NREL
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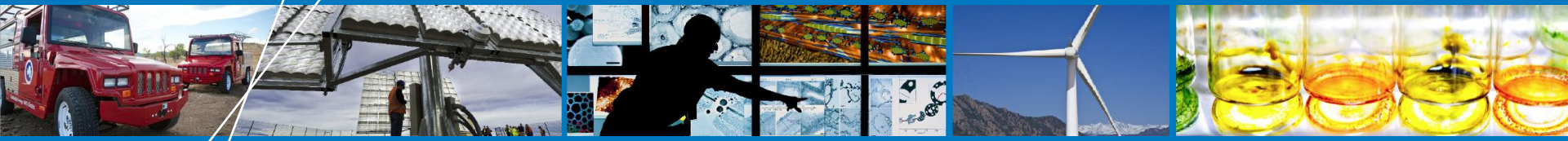
Biomass-to-Bioenergy Supply-Chain Scenario Analysis



21 May 2013

BETO Analysis Platform Peer Review

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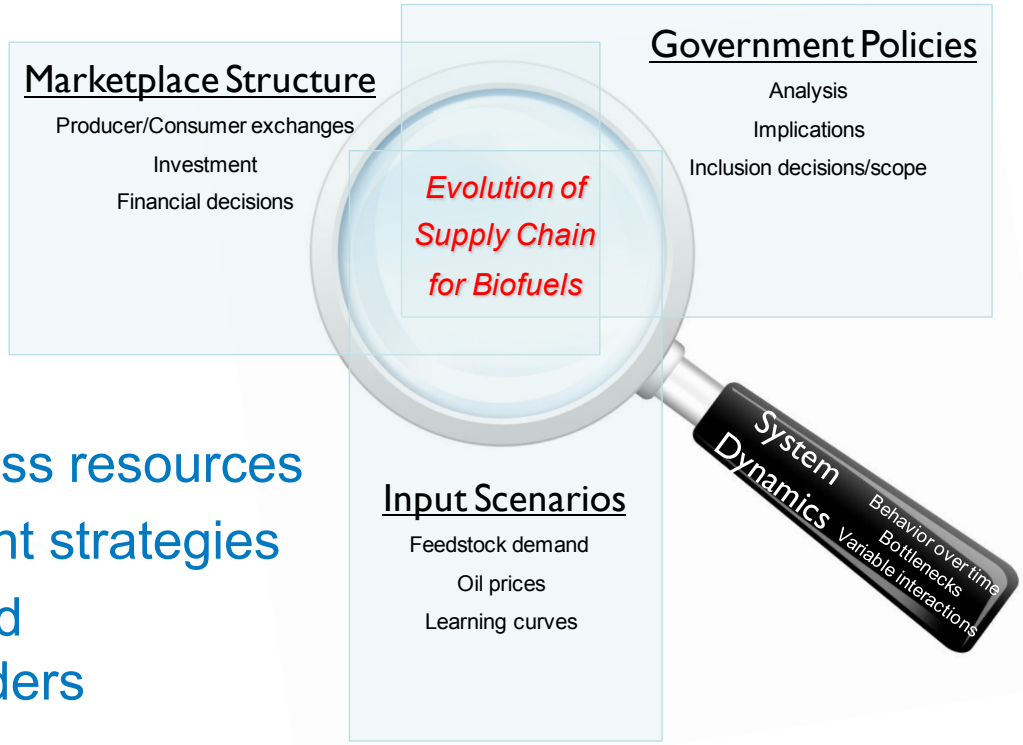
National Renewable Energy Laboratory

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Goals and Objectives

- *Deployment Analysis:* explore how rapidly biofuel technologies might be deployed to make a significant contribution to the country's transportation energy
  - Generate plausible scenarios
  - Understand the transition dynamics
  - Investigate potential market penetration scenarios
  - Analyze prospective policies and incentives
  - Identify high-impact drivers and bottlenecks
  - Study competition for biomass resources
  - Assess R&D and deployment strategies
  - Enable and facilitate focused discussion among stakeholders



Quad Chart Overview

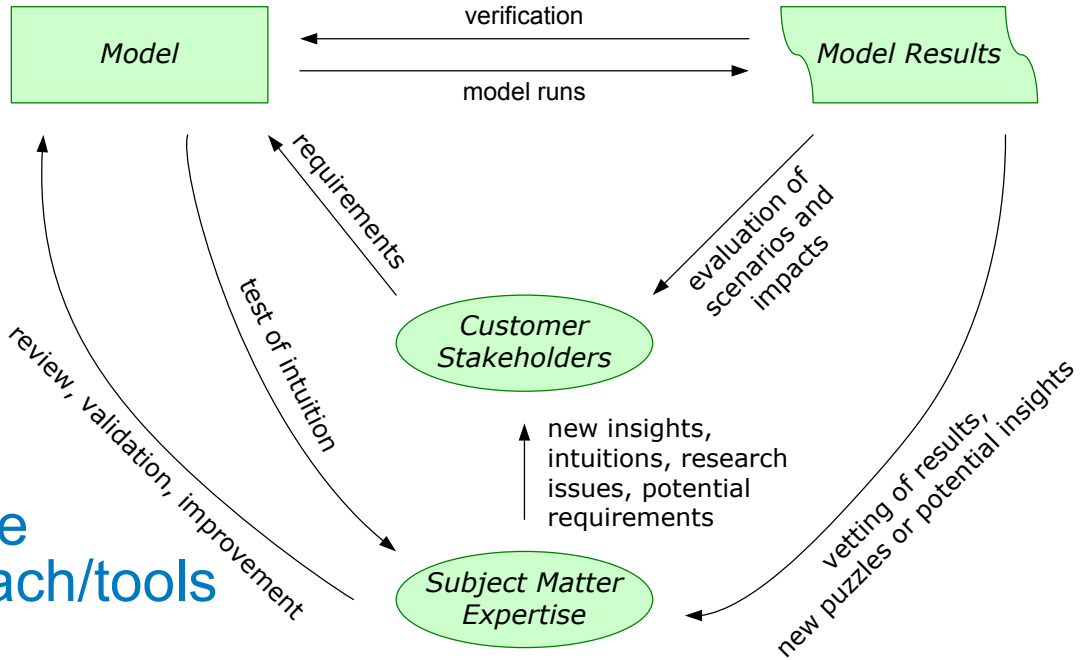
- Timeline
  - Started October 2006
  - Ongoing, annual renewal at BETO's discretion
  - 80% complete
- Budget
  - FY2011: $800k
  - FY2012: $780k
  - FY2013: $800k
  - Funded ~6 years*
  - Average ~$680/year*

* Historically, the Biomass Scenario Model (BSM) activities have not always been separately budgeted at the four-level WBS from other biomass systems integration work and have been combined with closely related biomass systems integration subcontracts that are included in the funding totals.

- Barriers
  - "Lack of comparable, transparent and reproducible analysis" [MYPP At-A]
  - "Limitations of analytical tools and capabilities for system-level analysis" [MYPP At-B]
  - "Inaccessibility and unavailability of data" [MYPP At-C]
- Partners
  - Project Lead: NREL Systems Engineering & Program Integration Office
  - Modeling & Analysis Support: Lexidyne LLC
  - Subject-Matter Expertise:
    - National Bioenergy Center
    - DOE Laboratories (especially, ORNL, INL, PNL)
    - Issue-focused subcontracts

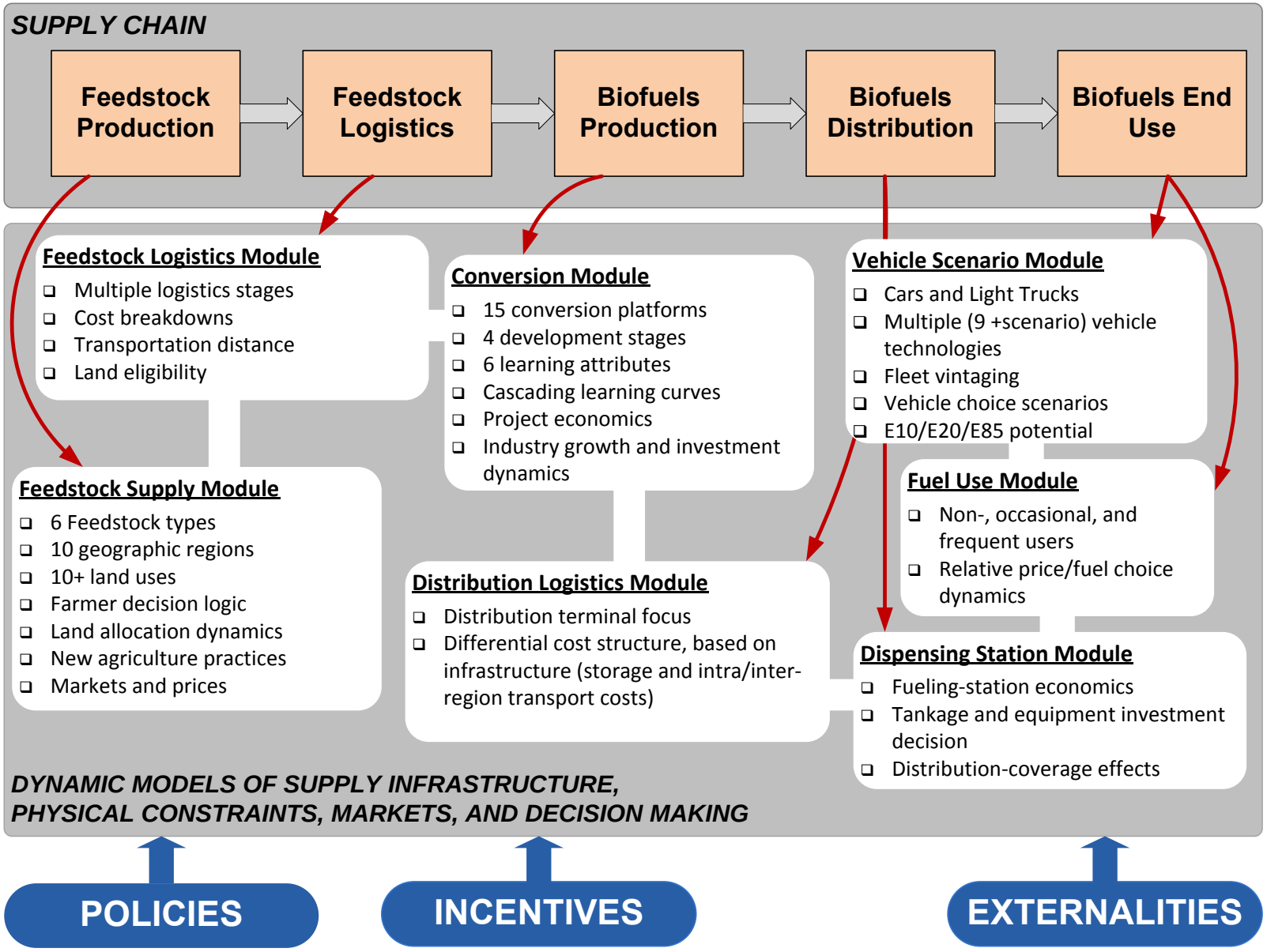
Project Overview

- Challenge/Objective
  - Develop an analytic platform to explore and understand the entire biofuels supply-chain evolution over the long term.
- Products
  - System dynamics simulation of the biofuels supply chain
  - Analyses providing insights into system behavior and policy effectiveness
  - Stakeholder workshops
  - Reports and datasets
- Modern, agile, and adaptive model development approach/tools
- Roles

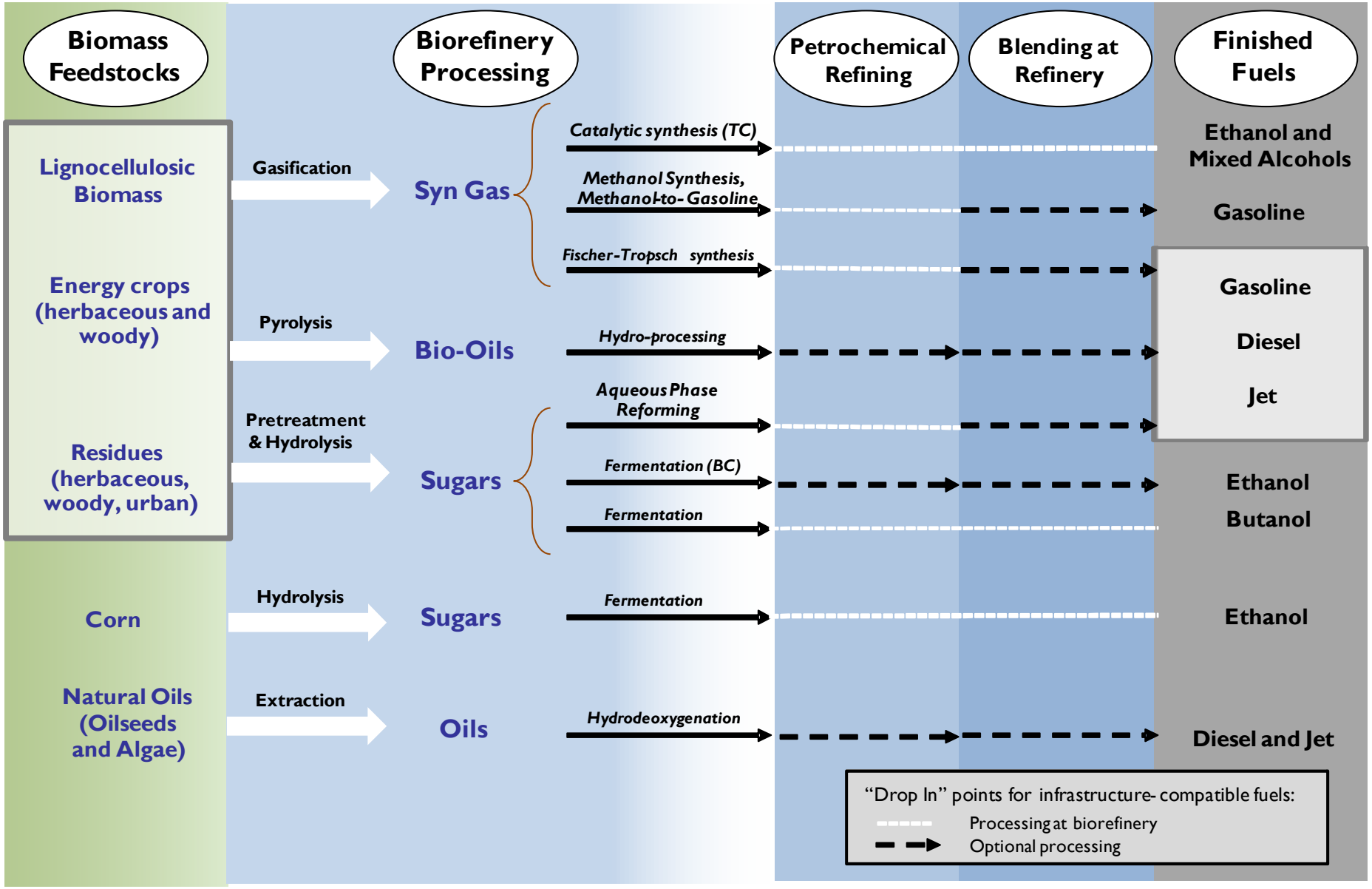


	Requirements	Review	Project Mgmt	Domain Expertise	Model Development	Data Processing	Analysis
DOE BETO	√	√		√			
NREL			√	√	√	√	√
Lexidyne LLC					√		√
Nat'l labs, federal agencies, universities, subcontractors		√		√			

Key Characteristics of BSM Modules

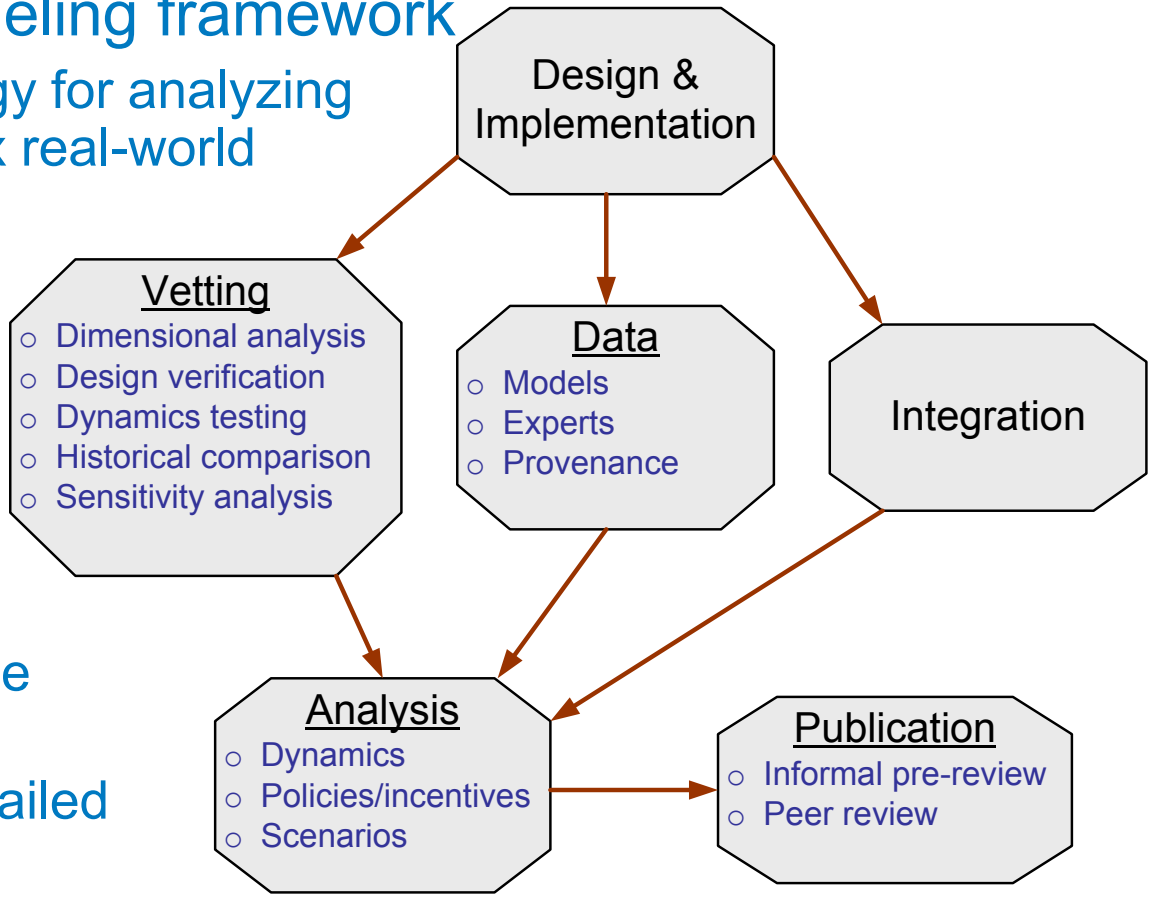


Biofuel Pathways in the BSM



Modeling and Analysis Process

- System-dynamics modeling framework
  - Established methodology for analyzing the behavior of complex real-world feedback systems over time
  - Broad, high level approach that captures entire supply chain
- Flexible, modular model architecture
  - Defensible and traceable inputs, with metadata
  - Data extracted from detailed analyses and models
    - POLYSYS agricultural sector economics, ASPEN Plus process models, BLM logistics model, etc.
  - Logic developed and validated through stakeholder meetings
    - interviews, reviews, workshops, and colloquies



Summary of Accomplishments (May 2011-2013)

- Analysis reports to BETO
  - Jet-fuel production scenarios
  - Advanced feedstock logistics
  - Rate-of-return for biofuels investments
  - References scenarios for cellulosic ethanol
  - RFS2 scenarios
  - Pathway diversification scenarios
  - Effects of industrial learning
  - Sensitivity analysis of BSM input parameters
  - Interaction of biofuels policies with land-use constraints
  - BETO/MYPP reference scenario
  - Effects of long-term biofuels subcontracts
- Other reports to BETO
  - BSM deployment options
- Model maintenance/enhancement
  - Biopower demand for feedstock
  - Vehicle choice scenarios
  - Vetting of results
  - Techno-economic and other data

Summary of Accomplishments (May 2011-2013)

- Development of scenario library
- Publications
  - Journal articles on supply chain analyses (2 published, 1 submitted, 6 in preparation)
  - Book chapter on cellulosic ethanol supply chain
  - Fact sheets on international biomass/biofuel trade (2)
  - Model and data documentation reports (2)
  - Report on competition for biomass resources between biofuel and biopower
- Subcontractor reports
  - Forest residue dynamics
  - Model documentation (2)
- Workshops and reviews
  - Biofuels price modeling
  - Supply-chain modeling
  - Scenario design/analysis (2)
  - External technical review meeting
  - External technical review report
- Deliveries to Bioenergy KDF

Key Insights from Supply-Chain Analyses

Four keys to industry development:

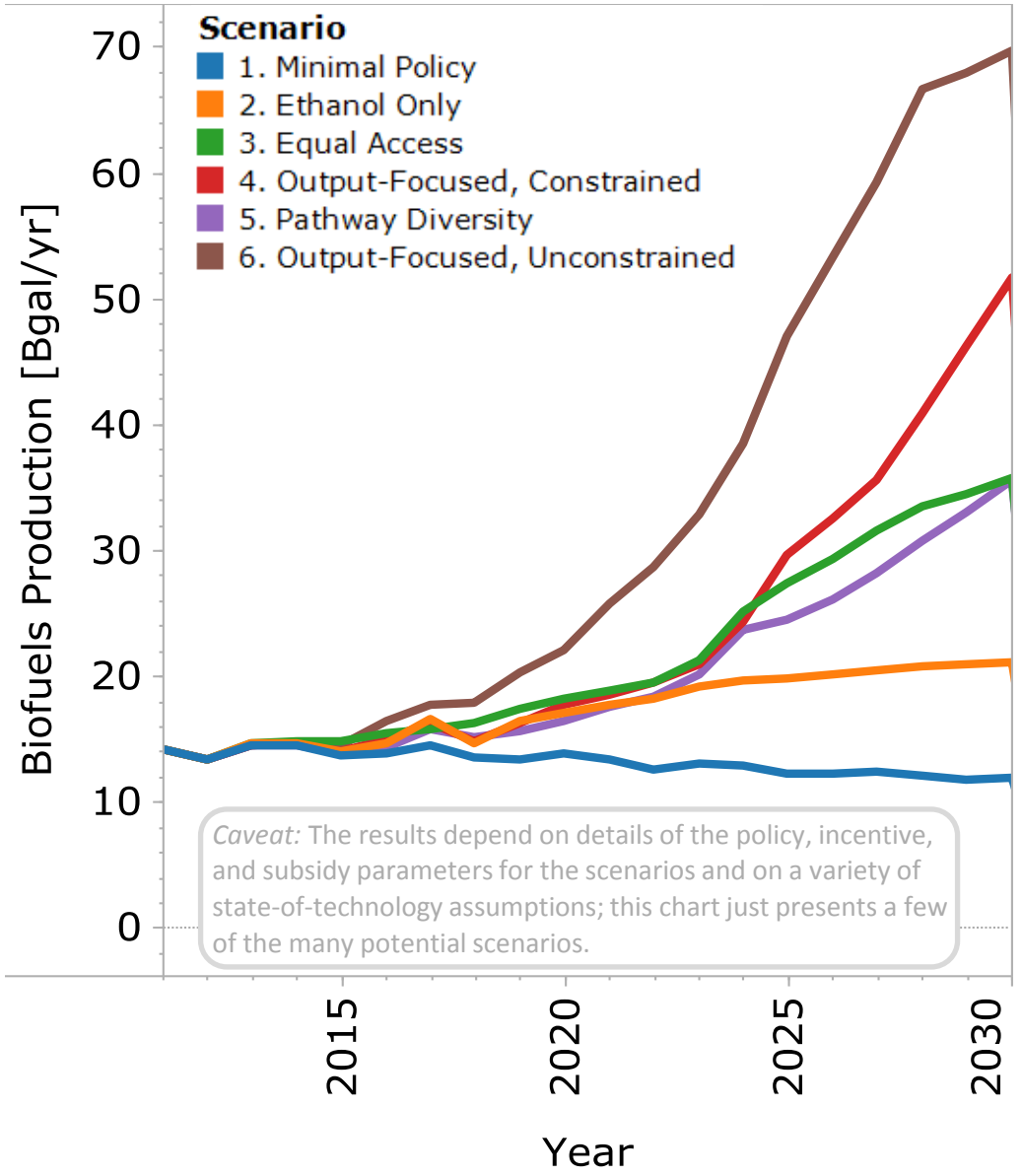
1. Profitability at point of production
2. High rates of industry learning
3. An aggressive start in building pilot, demo, and pioneer-scale plants
4. For ethanol, a high level of infrastructure investment to sustain low enough point-of-use prices

The "take off" is likely to be wild and wooly:

1. Unstable, higher than anticipated, feedstock prices
2. Boom/bust development of production capacity
3. Potential for biofuel price instability

Significant production volumes are feasible.

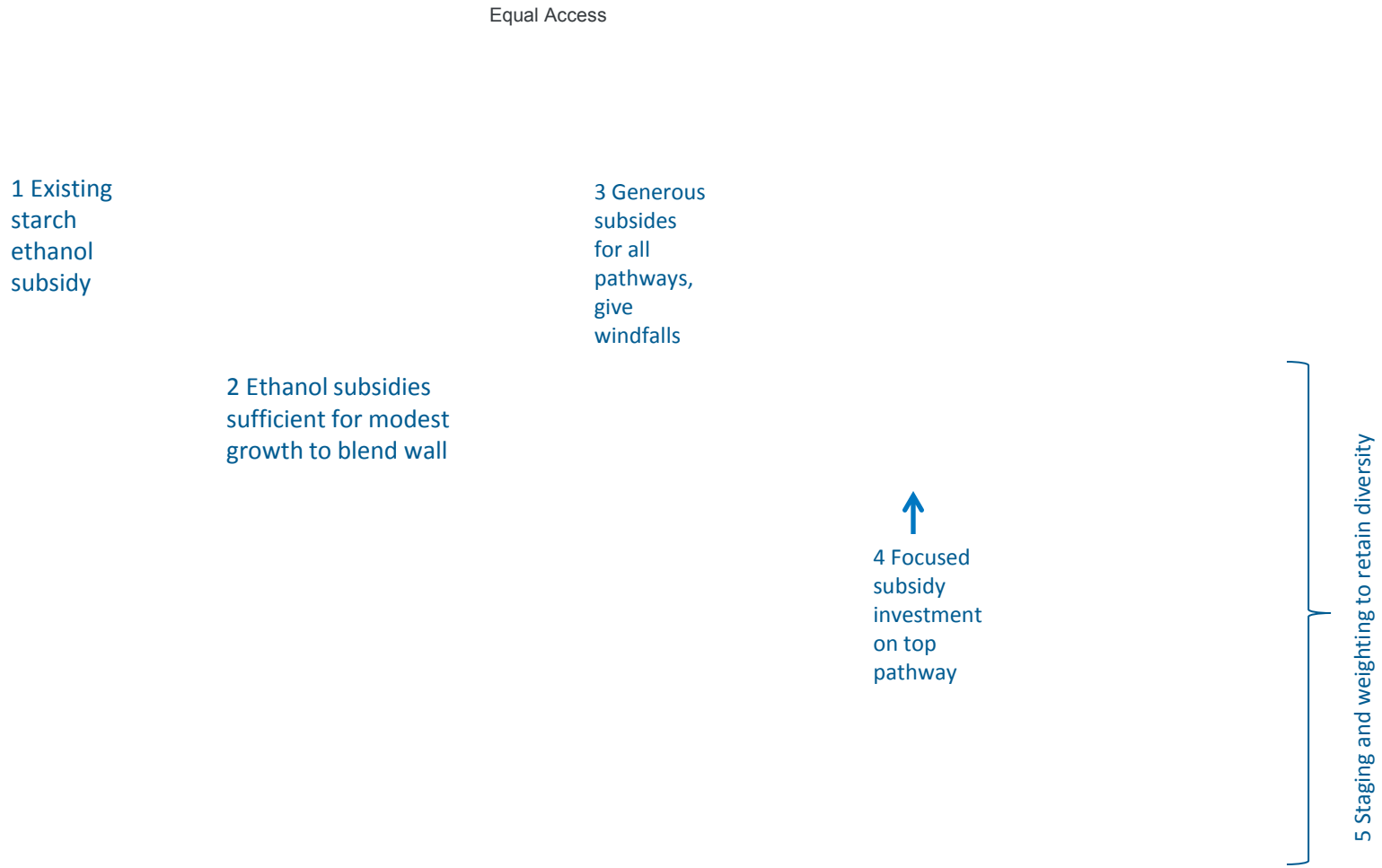
1. RFS2 volumes are achievable in 2030 with heavy startup subsidies.
2. When subsidies are focused to promote the most economically attractive pathway, production levels can exceed RFS2 levels.
3. Technologies with favorable long-term economic cost structures can succeed if subsidies are deliberately designed to overcome initial maturity deficiencies.



Development of Policy-Mix Scenario Library

Scenario	Subsidize …	Strategy
1: Minimal Policy	Starch until 2012	Apply only existing subsidies and policies
2: Ethanol Only	Ethanol pathways only	Provide support for ethanol only
3: Equal Access	All pathways in order to produce 36 billion gallons/year by 2031	Allow all fuel types equal access to generous scenario subsidies
4: Output-Focused, Constrained	To maximize growth restricted to $10 billion per year	Target most promising technology and withhold most subsidy access from other pathways
5: Pathway Diversity	To maximize pathways restricted to $10 billion per year	Design subsidy timeline to enable take-off of multiple fuel pathways by staggering start and end dates based on pathway progress and potential
6: Output-Focused, Unconstrained	To maximize growth with no spending limit	Design a subsidy scheme to most rapidly produce the maximum volume of biofuels that the system can produce

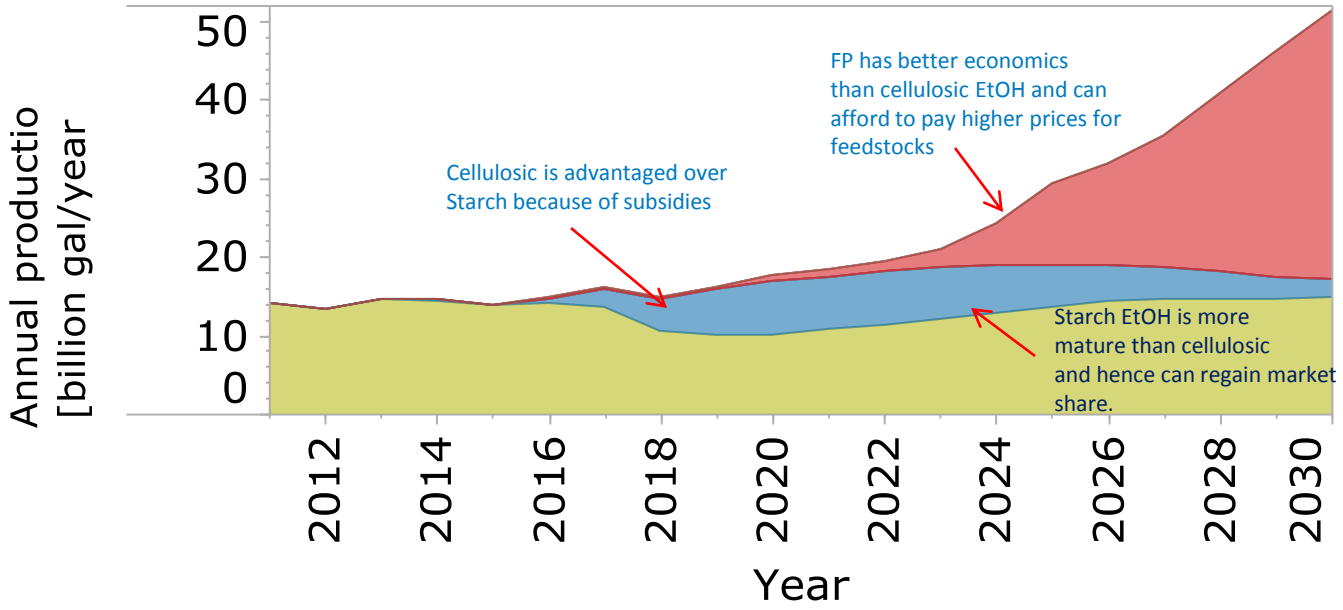
Complex Policies Representable as Scenarios

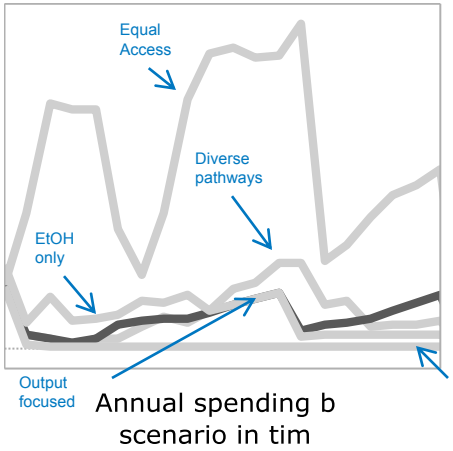


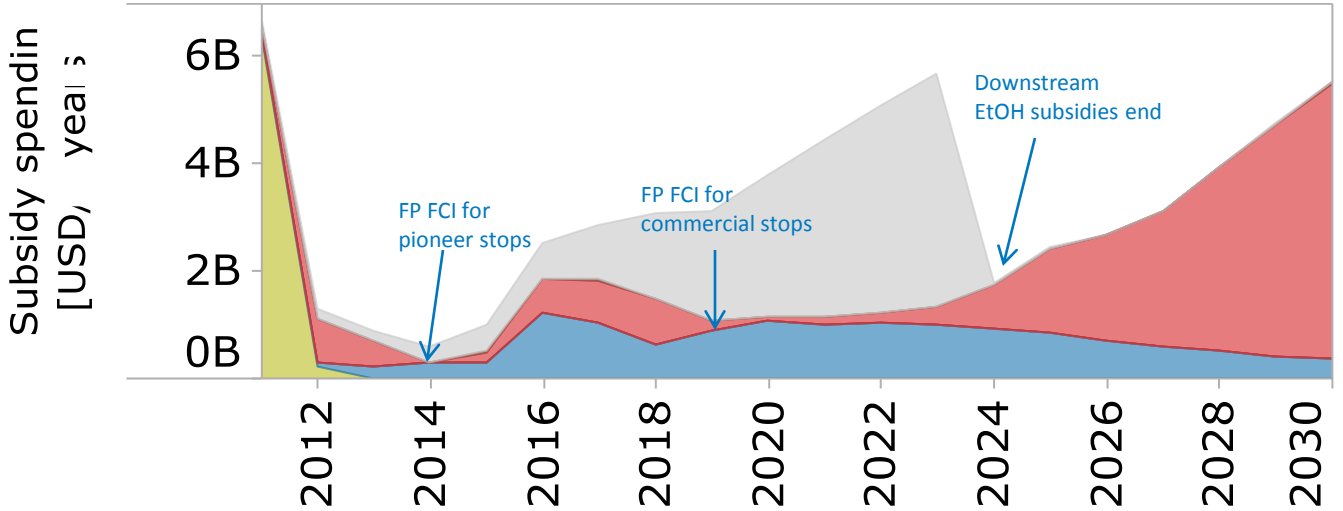
Some values may vary slightly from current runs

Competition for Feedstock and Market in #4 "Output Focused"

Pathway
- Downstream ethanol
- Fischer-Tropsch
- Fast pyrolysis
- Methanol to gasoline
- Fermentation
- Cellulosic ethanol
- Starch ethanol

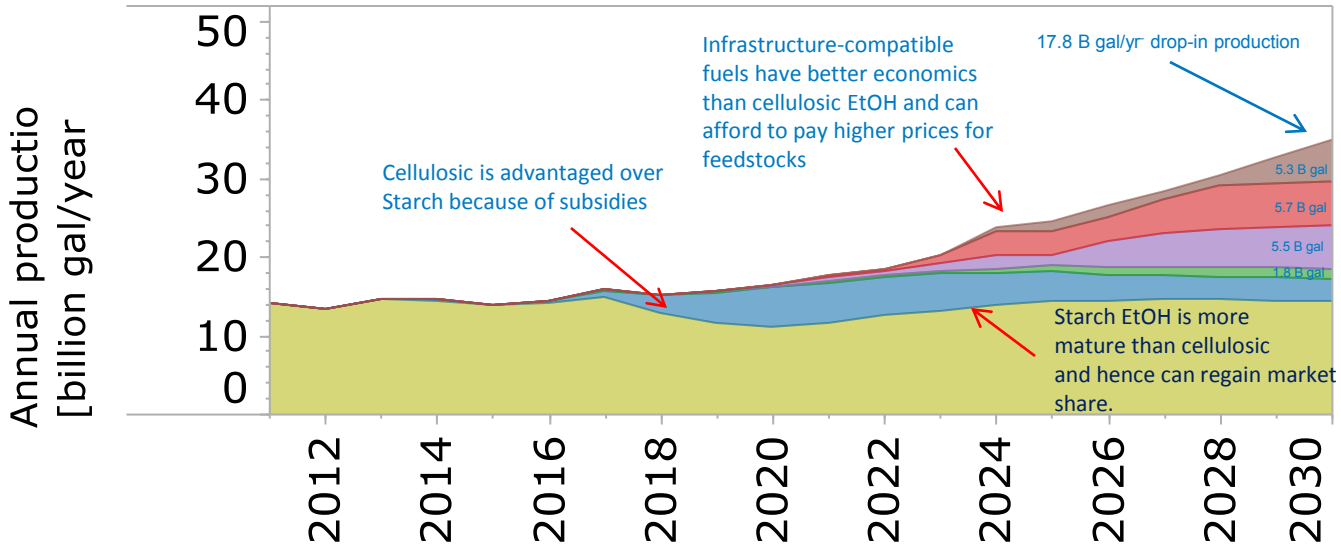


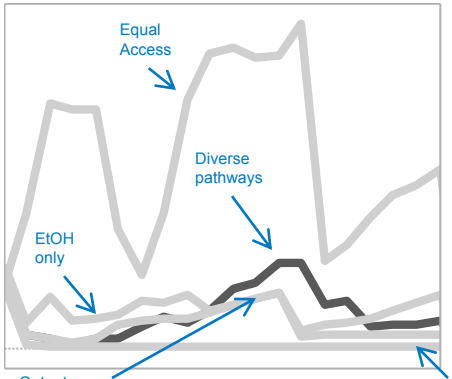




Competition for Feedstock and Market in #5 "Pathway Diversity"

Pathway
- Downstream ethanol
- Fischer-Tropsch
- Fast pyrolysis
- Methanol to gasoline
- Fermentation
- Cellulosic ethanol
- Starch ethanol





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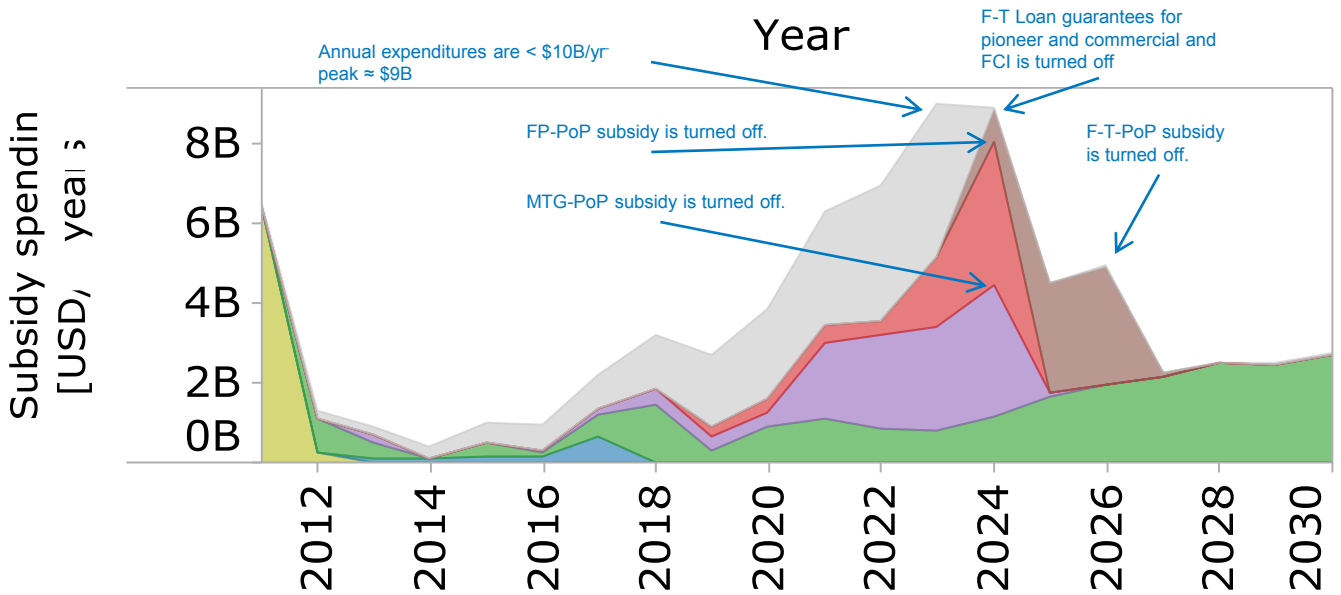
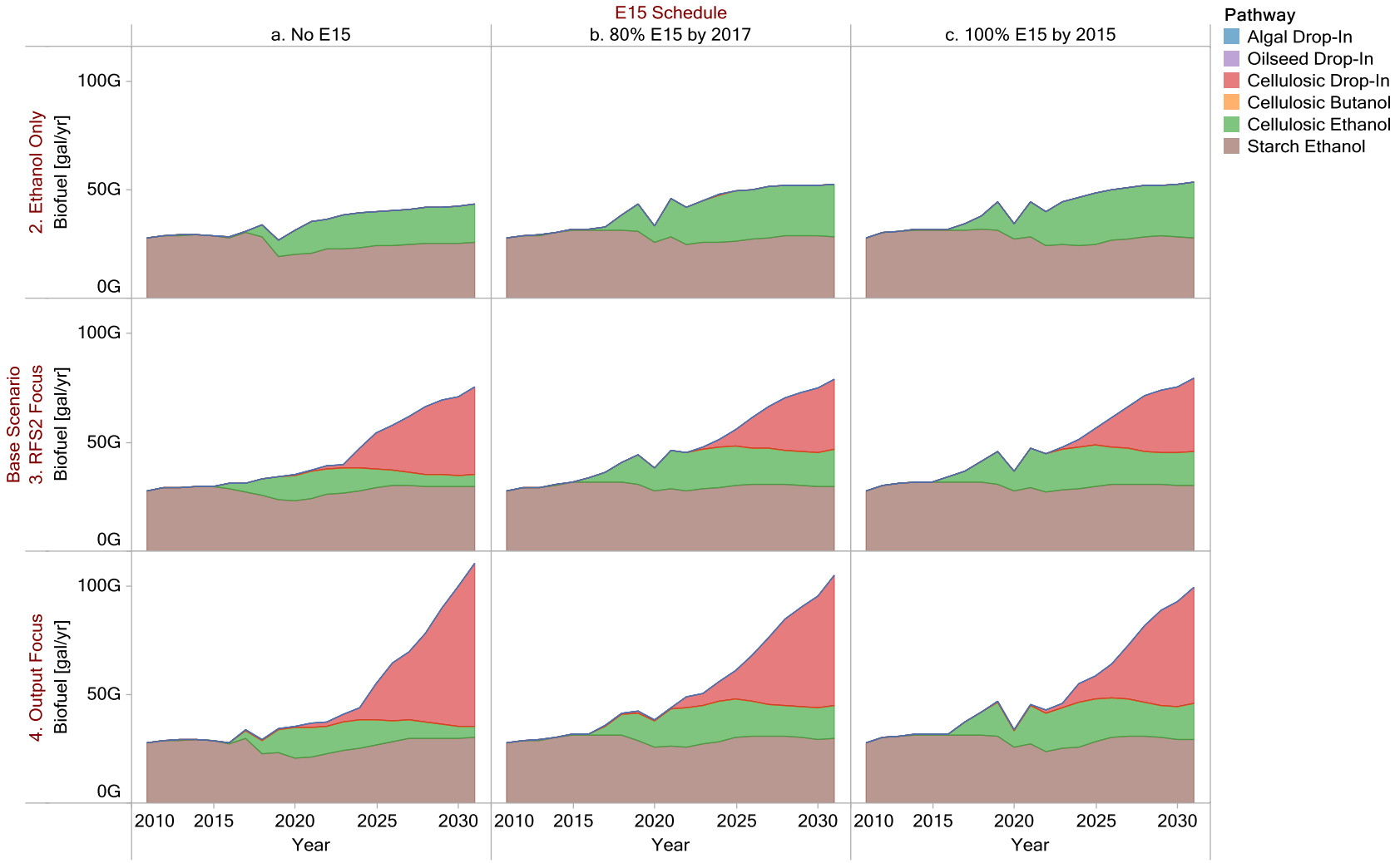
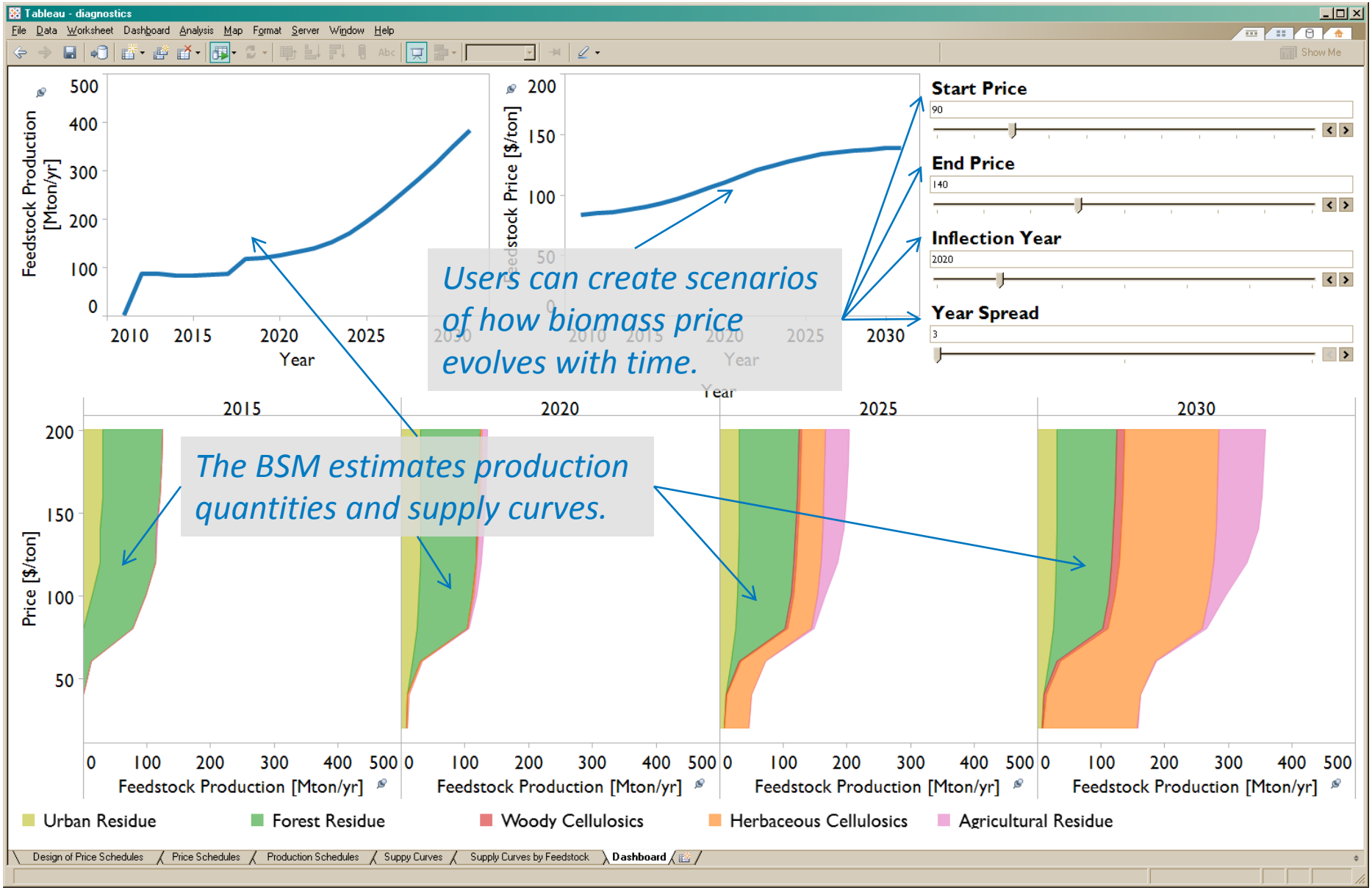


Insights Related to a Transition from E10 to E15

- Widespread E15 adoption moves the “blend wall” and can greatly alter the proportion of cellulosic ethanol in the mix of biofuels.



Library of Biomass Supply Curves



Summary of External Technical Review of BSM Project

- Format
  - 10 reviewers from government, industry, academia
  - 1.5 day workshop-format meeting with presentation, discussion, and hands-on experience with BSM and scenario analysis
- Key results (documented in review report to BETO)
  - Analysis and modeling
    - RIN market effects
    - Synergies with and drop-in points to petrochemical infrastructure
    - Feedstock contracts, markets, densification, and localized pretreatment
    - High-value bio-products
    - Investor behavior and risk
  - Documentation and outreach
    - Parameter estimate / sensitivity analysis
    - Publish methodology
    - Publish validation studies
    - Additional training opportunities and external workshops

Milestone/Deliverable History and Status

Period	Milestone/Deliverable	Status
FY2011	C.DL.3: Six analysis reports	completed w/ one extra
	C.DL.4: Deliveries to Bioenergy KDF	completed on schedule
	C.DL.5: Two stakeholder workshops	completed w/ one extra
	C.DL.6: Two conference/journal papers	completed on schedule
	C.DL.7: Comparative/collaborative use of BSM	completed w/ modification
	C.DL.8: Report on competition for biomass	completed on schedule
	C.DL.9: Report on BSM deployment	completed on schedule
FY2012	C.DL.2: Six analysis reports	completed on schedule
	C.DL.3: Deliveries to Bioenergy KDF	completed on schedule
	C.DL.4: One stakeholder workshop	completed on schedule
	C.DL.5: One conference/journal paper	completed on schedule
	C.DL.6: Briefing on BSM data inputs/model	completed on schedule
FY2013	C.DL.1: Four analysis reports	in progress / on schedule
	C.DL.2: Two conference/journal papers	in progress / on schedule
	C.DL.3: Deliveries to Bioenergy KDT	in progress / on schedule
	C.DL.4: One stakeholder workshop	completed on schedule
	C.DL.5: Report on external technical review	completed on schedule

Relevance to BETO Goals and Objectives

Element	MYPP Goal	BSM Contribution
Strategic Analysis	provide context and justification for decisions at all levels [p. 2-86]	1. Analysis of attainability of EISA targets 2. Study of rate-of-return of biofuels investments 3. Development of BETO/MYPP reference case
Feedstock Supply	develop commercially viable biomass utilization technologies to enable the sustainable, nationwide production of advanced biofuels [p. 2-13]	4. Analysis of interaction of biofuels policy with land use constraints 5. Analysis of transition to the use of advanced feedstock logistics 6. Computation of library of feedstock supply curves
Conversion R&D	develop commercially viable technologies for converting biomass feedstocks [p. 2-33]	7. Analysis of effects of industrial learning 8. Analysis of pathway competition and diversity 9. Study of technological lock-in
Demon-stration & Deployment	help create the conditions whereby all biofuels can safely, cost-effectively, and sustainably reach their market and be used by consumers as a replacement for petroleum fuels [p. 2-82]	10. Analysis of effects of long term biofuels contracts by the DOD or aviation industry 11. Analysis of impacts of a transition to E15 12. Analysis of competition between biofuels and biopower for feedstock resources 13. Studies of impact of IBR policies and incentives
Strategic Communi-cations	conduct strategic outreach that promotes the benefits of sustainable biomass and biofuels to the public and key stakeholders [p. 2-103]	14. Sponsorship of biennial biofuels supply-chain modeling workshop 15. Scenario design and analysis workshops 16. Journal and report publications 17. Presentation at EIA AEO biofuels workshop

Critical Success Factors

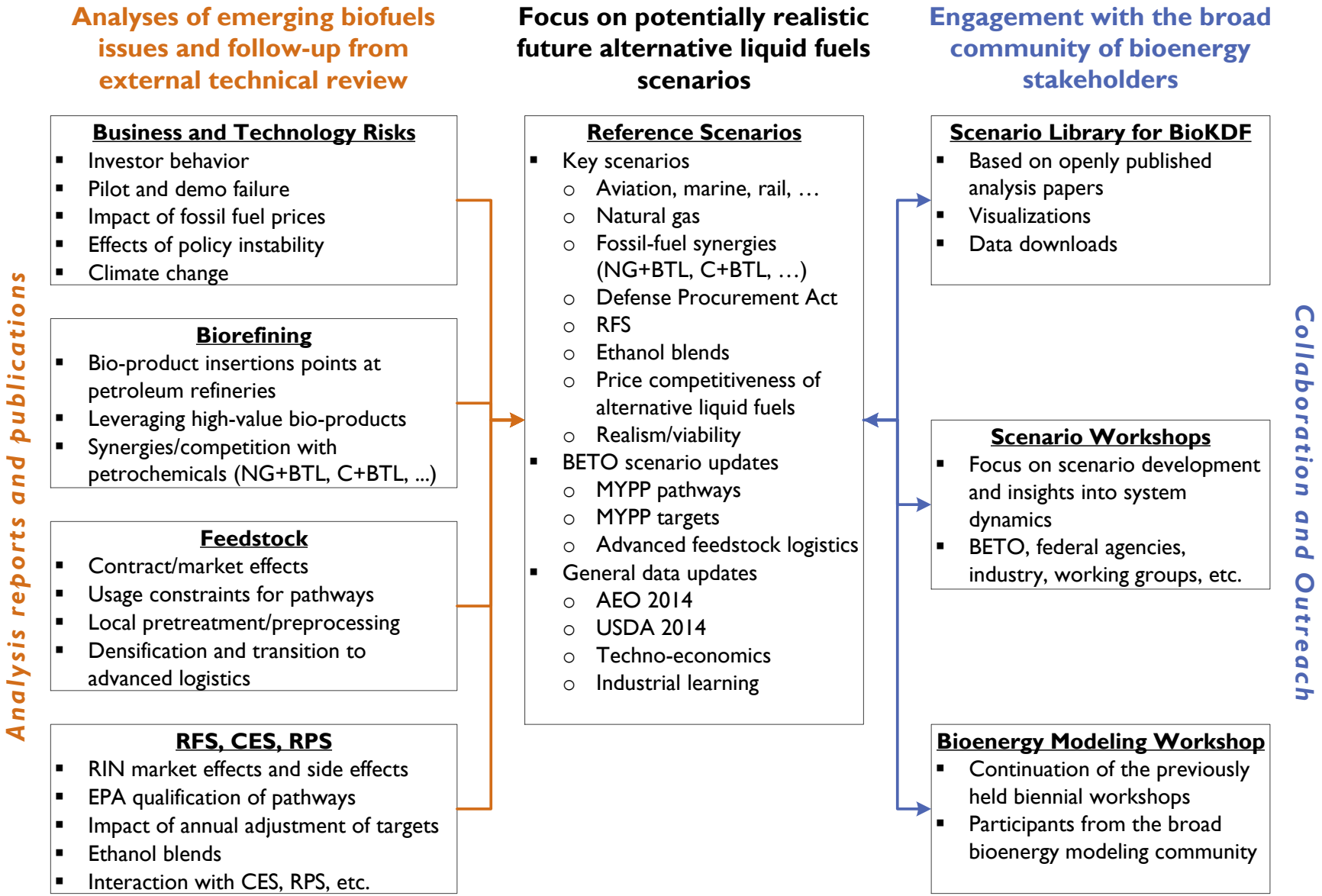
Capabilities

- *Identify optimal synergies* between policies/incentives across the supply chain that make coordinated policies/incentives superior to single or uncoordinated ones.
- *Force consistency in assumptions* and scenario inputs across the full supply chain in a manner lacking in analyses focused on single supply-chain elements.
- *Provide consistent ranking and assessment* of the importance of the influence of particular forces on the biomass/biofuels system.

Impacts

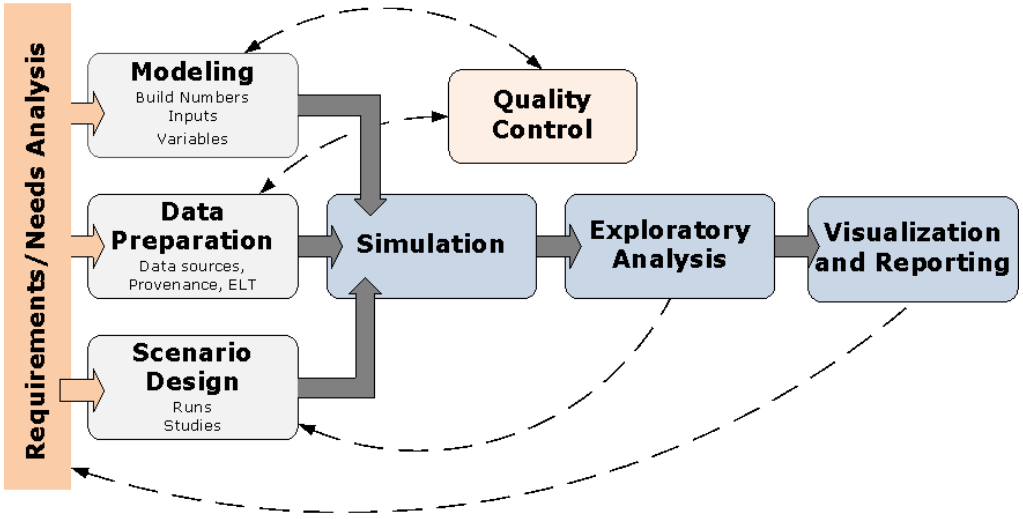
- Policy analyses supporting the tactical and strategic decision making within the Bioenergy Technology Office
- Development of a broad community understanding of the complex dynamics and feedbacks influencing the potential growth of the biofuels industry
- A transparent and accessible tool for the analysis of the evolution of and influences on the biofuels industry
- Publications documenting methodology and results of biofuels analysis

Tentative Plans and Future Directions



Summary

- Challenge/Objective
  - Develop an analytic platform to explore and understand the entire biofuels supply-chain evolution over the long term.
- High-impact BSM analyses tie RD&D to market realities and policies/incentives.
  - The model explicitly focuses on policy issues, their feasibility, and potential side effects.
  - The BSM is a carefully validated, third-generation model of the full biomass/biofuel supply chain.
- Products
  - System-dynamics simulation of the biofuels supply chain
  - Analyses providing insights into system behavior and policy/incentive effectiveness
  - Stakeholder workshops
  - Reports and datasets summarizing supporting research



Additional Slides

Responses to Previous Reviewers' Comments

- *"It is not clear if the model is flexible enough to account for risk and uncertainty. Monte-Carlo simulations might be a useful way to determine the sensitivity of parameters used in the model."*
  - In September 2012, we completed a sensitivity study of the BSM inputs parameters using the method of elementary effects.
- *"Considering there is no proven conversion technology, the inputs to the model limit the usefulness of the model as it is used now."*
  - We now regularly update the BSM input parameters for conversion technologies as new techno-economic analyses and field data become available.
- *"It appears that BSM scenario analysis have significant relevance to Biomass Program goals such as feedstock supply, cost-competitive conversion technologies, and determining the bottlenecks of markets penetration."*
  - In January 2013 we began the development of reference scenarios that will allow the assessment of implications of meeting MYPP targets.

Major BSM Publications (May 2011-2013)

- Book Chapters
  - Newes, E.; Inman, D.; Bush, B. (2012). "Understanding the Developing Cellulosic Biofuels Industry through Dynamic Modeling," Chapter 18. Bernardes, M., ed., Economic Effects of Biofuel Production. Rijeka, Croatia: InTech.
- Fact Sheets
  - Mulcahy, D. "International Trade of Biofuels." Golden, CO: National Renewable Energy Laboratory.
  - Mulcahy, D. "International Trade of Wood Pellets." Golden, CO: National Renewable Energy Laboratory.
- Journal Articles
  - Bush, B.; Sandor, D.; Peterson, S. (Forthcoming). "Dynamics of Deploying Cellulosic Feedstocks to Meet U.S. EISA Mandates." In preparation.
  - S. Peterson, C. Peck, D. Inman, L. Vimmerstedt, E. Newes, D. Hsu, B. Bush, "An Overview of the Biomass Scenario Model", 2013 International Conference of the Systems Dynamics Society, (submitted).
  - Clark, C.; Lin, Y.; Bierwagen, B.; Eaton, L.; Langholtz, M.; Morefield, P.; Ridley, C.; Vimmerstedt, L.; Peterson, S.; Bush, B. (Forthcoming). "Growing a Sustainable Biofuels Industry: Economics, Environmental Considerations, and the Role of the Conservation Reserve Program." Submitted to Environmental Research Letters.
  - Newes, E.; Bush, B.; Peck, C.; Peterson, S. (Forthcoming). "Exploration of Policy, Shocks, and Dynamic Interactions within the Cellulosic Ethanol Supply Chain." To be submitted to Biofuels, Bioproducts, and Biorefining.
  - Newes, E.; Bush, B.; Peck, C.; Peterson, S. (Forthcoming). "Insights into the Effect of Policy on the Potential Development of the Cellulosic Ethanol Industry."
  - Stright, D.; Bush, B. (Forthcoming). "Simulation Process and Data Flow for Large-scale System Dynamics Models."
  - Vimmerstedt, L.; Bush, B.; Peterson, S. (2012). "Ethanol Distribution, Dispensing, and Use: Analysis of a Portion of the Biomass-to-Biofuels Supply Chain Using System Dynamics." PLoS ONE (7:5).
- Subcontractor Reports
  - McDill, M. (2011). Woody Biomass as a Source of Renewable Energy in the U.S. Work performed by Penn State University School of Forest Resources, College Park, PA. Golden, CO: National Renewable Energy Laboratory. (Internal only).
  - Peterson, S. (2011). An Overview of the Biomass Scenario Model. Work performed by Lexidyne, LLC, Colorado Springs, CO. Golden, CO: National Renewable Energy Laboratory. (Internal only).
  - Peterson, S. (2012). An Overview of the Biomass Scenario Model. Work performed by Lexidyne, LLC, Colorado Springs, CO. Golden, CO: National Renewable Energy Laboratory. (Internal only).
- Technical Reports
  - Lin, Y.; Bush, B.; Newes, E.; Peterson, S.; Stright, D. (Forthcoming). Biomass Scenario Model Documentation: Data and References. Golden, CO: National Renewable Energy Laboratory.
  - Mulcahy, D.; Newes, E.; Stright, D. (Forthcoming). Comparison of Biomass and Conversion Data from Select Biofuels Publications. Golden, CO: National Renewable Energy Laboratory.
  - Newes, E.; Bush, B.; Inman, D.; Lin, Y.; Mai, T.; Martinez, A.; Mulcahy, D.; Short, W.; Simpkins, T.; Uriarte, C.; Peck, C. (May 2012). Biomass Resource Allocation Among Competing End Uses. NREL/TP-6A20-54217. Golden, CO: National Renewable Energy Laboratory.

Executive Summary of BSM External Review (1)

Executive Summary

This summary describes the external review meeting, presents potentially actionable recommendations, and documents meeting outcomes.

The Biomass Scenario Model (BSM) External Review was held December 10 and 11, 2012, in Washington, D.C., at the National Renewable Energy Laboratory's (NREL's) office. The meeting brought together subject matter experts and stakeholders, drawn from the federal government, laboratories, academia, and industry to:

- Review the soundness of the BSM analyses and the models, data, and processes on which they are based
- Recommend future emphases of the BSM project, including analyses to be undertaken, outreach/deployment activities, model refinement, and collaborations
- Engage and educate key stakeholders regarding BSM capabilities and directions.

Presenters included analysts from NREL and an NREL subcontractor from Lexidyne LLC:

- Brian Bush (NREL)
- Laura Vimmerstedt (NREL)
- Steve Peterson (Lexidyne LLC)
- Daniel Inman (NREL).

The presenters focused on the following topics:

- Scenario analysis and insights
- Interactive exploration of a scenario library
- Analysis process
- Policy analysis of volumetric targets
- Feedstock supply and logistics
- Model architecture and design
- Biorefineries
- Future plans.

The meeting was an open forum, allowing reviewers to offer their input, thoughts, feedback, and recommendations. The discussion concluded by going around the room to gain each reviewer's final thoughts, feedback, and recommendations.

The intent of this report is to capture key points in the presentations and discussions.

The information in this report was submitted to the U.S. Department of Energy (DOE) to assist DOE and national laboratories in research planning for future work.

Actionable Recommendations

Potentially actionable recommendations based on reviewers' comments are summarized in four categories: model structure, technology representation, market representation, and model community. These recommendations were not necessarily directly stated during the review, and consensus among reviewers was not rigorously assessed. The chronological notes contain cross-references indicating the basis for these recommendations in the discussion.

Model Structure

Reviewers' comments addressed diverse aspects of model structure, including design choices about model boundaries and handling boundary conditions; representation of cost and performance improvements through industry learning; selection and implications of regional structure; choices about the level of detail complexity and structural complexity, calibration and validation approaches; and calculation of metrics. Potentially actionable recommendations related to these items include the following:

Model boundaries. Recommendations include reconsidering model boundaries, assessing interactions of model runs with boundary conditions, and clearly communicating any analytic limitations associated with model boundaries. Important boundaries identified by the reviewers include: international trade in biomass-based commodities, competition for biomass resource, natural gas, petroleum, and demand markets. Boundary conditions may be of concern for some analyses and their impact on conclusions and insights needs to be assessed. It was also recommended that the model incorporate decision-maker expectations (e.g., of future prices or of policy continuity) in the modeling of their decision process.

Industrial learning. The reviewers recommended emphasizing industrial learning effects in calibration, validation, and sensitivity analysis activities. The rate at which cost and performance are assumed to improve with industrial learning (with learning estimated, for example, by hours of operation or volume of fuel production) is a very important model feature, especially in the earliest stages. Reviewers' questions about learning structures suggest that the BSM team explore alternatives that would allow learning to accrue more flexibly so that experience gained in one technology pathway could improve technological maturity for related pathways.

Regions. Reviewers discussed model regionality and recommended careful attention to analytic limitations it may impose, as well as consideration of possible alternative approaches for dealing with inter-regional and intra-regional dynamics. It was suggested that certain geospatial issues, such as an effective plant radius constraint, could be implemented analytically without altering regional structure. Additionally, regions outside the United States, such as Brazil, Argentina, and the European Union might be useful to include in the model.

Complexity. A recommendation was to perform further review of major design trade-offs, with an eye toward opportunities to streamline and simplify the model. Some recommended actions could add additional detail complexity (e.g., more dimensions of existing variables) or more structural complexity (e.g., new algorithms). Reviewers recognized the balance needed between model function and complexity.

Calibration and validation. Reviewers recommended publication of calibration and validation steps that have been taken to date as well as consideration of additional steps to take. The

Executive Summary of BSM External Review (2)

objective should be to establish credibility by documenting ranges and sensitivity for each input variable and being able to present or refer to publication of work to verify, validate, establish rationales, and understand accuracy and robustness. Sensitivity analysis on structural issues was recommended as well as input variables. Calibration using historical corn ethanol industry data should be published. Other approaches for calibration studies were recommended, such as development of calibration reports within specified constraints (especially for pricing). Validation and sensitivity analysis activities should be developed to the level that analyses can present the minimum change necessary to contradict any given conclusion and be able to characterize system properties and identify to what extent they are modeling artifacts.

Metrics. Reviewers recommended additional efforts to develop and present a compelling set of decision-relevant, accessible metrics, such as impacts of the biofuels industry on jobs (by region), the environment, and on petroleum trade.

Technology Representation

Discussions during the review raised topics related to technology representation, including feedstock supply and logistics; level of detail in representing feedstock-to-conversion systems, conversion pathways and biorefineries, insertion points and infrastructure compatibility, and use of biofuels in vehicles. Recommendations related to these items include:

Feedstock supply and logistics. One recommendation was to consider refining the representation of feedstock supply, including representing in greater detail the contracts and markets for feedstocks and the impact and industry learning of feedstock densification technologies and practices. Another was to explore new ways to represent effective plant radius for feedstock contracts without full geospatial disaggregation to assess realism of findings about competition for resource between nearby plants. Reviewers questioned whether this competition would idle plants, as model results suggested. Reviewers highlighted modeling challenges related to feedstock supply, including a set of interlinked questions about the impact of densification on feedstock logistics and competition among conversion facilities for biomass resources. Comments regarding land use focused on expanding land use categories to include quality grades, irrigation status, and ownership type, particularly federal vs. non-federal. Reviewers were unclear as to whether the varieties of forest and urban residue were adequately accounted for and the empirical justification for the BSM's assumptions around growers' conservatism against adopting new practices.

Feedstock-to-conversion detail. Reviewers recommended considering additional detail in modeling the feedstock-to-conversion processes to improve analysis of trade-offs between feedstock quality and price (i.e., explicit costs for each feedstock grade), different drop-in points, and different regions. This includes adding modeling constraints on feedstock characteristics that are likely or required for each conversion pathway.

Conversion pathways and biorefineries. An actionable recommendation was to review how well the conversion pathways in the model represent the emerging industry and the pathways now selected for DOE research and development. Another recommendation was to assess whether the model's characterizations of conversion pathways incorporates all of the key features that industry decision makers actually use. For example, an industry reviewer indicated that complexity of proposed processes is an issue in investment decisions. The potential for high value co-products or non-fuel primary products being produced by biorefineries needs to be more fully accounted for. Furthermore, reviewers suggested that natural gas and coal pathways (natural-gas-to-liquid-fuel, natural-gas-and-biomass-to-liquid-fuel, or coal-and-biomass-to-liquid-fuel) be considered for inclusion in the BSM. Finally, it may be useful to account for the possibilities of integrated biorefineries, where multiple conversion pathways are integrated in a single facility, which may also be collocated with a petroleum refinery and incremental capacity addition.

Insertion points and infrastructure compatibility. Reviewers discussed the diversity of insertion points and criteria for compatibility with infrastructure, and recommended identifying options that might approximate trade-offs for different insertion points. Reviewers also suggested that explicit modeling of intermediate feedstocks (sugar-based ones, in particular) would be useful because of those feedstocks' high value and fungibility.

Vehicles. Reviewers posed questions about modeling different types of vehicles and modes and asked about modeling vehicle manufacturing and choice. Further scenario analysis on flex-fuel and electric vehicle market shares was recommended.

Market Representation

The review resulted in a number of possible recommendations, including modeling of markets, especially feedstock, fuel, and RIN markets; investor decisions, especially for refineries but also for feedstock supply, including contracting practices; and policy issues. Discussions during the review raised topics related to technology representation, including feedstock supply and logistics; level of detail in representing feedstock-to-conversion systems, conversion pathways and their complexity, insertion points and infrastructure compatibility, and use of biofuels in vehicles. Recommendations related to these items include:

Markets. Reviewers recommended further consideration of whether additional features of market behavior and its influence on biofuel industry development could be added to the model. This was considered particularly important for RIN markets' effects on biofuel capacity and production growth. More detailed modeling of feedstock markets, which are likely to have different structures between the early and later years of biofuels adoption, was also recommended for consideration. Co-products or biomass-based non-fuel product markets might also need modeling.

Investor decisions. The review revealed that the model could represent refinery-related decisions in greater detail, including refinery capacity expansion investment decisions, effect of RIN markets on investment and production decisions, selection of feedstocks, refinery capacity utilization (including regional distribution), use of natural gas, and co-production of non-fuel products, which could be particularly important to boost industry profits during early growth of biofuels markets. While the model currently values opportunity cost, reviewers suggested that methodology merits further evaluation, with the possibility of additional detail. Another recommendation was to expand the representation of contracting by including an estimate of the strength of supplier contract and business plan in the financing algorithm and incorporate assumptions regarding long-term feedstock contracts.

Executive Summary of BSM External Review (3)

Policy. Reviewers expressed support for the application of the BSM to policy analysis and suggested that it could be expanded to include more explicit modeling of social and policy decision. Representation of some policies might benefit from further review and perhaps additional detail. For example, reviewers suggest including cost estimates, such as the costs associated with loan guarantees, possibly based on plant failures as a proxy for default.

Model Community

The review included discussions related to outreach and relations within the model community. One overall recommendation was that reviewers expressed enthusiasm for the potential that the BSM could have great value to a wider community, and they recommended continued outreach and support to broaden its use. Potential actionable recommendations included suggested priority applications of the model to studies of interest to stakeholders, suggestions for further review, and recommendations to improve presentation and communication about the model and results. Recommendations related to these items include:

Suggested priority applications of the BSM. Reviewers expressed interest in a wide variety of potential analyses, recognized a need to prioritize analytic topics, and suggested that there would be receptive audiences for studies covering topics, such as:

- Identifying policies and R&D investment strategies that are robust with respect to the broad range of major uncertainties in boundary conditions
- Feedstock supply and incentives
- Infrastructure-compatible biofuels
- Use of idled petroleum refinery capacity to complete biofuels processing
- Technology risk and business risk
- Global change mitigation and adaptation scenarios
- Flex-fuel and electric vehicles
- Higher ethanol blends
- Jet fuels.

Review. Review, and presentation of review results, was considered important to the credibility of the model. One suggestion for improving review was to engage one or more external reviewers in in-depth, hands-on examination and testing of the model extended over a considerable time.

Presentation. Reviewers recommended engaging numerous stakeholders, especially in the industry and in government, through presentations, workshops, and publications. They suggested focused, systematic approach for presentation, including convincing the audience of model validity, presenting results for compelling, metrics, and tailoring presentation of results to emphasize relevance to decisions of interest to each audience. Publication of methodology papers justifying algorithms and major assumptions could be an important part of establishing validity, and these publications could be cited to convince audiences.

Meeting Outcomes

The meeting revealed improvements, opportunities, and documentation for the BSM.

Improvements

External reviewers discussed some of the current limitations and boundaries of the BSM. Limitations to the architecture and design of the BSM and industry structure were discussed, as well as missing markets.

Suggestions to overcome limitations include:

- Further pursue the use of similar frameworks for multiple processes to keep the model simple
- Build social decisions into the model
- Look at how the BSM might be coupled to scenarios generated by larger global models
- Capture more detail on business issues, such as the quality of business plans and the disposition of failed plants
- Add spillover of industrial learning between technology pathways
- Incorporate standard background rates of general technology progress
- Frame within the context the scenarios are playing out in, what renewable fuel standards (RFS) are in place, and that the scenarios are really strategies to meet these standards/targets
- Link other goals to the BSM
    - Link to maximizing greenhouse gas reductions
    - Link to maximizing idled refinery capacity.

Reviewers proposed metrics they would like to see included in future versions of the model:

- Jobs by congressional district
- Balance of payments
- Different geographic areas (such as mountain west)
- Marginal lands and types of forest land
- Regional prices
- Separate government payments, government exposure from loan guarantees, and non-governmental costs, maybe even including items such as consumer surplus.

Opportunities

External reviewers suggested many additions to the BSM that they would find useful. The suggested additions included incorporating renewable identification numbers (RINs), densification of feedstock, learning curve studies, grower contracts, loan guarantees, impacts, linking feedstock to the best-suited technology, and developing infrastructure-compatible fuels.

Executive Summary of BSM External Review (4)

- RINs
  - Model RINs if the BSM is showing entry into the market
    - RINs will speed entry into the market
    - Without the business opportunities provided by RINs, refiners/investors will not go into the biofuels market
- Densification
  - Explore more scenarios around the forced densification of feedstock into the BSM
  - Use learning curve studies to refine the BSM
- Contracts
  - Have a strong supplier contract and business plan in order to get financing
  - Incorporate assumptions regarding long-term feedstock contracts
  - Include lessons learned from the history of guarantees and subsidies
- Vehicles
  - Explore more flex-fuel vehicle scenarios
  - Model the impacts of automobile electrification scenarios
  - Study scenarios that include compressed natural gas (CNG) vehicles for fuel cell electric vehicles (FCEVs) where the fuel (natural gas or hydrogen) is derived from inexpensive natural gas
- Fuels
  - Further develop infrastructure compatibility in the model
  - Explore E15 and E30 scenarios, in addition to E10 and E85
  - Incorporate market effects in the jet fuel sector into the model.

Documentation

External reviewers discussed useful resources to use and collaborative opportunities with other organizations to explore. Many reviewers encouraged validating and testing the model, improving the review process, and publishing more documents on the BSM.

- Useful resources
  - Parameter Estimation (PEST) software
  - Biomass Crop Assistance Program (BCAP) public data on rents in its project areas
- Collaborative opportunities
  - The National Advanced Biofuels Consortium (NABC)
  - Oak Ridge National Laboratory (ORNL)
- Model Validation
  - Test the reliability of the model by trying to break it through optimization techniques and using supporting literature and documentation
  - Show that the numbers have value and validity—learning curve development could show this
  - Use historical experience, where possible, for comparisons, including historical experience from analogous industries (e.g., pulp-and-paper mills, liquid natural gas terminals, and methanol)
  - Give more background information upfront during presentations
  - Compare the BSM to market equilibrium and optimization models (computable general equilibrium models, National Energy Modeling System, the Billion-Ton Study Update)
  - Identify structural uncertainties and uncertainties in decision algorithms embedded in the BSM, in addition to data and scenario uncertainties
- Review process improvements
  - Hold an external review and have external users to "break the model"
  - Market the model
    - Market to the public policy and investment communities
  - Offer more training opportunities on using the model
  - Hold additional interagency and industry workshops
- Publications
  - Publish a document on the model's methodology to show how the major equations are grounded in literature and to justify major assumptions
  - Document issues around modeling the transition to a large biofuels market and learning.