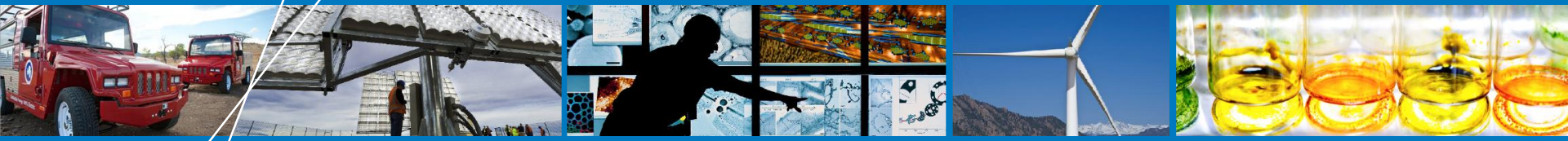
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Biomass Scenario Model



24 March 2015

BETO Analysis Platform Peer Review

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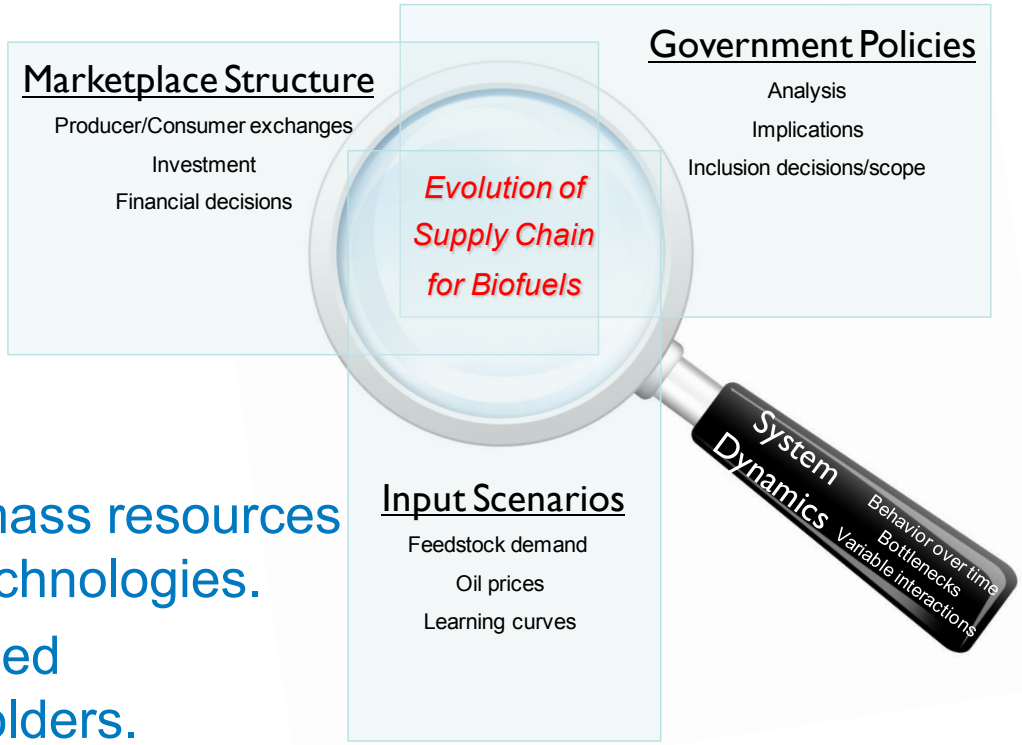
National Renewable Energy Laboratory

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 energy needs.
  - Generate plausible scenarios for bioenergy market penetration.
  - Understand the transition dynamics to a bioeconomy.
  - Analyze prospective policies, incentives, investments, R&D impacts, and strategies.
  - Identify high-impact drivers, points of leverage, and bottlenecks.
  - Study competition for biomass resources and between bioenergy technologies.
  - Enable and facilitate focused discussion among stakeholders.



Quad Chart Overview

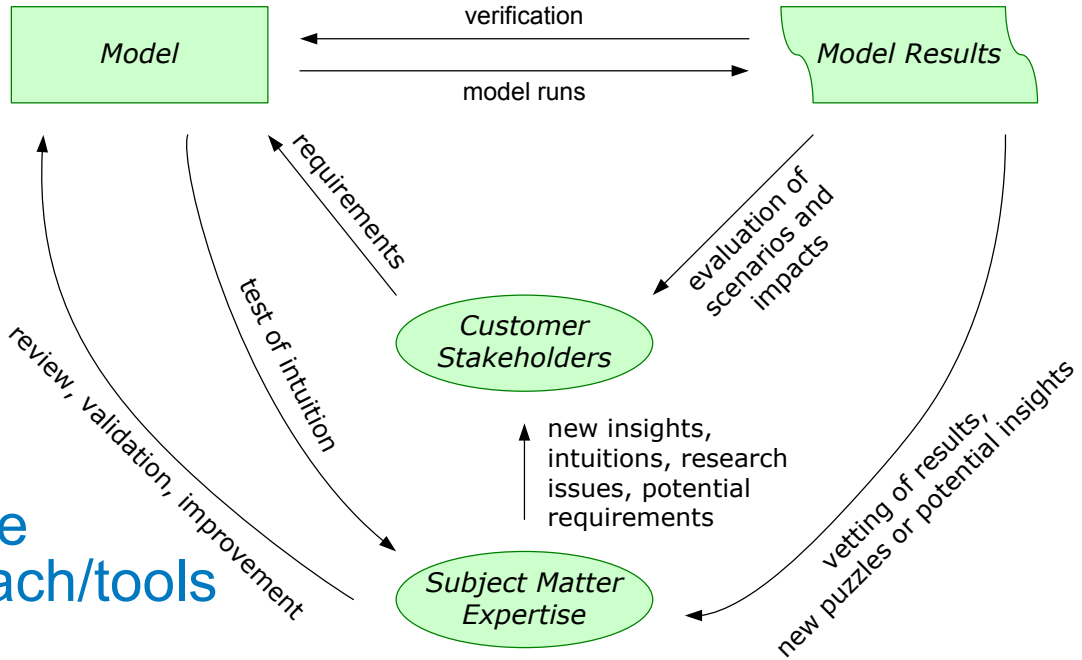
- Timeline
  - Started October 2006
  - Complete September 2017, per three-year plan
  - 80% complete

	Total Costs FY 10 –FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date
DOE Funded	$2400k	$800k	$950k	$2700k
Project Cost Share (Comp.)	0	0	0	0

- Barriers
  - Transparent, and Reproducible Analyses [MYPP At-A]
  - Analytical Tools and Capabilities for System-Level Analysis [MYPP At-B]
  - Data Availability across the Supply Chain [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 bioenergy supply-chain evolution over the long term.
- Products
  - System dynamics simulation of the bioenergy supply chain
  - Analyses providing insights into system behavior and policy effectiveness
  - Stakeholder workshops
  - Publications and datasets
- Modern, agile, and adaptive model development approach/tools
- Roles

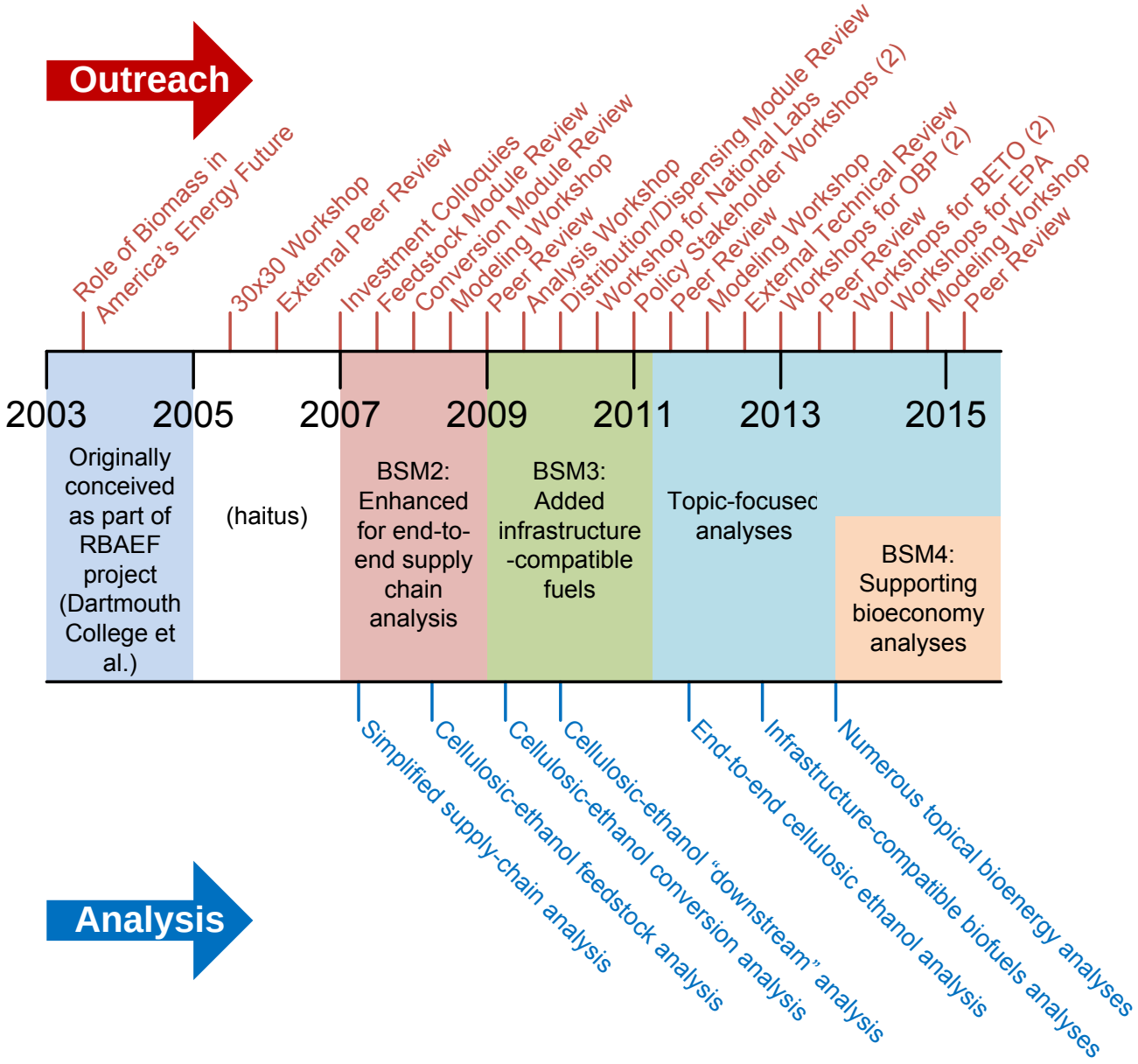


	Requirements	Review	Project Mgmt	Domain Expertise	Model Development	Data Processing	Analysis
DOE BETO	√	√		√			
NREL			√	√	√	√	√
Lexidyne LLC					√		√
Nat'l labs, federal agencies, universities, subcontractors		√		√			

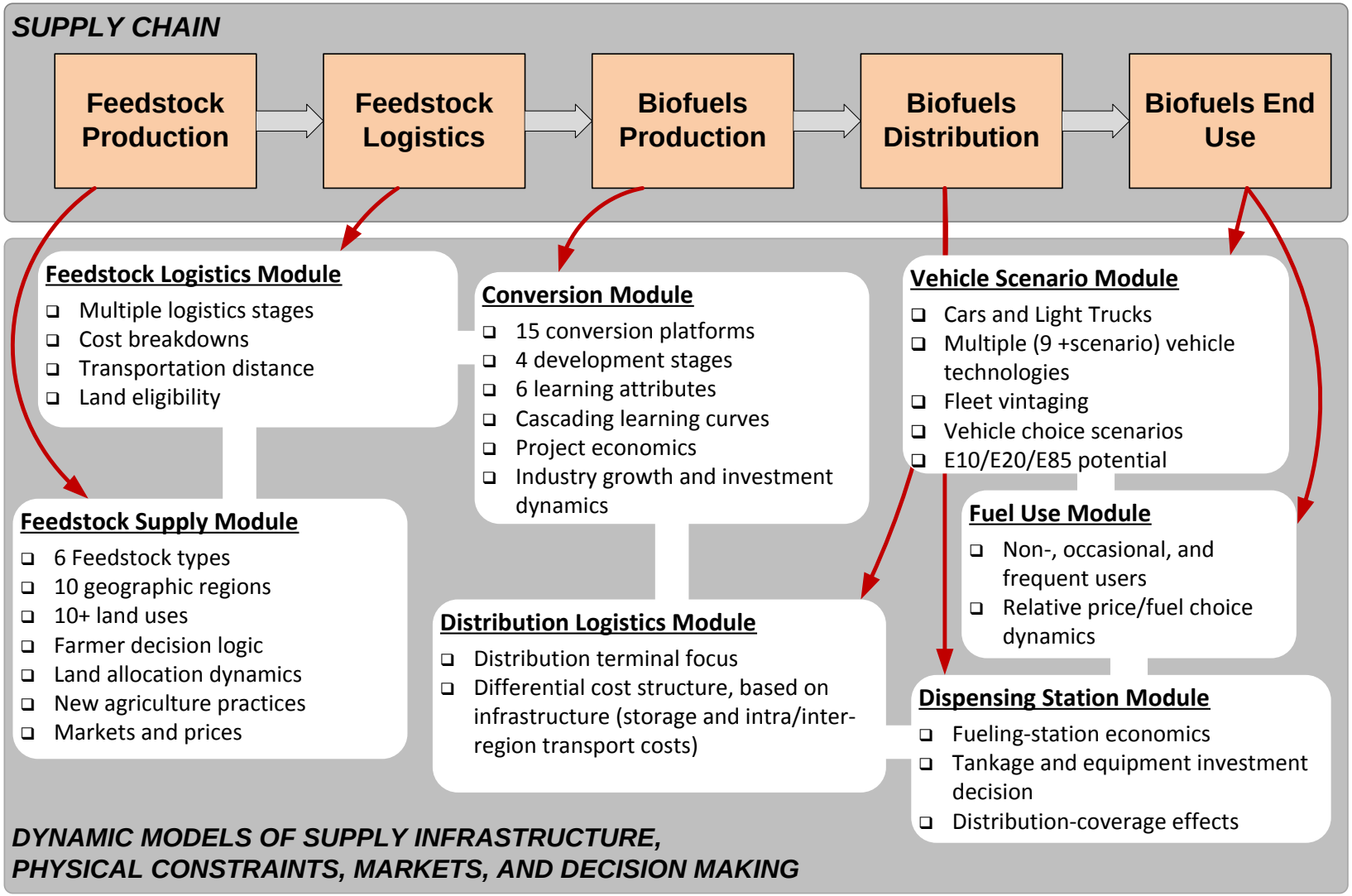
Project History

The BSM project has attempted to balance the needs of . . .

- performing and publishing analyses,
- advising BETO,
- educating stakeholders, and
- anticipating trends in the bioenergy industry.

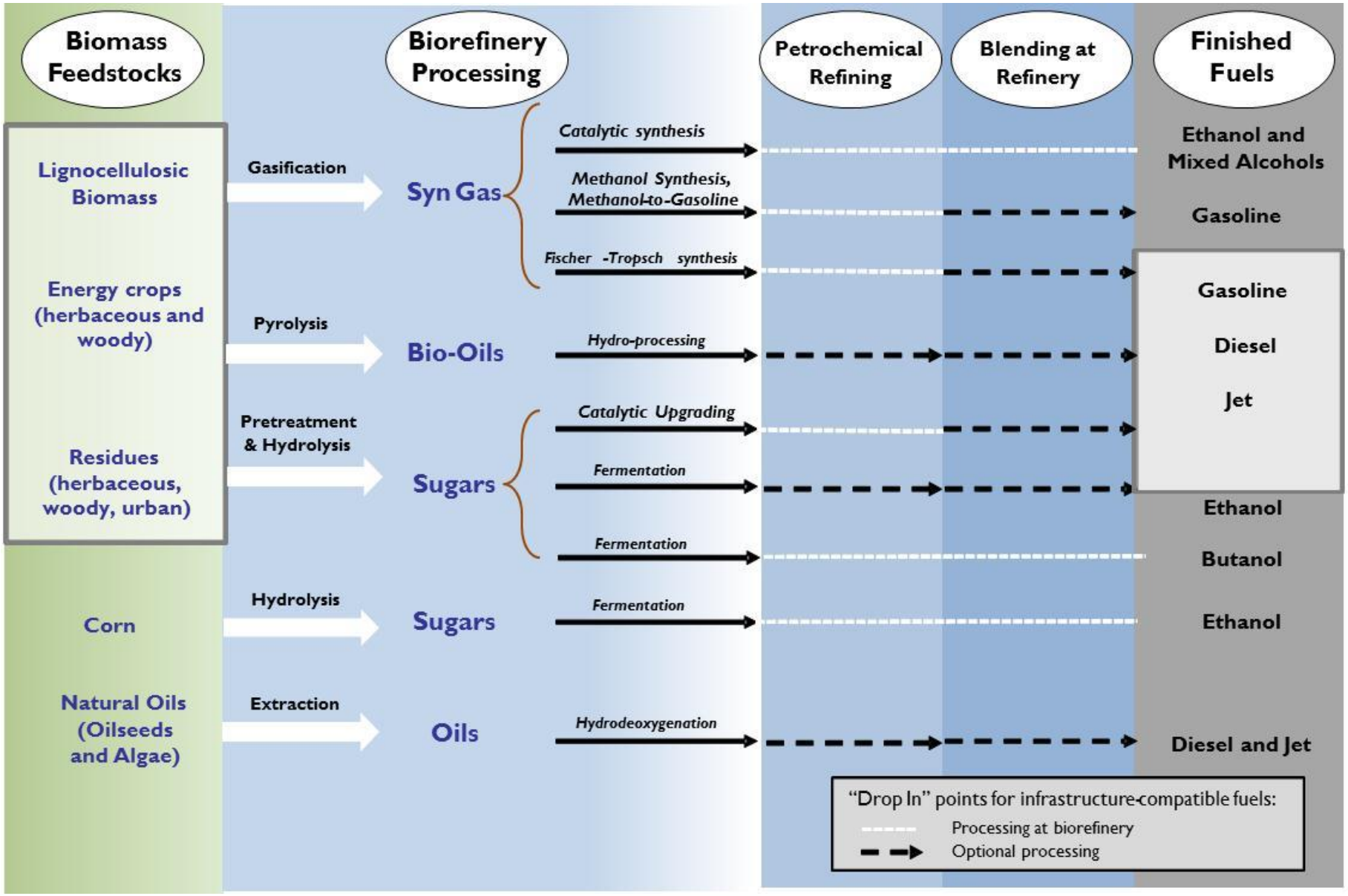


Key Characteristics of BSM Biofuels Modules



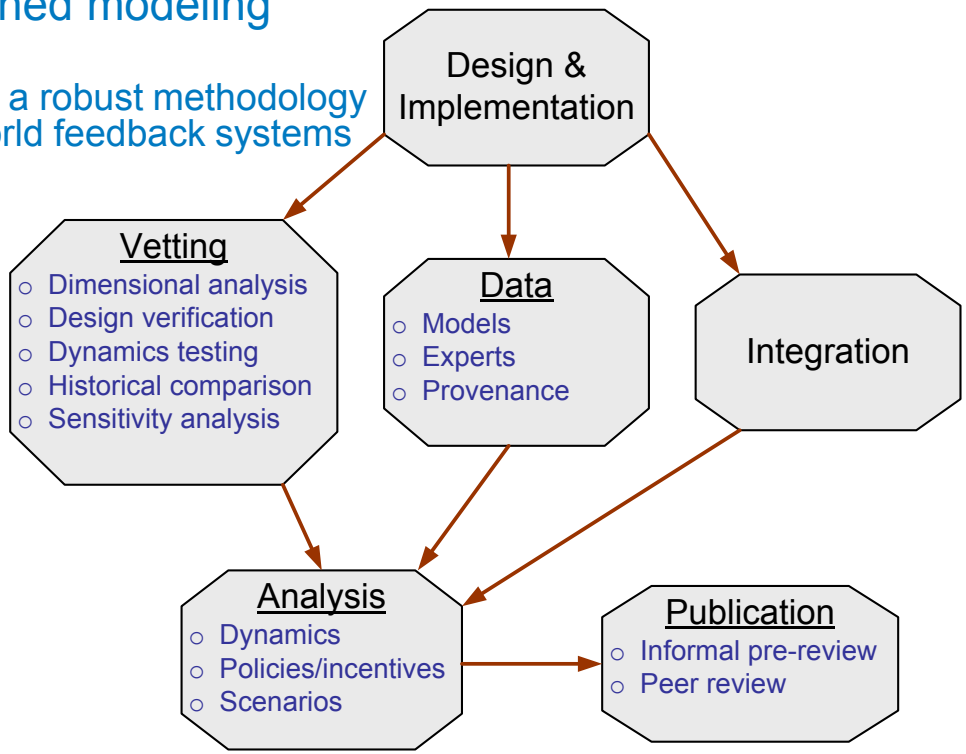
POLICIES **INCENTIVES** **EXTERNALITIES**

Biofuel Pathways in the BSM



Modeling and Analysis Process

- Frequent communication and reporting to BETO
  - Collaboration on scoping and designing analyses
  - Briefings and workshops on analysis results
  - Iterative refinement of analyses
- Emphasis on an agile development process
  - Involvement of team members with specialized areas of expertise
  - Collaboration with subject matter experts at BETO and national labs
  - Adaptive adjustment of analysis plans
  - Flexible, modular modeling architecture
- Reliance on appropriate and well established modeling techniques
  - The system-dynamics modeling framework is a robust methodology for analyzing the behavior of complex real-world feedback systems over time.
- Careful consideration of level of detail
  - Broad, high level approach that captures entire supply chain.
- State-of-the-art approach to reproducibility and quality
  - Defensible and traceable inputs, with metadata
  - Full archives of analysis results, from the inception of the project
  - Configuration management and issue tracking systems
  - Explicit quality assurance, quality control, verification, and validation



Critical Success Factors and Potential Challenges

Critical Success Factors

1. Effectively communicating technical results to a diverse community of stakeholders
   - *addressed through the use of multiple modes of communication (reports, workshops, presentations, fact sheets, web sites)*
2. Anticipating emerging analysis issues in order to perform and publish timely and relevant analyses
   - *addressed through numerous quick "screening" analyses aimed at flushing out potential scenarios and modeling requirements*

Potential Challenges

1. Maintaining up-to-date inputs for analyses
   - *addressed through networking with bioenergy community in order to obtain new data as soon as or prior to its public release*
2. Avoiding "scope creep"
   - *addressed through focusing on core issues relevant to the transition to a bioeconomy*
3. Choosing effective collaborations
   - *addressed by selecting high value collaborations that result in clear improvements in the quality of modeling and analysis*

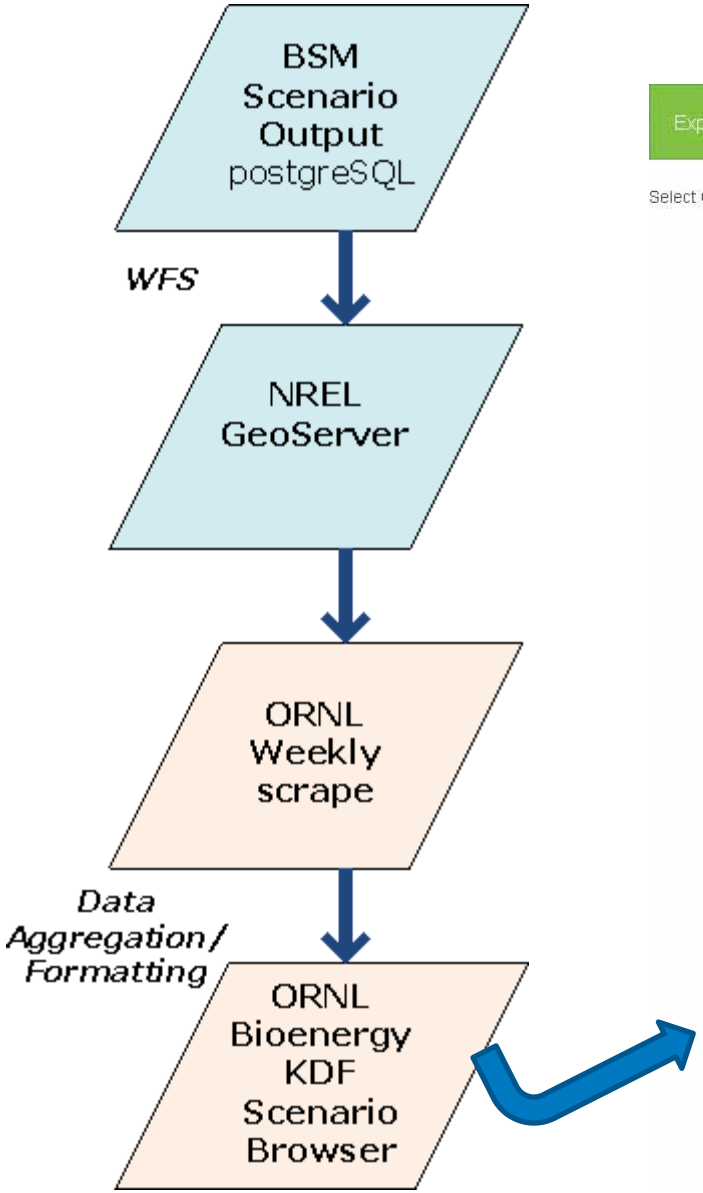
Summary of Accomplishments (March 2013-2015)

- Analysis reports to BETO
  - Benefits of biochemical production for biofuels
  - System implications of the advanced uniform feedstock supply system
  - Renewable inventory number (RIN) market variability study
  - Drought and climate change shocks to feedstock supplies and their market impact
  - Effects of international trade in wood pellets
  - Analysis of impact of updates to the fast pyrolysis and hydrotreating bio-oil techno-economic analyses
  - Aviation biofuels and the European Union emissions trading system (ETS)
  - Light-duty-vehicle (LDV) ethanol-demand scenario analysis
  - Long fixed-term contracts for infrastructure-compatible biofuels
  - Analysis in support of BETO resource-loaded plans and mutli-year program plans
  - Renewable super-premium (RSP = E20 to E45) scenario analysis
- Enhancement of scenario library
  - Published on ORNL's BioEnergy KDF
- Subcontractor reports
  - Model documentation

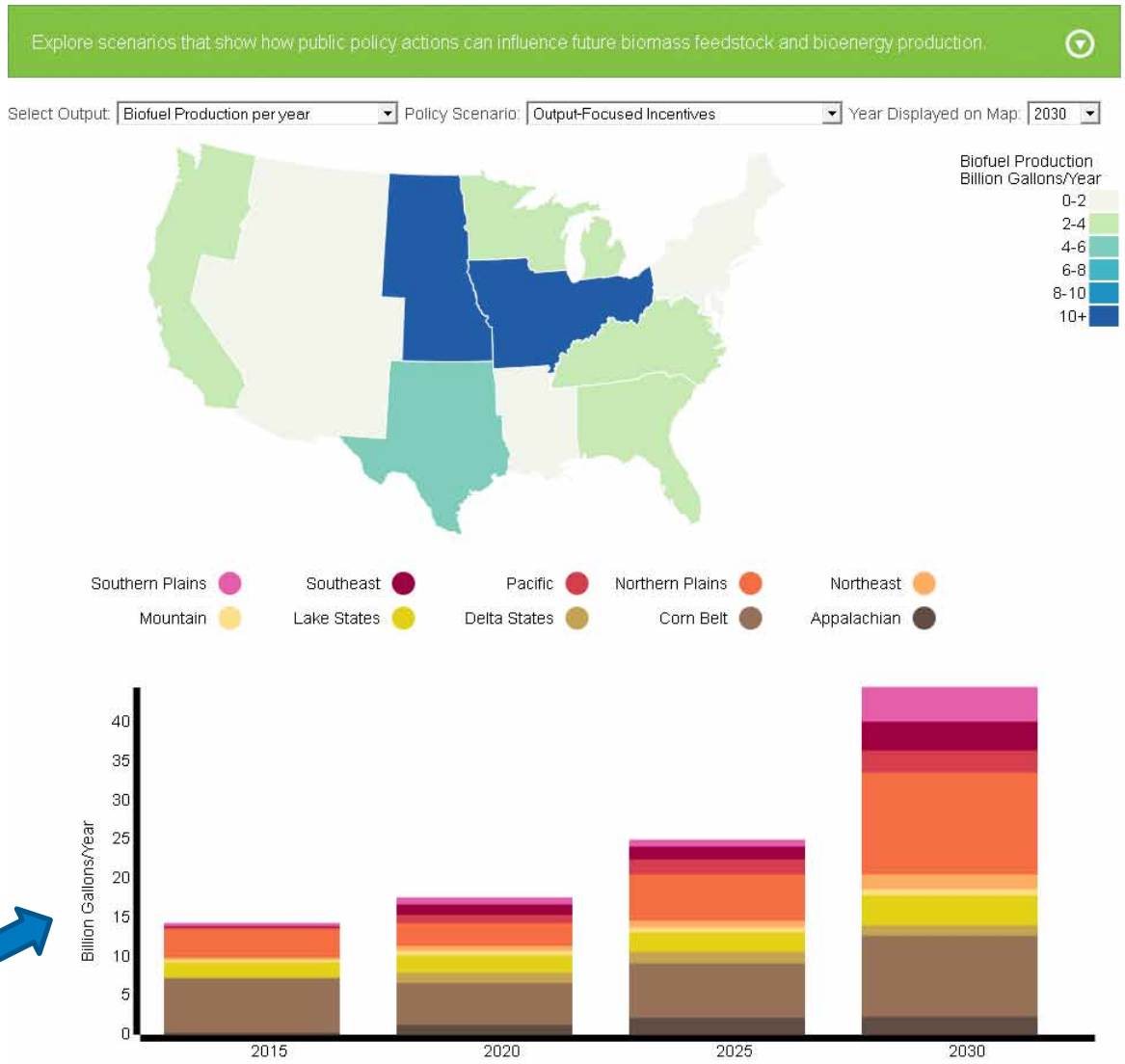
Summary of Accomplishments (March 2013-2015)

- Publications
  - Journal articles on supply chain analyses (2 published, 4 in preparation)
  - Conference papers/presentations on supply chain analysis (2)
  - Book chapter on system aspects of biofuels supply chain
  - Fact sheets on international biomass/biofuel trade (2)
  - Analysis technical reports (2 published, 4 in preparation)
  - Model and data documentation technical reports (3)
  - Report on competition for biomass resources between biofuel and biopower
- Workshops and reviews
  - Bioenergy supply-chain modeling
  - BETO (2)
  - EPA (2)
  - International (in U.K.)
- Model maintenance/enhancement
  - Feedstock specificity
  - Yield variation due to drought or climate change
  - Representation of imports and exports in biomass and fuels
  - Biorefinery coproducts
  - Techno-economic and other data updates

The BioEnergy KDF serves quantitative BSM results to public.

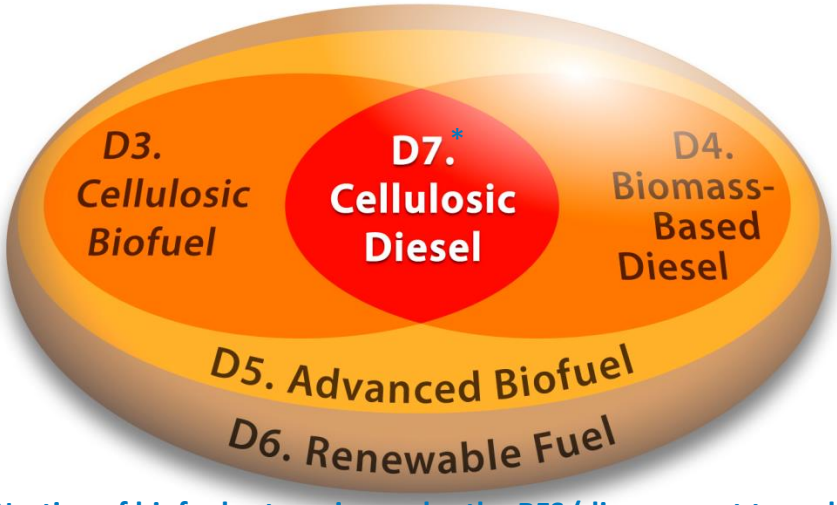


KDF BSM Tool

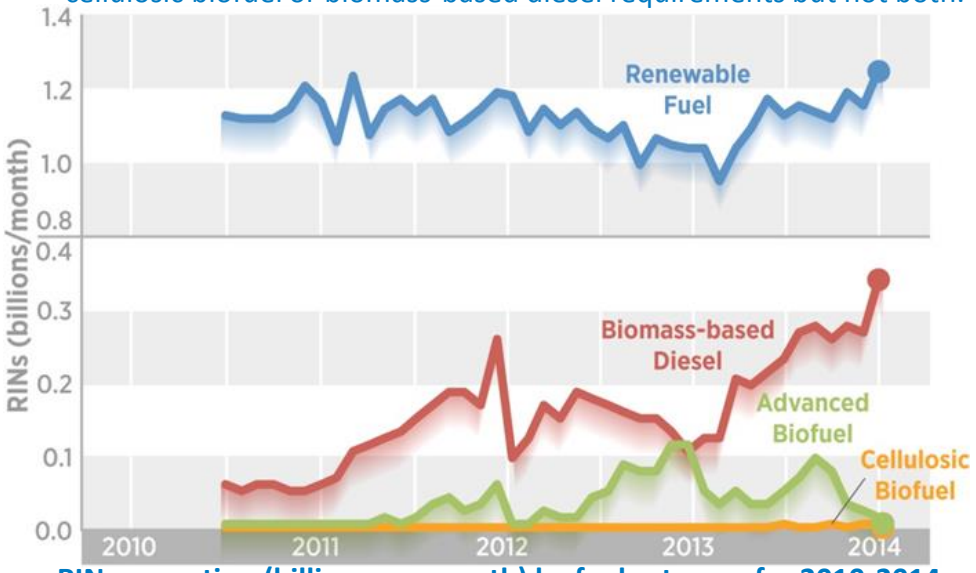


Market analysis of Renewable Identification Numbers (RINs) informs BSM.

- Summarized the legal and regulatory framework of the Renewable Fuel Standard (RFS) program that forms the structure the RIN credit market.
- Analyzed constraints on EPA's authority under the RFS program based on recent court decisions.
- Collected contextual data on biofuel markets (e.g., fuel prices), policies (e.g., biofuel tax credits), and RIN generation [see bottom right].
- Summarized, based on literature review, existing research topic areas, major historic drivers of RIN market prices, and interactions between the RIN market and market participants.
- Contributed to identification of gaps in knowledge about the RIN market and the role it plays in the biofuel industry.



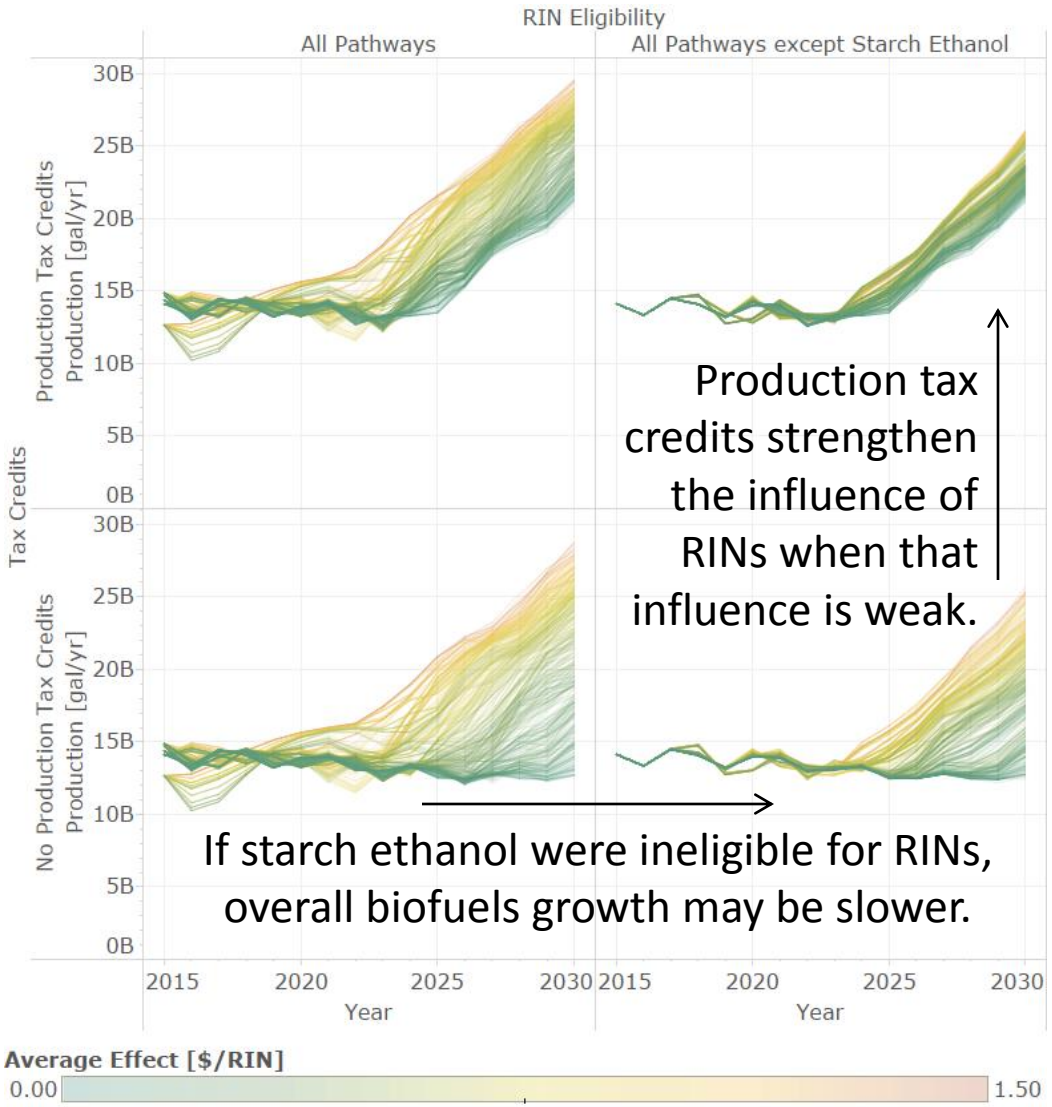
Nesting of biofuel categories under the RFS (diagram not to scale)
*Not an official fuel category under the RFS. Can count towards cellulosic biofuel or biomass-based diesel requirements but not both.



RIN generation (billions per month) by fuel category for 2010-2014
Sources: EPA's Moderated Transaction System

RIN price effects have significant interaction with other policies.

- RIN price trends that eventually increase seem to have a stronger influence than those that decrease, indicating that high RIN prices in early years might not be as impactful as those in later years.
- Tax credits and additional deployment are sufficient, even with decreasing effects of RINs, for the eventual attainment of RFS2-like biofuel volumes.
- Loss of production tax credits significantly hampers industry growth unless RIN prices increase to a high value.
- Excluding starch ethanol production from obtaining RINs somewhat discourages overall biofuel industry growth.



Biofuel Production given different levels of RIN effect and starch ethanol eligibility. Assumptions: additional deployment investment and potential tax credit extension.

Deployment of more IBRs leads to biofuels industry "take off".

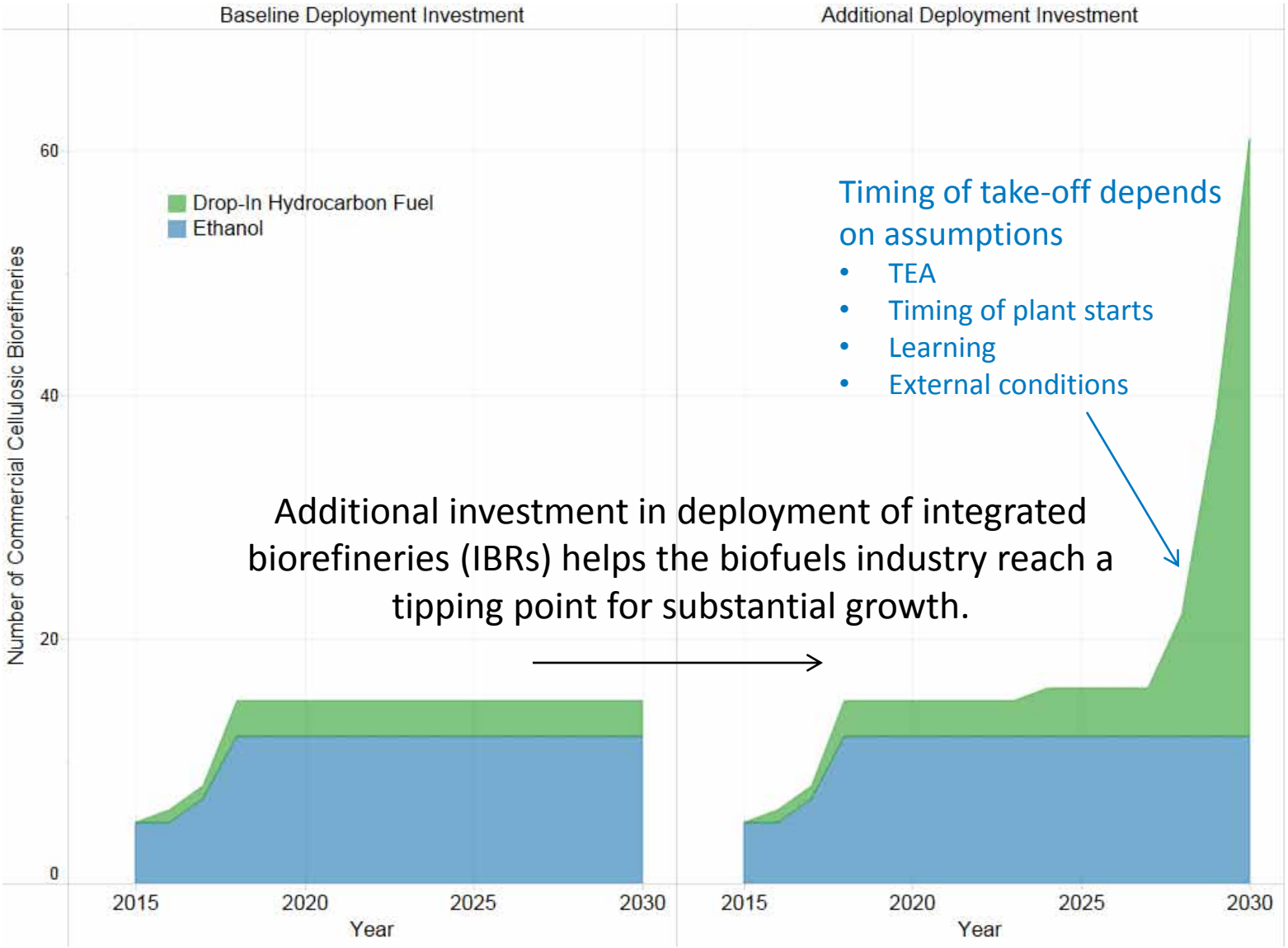
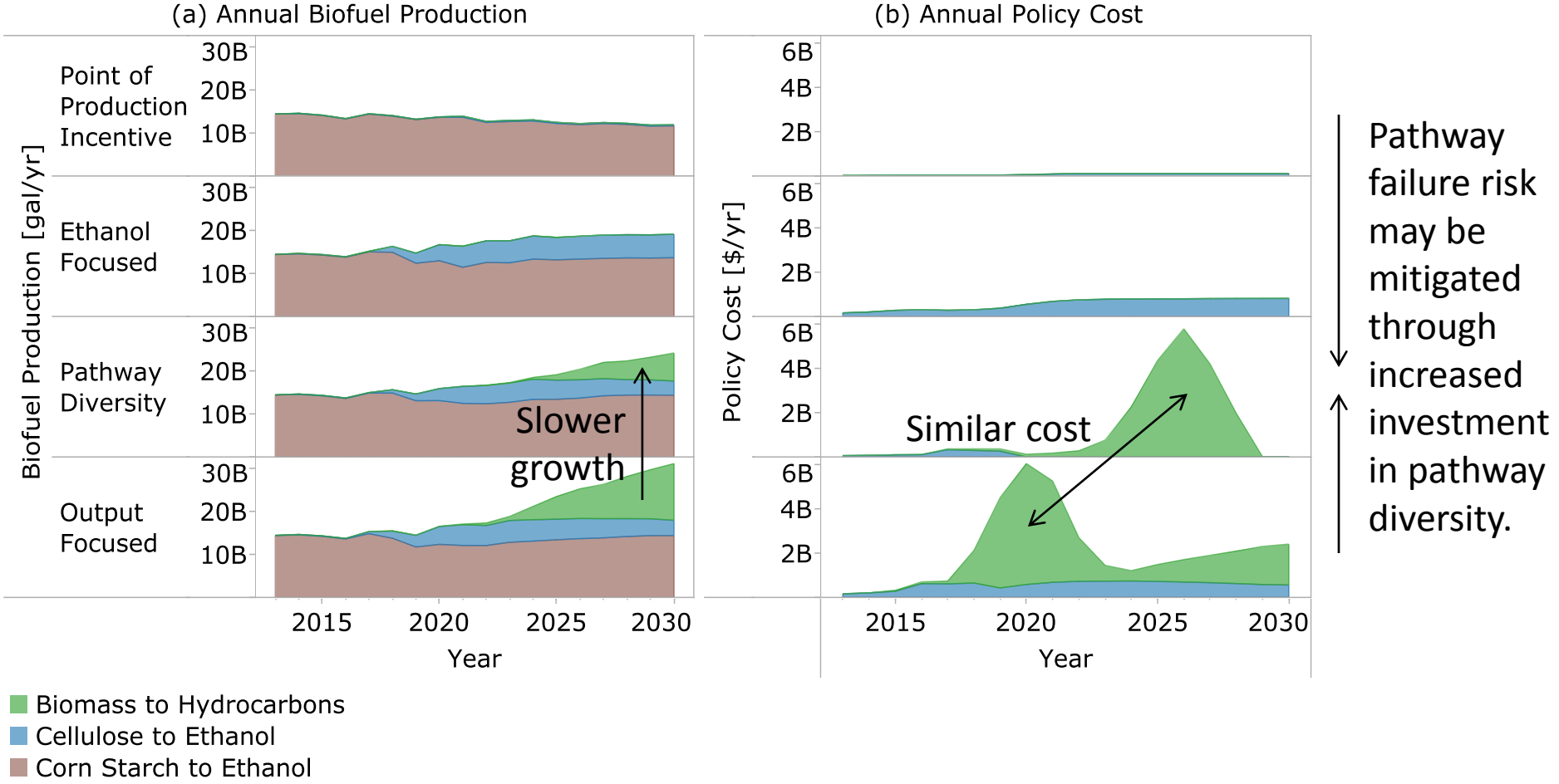


Figure from BETO's Multi-Year Program Plan (MYPP).

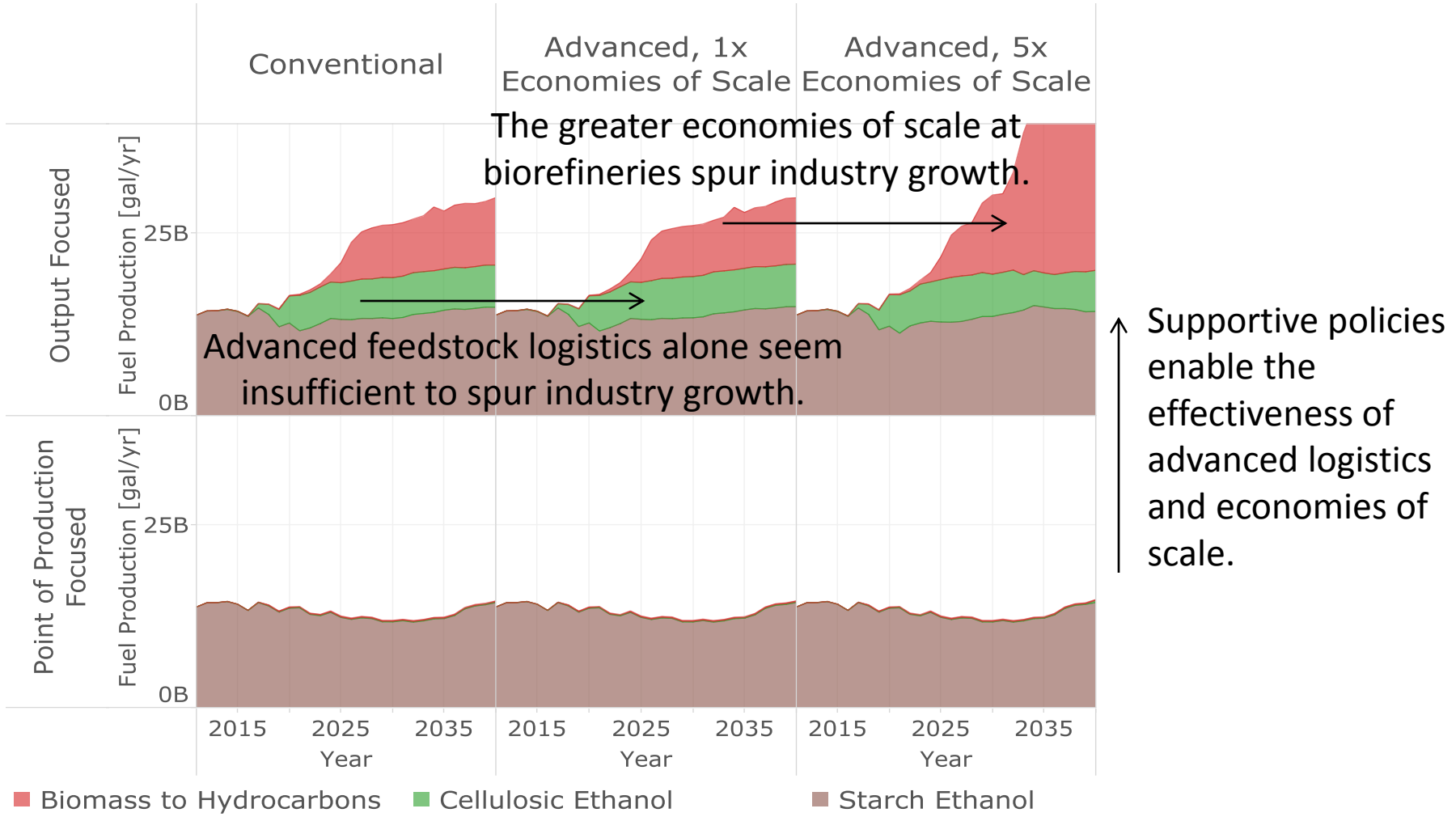
Diversification in pathway investments impacts industry growth.

Policy design faces trade-offs between pathway diversity (risk mitigation) and direct incentive cost because of uncertainty in maturation and techno-economics.



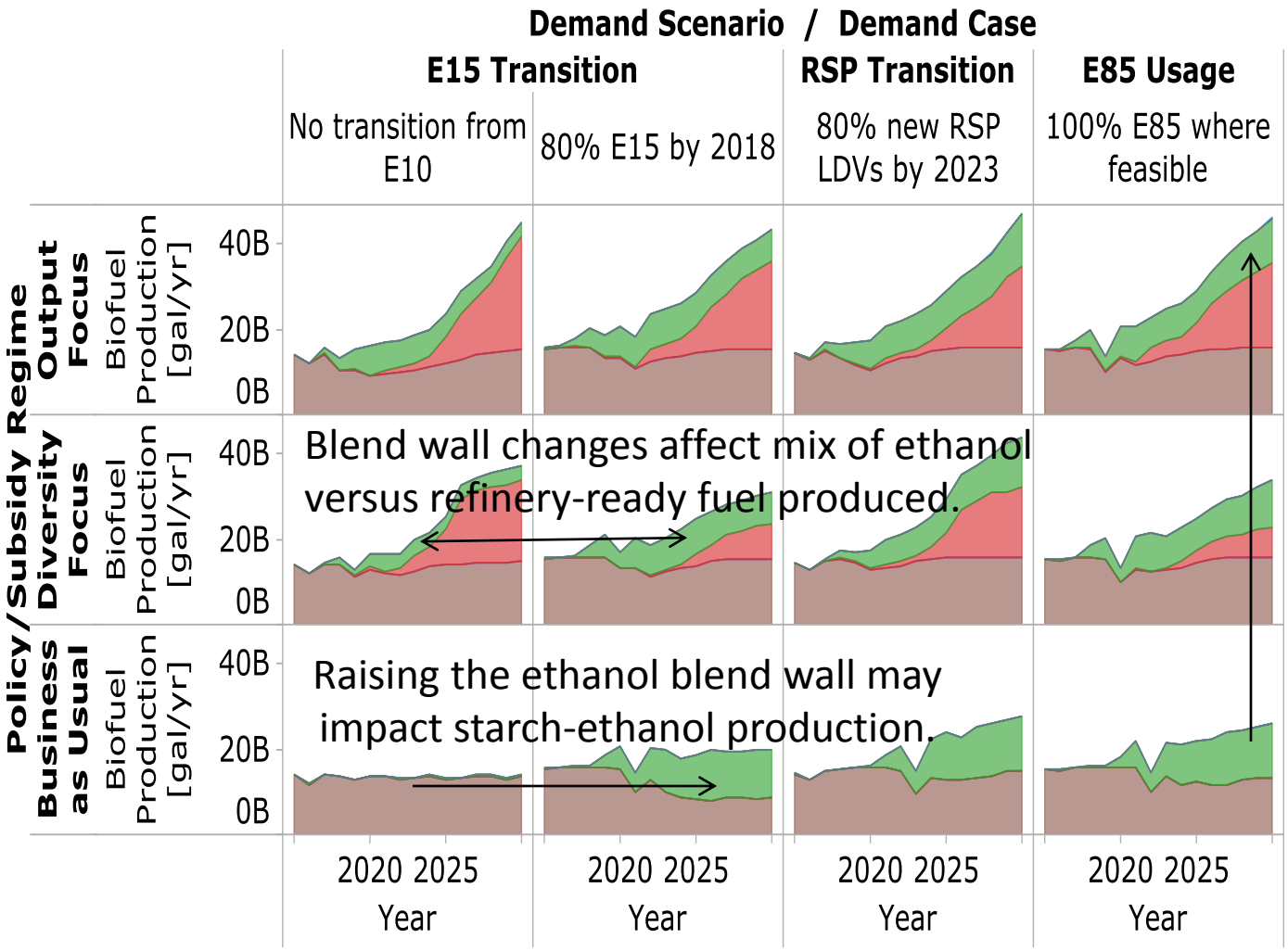
The Output Focused scenario reaches higher levels of production than the Pathway Diversity scenario, with a similar annual limit on incentive cost.

Advanced logistics enables favorable economies of scale.



A transition to an advanced uniform feedstock format, when coupled with high throughput biorefineries, helps to increase the rate of biorefinery learning-by-doing and encourages biofuel production under incentivized conditions.

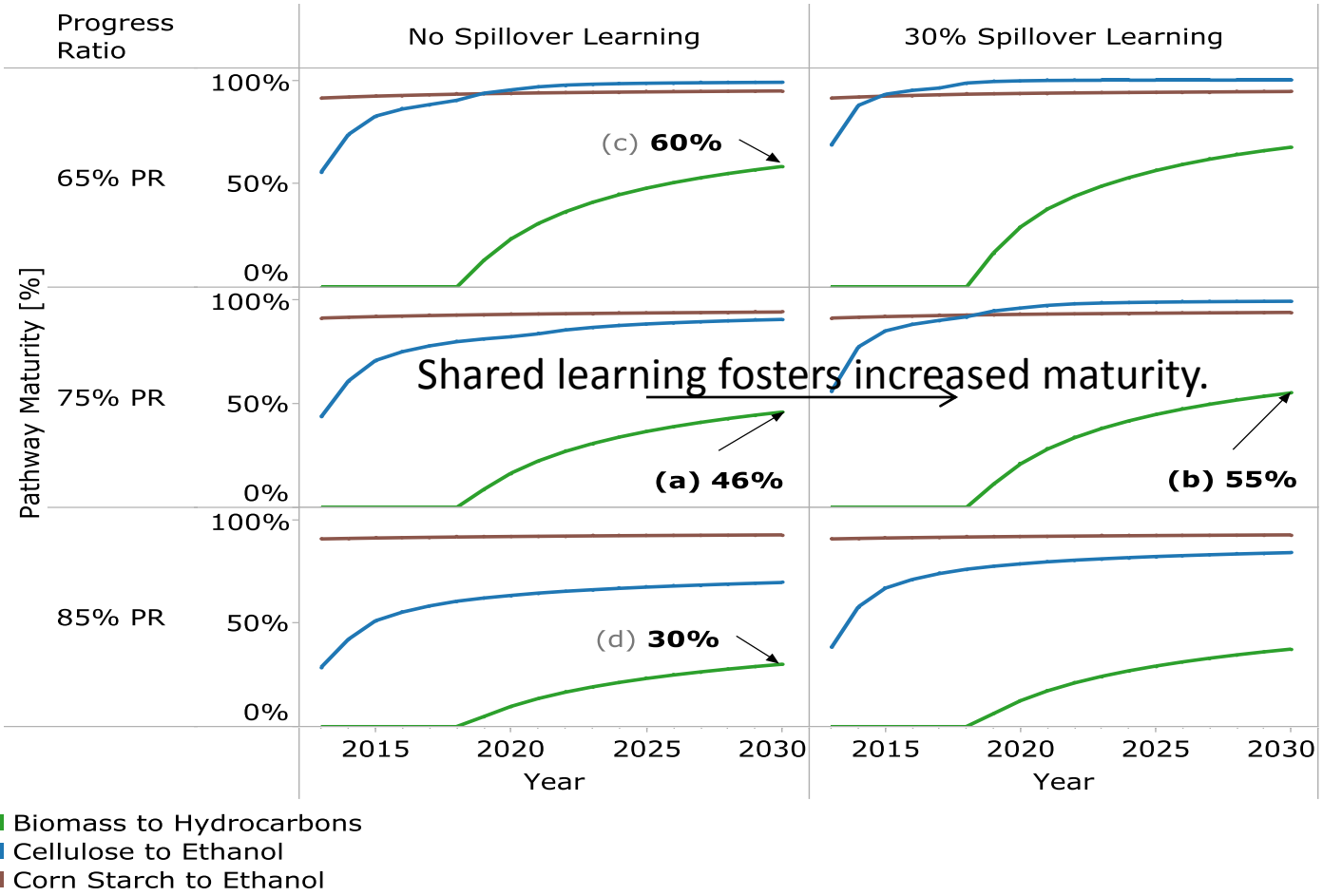
"Blend wall" changes affect ethanol vs other biofuel production.



Strongly supportive incentive policies have more potential to increase biofuel volumes than changes to the blend wall.

RSP = "Renewable Super Premium", a 20-45% ethanol blend with gasoline.

Sharing of learning between pathways accelerates industry maturity.



- Characteristics of learning, such as its rate and sharing across different pathways, can dramatically influence pathway competition timing and results.
- Commercial maturity is accelerated with more rapid learning from spillover or from more optimistic progress ratio assumptions.

Milestone/Deliverable History and Status

Period	Milestone/Deliverable	Status
FY2013	C.DL.1: Four analysis reports	Completed on schedule
	C.DL.2: Two conference/journal papers	Completed on schedule
	C.DL.3: Deliveries to Bioenergy KDF	Completed on schedule
	C.DL.4: One stakeholder workshop	Completed on schedule
FY2014	Q1: Post updated scenario library to KDF with results of FY2013 scenario analysis	Completed on schedule
	Q2: BSM Analysis Report "System Implications of the Advanced Uniform Feedstock Supply System	Completed on schedule
	Q2: BSM Analysis Report "The Potential Benefit of Biochemical Production to the Long-Range Outlook for Commodity Biofuels"	Completed on schedule
	Q3: Book chapter "Using system dynamics to model industry's developmental response to energy policy"	Completed on schedule
	Q4: Technical report "Effects of Deployment Investment on the Growth of the Biofuels Industry"	Completed on schedule
FY2015	Q1: Post updated scenario library to KDF with results of FY2014 scenario analysis	Completed on schedule
	Q2: Report, briefing, or workshop on scenario analysis on the implications of feedstock constraints for conversion pathways	On schedule
	Q3: Report, briefing, or workshop on scenario analysis on the role of aviation, marine, and rail biofuels in the development of the bioeconomy	On schedule
	Q4: Journal article, conference proceeding, or book chapter on integrated analysis on the effectiveness and cost of biofuels policies in the context of the development of a large scale domestic bioeconomy	On schedule

Relevance to BETO Goals and Objectives

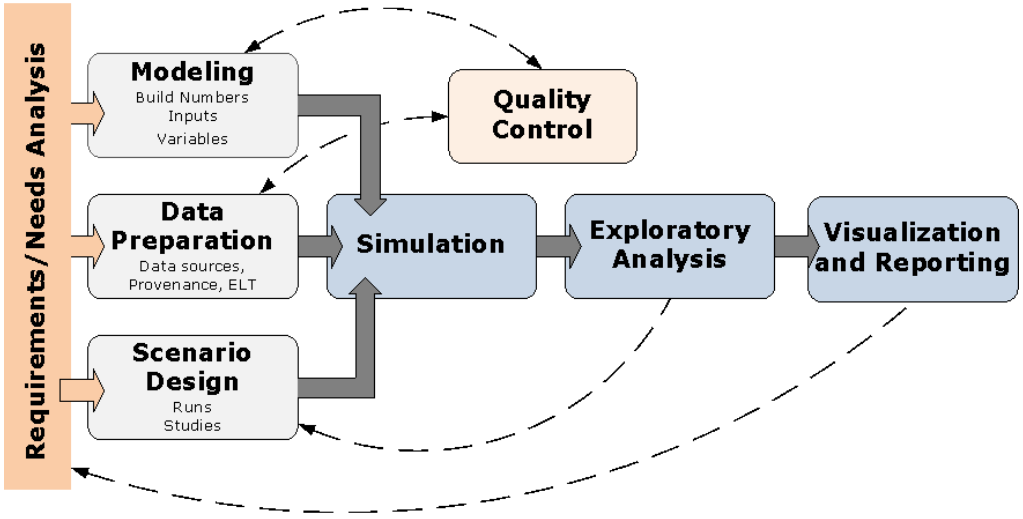
Element	MYPP Goal	BSM Contribution
Strategic Analysis	provide context and justification for decisions at all levels [p. 2-118]	1. Analysis of attainability of EISA targets 2. Potential long-term effects of RIN market 3. Analysis in support of MYPP
Feedstock Supply	develop commercially viable biomass utilization technologies to enable the sustainable, nationwide production of advanced biofuels [p. 2-91]	4. Analysis impacts of biomass yield variability due to drought or climate change 5. Analysis of transition to advanced logistics 6. Analysis of feedstock flexibility for conversion pathways
Conversion R&D	develop commercially viable technologies for converting biomass feedstocks [p. 2-49]	7. Analysis of effects of industrial learning 8. Analysis of pathway competition and diversity 9. Study of technological lock-in
Deployment and Market Transform-ation	develop commercially viable biomass utilization technologies that build and validate integrated biorefineries; and to develop supporting infrastructure to enable a fully [p. 2-91]	10. Analysis of effects of long-term aviation biofuels contracts and the EU's ETS 11. Analysis of impacts of a transition to E15 or RSP 12. Analysis of synergies from production of co-products 13. Studies of impact of investments in biorefineries
Strategic Communi-cations	conduct strategic outreach to target audiences, promoting the benefits of sustainable production of biofuels, bioproducts, and biopower [p. 2-126]	14. Bioenergy modeling workshop 15. Scenario design and analysis workshops 16. Journal and report publications 17. Presentations at energy conferences 18. Scenario results browser on BioEnergy KDF

Future Plans and Directions

FY2015	Q2	scenario analysis on the implications of feedstock constraints for conversion pathways
	Q3	scenario analysis on the role of aviation, marine, and rail biofuels in the development of the bioeconomy
	Q4	integrated analysis on the effectiveness and cost of biofuels policies in the context of the development of a large scale domestic bioeconomy
FY2016	Q1	updated scenario library posted to ORNL's BioEnergy KDF
	Q2	Enhanced biomass/bioenergy scenario modeling capabilities: (i) RIN market effects, (ii) synergies with and drop-in points to petrochemical infrastructure, (iii) feedstock contracts, markets, densification, and localized pretreatment, (iv) high-value bio-products, (v) pathway-specific feedstocks, (vi) biorefinery investor behavior and risk, (vii) sensitivity analysis, (viii) publication of methodology, and (ix) publication on calibration and validation
	Q3	scenario analysis on how feedstock depot systems, advanced logistics, and biorefinery economy of scale affects the evolution of the bioeconomy
	Q4	integrated analysis on risks and only policies mitigating those risks in the context of the development of a large bioeconomy

The BSM provides unique insights into bioeconomy transitions.

- Challenge/Objective
  - Develop an analytic platform to explore and understand the entire bioenergy 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 bioenergy supply chain.
- Products
  - System-dynamics simulation of the bioenergy 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

- *"Results are being reported in complex ways, and scenarios are described in somewhat obscure technical terms. This undermines the value of simple intuitions that are possible with such a model."*
  - The project team has continued to expand the communication modalities used to communicate model results and to diversify the audiences to which results are communicated.
- *"This model problem needs to be evaluated to see if it is becoming too complex. Not much real information on the details of the modeling approach have been supplied in this review, but even that limited description may suggest that the project team has pushed too far in the direction of complexity over utility."*
  - We agree that the BSM is complex, but we feel that the model has the level of detail appropriate to support that complexity. Moreover, we have endeavored to limit the scope of the model to the key aspects of the biofuels supply chain that affect the overall evolution of the biofuels industry and its responsiveness to government policy and other external factors.
- *"The project team may want to consider developing a simpler version of the model that could be easily used and understood by a broader audience, and which would thus be less likely to be inappropriately used by others as a forecasting tool."*
  - The project team has indeed recently completed such a tool, called the Competition for the Use of Biomass (CUB) model, that is an order of magnitude simpler than the BSM, but that still yields useful insights and intuitions.

Major BSM Publications (March 2013-2015)

- Fact Sheets & Brochures
  - National Renewable Energy Laboratory. (2013). International Trade of Wood Pellets. NREL/BR-6A20-56791. Golden, CO: National Renewable Energy Laboratory.
  - National Renewable Energy Laboratory. (2013). International Trade of Biofuels. NREL/BR-6A20-56792. Golden, CO: National Renewable Energy Laboratory.
- Journal Articles
  - Laura J. Vimmerstedt, Brian W. Bush, Dave D. Hsu, Daniel Inman, and Steven O. Peterson.. (2014). "Maturation of biomass-to-biofuels conversion technology pathways for rapid expansion of biofuels production: a system dynamics perspective". *Biofpr, Biofuels, Bioproducts and Biorefining*.
  - C. M. Clark, Y. Lin, B. G. Bierwagen, L. M. Eaton, M. H. Langholtz, P. E. Morefield, C. E. Ridley, L. Vimmerstedt, S. Peterson, and B. W. Bush. (2013). "Growing a sustainable biofuels industry: economics, environmental considerations, and the role of the Conservation Reserve Program." *IOPScience, Environmental Research Letters*, vol. 8, no. 2, p. 025016. JA-6A20-56025.
- Book Chapters
  - D. Inman, L. Vimmerstedt, E. Newes, B. Bush, and S. Peterson. (2015). "Using system dynamics to model industry's developmental response to energy policy" *The Handbook of Applied Systems Science* (Routledge Publishing).
- Subcontractor Reports
  - S. Peterson. (2013). An Overview of the Biomass Scenario Model. Work performed by Lexidyne, LLC, Colorado Springs, CO. Golden, CO: National Renewable Energy Laboratory.
- Technical Reports
  - D. Inman, L. Vimmerstedt, E. Newes, B. Bush, and S. Peterson. (2014). Biomass Scenario Model Scenario Library: Definitions, Construction, and Description. NREL/TP-6A20-60386. Golden, CO: National Renewable Energy Laboratory.
  - L. J. Vimmerstedt, B. W. Bush, and S. Peterson. (2013). Effects of Deployment Investment on the Growth of the Biofuels Industry. NREL/TP-6A20-60802. Golden, CO: National Renewable Energy Laboratory.
  - Y. Lin, E. Newes, B. Bush, S. Peterson, and D. Stright. (2013). Biomass Scenario Model Documentation: Data and References. NREL/TP-6A20-57831. Golden, CO: National Renewable Energy Laboratory.
- Conference Papers
  - S. Peterson, E. Newes, D. Inman, L. Vimmerstedt, D. Hsu, C. Peck, D. Stright, and B. Bush. (2013). An Overview of the Biomass Scenario Model. *31st International Conference of the System Dynamics Society*.
- Presentations
  - B. Bush. (2013). Biomass-to-Bioenergy Supply-Chain Scenario Analysis. PR-6A20-58631 (Internal only).
  - B. Bush. (2013). Applications of the Biomass Scenario Model. *U.S. Energy Information Administration Workshop on Biofuels Projections in the Annual Energy Outlook (AEO).*