Corn-to-Cellulosic Migration project

20 May 2013

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The Art of Science®

Modification of Corn Starch Ethanol Refinery to Efficiently Accept Various High-Impact Cellulosic Feedstocks

20 May 2013

Integrated BioRefineries

Daniel Derr, Ph.D.

Logos Technologies, LLC

Project Description

- Project Location: Visalia, CA – partner Edeniq's location
- Logos HQ: Merrifield, VA
- High level overview
  - Pelletized corn stover
  - Mechanical pretreatment, enzymatic saccharification, ethanol fermentation
  - Distillation
- Nominal capacity
  - 2 ton/day
  - 50,000 gal/year

Quad chart overview

Timeline

- Project start date 1/28/10
  - BP-1 completed 2/8/11
  - BP-2 planned completion 9/30/13
- Project end date 9/30/13
  - Varied by unit operation
    - Mechanical turnover
    - Start up
  - Commissioning complete 2/7/13
- 78% percent complete

Project Development

- Status: DOE funded pilot plant operations complete
  - Cost and scope shifted
  - Schedule adhered to
  - Full project completion scheduled for 9-30-13

Budget

- Total project funding $27.1M
  - DOE share $20.5M (all ARRA)
  - Contractor share $6.6M
- Funding received by fiscal year
  - 2010 - $1.9M
  - 2011 - $8.1M
  - 2012 - $8.2M
  - 2013 - $2.3M

Participants

- Logos Technologies
  - Management & engineering support
- Edeniq
  - Technology provider
  - Pilot plant owner/operator
  - Intellectual Property rights
- University of California, Davis
  - Life Cycle Assessment

Edeniq

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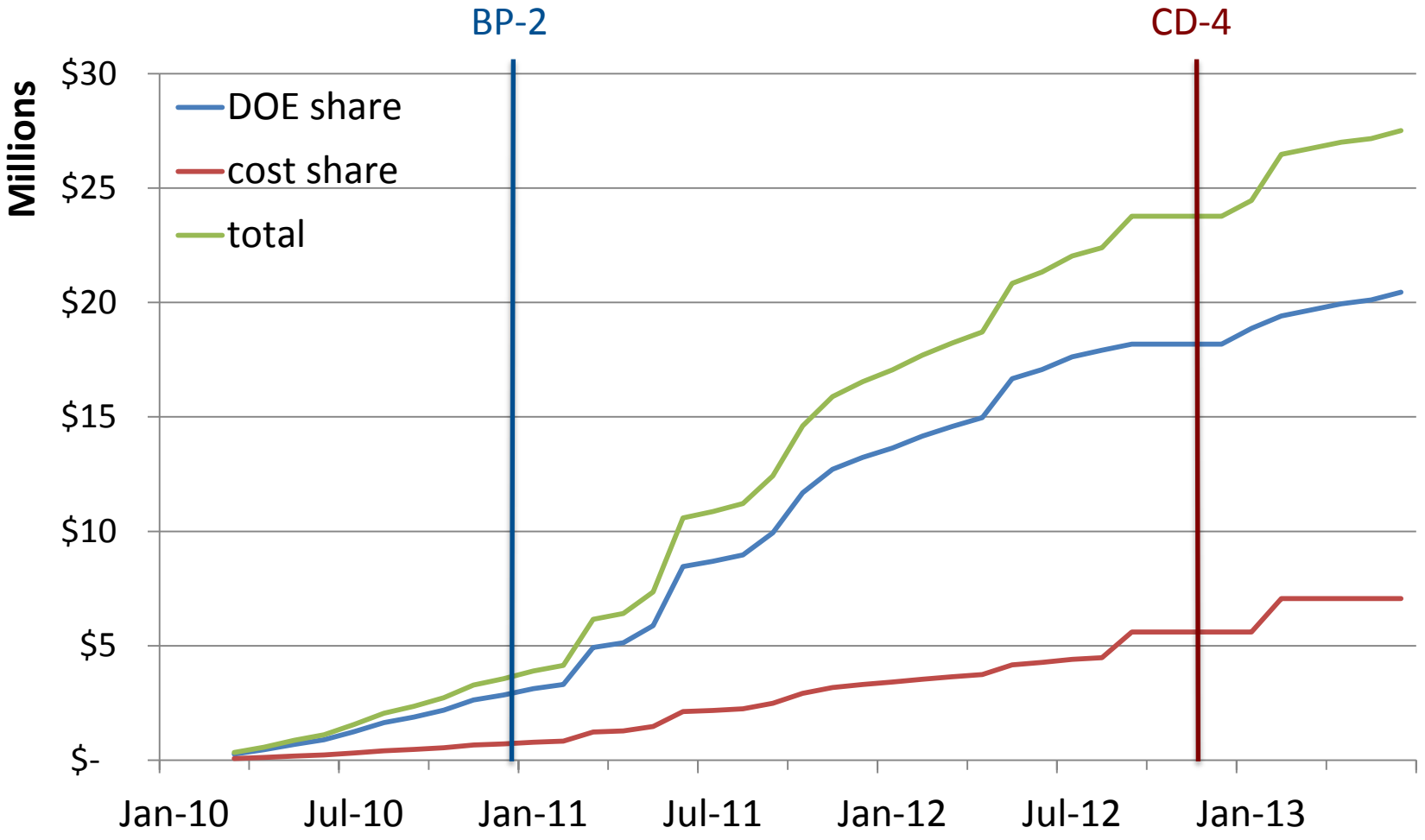
Spend plan



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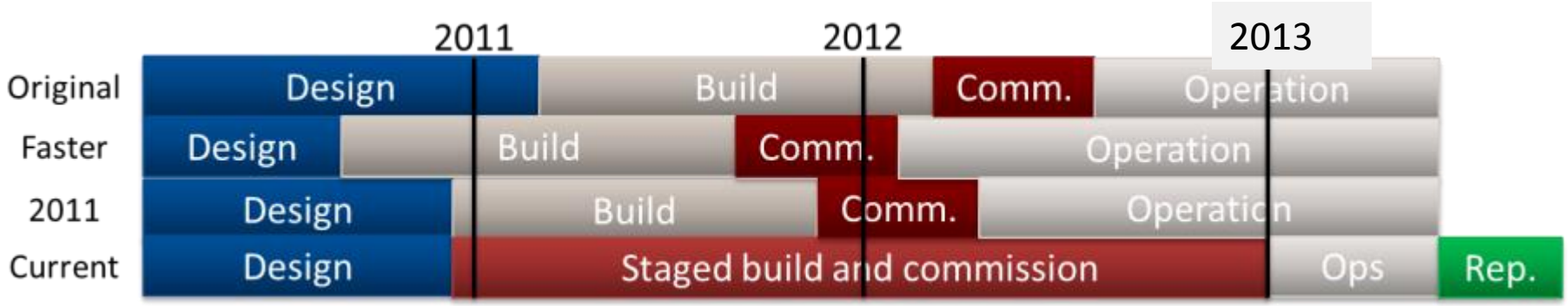
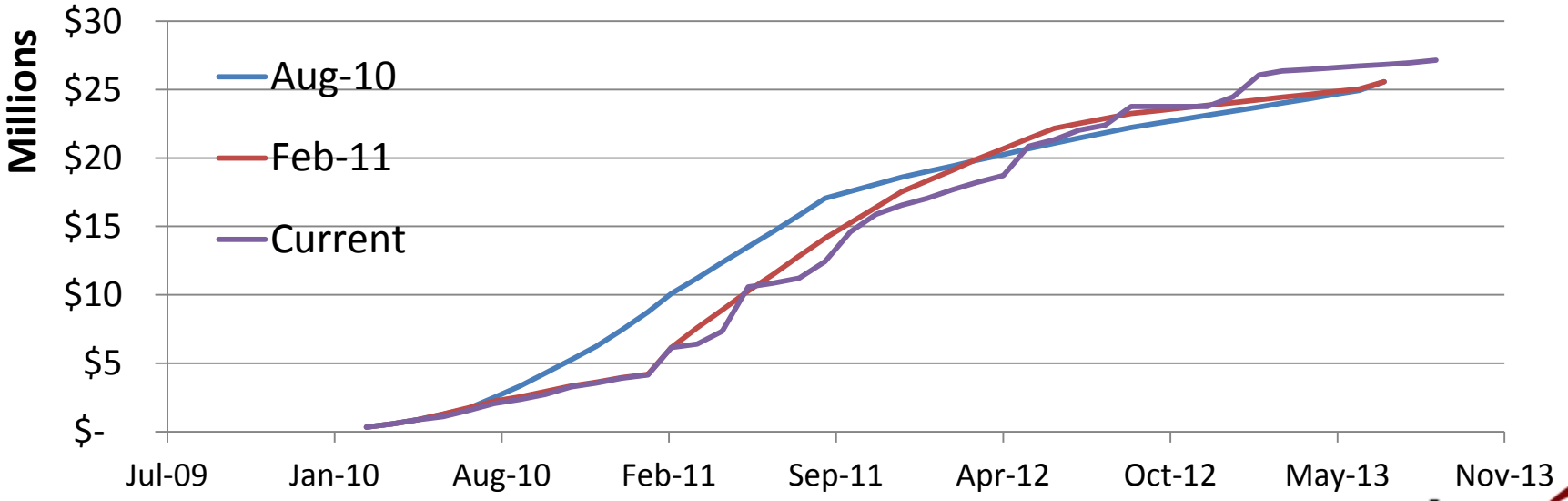
Schedule performance





Block flow diagram

Enzymes

Pelletized corn stover (et al.)

Pretreat (*t, T, P*)

Flash

Pre-Saccharification

Cellunator™

Water

Yeast & media

Propagation

Solid/liquid separation

Distillation

Saccharification & Fermentation

Cogeneration (model)

Ethanol fuel

Key operations

Enzymes

Key technologies

Pelletized corn stover (et al.)

Pretreat (*t, T, P*)

Flash

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Propagation

Water

Solid/liquid separation

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Technical barriers addressed

Key technical barrier addressed:
- Minimizing chemical inputs
- Interfacing feedstock & biochem

Enzymes

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Pretreat (*t, T, P*)

Flash

Pre-Saccharification

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Water

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Technical barriers addressed

Enzymes

Pelletized corn stover (et al.)

Pretreat (*t, T, P*)

Flash

Pre-Saccharification

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Water recycle

Water

Yeast & media

Propagation

Solid/liquid separation

Distillation

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Cogeneration (model)

Ethanol fuel

Project management

- Design/build/operate & ongoing research
- Integrated customer (DOE) and Independent Engineer feedback continuously
- Unique approach:
  - Cross-functional technical teams for unit ops, technology areas, and functions
  - Ensured there was personnel overlap/information transfer between teams

Team
Feedstock Acquisition & Logistics
Preprocessing Options
Pretreatment Optimization
Enzyme Package Optimization
Fermentation and Yeast Propagation Optimization
Preventive Maintenance & Spares
Solid/Liquid Separations; Water Management
Wear Mitigation
Process and Economic Modeling
Cleaning In Place (CIP)
Cogeneration
Data Collection & Distribution
Quality

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Technical team design & dynamics

- Technology Action Teams established by CCM Management – aimed at:
  - Prioritized issues focus
  - More effective utilization of all resources
  - Cross-functional communication and achievement
  - De-compartmentalization
- Technical leads & management champions
- Charters, membership, and areas of focus
- Action plans implemented; ongoing resource needs identified and load leveled
- Regular meeting schedule / content expectation

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Go/no-go's and metrics

- Preliminary design review by Independent Engineer – transition between BP-1 and BP-2
- Commissioning (IQ & OQ), shakedown, & start up – DOE's Critical Decision 4

Forest Products Laboratory

- Gallons/ton
  - Saccharification yields
  - Fermentation yields
- Residence times
  - Saccharification & fermentation
    - Staged – with Forest Products Lab
    - Simultaneous – internal
  - Propagation
- Operating expenses
  - Feedstock
  - Enzymes
  - Water recycle

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Block flow diagram

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Pretreat (*t, T, P*)

Flash

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Cellunator™

Water

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Distillation

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Cogeneration (model)

Ethanol fuel

Technical accomplishments

1000 h run is complete – actual continuous run time exceeded 1400 h

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Bag unloading

Transfer to pretreat

Block flow diagram

Enzymes

Pelletized corn stover (et al.)

Pretreat (*t, T, P*)

Flash

Pre-Saccharification

Cellunator™

Water

Yeast & media

Propagation

Solid/liquid separation

Distillation

Saccharification & Fermentation

Cogeneration (model)

Ethanol fuel

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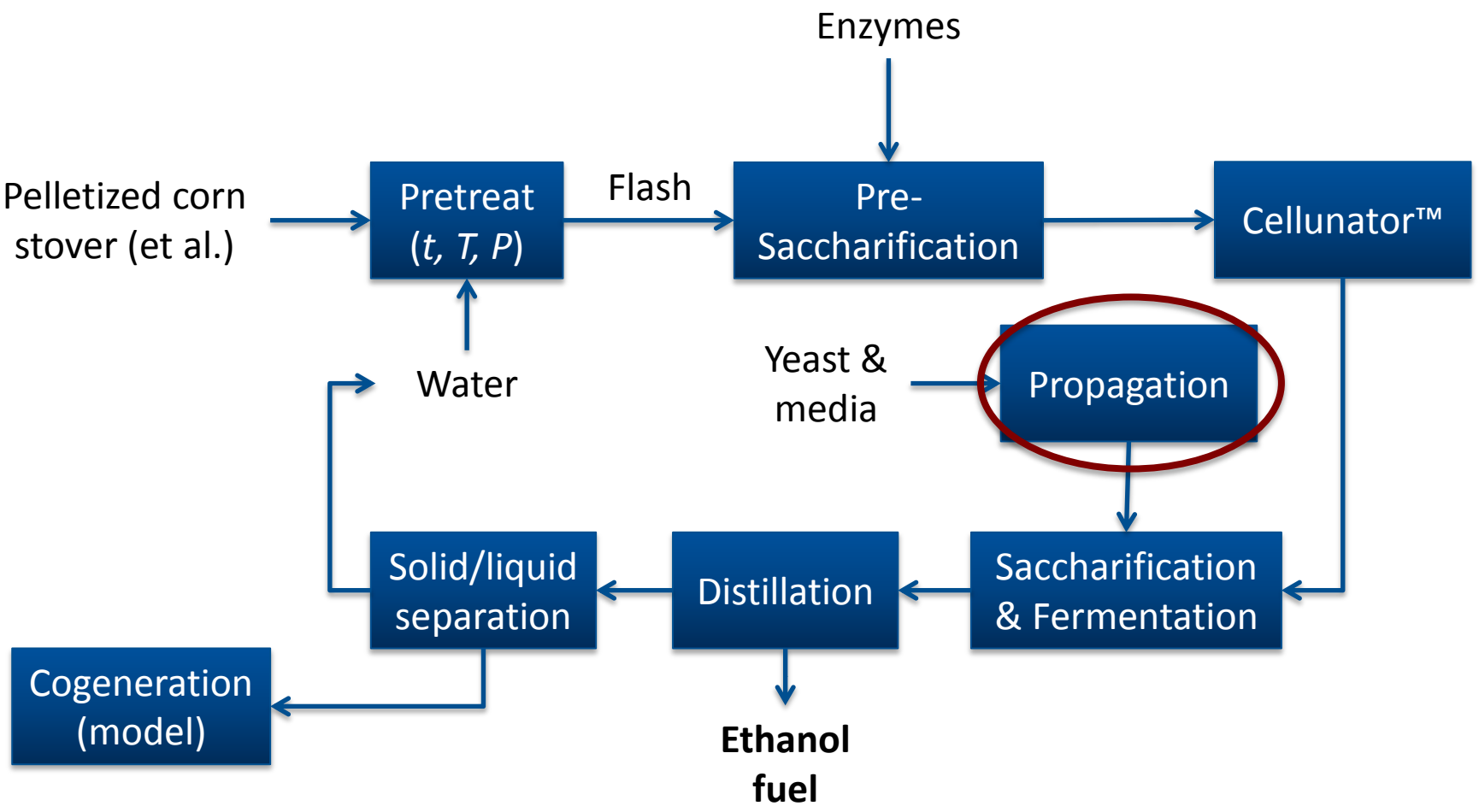
Pretreat and flash vessels

Block flow diagram

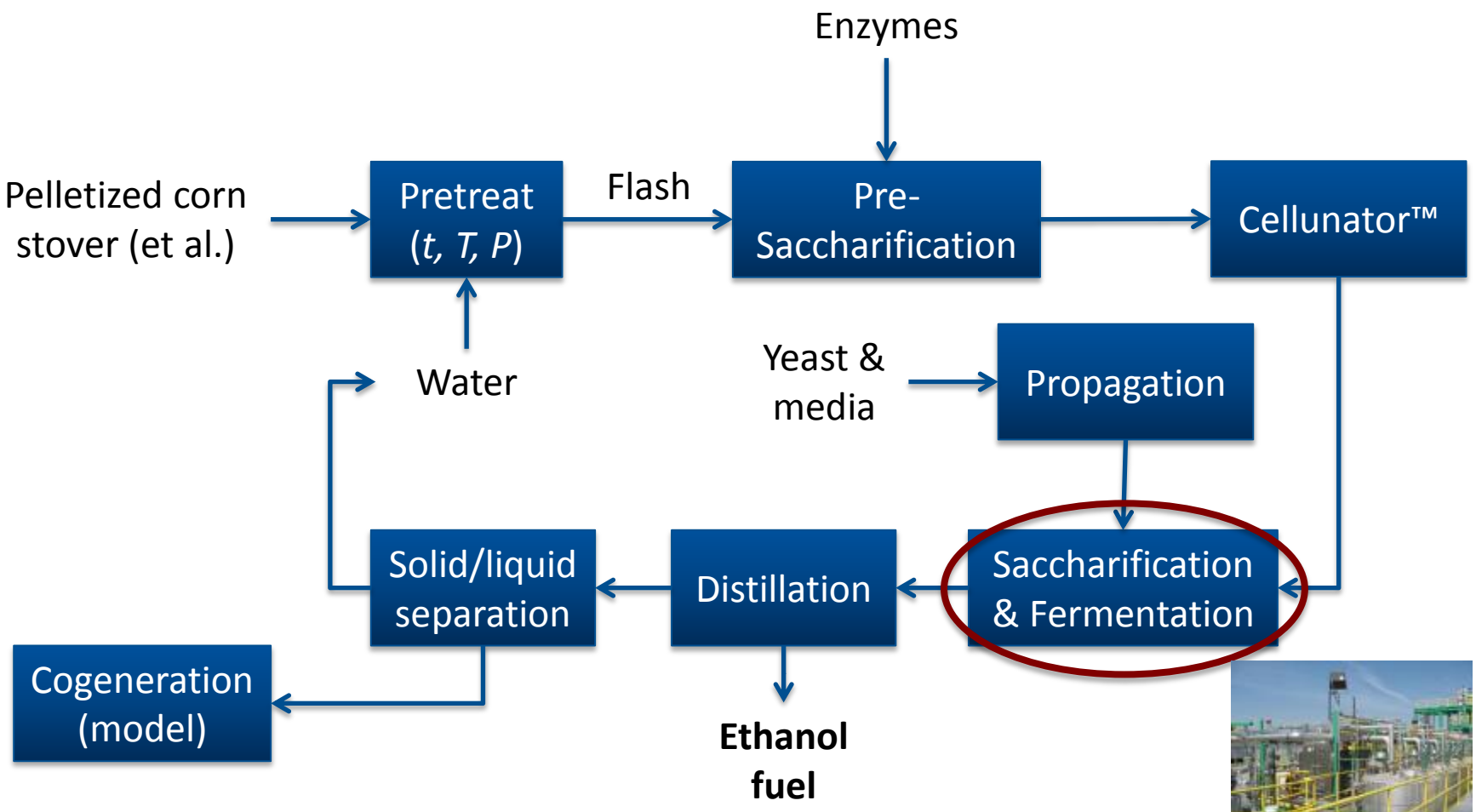
Cellunator™

Block flow diagram



Propagation

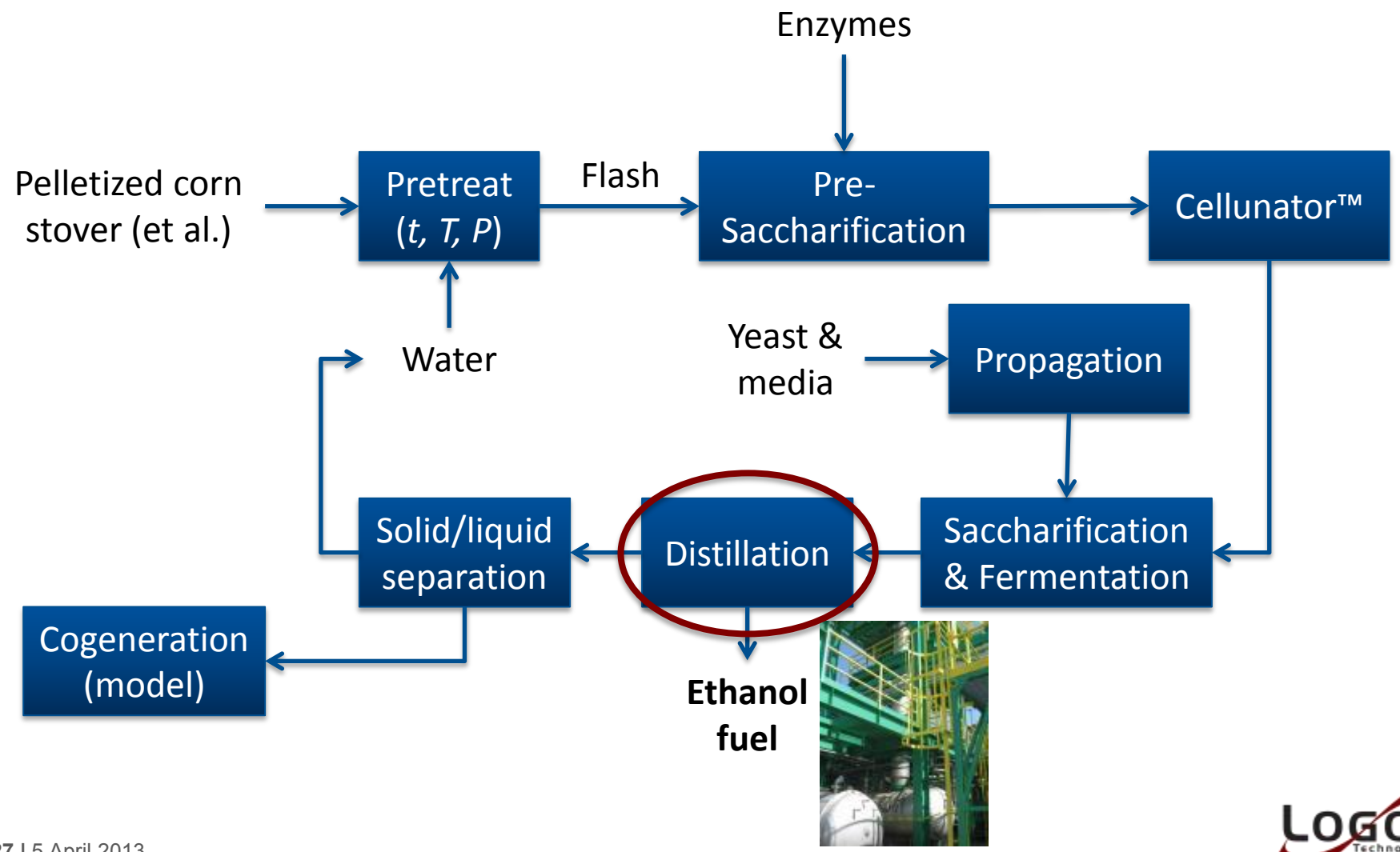
Block flow diagram



Fermentation

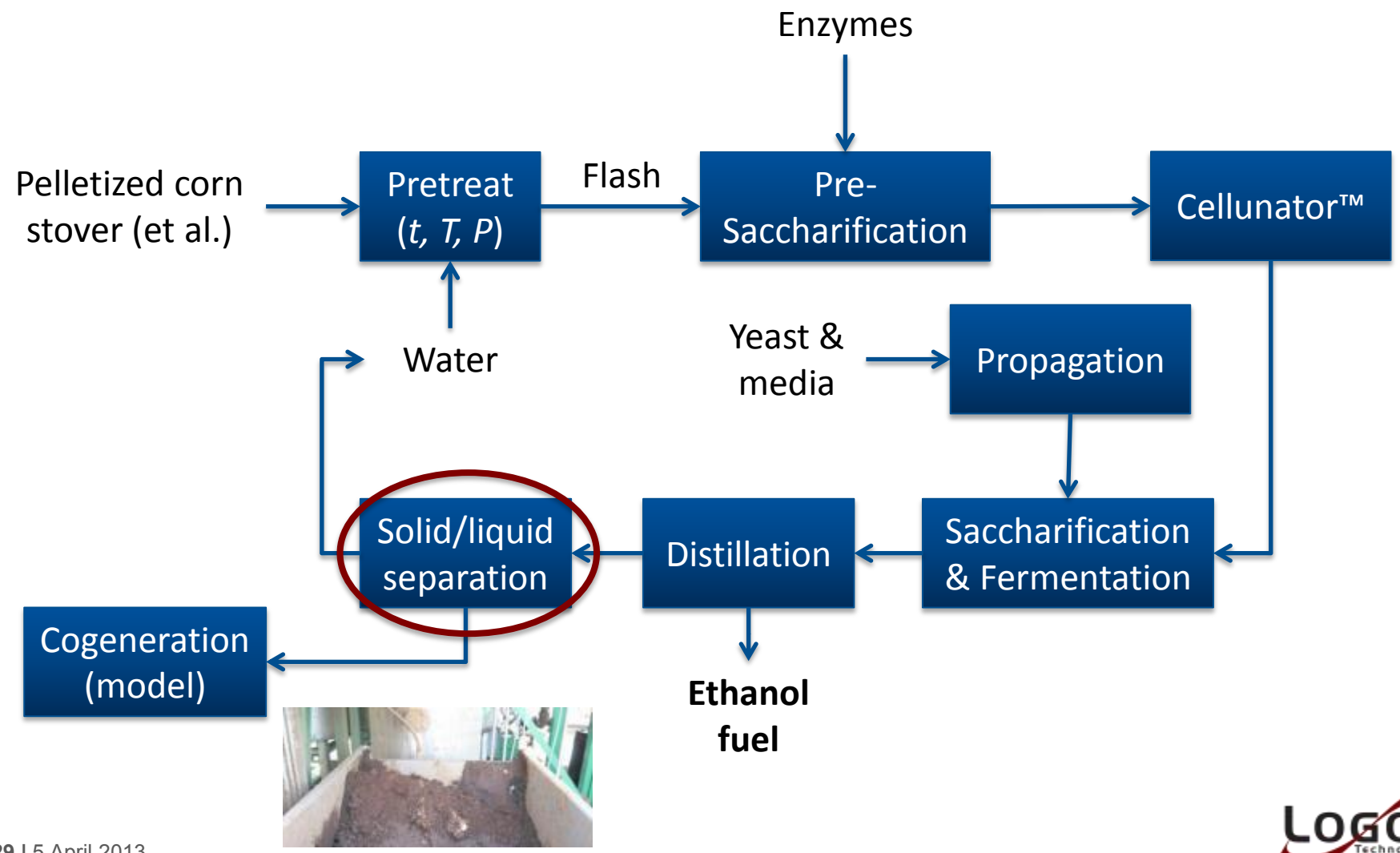
CIP, Beer wells, and water storage

Block flow diagram



Distillation

Block flow diagram



>400 µm solids removal

Solids dewatering

Fines (< 400 µm) removal

Water polishing for recycle

Utilities

Status

In tandem with California Energy Commission funding, alternative feedstocks will be run for the remainder of 2013 and results will be reported to DOE

CEC-600-2006-004-F

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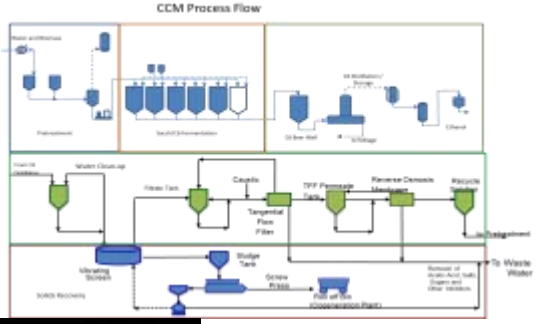
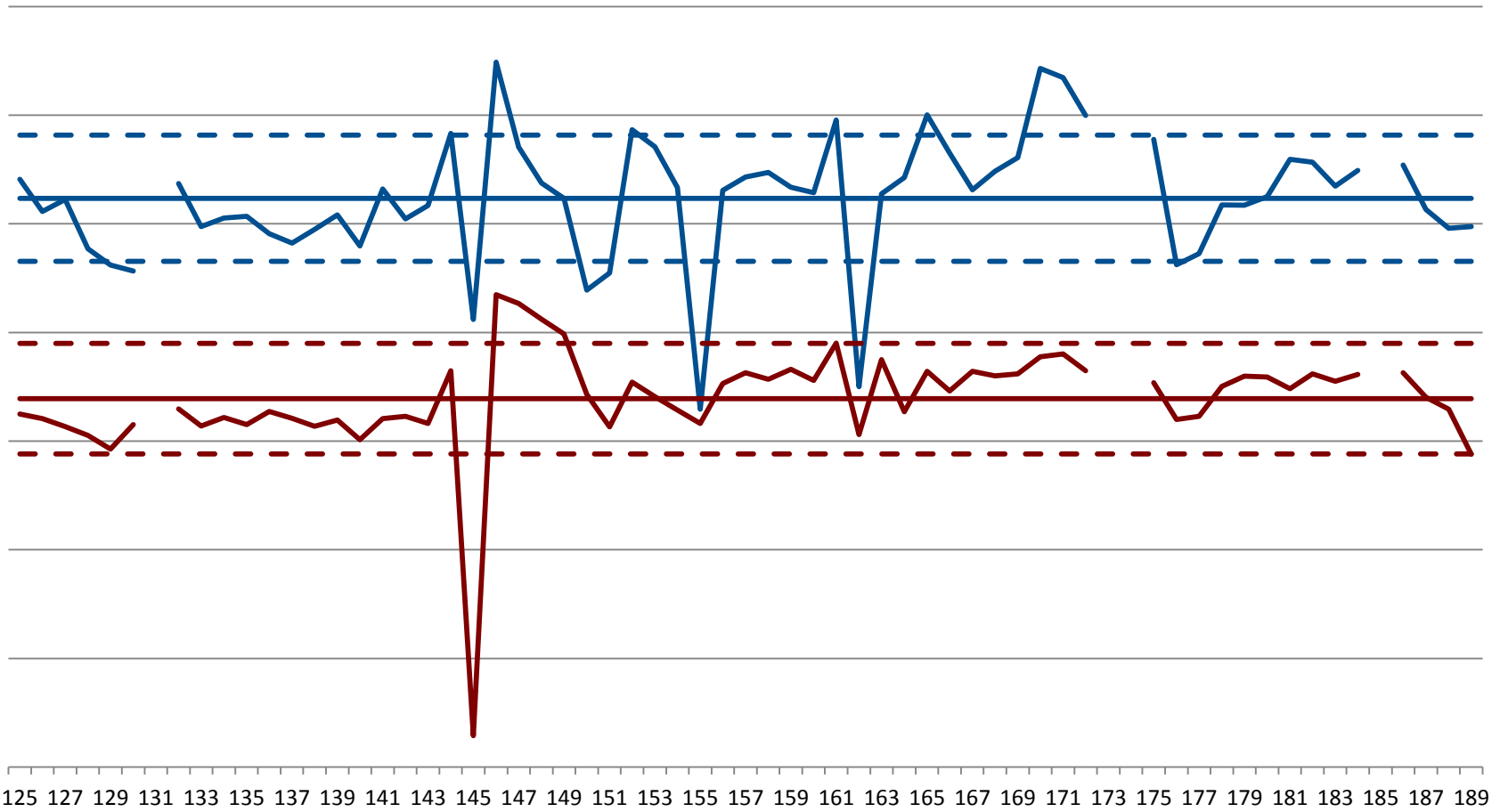
Executed tasks



- Design
- Construction
- Installation
- Commissioning
- Shakedown
- Start up
- Operation > 1400 h

Plant was in control for 1000 h run



Two intermediate analytes are controlled and track well.

Meeting BioEnergy Technology Office goals

- This project met the program and Recovery Act goals for demonstrating technology, creating jobs and developing potential commercial operations by:
  - Operating a lignocellulosic fed biochemical pilot-scale process for 1400 plus hours to produce cellulosic ethanol using the proprietary Cellunator™ technology.
  - Providing 27 direct jobs for operations and dozens of indirect jobs during construction
  - Cellunator™ is currently deployed in corn ethanol
  - Bolt on strategy of adding cellulosic capacity to corn plants allows demo scale deployment, bridging the "valley of death"

Project has resulted in opening of cellulosic markets to corn ethanol technologies

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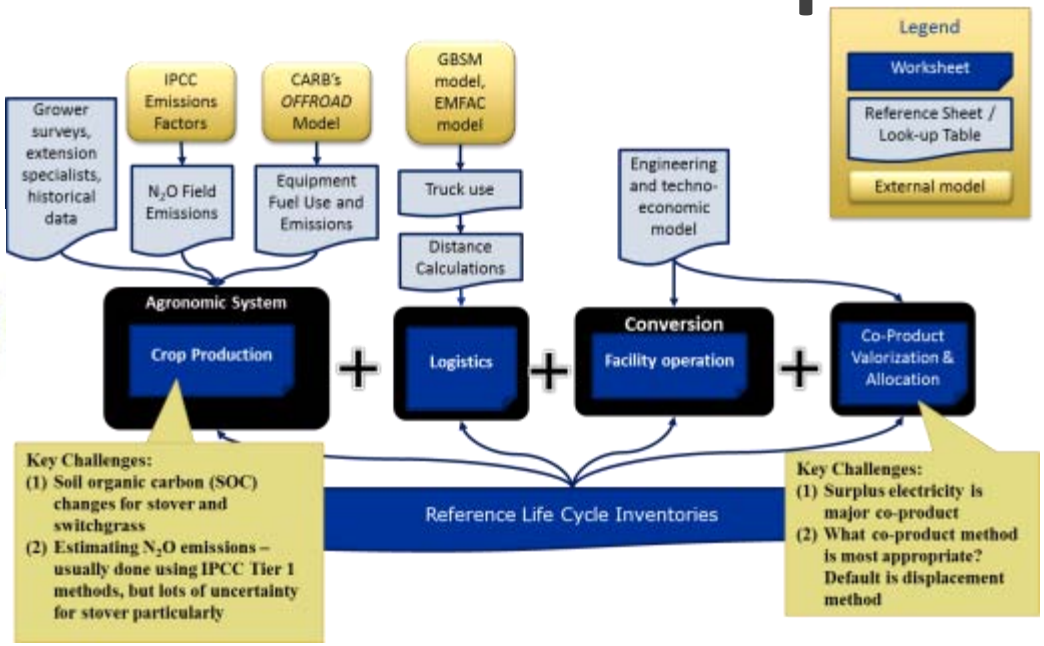
Life cycle assessment

Current estimate shows substantial reduction in GHG's vs. petroleum



Analysis is ongoing: soil organic carbon changes are a current focus.

Critical success factors

- Commercial viability
  - Yield
  - Throughput
  - OpEx
- Challenges
  - Management – complicated partnering arrangement
  - Technical – feedstock
  - Biologics
    - Staged sacc & ferm – FPL
    - SSCF - internal
- Successfully mitigated risks
  - Wear
  - Inhibitors in recycle
  - Construction delays
- Remaining programmatic risk
  - None – Program complete 9-30-13

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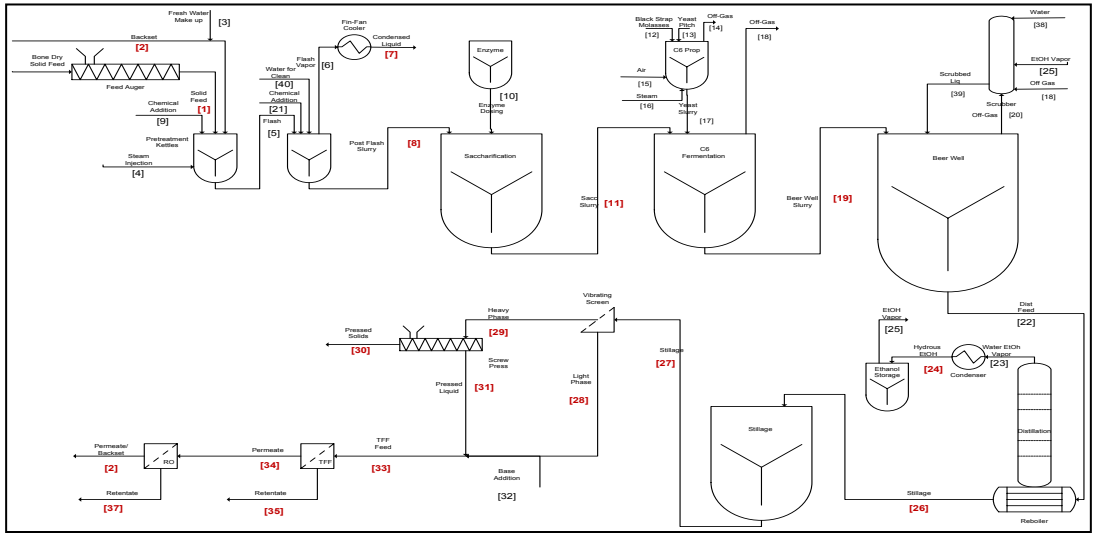
Future work

- Pro Forma finalization
  - EBITDA, ROI, water use, energy demand, & GHG reductions
- Final report



Summary

- 1400 h plus continuous operation
- Additional runs (CEC supported) to be reported to Department Of Energy
- Commercial ready technologies have been successfully piloted
  - Cellunator™ mechanical pretreatment
    - Being deployed in corn ethanol plants
    - Demonstration of real world cellulosic integration allows bolt on approach
  - Solid/liquid separation for CoGen and CoProducts
- Unique management approach worked in a complicated project structure

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Additional slides

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Responses to previous reviewers comments

- Progress was not easily judged in ‘11
  - Completion of 1000 h run alleviates
- Lacking in specifics
  - Specific components of the project will be commercialized, and public info is available on those components
- Logos / Edeniq relationship is complicated
  - This relationship was necessary to bring nascent technology into ARRA funding environment

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Patents, awards, publications and presentations

- Patents
  - "Improved Acetate Resistance in Yeast" Ken Zahn and Sandra Jacobson, 61/674,676, Edeniq, submitted 7-23-12.
- Publications
  - "Effects of Allocation Methods on Life-Cycle Inventory Development for Corn and Stover Production Systems" submitted by Professor Kendall's group at UCD to *Biomass & Bioenergy*.
  - Manuscript in preparation, also Kendall
- Presentations
  - "Cellulosic Migration in Renewable Fuels and Chemicals" at BioPro Expo, 3-16-11.
  - "Cellulosic Sugars in Corn to Cellulosic Migration (CCM) and Other Technologies" at Biomass 2012, 7-11-12.

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