Advanced Feedstock Supply Systems

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Cost, Quality, Quantity

- The terrestrial Feedstock Supply and Logistics Program focuses on:

  (1) reducing the delivered *cost* of sustainably produced biomass

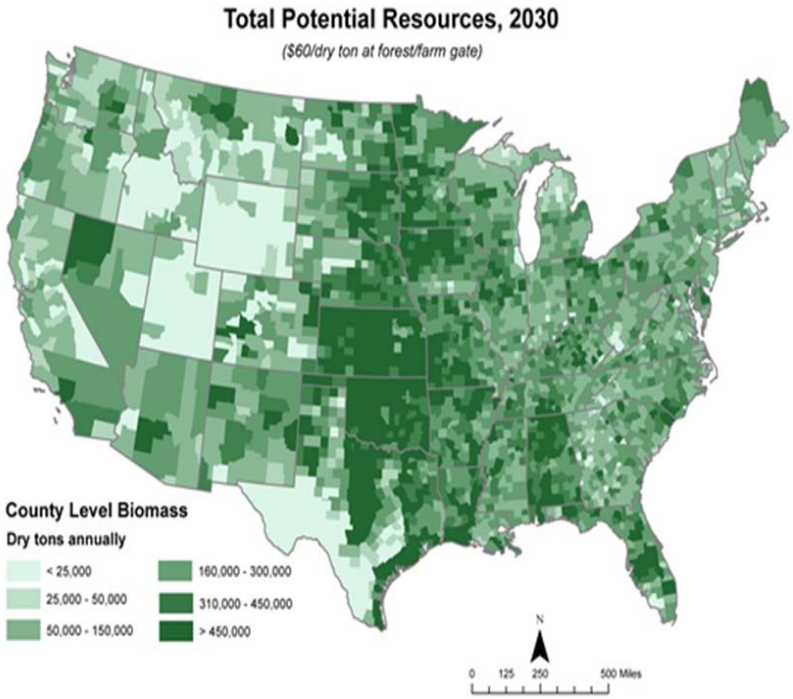
  (2) preserving and improving the physical and chemical *quality* parameters of harvested biomass to meet the individual needs of biorefineries and other biomass users

  (3) expanding the *quantity* of feedstock materials accessible to the bioenergy industry.

- This is done by identifying, developing, demonstrating, and validating efficient and economical integrated systems for harvest and collection, storage, handling, and transport and preprocessing raw biomass from a variety of crops to reliably deliver the required supplies of high-quality, affordable feedstocks to biorefineries as the industry expands.

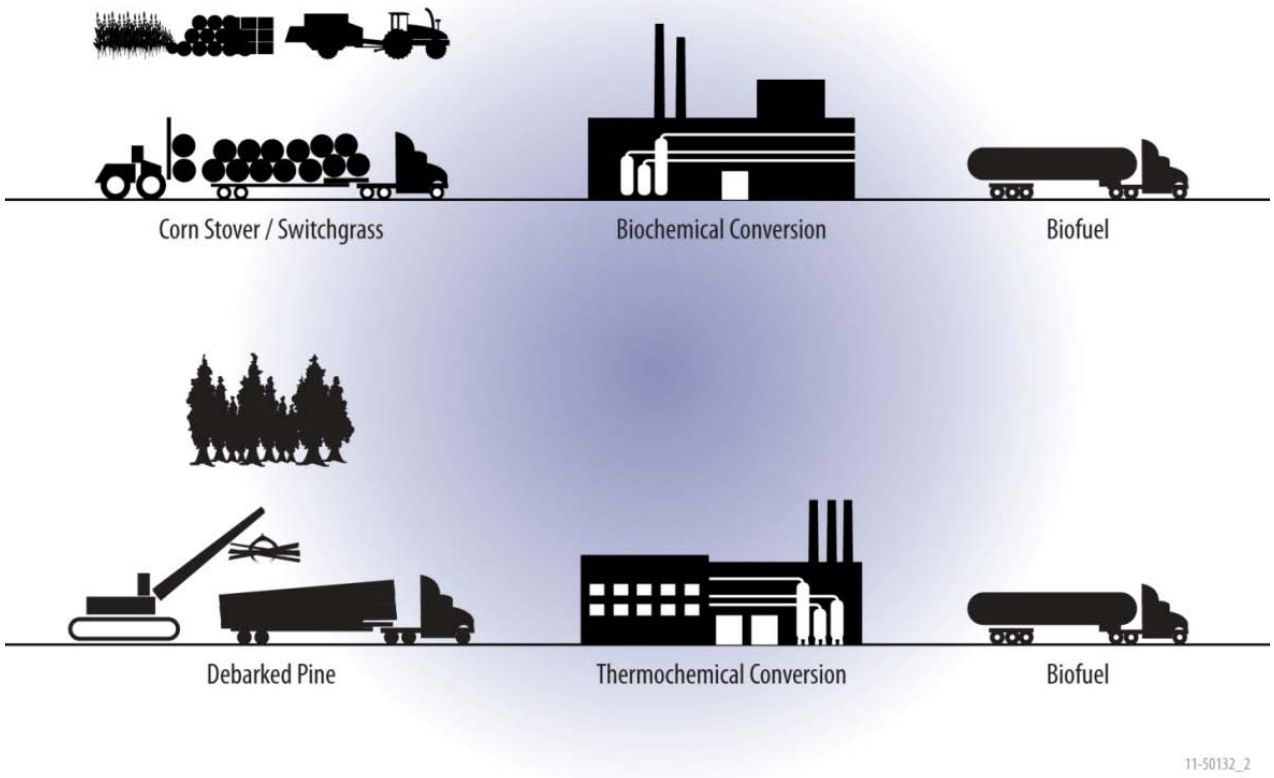
The Problem and The Opportunity

- DOE has recognized the importance of supporting the expansion of the US bioenergy industry.
  - energy security, jobs/economy, environment.
- Biomass resource assessments have identified over 1 billion tons of potentially available biomass in contiguous US by 2030.
  - Only about a third of this is accessible using “conventional” systems.
- This offers a huge opportunity for researchers and equipment manufacturers to develop innovative equipment and logistics systems to bridge that gap, mobilizing the additional 2/3 of biomass, and enabling the expansion of bioenergy use in the US.



Raw biomass is NOT a biorefinery feedstock!

Today: vertically-integrated, conventional feedstock supply systems



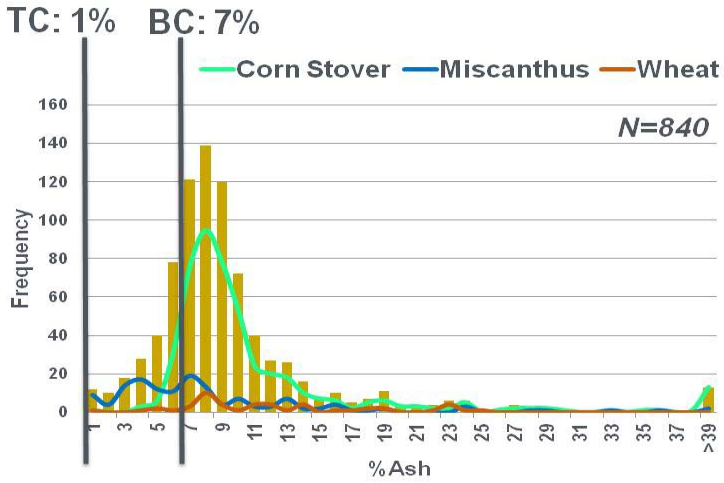
Vertically integrated supply systems, built off systems designs for conventional agriculture and forestry industries

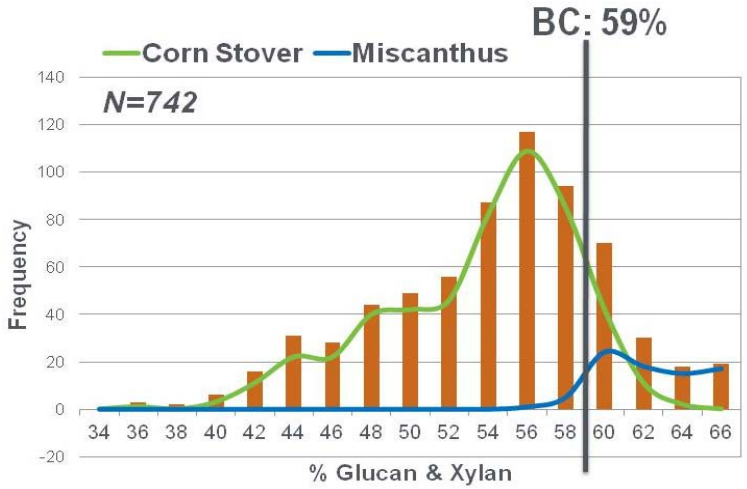
Features:

- Low density material hauled over short distance
- Refinery situated in center of high biomass yielding region
- Limited markets (often vertical integration)
- Physical and chemical variability addressed at biorefinery

Can We Economically & Sustainably Supply Feedstock?

- Conventional feedstock supply systems exist, and are very effective in doing what they were designed to do: *agriculture and forestry systems*.
- Through 2012, INL research focused on improving the efficiency (including minimizing losses) in conventional systems.
  - Success: Costs were reduced and DOE targets met in high-yielding regions
  - Challenges:
    - Conventional systems fall short of accessing the broad range of resources
    - Conventional systems do not address quality
    - Conventional systems do not address risk





The Densification Challenge

- After meeting its 2012 goals, DOE established more aggressive cost and quantity targets requiring new strategies to bring in more (and more diverse) resources from areas outside of high-yielding regions, while still meeting cost and quality targets required by conversion processes.
- Potential solution: densification, increasing biomass stability and transport/storage/handling efficiency.
- DOE solicited feedback from stakeholders on this densification challenge, hosting the "*Transforming Biomass into Feedstocks*" workshop.
- A key theme emerged from workshop participants:
  - *Increasing logistics equipment and conversion performance and reducing variability by transforming "as-harvested" biomass into feedstocks will be important for developing industrial-scale bioenergy.*
- In response to comments and feedback from the workshop, DOE developed the concept of Advanced Feedstock Supply Systems

Advanced Feedstock Supply System

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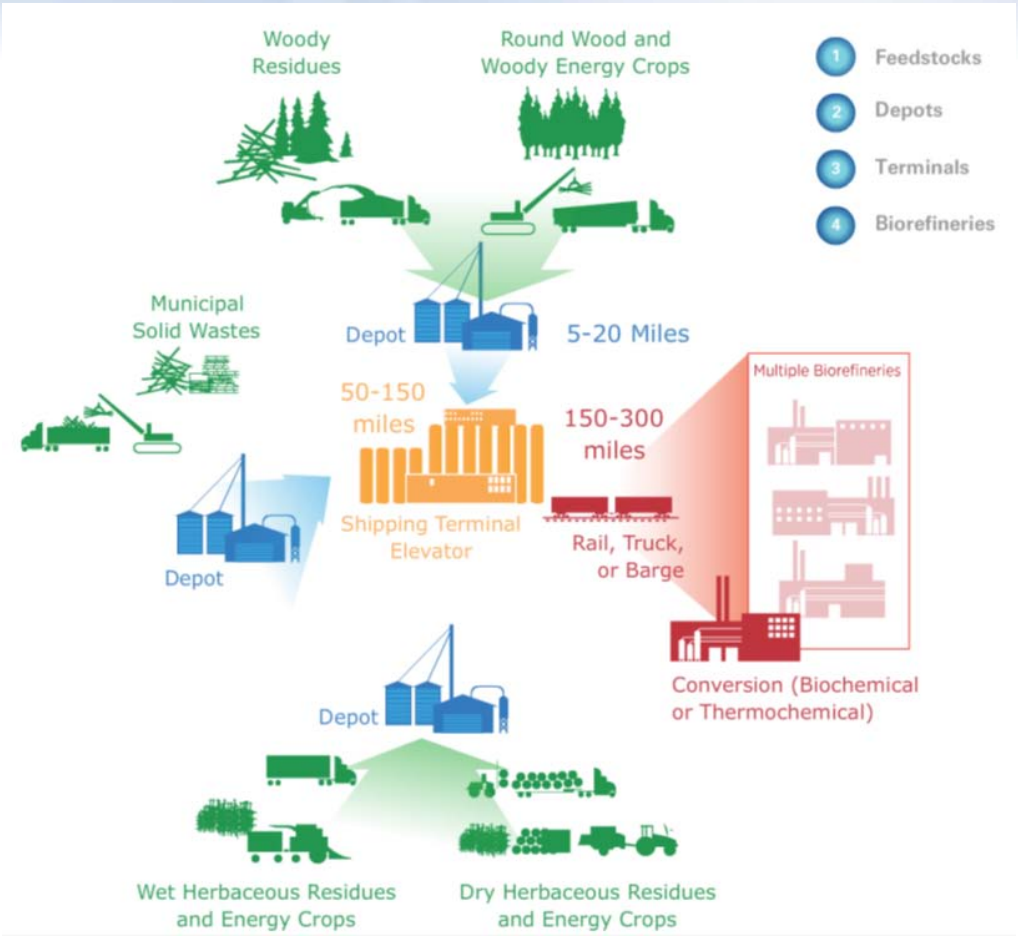
Objective: Transform raw biomass into high-density, stable, commodity feedstocks:

- Actively manage feedstock variability and supply uncertainty
- Feedstock specifications and conversion performance drive logistics and preprocessing
- Advanced preprocessing accesses low-grade and diffuse resources (i.e., use any and all available resources)

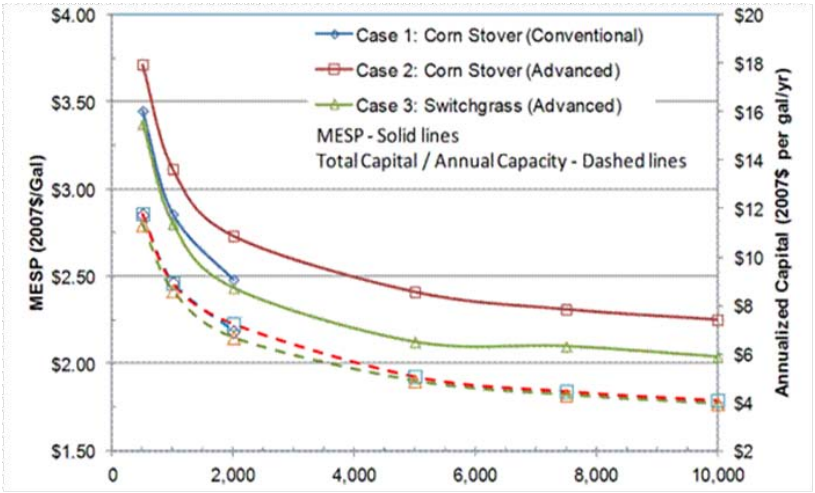
Approach: Advanced preprocessing and formulation of multiple raw biomass resources into least cost/performance-based feedstocks



Advanced feedstock supply systems service one industry: biofuels

Mobilizing the Billion Tons: a first cut

- Advanced feedstock supply systems incorporate “depots” to format biomass into a stable, tradable commodity, and leverage existing transportation and handling infrastructure.
- Advanced systems, particularly depots, enable facilities to increase in scale and to decrease production cost, rather than have the size determined based on biomass resources.
- Initial Advanced systems were vertically integrated with the energy industry and lacked a transition strategy from conventional to advanced systems.



Scale and volume, quality, and risk were the initial drivers for Advanced feedstock supply systems

AFSS Reduces Supply Risk to Biorefineries

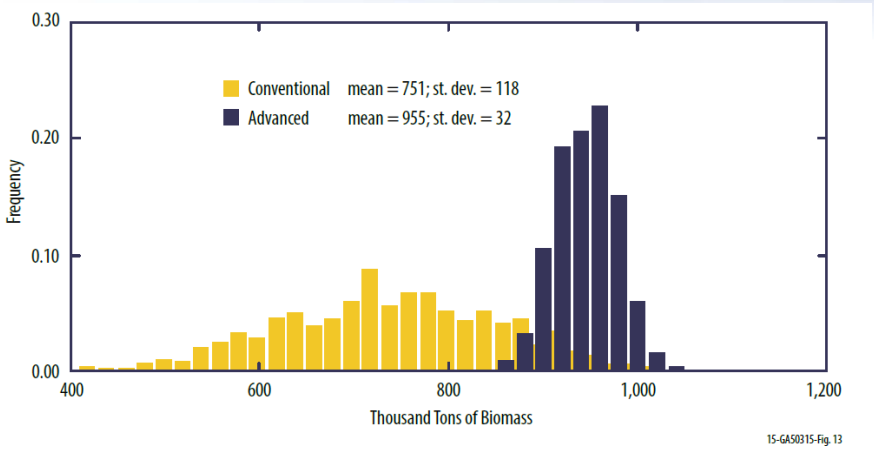


Fig. 1. Histogram of the yearly yield that can be expected from a conventional vs. Advanced Feedstock Supply System

- Biorefinery viability and profitability depends on consistent feedstock supply; profitability decreases if there is insufficient or if excess feedstock supply.
- Biomass yield is uncertain; feedstock supply varies from disruptions (e.g. drought, pests).
- Simulation modeling suggests feedstock supply variation to be almost 4 times greater in a conventional system; in Fig. 1, compare st. dev. 118 to 32.

- In an Advanced feedstock supply system, the biorefinery can diversify the feedstock supply portfolio, while meeting in-feed specs and hitting cost targets.
- Disruptions in one region need not devastate entire feedstock supply. For ex., in Fig. 2 not all depots are hit by drought.
- Using preprocessing depots to diversify feedstock supply mitigates risk.

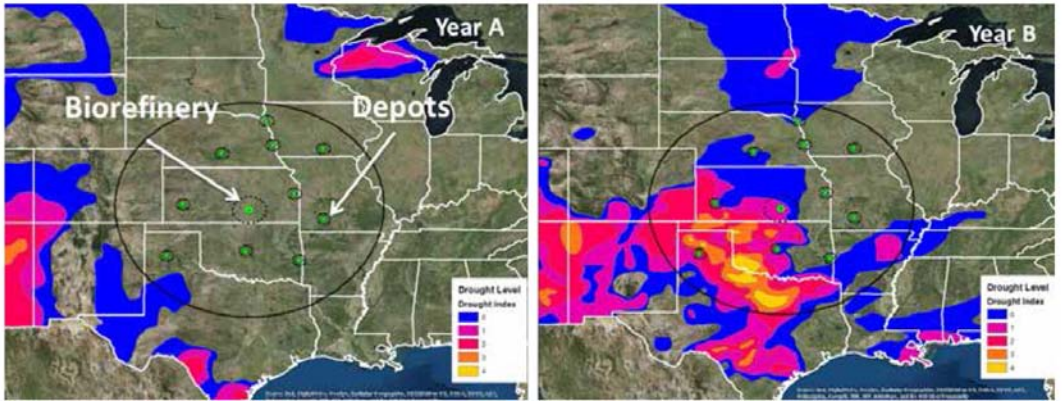


Fig. 2. Impact of drought levels on an example biorefinery sourcing radius in a conventional (dotted circle) and Advanced Feedstock Supply System (wider circle) over 2 years

Source: E Searcy, et al. (2015). Advanced Feedstock Supply System Validation Workshop Summary Report.

Advanced Feedstock Supply System Validation Workshop, Feb 3-4, Golden, CO

The purpose of the workshop was to bring together a diverse group of stakeholders to examine, discuss, and validate analysis assumptions used to move beyond conventional feedstock supply systems. Analysis assumptions discussed included:

- Feedstock supply systems limit biorefinery economies of scale
- Quality is limiting to the biorefinery industry and must be managed in the feedstock supply system
- Risk is important to the biorefinery industry and must be managed in the feedstock supply system.

Workshop Highlights

- 23 experts from industry and academia
  - Industry representation included biorefinery managers, equipment manufacturers, consultants.
- 1.5 days, 3 sessions (Scaling, Quality, Risk)
- Two resonant themes:
  - The distributed depot design is the future.
  - A transition from current to Advanced is vital.

Participant Feedback: Common Workshop Themes

- There are fundamental barriers to the expansion of the bioenergy industry in the United States.
  - feedstock variability and associated costs
  - financing challenges
  - sustainability considerations
  - conversion technology scale-up challenges
  - the lack of a long-term national energy policy to support long-term investments in conversion facilities
  - risk
  - others
- Conventional supply systems have a limited ability to support expansion of the biofuel industry in the United States.
  - However, these systems can be effective under certain circumstances and they continue to have a place in supporting expansion of the bioenergy industry.

Session Topics

The topics covered in each session included the following:

1. Barriers to delivering 1 billion tons of biomass to biorefineries annually
2. Advanced feedstock supply system concepts, including depots
3. Business models for advanced feedstock supply systems
4. Siting and sizing considerations for depots
5. Open discussion of unresolved issues.

Participant Feedback: Common Workshop Themes (cont'd)

- Advanced feedstock supply systems and depots could play a role in addressing many of the barriers that currently hinder industry growth.
  - Condition 1: the depot must provide added value
  - Condition 2: small and mid-sized farmers must be engaged (through securing contracts) and must benefit from a commodity system, rather than get forced out by larger producers.
- A transition strategy from conventional to Advanced feedstock supply systems is needed.
  - General consensus among the participants was that a significant barrier to achieving this billion-ton bioeconomy vision would be transition from the current conventional design to the Advanced feedstock supply system design.

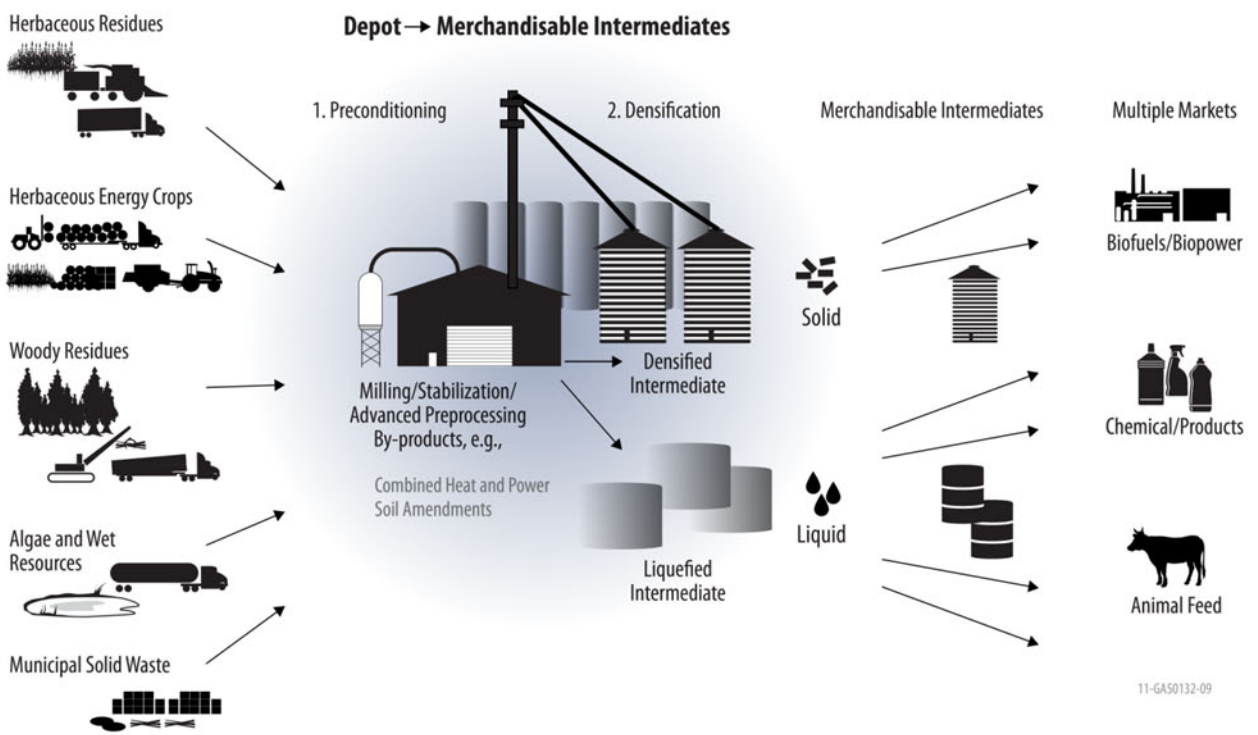
Mobilization is creating the economic drivers required for catalyzing the infrastructure investment and biomass resource development investment necessary to transition biomass from available resource (i.e., what is on the field) to a merchandisable resource (i.e., what is available for sale).

Transition Strategy: Merchandisable Intermediates

- Early depots could stabilize biomass for storage and transport.
  - could be owned by the biorefinery (i.e., vertical integration) to buffer supply variations and reduce storage footprint and harmonize in-feed operations.
- Fully independent and advanced technical designs may only emerge over time.
- 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.

Participant feedback from the workshop shifted the focus of Advanced systems to resource mobilization, value-add, and risk reduction

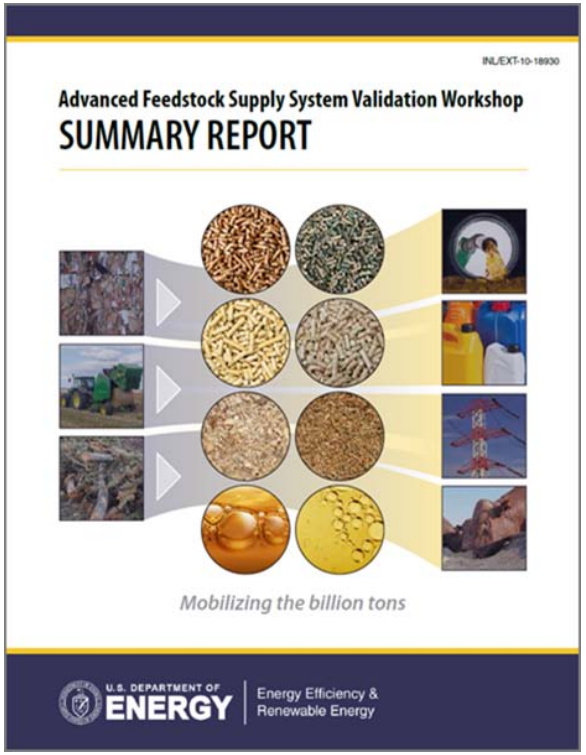
Leveraging Companion Markets



- How do you mobilize biomass into the marketplace without biorefineries to purchase the feedstock?
  - By leveraging companion markets (depots that produce value-add product intermediates that are fully functional in both the companion market and the biofuels refining market).
  - The stronger, established companion market mobilizes the biomass resource and that mobilization pushes the second generation biofuels market into existence.

Conclusions

- DOE investment has supported advancements in feedstock supply systems
  - focusing on cost, quality, quantity
  - DOE engages a variety of stakeholders, including through workshops
- Feedstock supply systems are evolving
- A transition strategy is needed to move from conventional to Advanced feedstock supply systems
- Path forward: leverage companion markets



Questions?