Modify lignin synthesis
- Modify cell wall linkages
- Expansin synergies with cellulases
- Oil and starch metabolism



Supply-Chain Operations



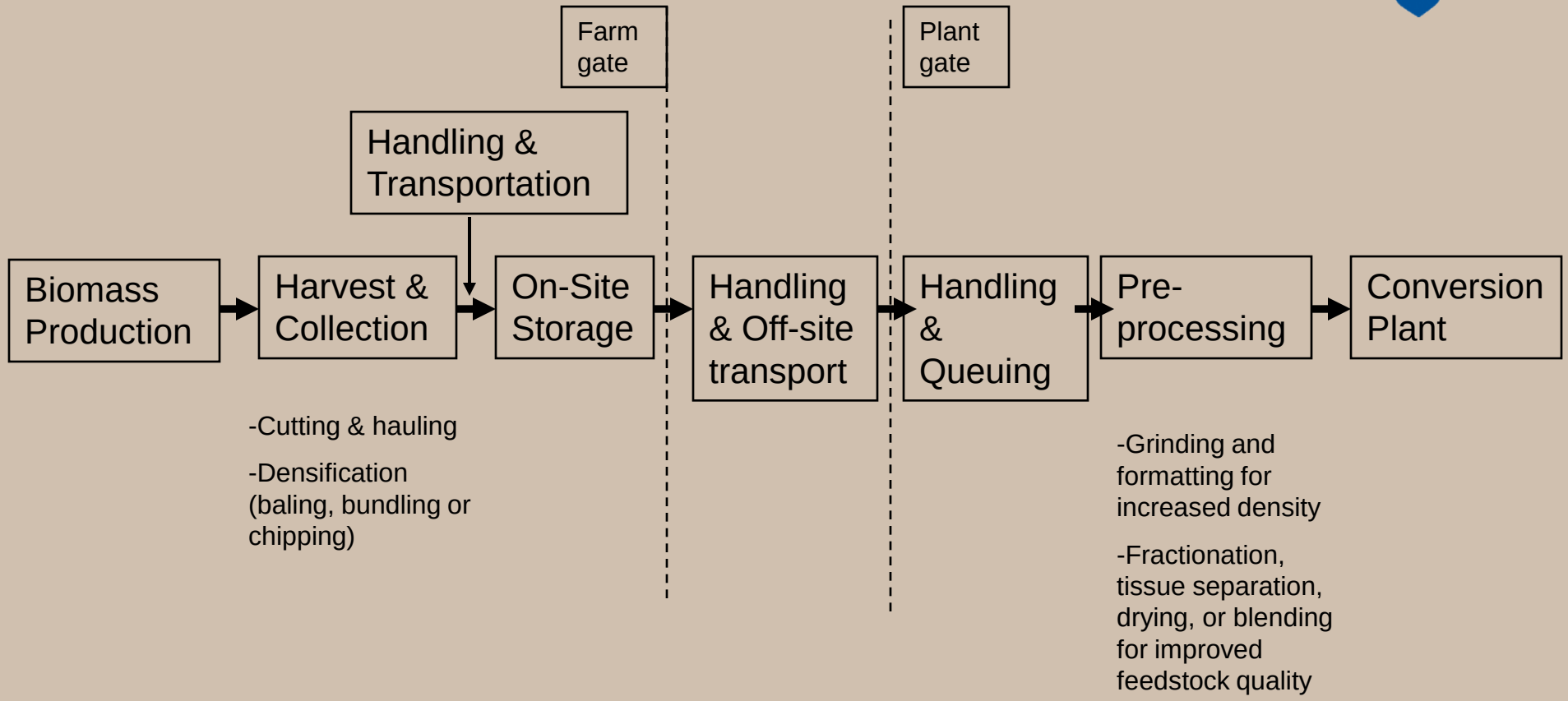
Suppliers of construction waste, woody biomass, and agricultural biomass

Biomass Conversion Facility

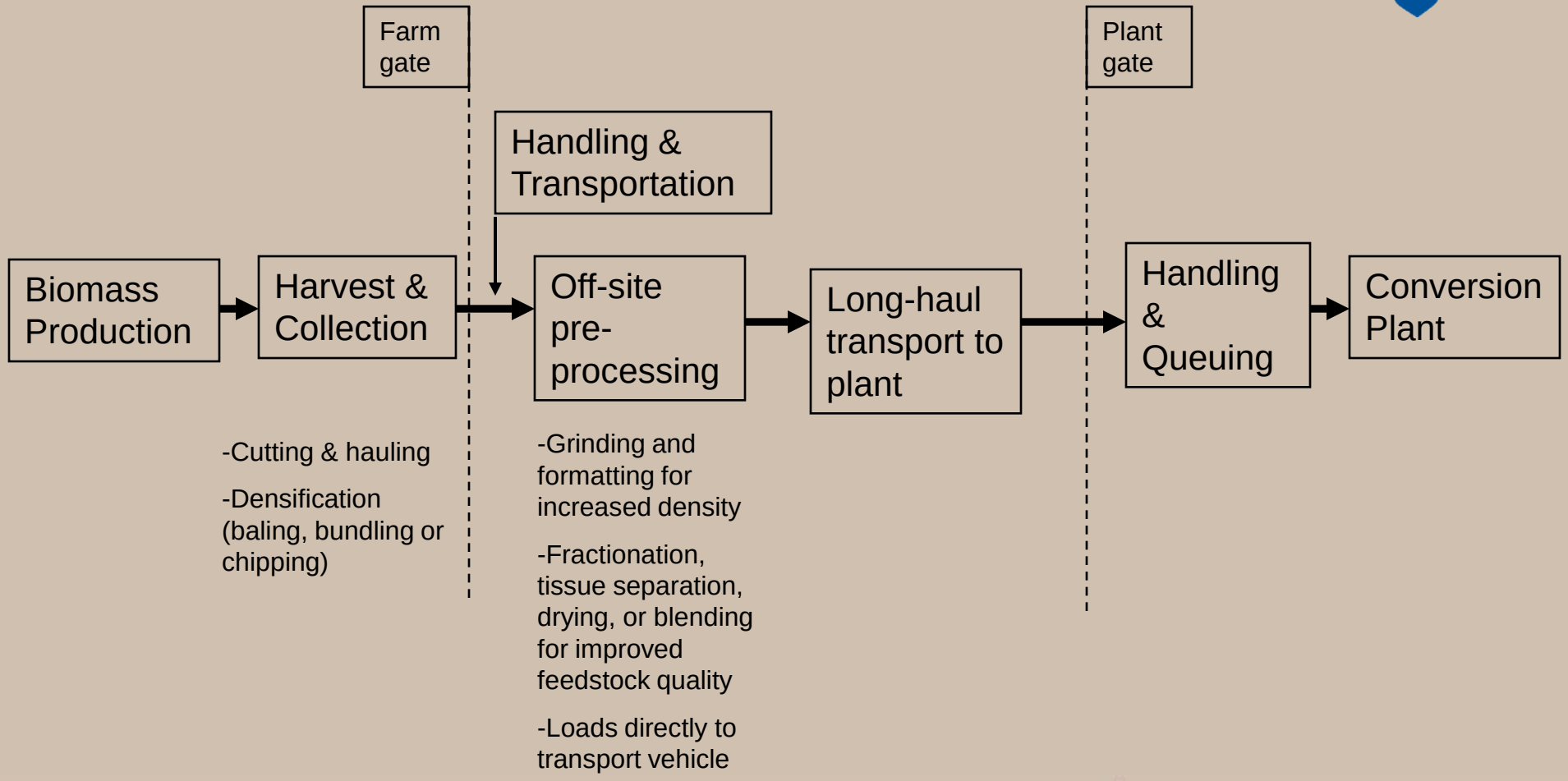
Downstream Operators

Source: SCOR 9.0, Supply-Chain Council (2008)

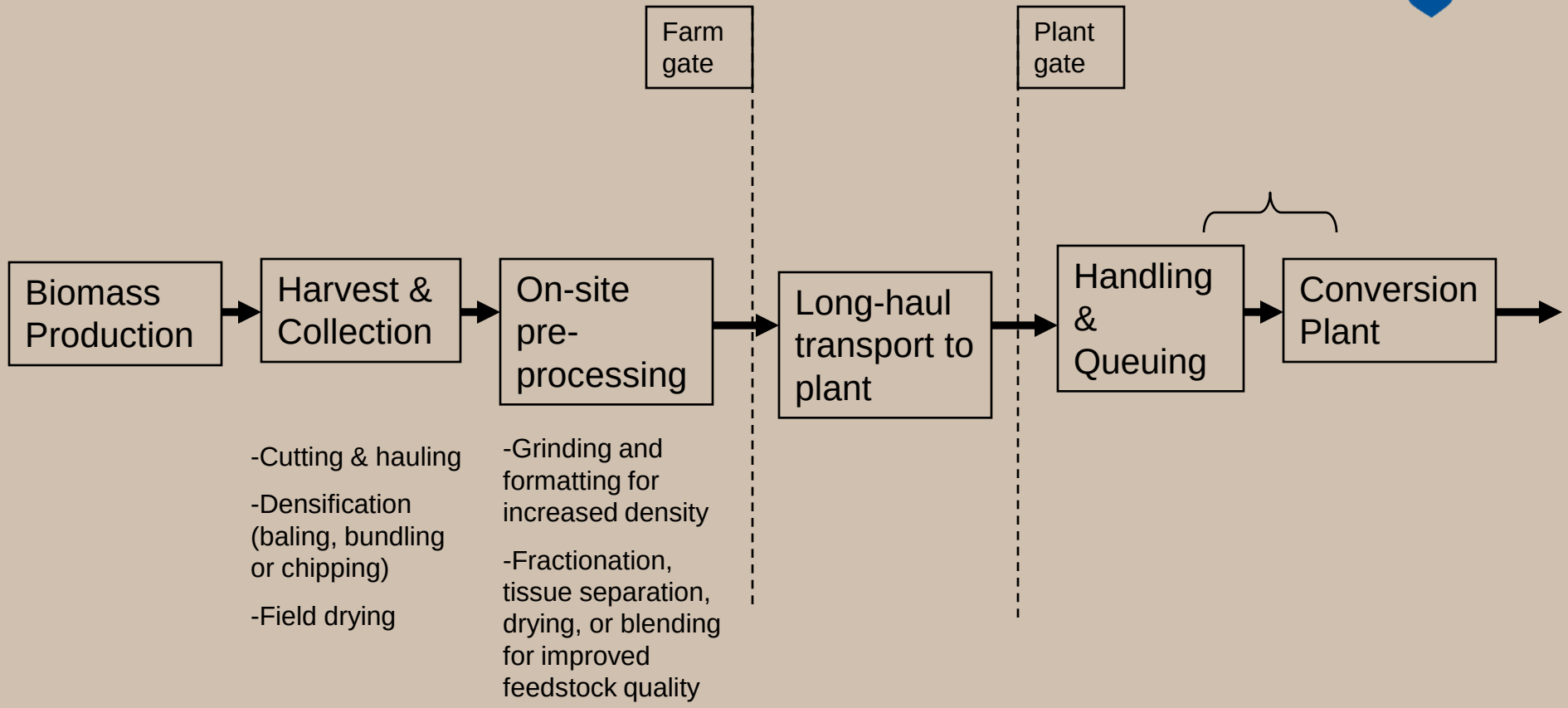
Feedstock Supply Elements



Feedstock Supply Elements



Feedstock Supply Elements



PSU Fermentation Test Facilities

Penn State has a fully functional fermentation facility

- Sixfors 6 x 500ml research fermentor
- Bioflow 1L to 5L benchtop fermentor
- New Brunswick 15L cell culture bioreactor
- New Brunswick 30L fermentor
- Bio Services 60L bioreactor
- 2 x New Brunswick 80L fermentors
- ABEC 100L Bioreactor
- Bio Service 150L fermentor
- Bio Service 300L fermentor
- Sharples T-1-P tube bowl centrifuge
- Sharples AS-16 centrifuge

10+ yr track record of industry short courses

EMS Energy Institute Biofuels Initiatives

- Stationary
  - Combustion: Watertube Boiler, Fluidized-Bed Combustor
  - Gasification
- Transportation
  - Engine combustion performance and emissions characterization
- Biomass processing

Transportation: Facilities

Engines

- 3 Light duty common-rail CI
- 1 Single cylinder marine CI
- Variable CR (Octane Rating)
- 1 Single cylinder SI
- All fully instrumented

Vehicles

- Entire fleet for testing
- Test track and dynamometer

Emissions

- Gas
  - AVL Diesel Emissions Bench
  - AVL Gasoline Emissions Bench
  - CA Emissions Bench
- PM
  - TSI SMPS
  - TEOM
  - Sierra BG-3

Alternative Fuels

- Butanol
- Dimethyl Ether (DME)
- Fischer-Tropsch (FT)
- Hydrogen
- Jet Fuel
- SVO

Air Products, US DOE, PA DEP, Conoco Phillips

Addressing Stakeholder Concerns

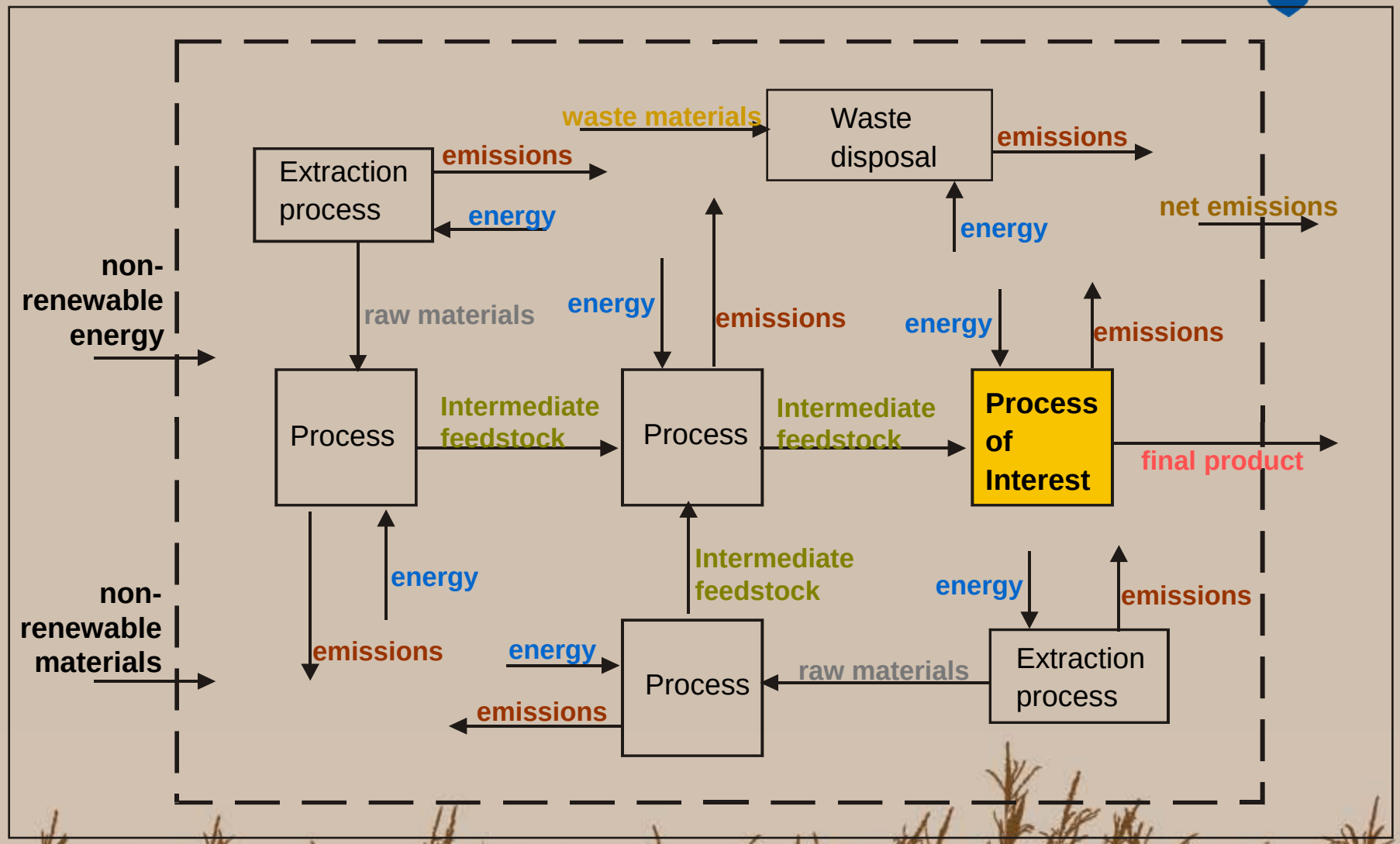
Will trade-offs be necessary between environmental benefits and economic growth?

Who will invest in processing and biorefineries?

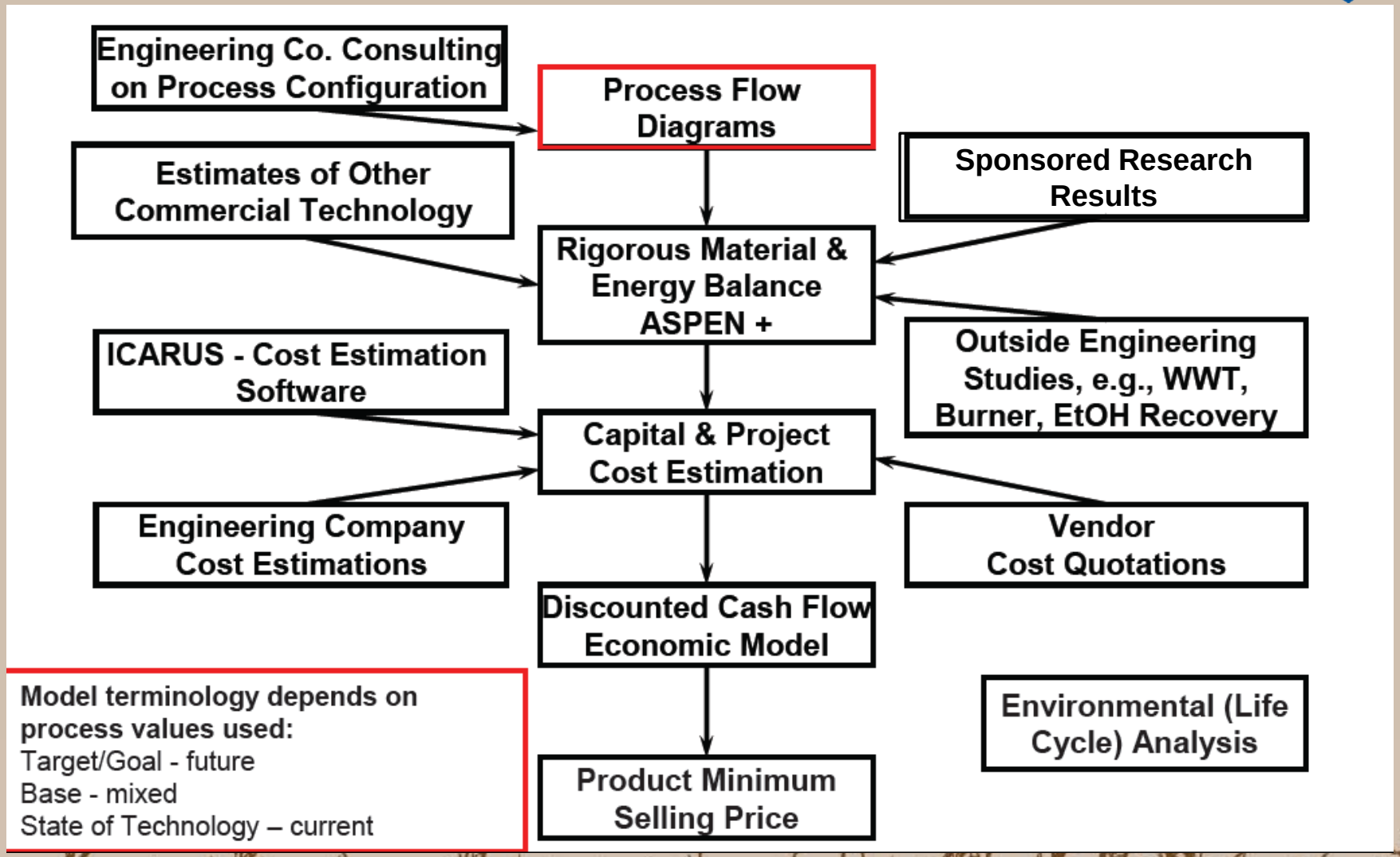
What role will famers have in the coming ‘bioeconomy”?

Will CRP and other governmental regulations/policies help facilitate switchgrass production for energy?

Life Cycle Assessment



Technoeconomic Analysis



The Penn State Research Engine

- Penn State's diverse research portfolio and interdisciplinary programs make it the ideal institution to lead this BioEnergy Bridge initiative
- Penn State is a national leader in industry – university research
- Penn State has an excellent reputation for speed and ease of doing business with the University through our customer friendly Industrial Research Office

Some of our Bioenergy Industrial Partners

- ADM
- Air Products
- Bioenergy International
- DuPont
- Ernst Conservation Seeds
- Foster Wheeler
- Expansin Technologies
- Freedom Energy
- Genencor International
- General Electric
- Keystone Biofuels
- Lake Erie Biodiesel
- Mascoma
- New Holland
- North Shore Energy
- Volvo
- And you!

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