U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

1.2.1.1000: Development of a Wet Logistics System for Bulk Corn Stover

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Technology Area Review:
Feedstock Supply and Logistics

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Overall Project Goal

Context

- Dry bale storage is the current herbaceous state of technology (SOT), but recent bale yard fires have prompted industrial interest in wet storage

Switchgrass bale storage in Vonore, TN
(https://news.tn.gov/node/8576)

Project Objective

- Design a high-moisture, bulk feedstock logistics system that
  - Reduces the risk of catastrophic loss of feedstock to fire
  - Preserves feedstock value in wet climates
  - Competes with the cost of the dry, baled logistics supply chain

DOE-BETO Link

- High-moisture feedstock is required to enable a Billion Tons
  - Represents 50% of herbaceous crops in Billion Ton Study

Outcome and Industrial Relevance

- A cost-competitive wet logistics system is compatible with the existing logistics operations and conversion technology, leading to a quick entry into the marketplace

Quad Chart Overview

Timeline

- Project start date: Oct 1, 2014
  - Funds received mid-Nov 2014
- Project end date: Sept 30, 2017
- 1% scope complete

Budget

	Total Costs FY 2010 –2012	FY 2013 Costs	FY 2014 Costs	Total Planned Funding (FY 2015-Project End Date)
DOE Funded	-	-	-	$1,115K
Project Cost Share (Comp.)*	-	-	-	$1,092K (2%)

Barriers

- Ft-H. Biomass Storage Systems
- Ft-G. Quality and Monitoring
- Ft-L. Biomass Material Handling and Transportation
- Ft-K. Biomass Physical State Alteration
- Ft-D. Sustainable Harvesting

Partners

- DOE Partners
  - FY17: ORNL, LBNL ABPDU
- Abengoa Bioenergy
- Harris Group

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Project Overview

Aerobically stored feedstock is at risk of:

Dry matter loss due to microbial degradation

- Losses of over 30% dry matter have been observed in high-moisture aerobic bale storage
- Dry matter loss = sugar loss
- **Wet anaerobic storage preserves dry matter and sugar**

Corn stover bale stack stored in Kansas for 12 months, losses up to 31%

Switchgrass bale on top of uncovered stack stored in Oklahoma for 18 months, losses up to 37%

Catastrophic loss to fire

- Insurance costs of dry bale storage are undefined
- **Wet anaerobic storage reduces risk of fire**

July 2014, Emmetsburg, IA
(http://ktiv.com)

March 2014, Nevada, IA
(http://nevadaiowajournal.com)

May 2013, Moscow, KS
(http://biobasedchems.blogspot.com)

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Project Overview

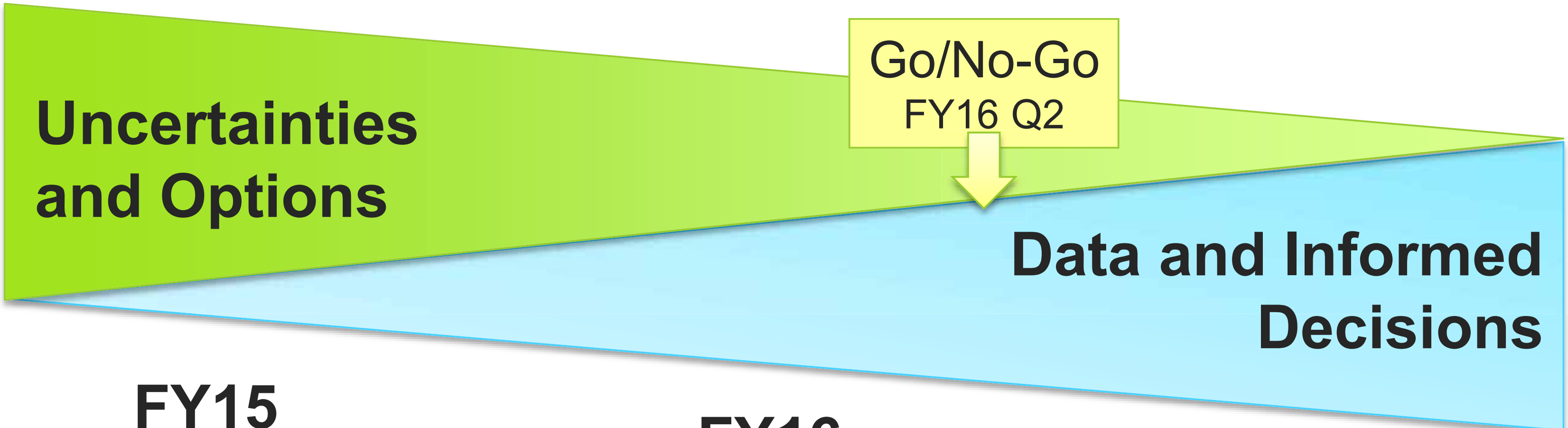
Can wet biomass storage be cost effective for bioenergy?

- Anaerobic storage, or ensiling, has been used for centuries to preserve high-moisture biomass for livestock
  - Anaerobic conditions created mechanically and biologically
  - Acid-fermentation lowers pH and stabilizes biomass
  - Dry matter losses of <5% possible
- But, the cost of wet storage in the existing supply chain is high
  - Harvest, collection, storage, and transportation costs for wet storage were **\$14 to \$23/DMT higher** than the dry baled system, not including the cost of drying and size reduction (1.2.1.1 FY14 Q3 milestone)
- Does moving unit operations lower costs?
  - Rearrange storage and preprocessing in supply chain
  - Size reduce in field with existing forage harvesting equipment
  - Large-scale storage within refinery gate

Investigate centrally located wet biomass storage and the enabling logistics operations at an industrially relevant scale

Approach – Timeline

Technoeconomic analysis (TEA) informs wet logistics system selection



FY15

Initial Logistics Design
- Biomass Logistics Model
  - INL
- Engineering design
  - Harris Group
- Laboratory research
  - INL storage reactors

FY16

Field Demonstration
- Small scale
- Build storage pile
  - Abengoa
- Storage performance
  - INL, Abengoa
- Logistics performance
  - INL

FY17

Field Demonstration
- Large scale
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- Logistics performance
  - INL, ORNL

Initial TEA → **Data Collection** → **Final TEA**

Technical Approach – Storage Solutions

Gaps in published wet storage research exist:
- Mass closures of dry matter
- Individual structural sugars concentrations
- Conversion to biofuels

Recreate field conditions using INL storage reactors
- 100-liter storage reactors measure storage performance
- Storage metrics include dry matter loss, greenhouse gas production, chemical composition, conversion performance

Proposed storage solutions:
- Industrial-scale silage pile
  - 40 to 50% moisture w.b. during storage
  - Compacted by tractors or similar heavy machinery
- Modified-Ritter pile
  - Pile constructed and compacted with slurried biomass
  - Biomass 70 to 80% w.b. moisture content during storage, dewatered upon exit
  - Possible co-products offset costs

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Management Approach

Engage Industry

- Abengoa
- Harris Group

Engage National Laboratories

- ORNL
- LBNL ABPDU

Success Factors

- Stability of biomass during laboratory and field-scale storage
- Cost competitiveness of the defined wet logistics system
- Large-scale storage demonstration with industrial partner

Challenges

- Transporting the water in high-moisture biomass increases costs
- Receiving 9 to 12 months of feedstock at a central location during a harvest season of roughly 2 months will be a logistical challenge
- Reliance on field-scale demonstration by industrial partner

Technical Progress

Define storage performance through laboratory research

- Q2 milestone met
- INL's 100-liter storage reactors have been adapted for anaerobic storage
- Ensiling and modified-Ritter storage of corn stover initiated in laboratory reactors

Logistics Modeling

- Wet, bulk feedstock logistics system outlined with operations and possible equipment specifications
- Defined work scope of engineering design has been discussed with Harris Group; subcontract in place; non-disclosure agreement initiated
- Two visits from Abengoa; CRADA in progress

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Relevance

BETO MYPP Contributions

- Addresses barriers, including Ft-H, Biomass Storage Systems; Ft-G, Quality and Monitoring; Ft-L, Biomass Material Handling and Transportation; Ft-K, Biomass Physical State Alteration; and Ft-D, Sustainable Harvesting

Impact

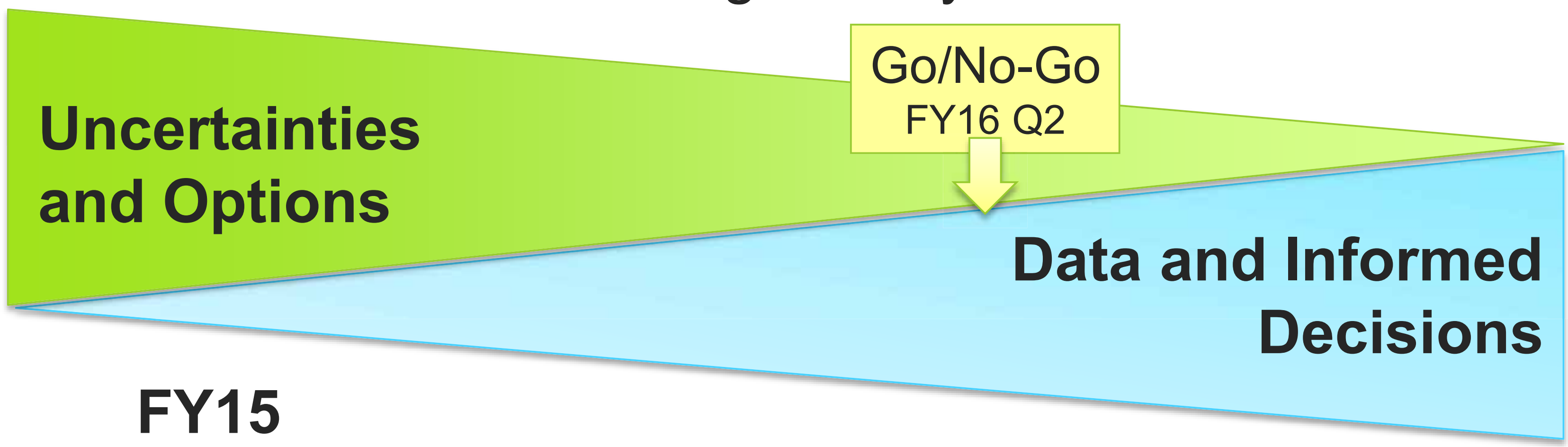
- Advance storage beyond current state of technology (SOT) by incorporating the logistics of wet bulk, not just dry baled, herbaceous biomass; baselining against conventional SOT

Stakeholders

- **Industry**
  - Provide alternative pathways to manage year-round supply risks
  - Fire protection
- **Producers**
  - Deliver biomass at peak conversion value for optimum payment
  - Enable multi-cropping in southern latitudes by residue removal early in the season when plant moisture content is still high
- **Equipment manufacturers**
  - Inform selection of equipment and encourage new equipment design

Future Work – FY15

TEA informs wet logistics system selection



FY15

Initial Logistics Design

- Biomass Logistics Model
  - INL
- Engineering Design
  - Harris Group
- Laboratory Research
  - INL storage reactors

Harvest, Storage, and Transportation

- Unit operations and costs

Large-Scale Storage Design

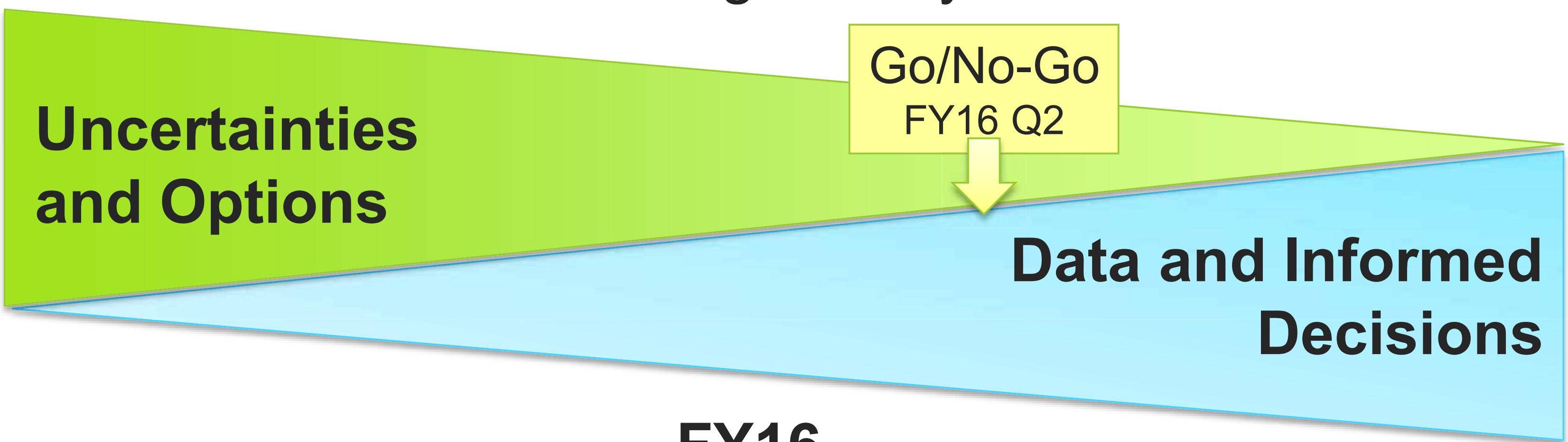
- CAPEX/OPEX of operations to move biomass in and out of storage

Anaerobic storage

- Ensiled and Ritter storage methods

Future Work – FY16

TEA informs wet logistics system selection



FY16

Field Demonstration
- Small scale
- Build storage pile
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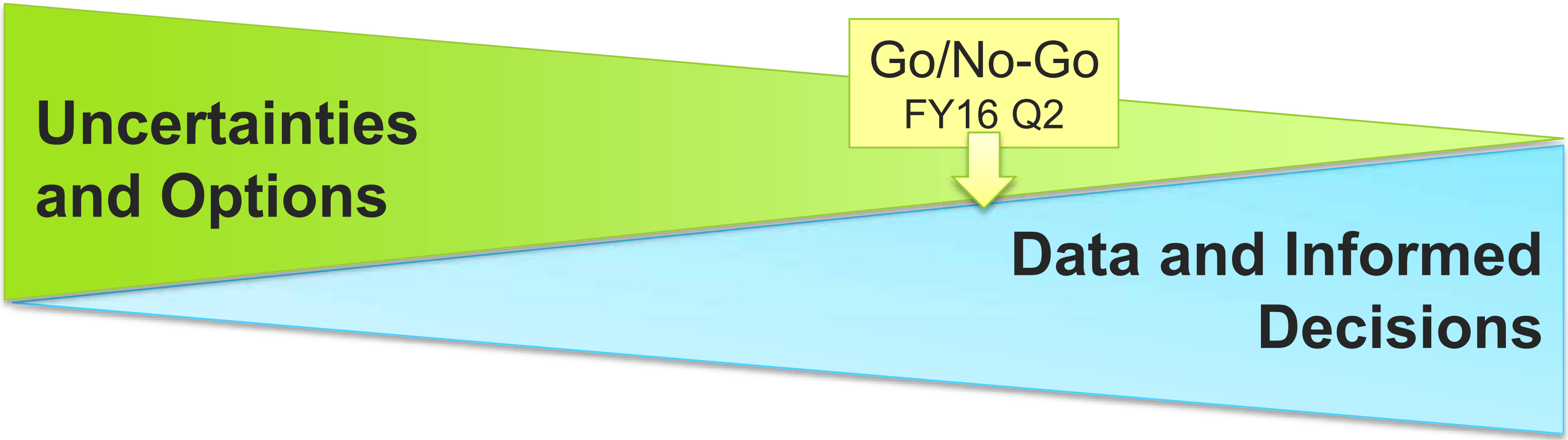
- Storage performance
  - INL, Abengoa
- Logistics performance
  - INL

Revise Logistics Design
- Update estimated performance with observed

Go/No-Go: Recommend storage method for large-scale demonstration in FY 2017

Future Work – FY17

TEA informs wet logistics system selection



FY17

Conversion Testing
- Additional pretreatment chemistry
- Engage LBNL ABPDU

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Final Logistics Design
- Update estimated performance with observed
- Engage ORNL

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Field Demonstration
- Large scale
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Final TEA of wet storage and enabling logistics system

Future Work – Additional Laboratory Research

What is the stability of materials removed from the storage pile?

- Determine aerobic stability of stored biomass from INL reactors
- Transfer recommendations to engineering design of large-scale storage system to minimize air exposure during removal of biomass from storage

Is a plastic covering necessary for industrial-scale storage?

- Understand oxygen infiltration into outer portions of an uncovered storage pile using computational modeling (FY16)
- Determine dry matter loss and conversion performance of aerobically-stored corn stover using INL reactors (FY16)

What is the impact of drying of outer regions in large-scale storage?

- Determine dry matter loss and conversion performance of lower moisture content (~35% w.b.) corn stover using INL reactors (FY17)

Summary

Overview

- Design a high-moisture, bulk feedstock logistics system that relies on storage at the biorefinery gate

Relevance

- Wet logistics systems protects feedstock from aerobic deterioration and risk of fire compared to dry systems and is necessary for enabling a Billion Tons

Approach

- TEA informs wet logistics system selection

Progress

- New start in FY 2015; modeling and laboratory research have been initiated

Future Work

- Perform initial TEA based on engineering designs and laboratory research, collect observational and performance data to refine assumptions, and use information to deliver final TEA on wet storage logistics

Thank you!

Definitions

- INL: Idaho National Laboratory
- ORNL: Oak Ridge National Laboratory
- LBNL ABPDU: Lawrence Berkeley National Laboratory Advanced Biofuels Process Demonstration Unit
- TEA: technoeconomic analysis
- DMT: dry matter ton
- DML: dry matter loss
- w.b.: wet basis
- CAPEX: capital expenditure
- OPEX: operational expenditure