CLEAN ENERGY MANUFACTURING ANALYSIS CENTER

CEMAC: Evaluation of Agricultural Equipment Manufacturing for a Bio-based Economy

WBS NREL 6.3.0.8, INL 6.3.0.10, ORNL 6.3.0.9

2017 BETO Peer Review
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Goal Statement of Project

GOAL: Develop analyses and methodologies:

- To understand any ***transitional needs in agricultural equipment manufacturing*** that would be necessary to ***enable a billion-ton bioeconomy.***
- To investigate ***the pinch points and barriers*** of the current state of the industry that limit the ability to meet a billion-ton bioeconomy.
- That can be ***leveraged by decision-makers to inform investment strategies, policy, and other decisions*** to promote economic growth and competitiveness in the transition to a clean energy economy.

RELEVANCE: Assess feedstock development needs for the emerging bioeconomy and outline barriers and development needs to meet future feedstock demands.

OUTCOME: Analyses of feedstock equipment manufacturing logistics. Detailed report that includes the results of the study and incorporates stakeholder feedback on the outlook on emerging equipment manufacturing.

Quad Chart Overview

Timeline

Start Date: October 1, 2016
End Date: March 31, 2018
20%

Barriers

- Ft-E: Terrestrial Feedstock Quality, Monitoring and Impact on Conversion Performance
- Ft-H: Biomass Material Handling and Transportation
- Ft-I: Overall Integration and Scale-Up

Budget

	Total Costs FY 12 – FY 14	FY 15 Costs	FY 16 Costs	Total Planned Funding (FY 17-Project End Date)
DOE Funded	$0	$0	$0	$275K (INL) $75K (ORNL $50K (NREL)

Partners

INL (69%)
ORNL (19%)
NREL (12%)

CEMAC Project Overview: *History*

CEMAC Clean Energy Manufacturing Analysis Center

Operated by the Joint Institute for Strategic Energy Analysis

The Clean Energy Manufacturing Analysis Center (CEMAC) provides **unique and high-impact analysis, benchmarking, and insights of supply chains and manufacturing for clean energy technologies that can be leveraged by decision makers to inform research and development strategies,** and other policy and investment decisions. Housed at the National Renewable Energy Laboratory and operated by the Joint Institute for Strategic Energy Analysis, CEMAC engages the DOE national lab complex, DOE offices, U.S. federal agencies, universities, and industry to promote economic growth and competitiveness in the transition to a clean energy economy.

CEMAC was established in 2015 by the U.S. Department of Energy's Clean Energy Manufacturing Initiative.

CEMAC Overview: *Objective*
Create Partnerships and Bridge Strategic Gaps

Key questions

- What is the global & regional supply chain?
- What drives competitiveness?
- How is competitiveness changing?
- How does competitiveness align with roadmaps?

Clean Energy Manufacturing Analysis Program

- Transparent, consistent, validated methods
- Regular update process
- Widely available reports and insights
- Protection of proprietary data

… a collaboration between organizations

… a framework for world-leading strategy

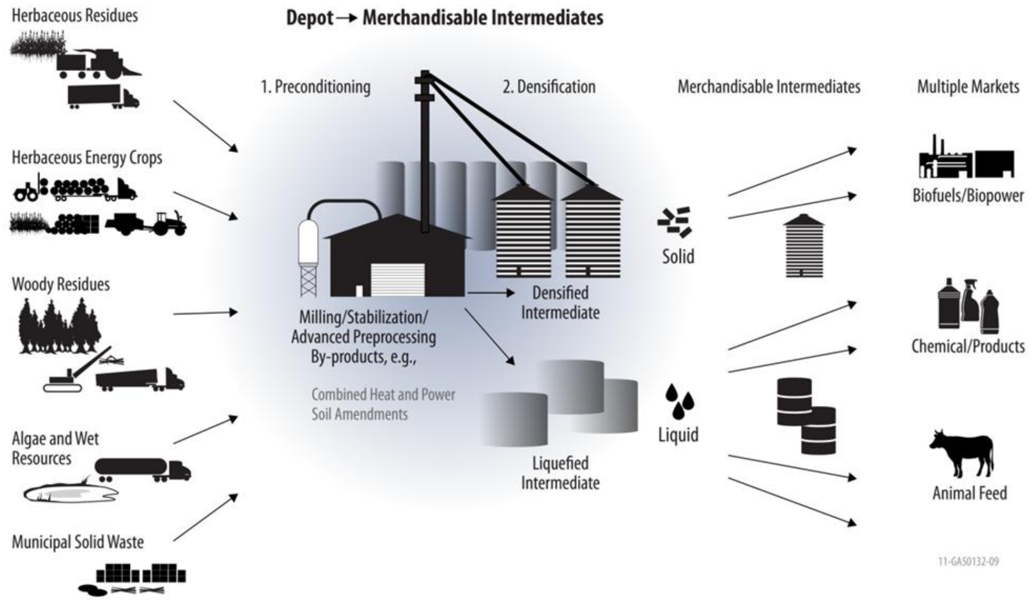
… a hub to accelerate innovation

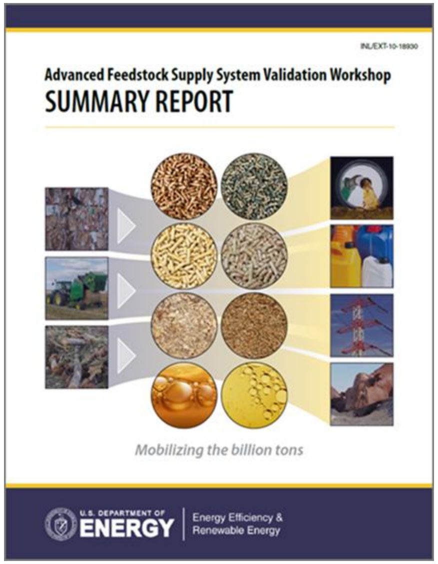
Key partners

- DOE Offices
- F500 Firms
- Startups
- State & local gov't
- National Labs
- Federal officials
- Academics

Feedstocks Overview

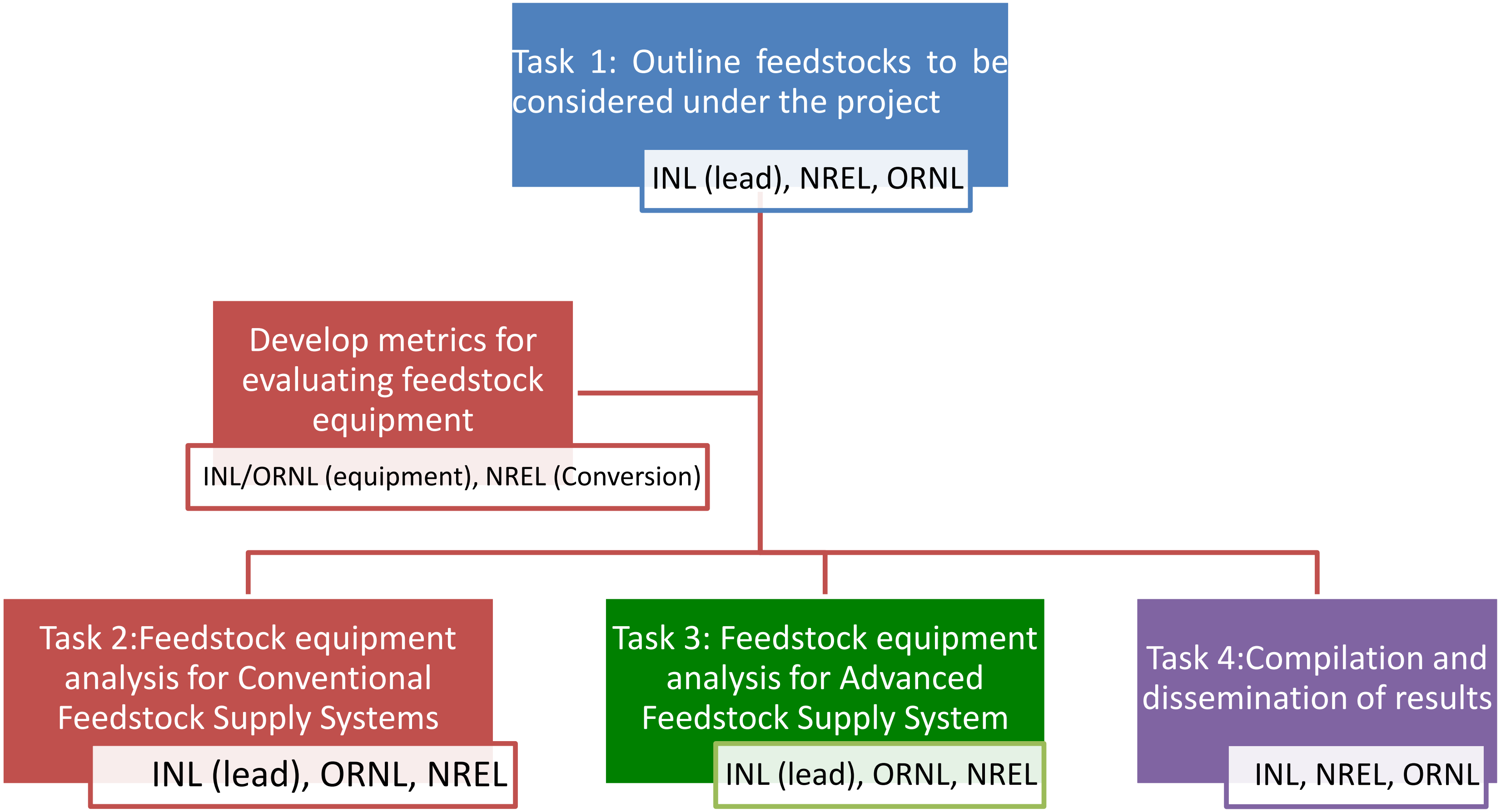
- Advanced Feedstock Supply Systems (AFSS) are expected to meet DOE goals of producing high volumes of biofuels, requiring the sustainable and cost effective supply of high volumes of quality feedstocks to future biorefineries.
- Per feedback from participants at the BETO-sponsored AFSS Validation Workshop held in February 2015, a transition strategy will be necessary to move from conventional feedstock supply systems (CFSS), i.e. those designed to support traditional agricultural and forestry industries, to AFSS.
- Equipment manufacturers may also require several years to modify existing equipment or develop new technologies to improve the efficiency in harvesting, transportation, and storing large volume of commodity-based biomass feedstock.





The fundamental idea of Advanced Feedstock Supply System technologies is that there are two independently viable industries (i.e., a feedstock industry and a conversion industry) for advancing the cellulosic biofuels industry.

Project Approach: *Management*



- Monthly calls with entire team (including DOE) to discuss progress and next steps.
- Clear timeline on tasks/due date of deliverables and clear definition of responsibility.
- Yearly meeting with entire CEMAC team and external advisory board.
- Yearly CEMAC analyst day held at DOE to review project details.

Project Approach: *Technical*

Task 1: Outline feedstocks to be considered under the project

Task 2: Feedstock equipment analysis for Conventional Feedstock Supply Systems

- Evaluate the requirements that would be needed for meeting the projections of the most recent version of the Billion-Ton assessment (BT16) utilizing the conventional system.
- Outline any barriers or pinch points in the supply chain to meet this volume of biomass production.

Task 3: Feedstock equipment analysis for Advanced Feedstock Supply System

- Based on identified pinch points/barriers for conventional system, review opportunities for advanced feedstock supply system to overcome challenges.
- Market analysis and considerations will be incorporated in the study to understand the market drivers and potential barriers, as well as the costs and timelines associated with equipment manufacturing.

Task 4: Compilation and Dissemination of Results

Task 1 - Feedstock Considerations for Project: *Progress*

Consider both supply potential of feedstocks and conversion process feedstock specifications.

Feedstock	Conversion Pathway	BT 16 Projections (million dry tons)		
		2022	2030	2040
Corn stover	Biochemical	106	129	154
Switchgrass	Biochemical	46	107	161
Miscanthus	Biochemical	28	79	160
Energy Sorghum	Biochemical		4	19
Yard trimmings	Thermochemical	4.3		4.3
Logging residues	Thermochemical	19.4	21.4	20.7
Willow/Eucalyptus	Thermochemical	3	17	26
Pine/Poplar**	Thermochemical		33	45
C&D Waste	Thermochemical	15.5	16.4	17.4

Source: BT-16, 2016

- Each feedstock will require its own production route and agricultural equipment needs.

Task 1 - Feedstock Considerations for Project: *Progress*

Consider both supply potential of feedstocks and conversion process feedstock specifications.

Example Feedstock Specification for Biochemical Process

Component	**Composition (dry wt %)**
Glucan	35.05
Xylan	19.53
Lignin	15.76
Ash	4.93
Acetate	1.81
Protein	3.10
Extractives	14.65
Arabinan	2.38
Galactan	1.43
Mannan	0.60
Sucrose	0.77
Total structural carbohydrate	*58.99*
Total structural carbohydrate + sucrose	*59.76*
Moisture (bulk wt %)	*20.0*

- Each biorefinery process will require distinct compositional specifications for optimal performance.

Relevance

Directly supports BETO's goal (per 2016 MYPP) for Optimization of Supply Chain Interfaces and Cross-System Integration:

> *"The commercialization of biofuels technology …will require integration and optimization of technologies within and across agricultural, forestry, equipment manufacturing, and biorefinery sectors to address cross-system risks ... "*

- Collaborative effort by community of analysts to ***investigate supply chain needs*** and potential risk.
- ***Working with industry*** to provide input into these challenges, barriers, and development needs.

Relevance

Project directly supports BETO's strategic goal (per 2016 Strategic Plan) to "Conduct Supply Chain Analyses of Current and Alternative Supply and Logistics Systems for Identification of Benefits/Limitations"

"Current and alternative supply and logistics systems must limit costs, preserve and enhance quality, and control risks. BETO will support the development of a thorough set of analyses, methodologies, and tools to gain necessary insights into the inter-dependencies of an economically and environmentally sustainable bioenergy supply chain."

- ***Developing methodologies and analyses to identify*** the needs for production and deployment of biomass at large scale.

Relevance

Project directly supports BETO's strategic goal (per 2016 Strategic Plan) to "Better Understand the Benefits of Bioenergy to Rural Communities"

> *"Biomass production can revitalize rural communities, create jobs, and provide additional social and environmental values by supporting agricultural and forestry, hauling and shipping, and coproduct industries. These benefits can take the form of diversification of skilled and professional jobs, with expansion of investments in infrastructure, access to services, and growth in ancillary sectors."*

- Analyses and studies to understand ***the growth potential of agricultural equipment manufacturing*** to support the bioeconomy.
- Project goal is to develop preliminary ***estimates on how expansion could impact the US economy.***

Evaluate equipment needs through the entire value chain

Example approach for equipment needs:
Crop, field equipment, and post harvest handling

Biomass	Harvest equipment	Transport equipment	Storage
	Shredder	Wheel loader - bale grappler	Open no tarp
	Rake	Tele-handler	Tarped
Stover	Round Baler	Gooseneck trailer	Shed open front for bale
	Large rectangular baler	Flat bed truck	Enclosed flat storage
	Forage harvester pull type	Auto bale collector Stinger	

Key metrics to understand for equipment:
- Advantage/disadvantage of equipment option
- Average life of equipment (turnover/replacement time)
- Cost of equipment
- Number of units required support demand

Task 2/3 - Understanding Equipment Needs: *Future Work*

Example of metrics for stover harvesting

What scales are needed? What are the costs?

	For a 25 MGY biorefinery			For the U.S.	
Field Equipment	Price ($/unit)	Units	Million $	Total units	Million $
Flail Chopper	35,000	165	5.8	46,365	1,623
Baler	140,000	135	18.9	37,935	5,311
SP collector/stacker	250,000	69	17.3	36,249	5,166
Telescopic Loader	90,000	30	2.7	8,430	506
Tractor	200,000	240	48.0	67,440	13,488
Bale trucks	195,000	23	4.5	12,926	1,745

Field equipment needs:
Number and value of field equipment for delivery of baled stover

Maximum inventory level in each intermediate storage site	30,000 dry tons
Bale density	12 lb/ft^3
Bale size	3×4×8 ft
Stack configuration [1]	6x6x60
Size of each intermediate storage (ac)	14.7
Total land requirement (ac)- eight storage sites	117.6

Needs for single biorefinery:
Storage requirements for 30,000 tons intermediate storage

State	Stover inventory (million dry tons)	No. storage sites	Land for storage (ac)	No. of storage operators
Iowa	15.2	552	8,114	276
Nebraska	9.7	352	5,174	176
United States	61.9	2,248	33,045	1,124

Needs for US Inventory:
Storage requirements for 61.9 million dry tons of stover

Source: Ebadian, M., Sokhansanj, S., & Webb, E. (2016). Estimating the required logistical resources to support the development of a sustainable corn stover bioeconomy in the USA. Biofuels, Bioproducts and Biorefining. (Featured on the Journal cover page)

Task 2/3 - Understanding Equipment Needs: *Future Work*

Understanding the barriers that AFSS can overcome to enable larger scale deployment

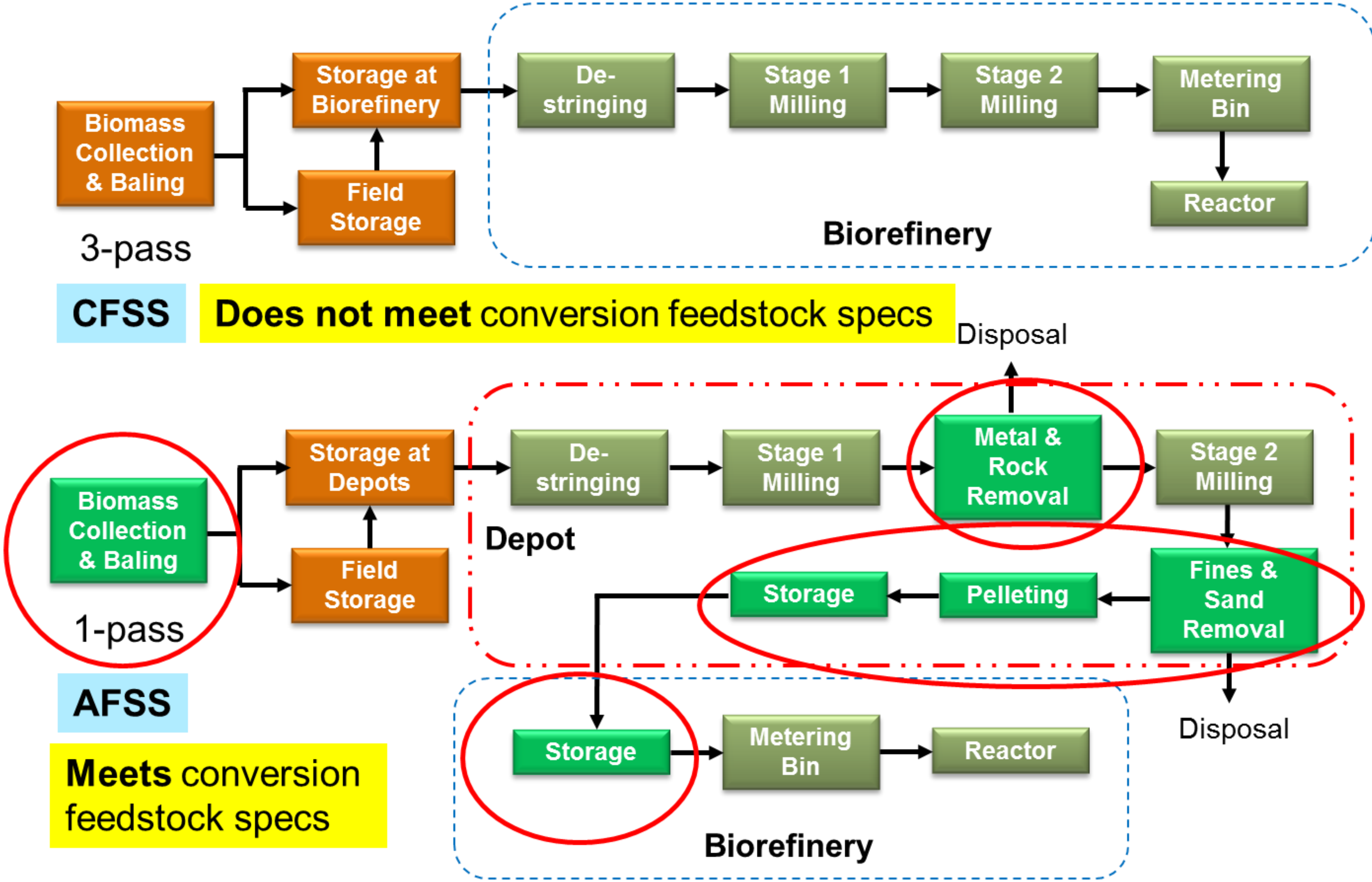
- CFSS (bale systems) do not sufficiently manage quality
  - Traditionally used for animal feed and bedding operations
  - Three-pass collection and baling
  - Bale storage at satellite locations and at biorefinery
  - Biomass preprocessed to inconsistent feedstock properties
  - Preprocessing integrated with conversion at biorefinery
  - Low throughput
- AFSS refers to active management of quality & properties
  - Goal: Improve throughput and quality of biorefinery feedstock
  - Examples of potential advancements in an AFSS
    - Single-pass collection and baling to reduce dirt content
    - Preprocessing decoupled from biorefinery to improve reliability
    - Biomass preprocessed to uniform feedstock at depots
    - Large storage capacity of feedstock at depots and biorefinery





Task 2/3 - Understanding Equipment Needs: *Future Work*

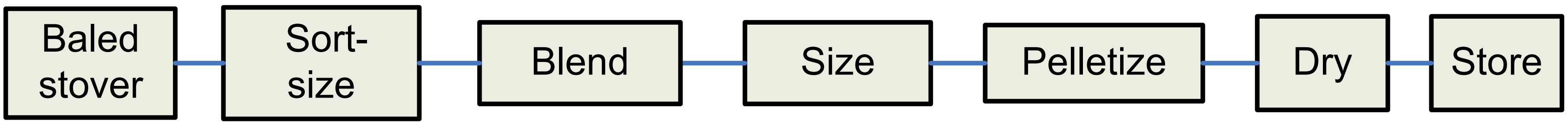
Block Flow Diagrams of a CFSS and an example AFSS



Task 2/3 - Understanding Equipment Needs: *Future Work*

Outline any barriers or pinch points in the supply chain to meet large volume of biomass production

Transition to advanced feedstock supply system



- Based on identified pinch points/barriers for conventional system, review opportunities for advanced feedstock supply system to overcome challenges.
- Key questions for equipment analysis include:
  - What equipment is required to support this transition?
  - To enable this transition, will this equipment be an expansion of existing equipment production, modifications to existing equipment, or completely new equipment designs?
  - Where would the manufacturing of this equipment take place?
  - What requirements are needed for manufacturers to pursue the production of this additional and/or new equipment?
  - What are the drivers and barriers for the manufacturing of the equipment throughout the supply chain?

Task 2/3 - Support Analysis through Industrial Engagement: *Future Work*

Special session at the Agricultural Equipment Technology Conference (AETC) in Louisville, KY February 13-15, 2017

Session led AGCO

Industry Panel Discussion focused on:

- Major drivers that will enable the expansion of existing production facilities, as well as the development of new production facilities.
- Market drivers and barriers.
- The timelines required to bring equipment to market.
- Costs and infrastructure associated with transitioning to these new systems.
- Summarize business decisions and drivers regarding where to locate manufacturing facilities (in the US or abroad).
- Requirements (value proposition) for manufactures to purse the production of this additional and/or new equipment.
- Preliminary estimates on how expansion could impact the US economy.

Upcoming special session at The Annual International Meeting of the ASABE in Spokane July 14-17 to engage a wider array of stakeholders.

Summary

Approach

- Multi-lab collaborative project to evaluate the manufacturing of agricultural equipment that would be necessary to enable the transition from the current state of the industry to a future commodity-based feedstock supply system.
- Working with industry to support evaluations and to provide input into analysis methodology and data.

Relevance

- Directly aligns with BETO Strategic Goals to “Conduct Supply Chain Analyses of Current and Alternative Supply and Logistics Systems for Identification of Benefits/Limitations”.

Future work

- Two industry focused sessions at Agricultural Equipment Technology Conference and The Annual International Meeting of the ASABE to obtain industrial feedback.
  - Market drivers and barriers.
  - Timelines required to bring equipment to market and the costs associated with transitioning to these new systems.
  - Business decisions and drivers regarding where to locate manufacturing facilities (in the US or abroad).
- Publication of final report; presentations on CEMAC methodologies and analysis.

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Back-up slides