National Renewable Energy Laboratory
Innovation for Our Energy Future

The Integrated Biorefinery Research Facility (IBRF) – Advancing Biofuels Technology

Biomass 2010

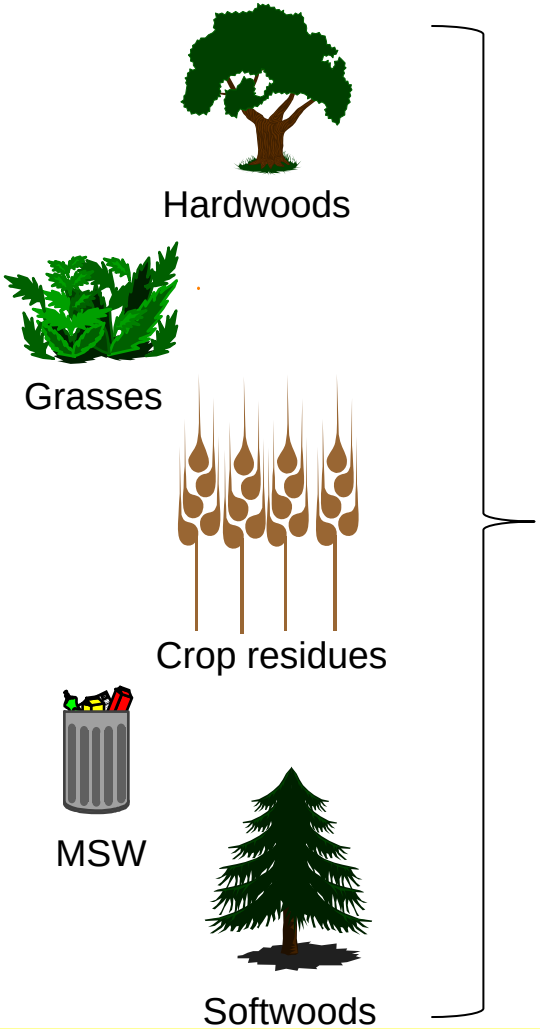
Jane Fisher, P.E.

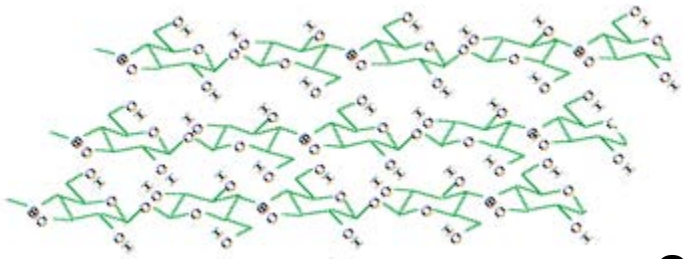
March 31, 2010

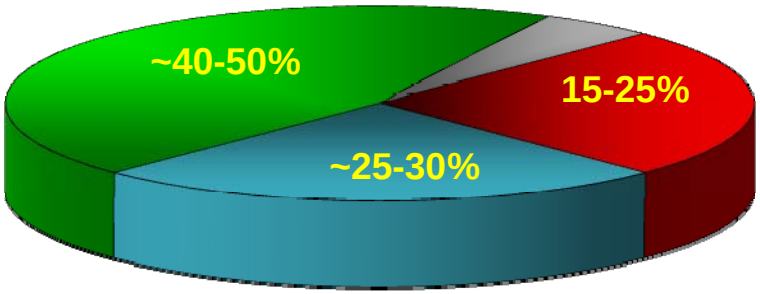
Agenda

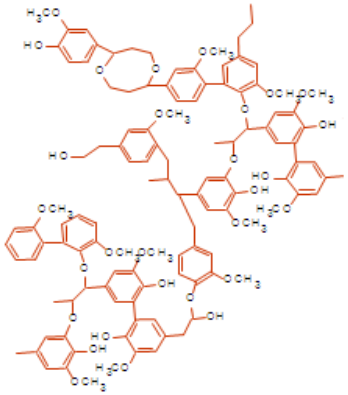
- Biofuels overview
- Project goals and objectives
- Bridging the gap to commercial scale deployment
- Project details (scope/capabilities, implementation approach, cost, and schedule)
- Summary and conclusions

What is Lignocellulosic Biomass?









Over 1 billion tons/yr of non-food lignocellulosic biomass could be available in the U.S.

➔ *Potential to displace >> 30% of U.S. gasoline* use (Perlack *et al.*, 2005)

http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

Biochemical Platform – Goals

Near Term: Demonstrate Cost Competitive Cellulosic Ethanol by 2012

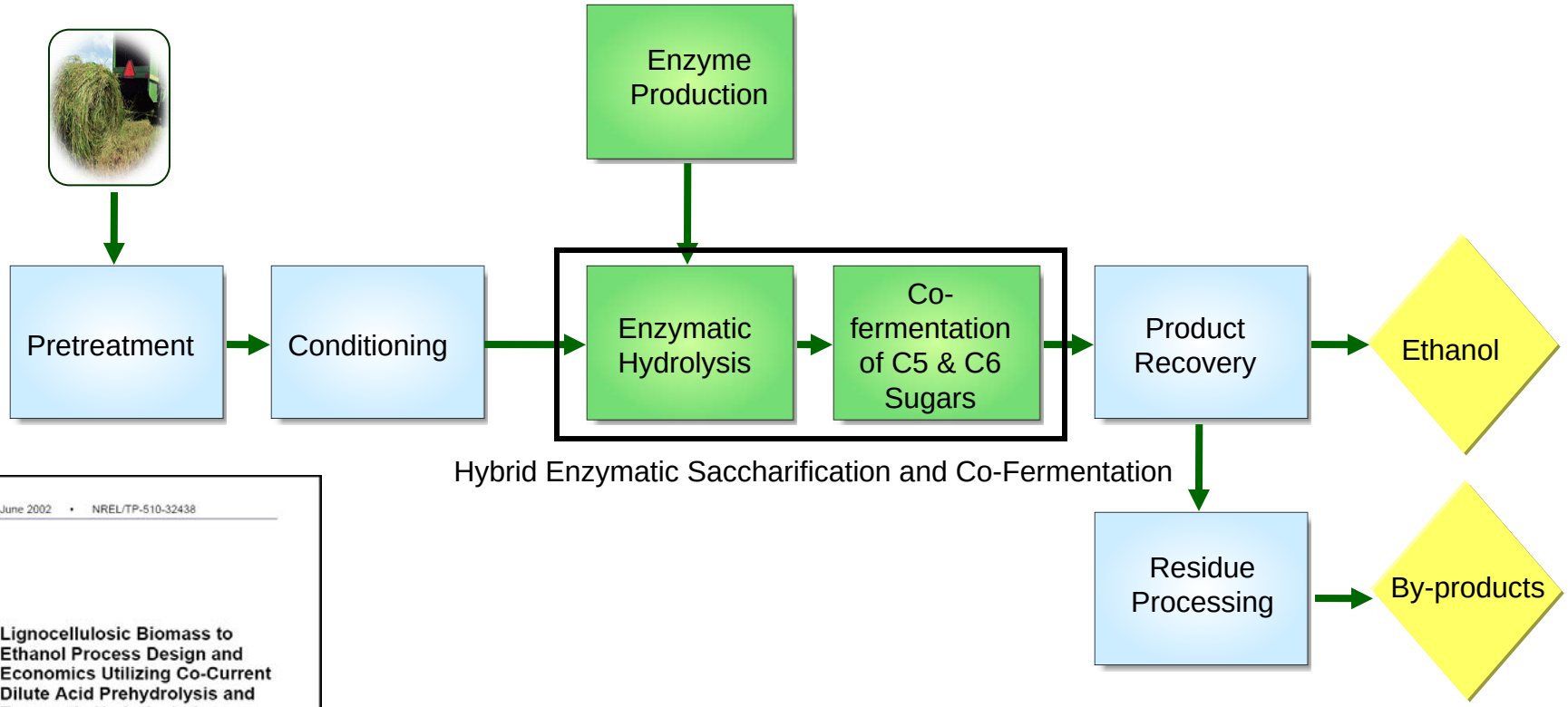
- Pilot integrated enzyme-based bioethanol technology (corn stover @ 1 ton/d)
- Performance data combined with process design and cost estimates validate a Minimal Ethanol Selling Price (MESP) of $1.49/gallon
- Well-defined R&D plan being implemented, with multiple paths to success

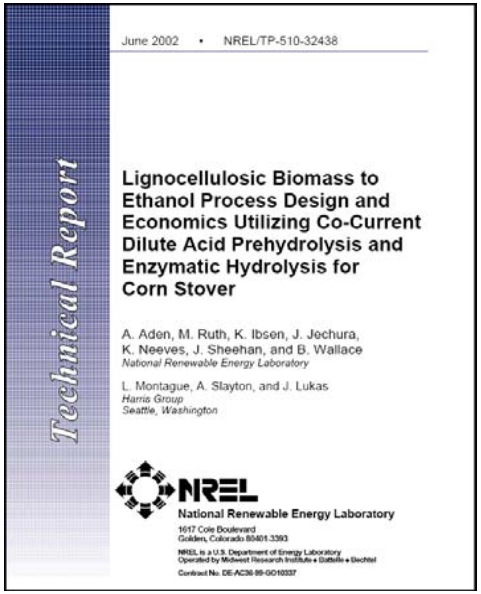
Longer Term: Develop Advanced Technologies that Can Contribute to Out Year 36B (2022) and 60B (2030) Gallon Targets

- Demonstrate cellulosic ethanol processes for other feedstocks
  - Continue focusing on technology advances that reduce cost
- Extend R&D to alternative advanced biofuels processes (“Energy Dense/Infrastructure Compatible)
  - Demonstrate multiple cost-competitive biomass to fuel options with the potential to displace gasoline, diesel and/or jet fuel

➔ *NREL’s biofuels R&D historically focused mainly on cellulosic ethanol. Now examining other advanced biofuels through funded NABC and algal biofuels R&D projects*

Biochemical Conceptual Design Report Drives R&D Direction





June 2002 • NREL/TP-510-32438

Technical Report

Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover

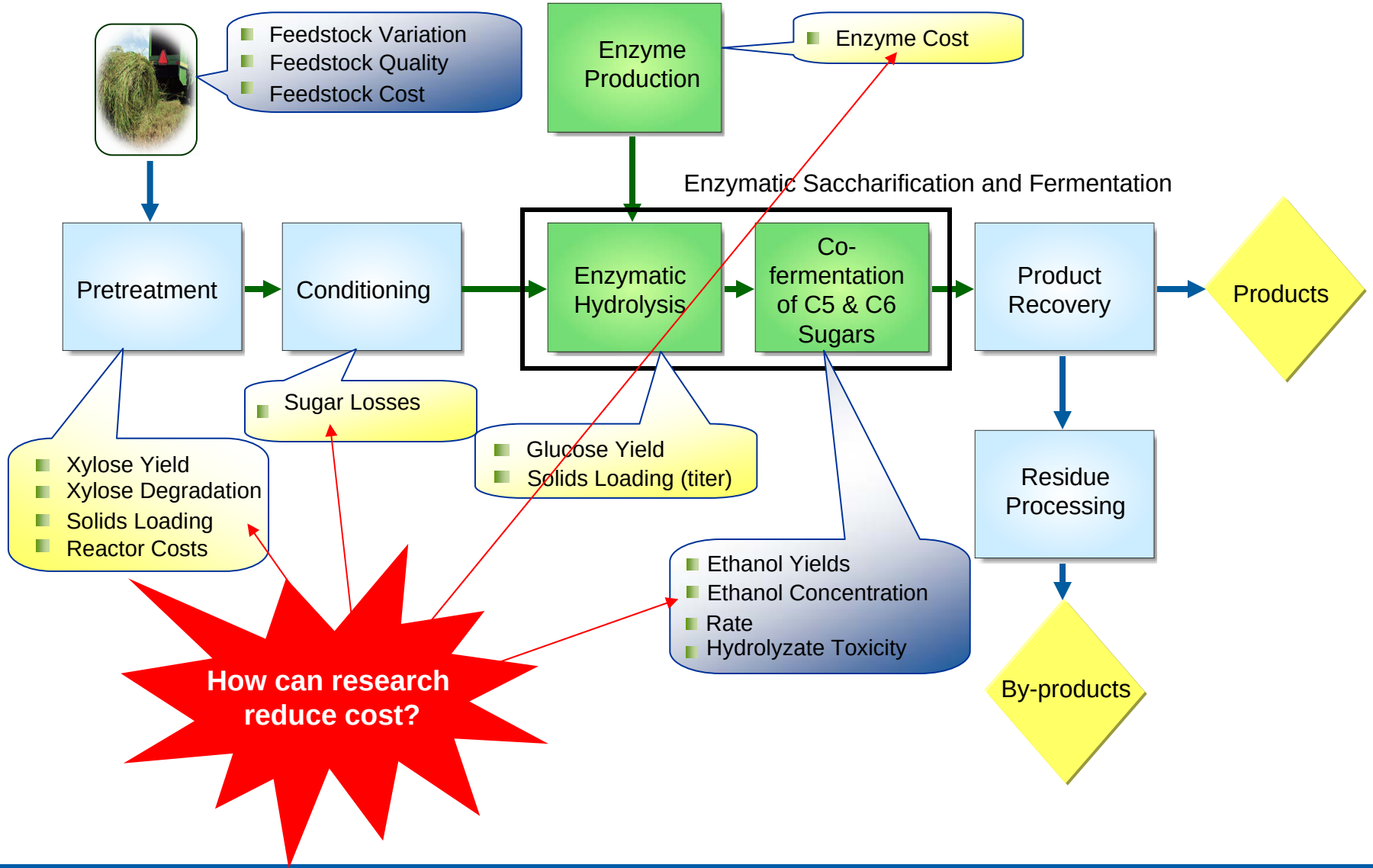
A. Aden, M. Ruth, K. Ibsen, J. Jechura, K. Neeves, J. Sheehan, and B. Wallace
National Renewable Energy Laboratory

L. Montague, A. Slayton, and J. Lukas
Harris Group
Seattle, Washington

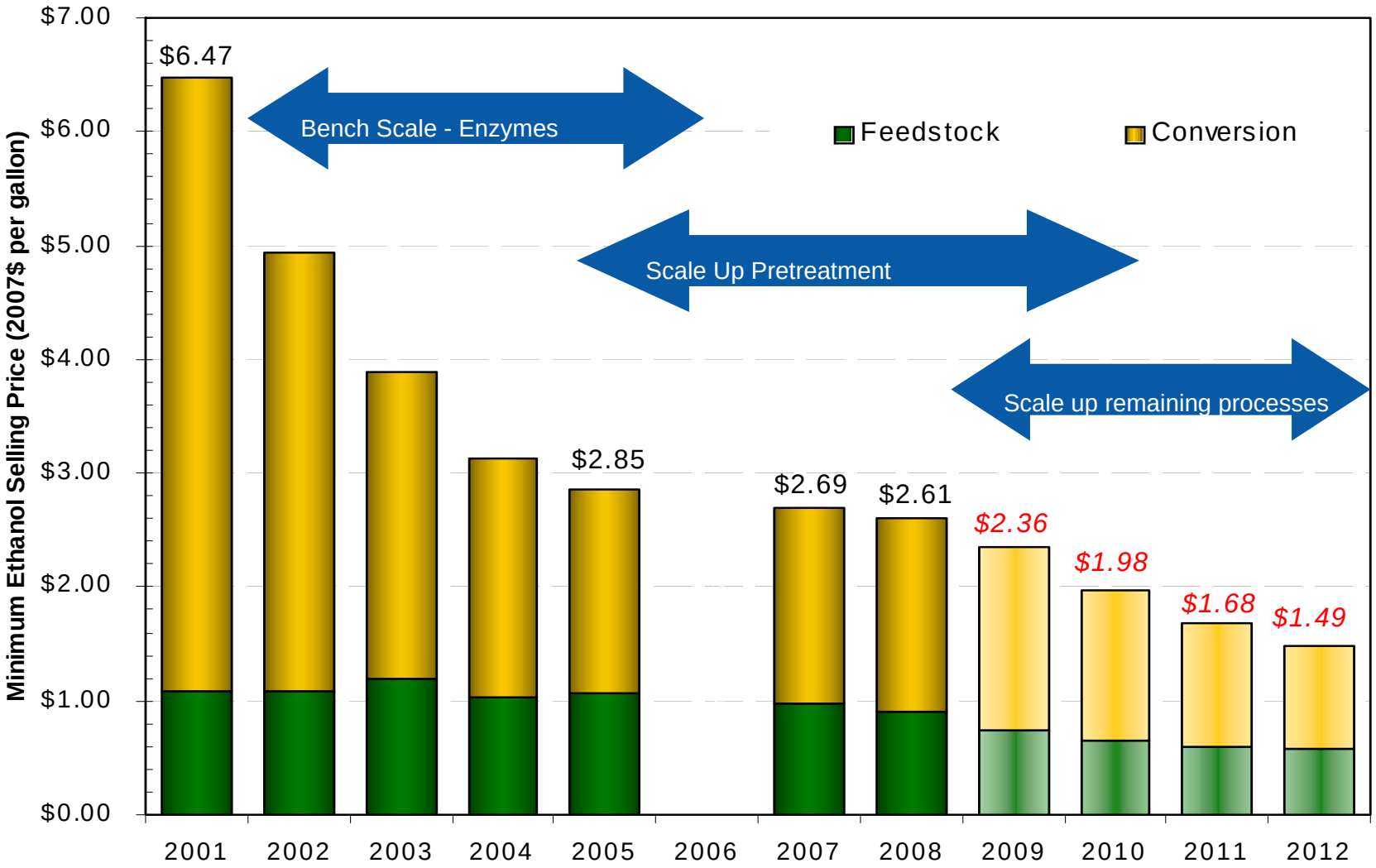
NREL
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
NREL is a U.S. Department of Energy Laboratory
Operated by Midwest Research Institute • Battelle • Bechtel
Contract No. DE-AC36-99-GO10337

- **Conceptual n^{th} plant design of 2,000 tonnes/d facility**
- **NREL pilot testing based around this process**
- **Basis for translating R&D targets to cost targets**

Technical Barriers for the Biochemical Platform



Biochemical Platform Research Status and Potential FY08 State of Technology (yr $2007)



Project Goals and Objectives

1. Accelerate cellulosic ethanol technology development in support of President's 2012 and 2030 goals and the 2007 Energy Independence and Security Act requirements through enhancement of NREL's existing biochemical conversion research facilities
2. Comply with high performance and sustainable building guidelines established by Executive Order and comply with DOE TEAM Initiative to attain LEED Gold Certification

Project Goals and Objectives

3. Accommodate broader and more flexible range of equipment and processing options and configurations
   - Front end flexibility to feed/mill/test a wide variety of feedstocks

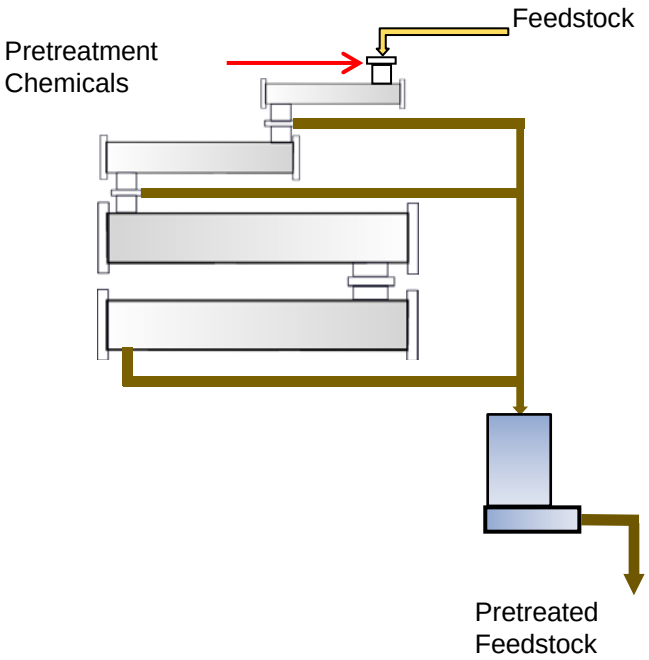
SWITCHGRASS

CORN STOVER

POPLAR

Project Goals and Objectives

3. Accommodate broader and more flexible range of equipment and processing options and configurations
   - Enhanced pretreatment capabilities (broader range of operating conditions and chemistries can be evaluated)



Project Goals and Objectives

3. Accommodate broader and more flexible range of equipment and processing options and configurations
   - Skid mounting of equipment to more easily enable alternative treatment process configurations to be evaluated
   - Provisions to test internal water recycle and process wastewater treatment options
   - More effectively handle high solids concentrations

High Solids Concentrations Handling Capabilities

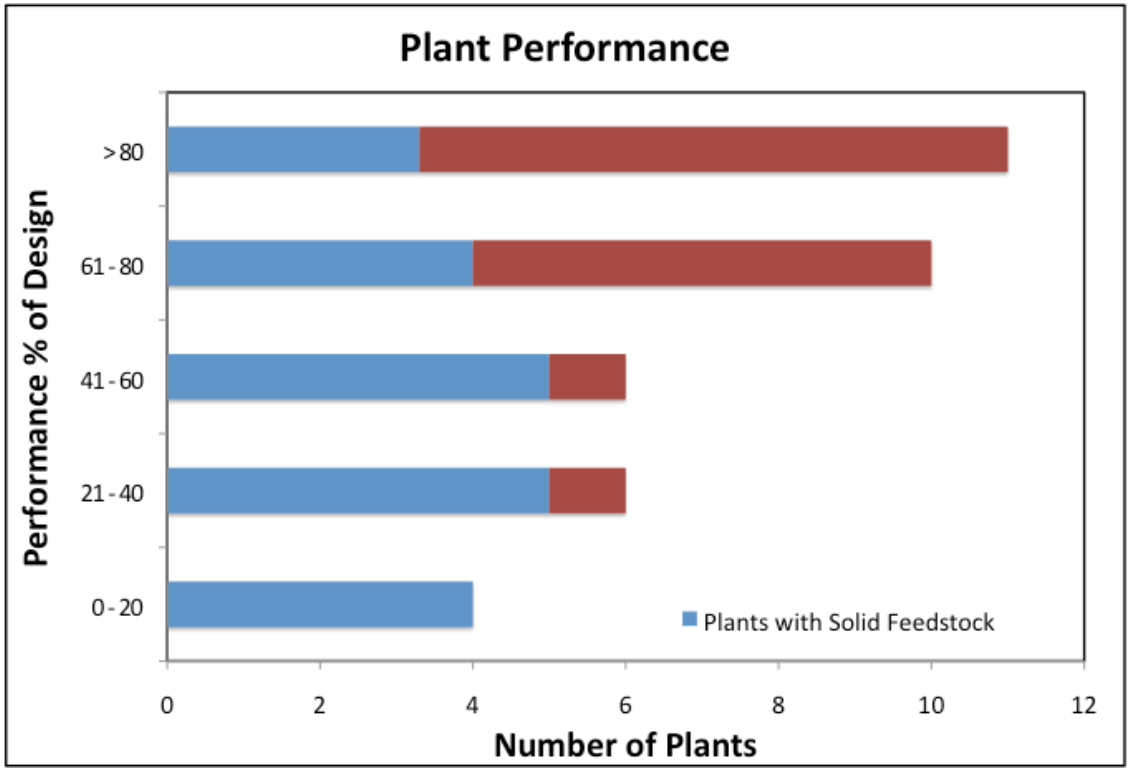
Project Goals and Objectives

4. Efficiently leverage existing infrastructure (full integration with existing fermentation and distillation testing equipment)
5. Complete high bay space no later than June 2010 as necessary to support demonstration and documentation of 2012 cost target

Bridging the Gap to Commercial Scale Deployment

Apply lessons learned from past pioneer processing plants[1,2]

- Plants using solid feedstocks (e.g., biomass) generally perform poorly due to difficult solids handling issues

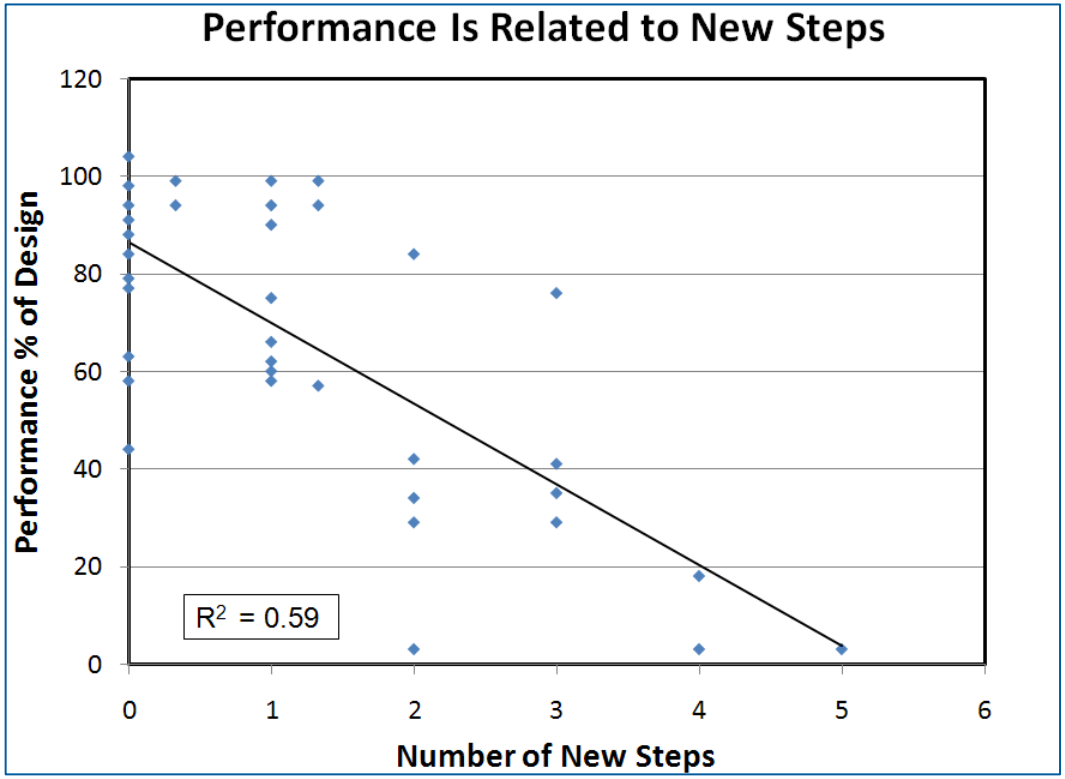


1. "Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants" a 1981 Rand Corporation Study for USDOE
2. "Linking R&D to Problems Experienced in Solids Processing", CEP, May 1985

Bridging the Gap to Commercial Scale Deployment

Linking R&D and Plant Performance[1,2]

- Performance strongly correlated with innovation of the plant (number of new steps)

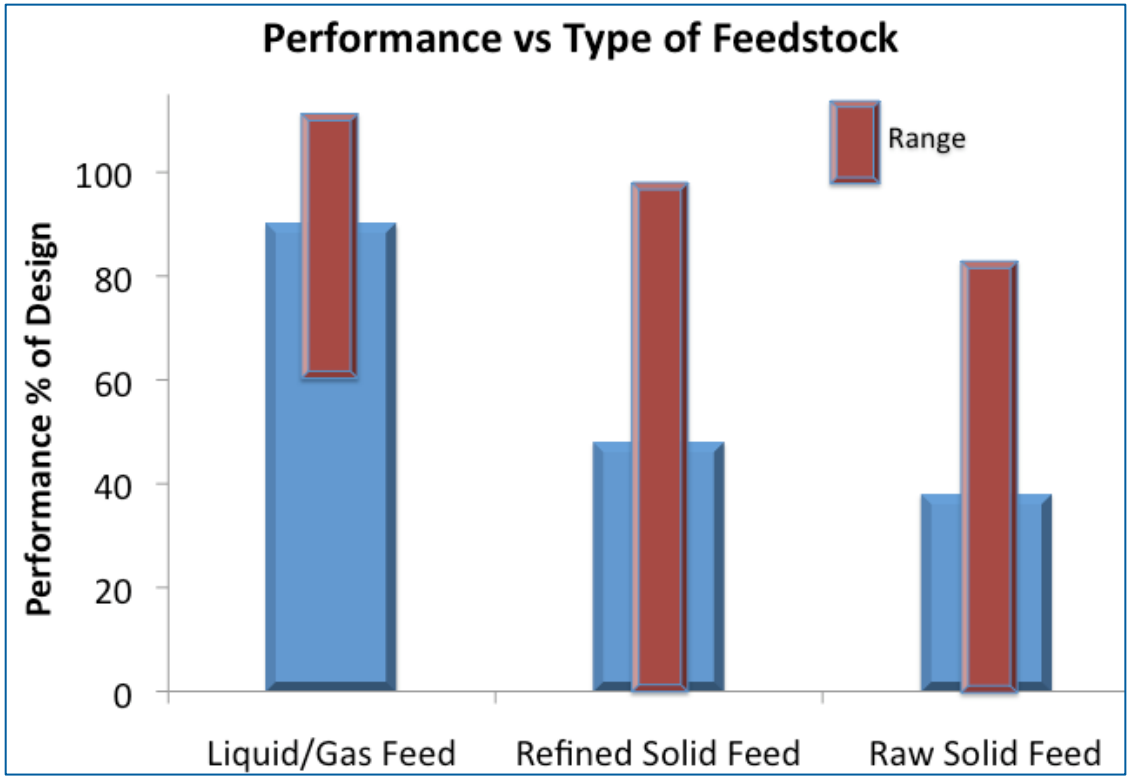


1. "Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants" a 1981 Rand Corporation Study for USDOE
2. "Linking R&D to Problems Experienced in Solids Processing", CEP, May 1985

Bridging the Gap to Commercial Scale Deployment

Linking R&D and Plant Performance[1,2]

- Performance strongly correlated with extent of problems with solid feedstocks

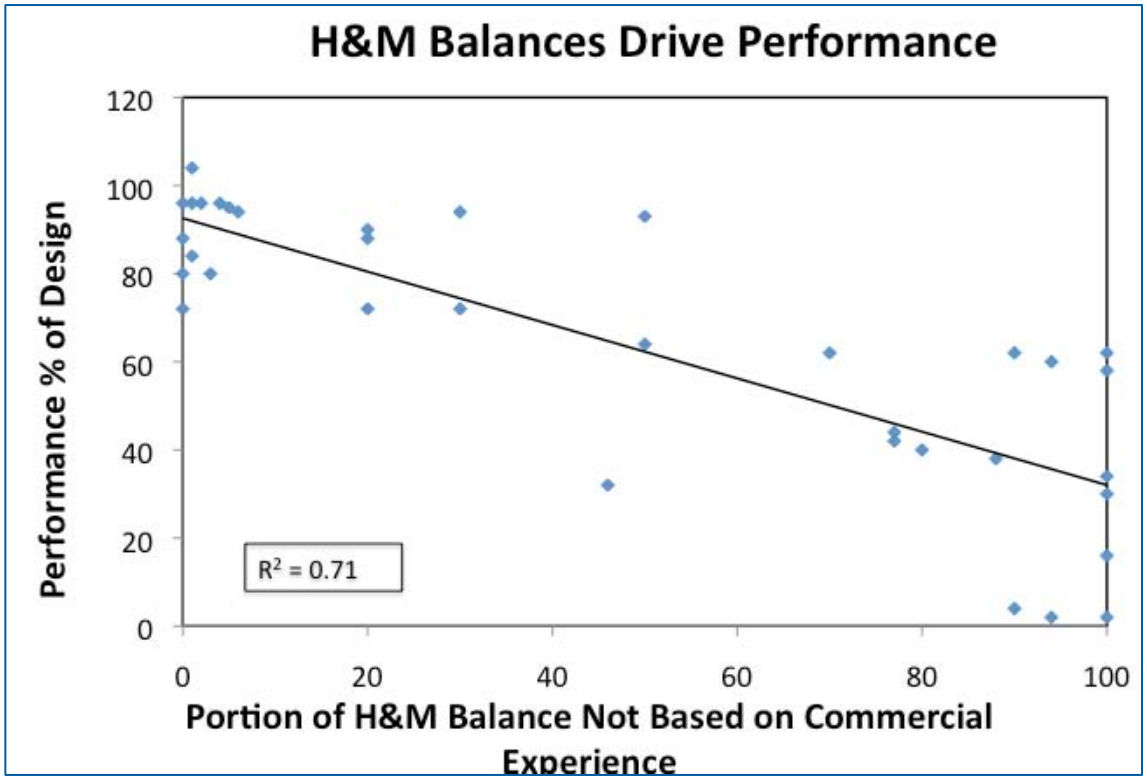


1. "Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants" a 1981 Rand Corporation Study for USDOE
2. "Linking R&D to Problems Experienced in Solids Processing", CEP, May 1985.

Bridging the Gap to Commercial Scale Deployment

Linking R&D and Plant Performance[1,2]

- Performance strongly correlated with extent to which heat and mass balance equations based on actual versus estimated (assumed?) data

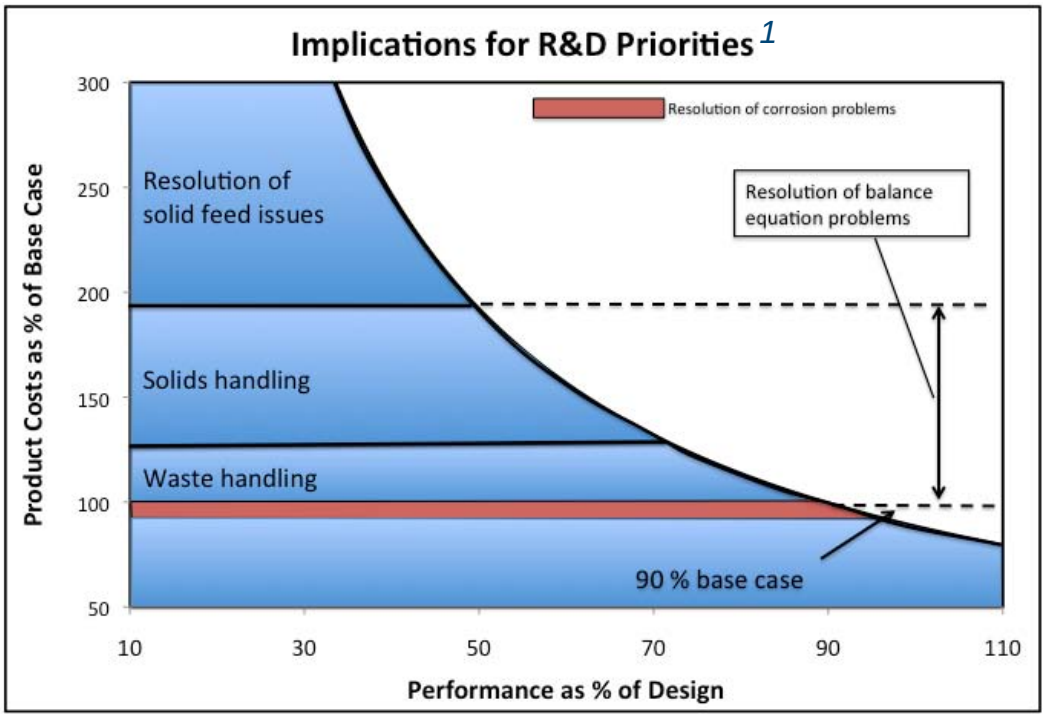


1. "Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants" a 1981 Rand Corporation Study for USDOE
2. "Linking R&D to Problems Experienced in Solids Processing", CEP, May 1985

Bridging the Gap to Commercial Scale Deployment

How does the IBRF enable these R&D gaps to be addressed?

- Capability to evaluate performance of multiple solid feedstocks (assess the challenges and develop and test solutions to mitigate)
- Fully integrated processing (evaluate multiple processing steps and develop actual heat and mass balance data under realistic operating conditions)



1. "Linking R&D Problems to Problems Experienced in Solids Processing", CEP, May 1985

Project Details

Scope

- State of the art 27,000 ft^2 pilot scale R&D facility capable of demonstrating 2012 targets and beyond
- Two parallel processing trains enabling focus on key cost reduction areas (pretreatment and enzymatic hydrolysis)
- Primary DOE facility for fully integrated biochemical process R&D going forward
- Provides significantly enhanced opportunity for value-added partnerships

Project Details

Implementation Approach

- Stage I ($20M CLI funded)
  - High bay and associated process equipment as needed to demonstrate 2012 goal
  - Scheduled completion: June 2010
  - Ready for industry use: FY 2011

- Stage II ($13.5M ARRA funded)
  - Second process train, modified labs, and supporting office space
  - Planned completion: Sept. FY 2011

Summary and Conclusions

- Biofuels development is booming but many full-scale commercialization and deployment risks remain unresolved:
  - Continuous handling of solid feedstocks
  - Pilot scale integration of key conversion unit operations (pretreatment, enzymatic hydrolysis and fermentation), including obtaining heat and mass balances across unit operations and overall process
- NREL's IBRF will be a key R&D contributor in mitigating these risks and enabling achievement of national advanced biofuels targets

Acknowledgements

Funding

- US DOE EERE Office of the Biomass Program

Contributors

- NREL's National Bioenergy Center, Center for Chemical and Biochemical Sciences, and Biomass Program

Questions?