Biomass Scenario Model (BSM)
Previously Explored Analysis Questions and Publications

BSM Analysis Questions

The BSM has been used to explore a variety of bioenergy-related questions. Major topics of BSM analysis are listed below, along with overarching analytic questions for some of these topics, related publications, and detailed analytic questions. The detailed analysis questions have all been explored using the BSM, and some of these explorations supported publications. The Caveats documentation gives a summary of limitations of BSM analysis (http://www.nrel.gov/docs/fy17osti/68438.pdf).

Major Topics Index (click topic to skip to that section)

Bioeconomy

What conditions favor development of a bioeconomy, and what might be their effects?

Publications 1, 27

Detailed Questions

1. How might greater use of biomass develop across multiple economic sectors, and what are the effects of such development?
2. What are the implications of a "chemicals from biomass" industry for the development of the biofuel industry?
3. How can the BSM be used to explore a bioeconomy?

Aviation

How might an alternative jet fuel market grow, and what are its potential effects, including effects on biofuels industry development?

Publications 2, 3, 4, 17

Detailed Questions

4. How do offtake agreements between biomass-to-biofuel conversion facilities and airlines impact future biofuels industry growth?
5. What is the potential magnitude of premium paid for alternative jet fuel?
6. What is the overall impact that long-term production contracts for infrastructure-compatible fuels could have on the biofuels industry?
7. What are the broad near- and long-term biofuels industry impacts of scenarios involving the government-financed construction of biomass-to-jet-fuel production plants?

Marine

Detailed Questions

8. With the more stringent North America Emissions Control Area, can biofuels play a role in meeting low-sulfur emission requirements?
9. Does a partially upgraded pyrolysis oil have the potential to compete with a low-sulfur diesel in marine applications?

Deployment

What are the potential effects of varying levels of deployment investment on biorefinery construction?

Publications 7, 19

Feedstock

What are the potential effects of different feedstock system conditions, such as production, technologies, and incentives, on the biofuels system as a whole?

Publications 21, 26

Detailed Questions

10. What impact do potential feedstock-conversion coupling options have on the biofuel industry?
11. What are the system implications of an advanced uniform format feedstock supply and logistics system?
12. What are the potential impacts of extreme weather, climate change, and feedstock exports on feedstock supply and the biofuel industry?
13. What are the effects of different land bases and subsidy schemes on the development of the biofuels industry, especially conservation reserve program land?
14. What is the impact of the Biomass Crop Assistance Program and feedstock prices on the cellulosic ethanol industry supply chain?
15. What is the impact of a transitioning to a more advanced biomass logistics system on the cellulosic biofuels supply chain?

Conversion Pathways

Detailed Questions

16. How do changes in techno-economic assumptions about biomass-to-biofuels conversion technology pathways affect biofuels production?

Policies and Incentives

What policies and incentives most effectively grow a biofuels industry?

Publications 6, 14, 18, 29

Detailed Questions

17. What is the influence of trends and variability in renewable identification number prices upon the long-term growth of the biofuels industry under several policy and incentive scenarios?
18. What are the potential impacts of international emissions trading?
19. How can the BSM be applied to assess technology and industry goals and incentive costs?
20. What is the rate of return for broad government-financed investment and incentives in the biomass-to-biofuels supply chain?
21. What is an effective policy set that facilitates the development of the biofuels supply chain while maintaining a low risk of unintended consequences, such as excessive government expenditures or boom-and-bust cycles in commodity markets?
22. What impact would a reverse auction (as proposed in Energy Policy Act of 2005, Section 942) have on the cellulosic ethanol industry?
23. What is the tradeoff in effectiveness between volumetric ethanol credits (such as the Volumetric Ethanol Excise Tax Credit and other tax credits for starch and/or cellulosic ethanol) versus capital cost reduction for conversion plants and distribution/dispensing infrastructure?
24. What will it take for the cellulosic ethanol industry to develop, and what are the repercussions?

Fuel Demand by Fuel Type

Publications 9, 28

Detailed Questions

25. What is the influence of light-duty-vehicles' demand for ethanol on the overall evolution of the biofuels industry?
26. When hydrocarbons are included in the BSM, what are the implications for the cellulosic ethanol industry and for reaching Renewable Fuel Standard (RFS) volumes?

Sensitivity Analysis

Which of the model variables have the largest impact on BSM results?

Publication 14

Model Development

Detailed Questions

27. What is the correct formulation of E85 price for models like the BSM?
28. What are the learning dynamics involved in the decision to build a cellulosic conversion facility? (Publications 13, 16)
29. What are sources for key data? (Publications 10, 15, 23, 24)

BSM Publications

Publications from 2012-2017 are listed below in reverse chronological order. These are cross-referenced to analytic questions above. A complete list of publications may be found here: https://www.zotero.org/groups/209264/bsm_publications/items. Publications that provide overviews of the BSM include numbers 5, 8, 11, 12, 20, 22, 25.

1. Exploring Bioeconomy Growth through the Public Release of the Biomass Scenario Model

Mary Biddy, Brian Bush, Daniel Inman, Emily Newes, Steve Peterson, Laura Vimmerstedt

July 2017
Document: Poster
Document No.: NREL/PO-6A20-68784

https://www.nrel.gov/docs/fy17osti/68784.pdf

The Biomass Scenario Model (BSM) is an important tool for exploring vibrant future bioeconomy scenarios that leverage domestic resources. Developed by NREL and BETO, this model of the domestic biofuels supply chain has been used to explore success strategies for BETO's activities towards bioeconomy growth. The BSM offers a robust test bed for detailed exploration of effects of BETO activities within the complex context of resource availability; physical, technological, and economic constraints; behavior; and policy. The public release of the model in 2017 will allow broad engagement with the theme of the conference as model users can analyze bioeconomy growth, domestic biomass resource use, and associated effects. The BSM is a carefully validated, state-of-the-art, dynamic model of the biomass to biofuels supply chain. Using a system dynamics simulation modeling approach, the model tracks long-term deployment of biofuels given technology development and investment, considering land availability, the competing oil market, consumer demand, and government policies over time. Sample outputs include biofuels production, feedstock use, capital investment, incentives, and costs of feedstocks and fuels. BSM scenarios reveal technological, economic, and policy challenges, as well as opportunities for dynamic growth of the bioeconomy with strategic public and private investment at key points in the system. The model logic and results have been reviewed extensively, through collaborative analysis, expert reviews and external publications (https://www.zotero.org/groups/bsm_publications/).

2. ASCENT 1 Scenario Analyses using the Freight and Fuel Transportation Optimization Tool (FTOT) and Biomass Scenario Model (BSM)

Lewis, K., Newes, Emily, Steve Peterson, M. Pearlson, E. Lawless, M. Wolcott, D. Camezind

Document: Poster (publication pending)

3. Potential Avenues for Significant Biofuels Penetration in the U.S. Aviation Market

Emily Newes, Jeongwoo Han, Steve Peterson

April 2017
Document: Technical Report
Document No.: NREL/TP-6A20-67482

https://www.nrel.gov/docs/fy17osti/67482.pdf

Industry associations have set goals to reduce greenhouse gas (GHG) emissions and increase fuel efficiency. One focal area for reducing GHG emissions is in the use of aviation biofuel. This study examines assumptions under which the United States could see large production in aviation biofuel. Our results suggest that a high penetration (6 billion gallons) of aviation biofuels by 2030 could be possible, but factors around policy design (in the absence of high oil prices) contribute to the timing and magnitude of aviation biofuels production: 1) Incentives targeted towards jet fuel production such as financial incentives (e.g., producer tax credit, carbon tax) can be sufficient; 2) Investment in pre-commercial cellulosic technologies is needed to reduce the cost of production through learning-by-doing; 3) Reduction of investment risk through loan guarantees may allow production to ramp up more quickly through accelerating industry learning. In cases with high levels of incentives and investment in aviation biofuels, there could be a 25 percent reduction in overall GHG emissions from the aviation sector.

4. Effect of Additional Incentives for Aviation Biofuel: Results from the Biomass Scenario Model

Laura Vimmerstedt and Emily Newes

March 2017
Document: Presentation

https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/031717nrel_presentation.pdf

5. Systems Analysis and Modeling-Biomass Scenario Model

Emily Newes

March 2017
Document: Presentation

https://www.energy.gov/sites/prod/files/2017/05/f34/analysis_and_sustainability_newes_4.1.2.1.pdf

6. Using system dynamics to model industry's developmental response to energy policy

Brian Bush, Daniel Inman, Emily Newes, Corey Peck, Steve Peterson, Dana Stright, Laura Vimmerstedt

November 2016
Document: Book Chapter

https://www.routledgehandbooks.com/doi/10.4324/9781315748771.ch15

In this chapter we explore the potential development of the biofuels industry using the Biomass Scenario Model (BSM), a system dynamics model developed at the National Renewable Energy Laboratory through the support of the U.S. Department of Energy. The BSM is designed to analyze the implications of policy on the development of the supply chain for biofuels in the United States. It explicitly represents the behavior of decision makers such as farmers, investors, fueling station owners, and consumers. We analyze several illustrative case studies that explore a range of policies and discuss how incentives interact with individual parts of the supply chain as well as the industry as a whole. The BSM represents specific incentives that are intended to approximate policy in the form of selected laws and regulations. Through characterizing the decision making behaviors of economic actors within the supply chain that critically influence the adoption rate of new biofuels production technologies and demonstrating synergies among policies, we find that incentives with coordinated impacts on each major element of the supply chain catalyze net effects of decision maker behavior such that the combined incentives are greater than the summed effects of individual incentives in isolation.

7. Effects of Deployment Investment on the Growth of the Biofuels Industry: 2016 Update

Laura Vimmerstedt, Ethan Warner, Dana Stright

March 2016
Document: Technical Report
Document No.: NREL/TP-6A20-65903

https://www.nrel.gov/docs/fy16osti/65903.pdf

This report updates the 2013 report of the same title. Some text originally published in that report is retained and indicated in gray. In support of the national goals for biofuel use in the United States, numerous technologies have been developed that convert biomass to biofuels. Some of these biomass to biofuel conversion technology pathways are operating at commercial scales, while others are in earlier stages of development. The advancement of a new pathway toward commercialization involves various types of progress, including yield improvements, process engineering, and financial performance. Actions of private investors and public programs can accelerate the demonstration and deployment of new conversion technology pathways. These investors (both private and public) will pursue a range of pilot, demonstration, and pioneer scale biorefinery investments; the most cost-effective set of investments for advancing the maturity of any given biomass to biofuel conversion technology pathway is unknown. In some cases, whether or not the pathway itself will ultimately be technically and financially successful is also unknown. This report presents results from the Biomass Scenario Model--a system dynamics model of the biomass to biofuels system--that estimate effects of investments in biorefineries at different maturity levels and operational scales. The report discusses challenges in estimating effects of such investments and explores the interaction between this deployment investment and a volumetric production incentive. Model results show that investments in demonstration and deployment have a substantial growth impact on the development of the biofuels industry. Results also show that other conditions, such as accompanying incentives, have major impacts on the effectiveness of such investments. Results from the 2013 report are compared to new results. This report does not advocate for or against investments, incentives, or policies, but analyzes simulations of their hypothetical effects.

8. Overview of the Biomass Scenario Model

Steve Peterson, Corey Peck, Dana Stright, Emily Newes, Danny Inman, Laura Vimmerstedt, David Hsu, Brian Bush

February 2015
Document: Conference Report
Document No.: NREL/CP-6A20-60172

https://www.nrel.gov/docs/fy15osti/60172.pdf

Biofuels are promoted in the United States through legislation, as one part of an overall strategy to lessen dependence on imported energy as well as to reduce the emissions of greenhouse gases (Office of the Biomass Program and Energy Efficiency and Renewable Energy, 2008). For example, the Energy Independence and Security Act of 2007 (EISA) mandates 36 billion gallons of renewable liquid transportation fuel in the U.S. marketplace by the year 2022 (U.S. Government, 2007). Meeting the volumetric targets has prompted an unprecedented increase in funding for biofuels research, much of it focused on producing ethanol and other fuel types from cellulosic feedstocks as well as additional biomass sources (such as oil seeds and algae feedstock). In order to help propel the biofuels industry, the U.S. government has enacted a variety of incentive programs (including subsidies, fixed capital investment grants, loan guarantees, vehicle choice credits, and corporate average fuel economy standards) -- the short-and long-term ramifications of which are not well understood. Efforts to better understand the impacts of incentive strategies can help policy makers to develop a policy suite which will foster industry development while reducing the financial risk associated with government support of the nascent biofuels industry.

9. High-Octane Mid-Level Ethanol Blend Market Assessment

Caley Johnson, Emily Newes, Aaron Brooker, Robert McCormick, Steve Peterson, Paul Leiby, Rocio Uria Martinez, Gbadebo Oladosu, Maxwell Brown

December 2015
Document: Technical Report
Document No.: NREL/TP-6A20-63698

https://www.nrel.gov/docs/fy16osti/63698.pdf

The United States government has been promoting increased use of biofuels, including ethanol from non-food feedstocks, through policies contained in the Energy Independence and Security Act of 2007. The objective is to enhance energy security, reduce greenhouse gas (GHG) emissions, and provide economic benefits. However, the United States has reached the ethanol blend wall, where more ethanol is produced domestically than can be blended into standard gasoline. Nearly all ethanol is blended at 10 volume percent (vol%) in gasoline. At the same time, the introduction of more stringent standards for fuel economy and GHG tailpipe emissions is driving research to increase the efficiency of spark ignition (SI) engines. Advanced strategies for increasing SI engine efficiency are enabled by higher octane number (more highly knock-resistant) fuels. Ethanol has a research octane number (RON) of 109, compared to typical U.S. regular gasoline at 91-93. Accordingly, high RON ethanol blends containing 20 vol% to 40 vol% ethanol are being extensively studied as fuels that enable design of more efficient engines. These blends are referred to as high-octane fuel (HOF) in this report. HOF could enable dramatic growth in the U.S. ethanol industry, with consequent energy security and GHG emission benefits, while also supporting introduction of more efficient vehicles. HOF could provide the additional ethanol demand necessary for more widespread deployment of cellulosic ethanol. However, the potential of HOF can be realized only if it is adopted by the motor fuel marketplace. This study assesses the feasibility, economics, and logistics of this adoption by the four required participants--drivers, vehicle manufacturers, fuel retailers, and fuel producers. It first assesses the benefits that could motivate these participants to adopt HOF. Then it focuses on the drawbacks and barriers that these participants could face when adopting HOF and proposes strategies--including incentives and policies--to curtail these barriers. These curtailment strategies are grouped into scenarios that are then modeled to investigate their feasibility and explore the dynamics involved in HOF deployment. This report does not advocate for or against incentives or policies, but presents simulations of their effects.

10. 2015 Survey of Non-Starch Ethanol and Renewable Hydrocarbon Biofuels Producers

Amy Schwab, Ethan Warner, John Lewis

January 2016
Document: Technical Report
Document No.: NREL/TP-6A20-65519

https://www.nrel.gov/docs/fy16osti/65519.pdf

In order to understand the anticipated status of the industry for non-starch ethanol and renewable hydrocarbon biofuels as of the end of calendar year 2015, the National Renewable Energy Laboratory (NREL) conducted its first annual survey update of U.S. non-starch ethanol and renewable hydrocarbon biofuels producers. This report presents the results of this survey, describes the survey methodology, and documents important changes since the 2013 survey.

11. Biomass Scenario Model Fact Sheet

Brian Bush

October 2015
Document: Fact Sheet
Document No.: NREL/FS-6A20-64956

http://www.nrel.gov/docs/fy16osti/64956.pdf

The Biomass Scenario Model (BSM) is a unique, carefully validated, state-of-the-art dynamic model of the domestic biofuels supply chain which explicitly focuses on policy issues, their feasibility, and potential side effects. It integrates resource availability, physical/technological/economic constraints, behavior, and policy. The model uses a system dynamics simulation (not optimization) to model dynamic interactions across the supply chain.

12. "An Overview of the Biomass Scenario Model: July 2006 – July 2011"

Steve Peterson

September 2015
Document: Subcontractor Report
Document No.: NREL/ SR-6A20-62459

http://www.nrel.gov/docs/fy16osti/62459.pdf

This report describes the structure of the October 2012 version of the Biomass Scenario Model (BSM) in considerable detail, oriented towards readers with a background or interest in the underlying modeling structures. Readers seeking a less-detailed summary of the BSM may refer to Peterson (2013). BSM aims to provide a framework for exploring the potential contribution of biofuel technologies to the transportation energy supply for the United States over the next several decades. The model has evolved significantly from the prototype developed as part of the Role of Biomass in America's Energy Future (RBAEF) project. BSM represents the supply chain surrounding conversion pathways for multiple fuel products, including ethanol, butanol, and infrastructure-compatible biofuels such as diesel, jet fuel, and gasoline.

13. Dynamic Modeling of Learning in Emerging Energy Industries: The Example of Advanced Biofuels in the United States

Laura J. Vimmerstedt and Brian W. Bush

July 2015
Document: Conference Paper
Document No.: NREL/CP-6A20-60984

http://www.nrel.gov/docs/fy15osti/60984.pdf

This paper (and its supplemental model) presents novel approaches to modeling interactions and related policies among investment, production, and learning in an emerging competitive industry. New biomass-to-biofuels pathways are being developed and commercialized to support goals for U.S. advanced biofuel use, such as those in the Energy Independence and Security Act of 2007. We explore the impact of learning rates and techno-economics in a learning model excerpted from the Biomass Scenario Model (BSM), developed by the U.S. Department of Energy and the National Renewable Energy Laboratory to explore the impact of biofuel policy on the evolution of the biofuels industry. The BSM integrates investment, production, and learning among competing biofuel conversion options that are at different stages of industrial development. We explain the novel methods used to simulate the impact of differing assumptions about mature industry techno-economics and about learning rates while accounting for the different maturity levels of various conversion pathways. A sensitivity study shows that the parameters studied (fixed capital investment, process yield, progress ratios, and pre-commercial investment) exhibit highly interactive effects, and the system, as modeled, tends toward market dominance of a single pathway due to competition and learning dynamics. https://www.zotero.org/groups/209264/bsm_publications/items.

14. "Potential leverage points for development of the cellulosic ethanol industry supply chain"

Emily K. Newes, Brian W. Bush, Corey T. Peck & Steven O. Peterson

May 2015

Document: Journal Article
Document No.: NREL/ JA-6A20-62473

http://www.tandfonline.com/doi/full/10.1080/17597269.2015.1039452#.VbfXR_lVhBc

The potential long-term impacts and systemic effects of incentives are of great interest to the biofuels industry and decision makers, particularly with regards to forthcoming mandates for biofuels. We have used the Biomass Scenario Model (BSM) to build a theoretical understanding of the role of incentives on the evolution of the biomass-to-biofuels market. It models a broad range of biofuels such as renewable gasoline, diesel, and aviation fuel. In this paper, we focus on cellulosic ethanol as we describe model-based insights into potential incentives that are aimed at stimulating industry growth while tempering overall incentive-related government expenditures. Subsequent research can test the key insights gained through BSM simulations against actual policy implementation and actual outcomes.

15. "2013 Survey of Non-Starch Ethanol and Renewable Hydrocarbon Biofuels Producers"

A. Schwab, J. Geiger, J. Lewis

January 2015
Document: Research Report
Document No.: NREL/TP- 6A10-63389

http://www.nrel.gov/docs/fy15osti/63389.pdf
10.2172/1169794

In order to understand the status of the industry for non-starch ethanol and renewable hydrocarbon biofuels as of the end of calendar year 2013, the National Renewable Energy Laboratory (NREL) conducted a survey of U.S. non-starch ethanol and renewable hydrocarbon biofuels producers. This report presents the results of this survey and describes the survey methodology. These survey results were also used to update the baseline plant start schedule in the BSM in September 2014.
Seventy-four companies were selected because of their reported commercial-scale biofuels production capacity (or intentions of developing commercial-scale production capacity) as of December 31, 2013. Representatives from these companies were asked a standard set of questions during the second half of 2014. The questionnaire topics included facility stage of development, facility scale, feedstock, and biofuel products. The responses were validated by industry experts from NREL and the U.S. Department of Energy (DOE) and compared with publicly available data. Missing survey data elements were supplemented (when possible) with publicly available data obtained directly from company websites, press releases, and public filings. Sufficient data from 25 non-starch ethanol facilities (24 cellulosic ethanol facilities plus one algal-derived ethanol facility) and 17 renewable hydrocarbon facilities (for production of cellulosic renewable gasoline and/or cellulosic diesel) were obtained and validated to

justify inclusion of these facilities in this survey report. Data for these 42 facilities were included in this report.

16. "Maturation of biomass-to-biofuels conversion technology pathways for rapid expansion of biofuels production: a system dynamics perspective"

Laura J. Vimmerstedt, Brian W. Bush, Dave D. Hsu, Daniel Inman, and Steven O. Peterson

August 2014
Document: Journal Article
Document No.: NREL/JA-6A20-60444

http://dx.doi.org/10.1002/bbb.1515

The Biomass Scenario Model (BSM) is a system-dynamics simulation model intended to explore the potential for rapid expansion of the biofuels industry. The model is not predictive — it uses scenario assumptions based on various types of data to simulate industry development, emphasizing how incentives and technological learning-by-doing might accelerate industry growth. The BSM simulates major sectors of the biofuels industry, including feedstock production and logistics, conversion, distribution, and end uses, as well as interactions among sectors. The model represents conversion of biomass to biofuels as a set of technology pathways, each of which has allowable feedstocks, capital and operating costs, allowable products, and other defined characteristics. This study and the BSM address bioenergy modeling analytic needs that were identified in recent literature reviews. Simulations indicate that investments are most effective at expanding biofuels production through learning-by-doing when they are coordinated with respect to timing, pathway, and target sector within the biofuels industry. Effectiveness metrics include timing and magnitude of increased production, incentive cost and cost effectiveness, and avoidance of windfall profits. Investment costs and optimal investment targets have inherent risks and uncertainties, such as the relative value of investment in more-mature versus less mature pathways. These can be explored through scenarios, but cannot be precisely predicted. Dynamic competition, including competition for cellulosic feedstocks and ethanol market shares, intensifies during times of rapid growth. Ethanol production increases rapidly, even up to Renewable Fuel Standards-targeted volumes of biofuel, in simulations that allow higher blending proportions of ethanol in gasoline-fueled vehicles.

17. "An Overview of Aviation Fuel Markets for Biofuels Stakeholders"

Carolyn Davidson, Emily Newes, Amy Schwab, and Laura Vimmerstedt

July 2014
Document: Research Report
Document No.: NREL/TP-6A20-60254

http://www.osti.gov/scitech/biblio/1148623/

This report is for biofuels stakeholders interested the U.S. aviation fuel market. Jet fuel production represents about 10% of U.S. petroleum refinery production. Exxon Mobil, Chevron, and BP are top producers, and Texas, Louisiana, and California are top producing states. Distribution of fuel primarily involves transport from the Gulf Coast to other regions. Fuel is transported via pipeline (60%), barges on inland waterways (30%), tanker trucks (5%), and rail (5%). Airport fuel supply chain organization and fuel sourcing may involve oil companies, airlines, airline consortia, airport owners and operators, and airport service companies. Most fuel is used for domestic, commercial, and civilian flights. Energy efficiency has substantially improved due to aircraft fleet upgrades and advanced flight logistic improvements. Jet fuel prices generally track prices of crude oil and other refined petroleum products, whose prices are more volatile than crude oil price. The single largest expense for airlines is jet fuel, so its prices and persistent price volatility impact industry finances. Airlines use various strategies to manage aviation fuel price uncertainty. The aviation industry has established goals to mitigate its greenhouse gas emissions, and initial estimates of biojet life cycle greenhouse gas emissions exist. Biojet fuels from Fischer-Tropsch and hydroprocessed esters and fatty acids processes have ASTM standards. The commercial aviation industry and the U.S. Department of Defense have used aviation biofuels. Additional research is needed to assess the environmental, economic, and financial potential of biojet to reduce greenhouse gas emissions and mitigate long-term upward price trends, fuel price volatility, or both.

18. "Biomass scenario model scenario library: definitions, construction, and description,"

D. Inman, L. Vimmerstedt, E. Newes, B. Bush, and S. Peterson

April 2014
Document: Research Report
Document No.: TP-6A20-60386

http://dx.doi.org/10.2172/1129277

Understanding the development of the biofuels industry in the United States is important to policymakers and industry. The Biomass Scenario Model (BSM) is a system dynamics model of the biomass-to-biofuels system that can be used to explore many aspects of the industry. Because of the complexity of the model, as well as the wide range of possible future conditions that affect biofuels industry development, we have not developed a single reference case but instead have designed a set of six incentive-focused scenarios. The purpose of this report is to describe the scenarios that comprise the BSM scenario library. At present, we have the following six incentive-focused scenarios in our library: minimal incentives scenario; ethanol-focused incentives scenario; equal access to incentives scenario; output-focused incentives scenario; pathway-diversity-focused incentives scenario; and the point-of-production-focused incentives scenario. This report describes the model settings and rationale for each scenario.

19. “Effects of Deployment Investment on the Growth of the Biofuels Industry”

L. J. Vimmerstedt, B. W. Bush, and S. Peterson

December 2013
Document: Research Report
Document No.: NREL/TP-6A20-60802

http://dx.doi.org/10.2172/1118095

In support of the national goals for biofuel use in the United States, numerous technologies have been developed that convert biomass to biofuels. Some of these biomass-to-biofuel conversion technology pathways are fully commercial, while others are in earlier stages of development. The advancement of a new pathway towards commercialization involves various types of improvements, including yield improvements through chemical and biochemical refinements, process engineering, and financial performance. Actions of private investors and public programs can accelerate the demonstration and deployment of new conversion technology pathways. These investors (both private and public) will pursue a range of pilot-, demonstration-, and pioneer-commercial-scale biorefinery investments, because the most cost-effective set of investments for advancing the maturity of the pathway is unknown. In some cases whether or not the pathway itself will ultimately be technically and financially successful is unknown. This report presents results from the Biomass Scenario Model—a system dynamics model of the biomass-to-biofuels system—that estimate effects of investment in one particular demonstration and deployment plan. This plan is a multi-stage combination of pilot, demonstration, and pioneer-commercial-scale biorefineries. The report discusses challenges in estimating effects of such investments. The report concludes that investment in demonstration and deployment appears to have a substantive positive effect on the development of the biofuels industry, and that other conditions, such as supportive policies, are likely to have major impacts on the effectiveness of such investments.

20. “An Overview of the Biomass Scenario Model”

S. Peterson, E. Newes, D. Inman, L. Vimmerstedt, D. Hsu, C. Peck, D. Stright, and B. Bush

July 2013
Document: Conference Paper

http://www.systemdynamics.org/conferences/2013/proceed/papers/P1352.pdf

Biofuels are promoted in the United States through aggressive legislation as one part of an overall strategy to lessen dependence on imported energy as well as to reduce the emissions of greenhouse gases. Meeting mandated volumetric targets has prompted substantial funding for biofuels research, much of it focused on producing ethanol and other fuel types from biomass feedstocks. A variety of incentive programs (including subsidies, fixed capital investment grants, loan guarantees, vehicle choice credits, and aggressive corporate average fuel economy standards) have been developed, but their short-and long-term ramifications are not well known. This paper describes the Biomass Scenario Model, a system dynamics model developed under the support of the U.S. Department of Energy as the result of a multi-year project at the National Renewable Energy Laboratory. The model represents multiple pathways leading to the production of fuel ethanol as well as advanced biofuels such as biomass-based gasoline, diesel, jet fuel, and butanol). This paper details the BSM system dynamics architecture, the design of the supporting database infrastructure, the associated scenario libraries used in model runs, as well as key insights resulting from BSM simulations and analyses.

21. "Growing a sustainable biofuels industry: economics, environmental considerations, and the role of the Conservation Reserve Program"

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

***Environ. Res. Lett.*, vol. 8, no. 2, p. 025016**

June 2013
Document: Journal Article
Document No.: JA-6A20-56025

http://dx.doi.org/10.1088/1748-9326/8/2/025016

Biofuels are expected to be a major contributor to renewable energy in the coming decades under the RFS. These fuels have many attractive properties including the promotion of energy independence, rural development, and the reduction of national carbon emissions. However, several unresolved environmental and economic concerns remain. Environmentally, much of the biomass is expected to come from agricultural expansion and/or intensification, which may greatly affect the net environmental impact, and economically, the lack of a developed infrastructure and bottlenecks along the supply chain may affect the industry's economic vitality. The approximately 30 million acres (12 million hectares) under the Conservation Reserve Program (CRP) represent one land base for possible expansion. Here, we examine the potential role of the CRP in biofuels industry development, by (1) assessing the range of environmental effects on six end points of concern, and (2) simulating differences in potential industry growth nationally using a systems dynamics model. The model examines seven land-use scenarios (various percentages of CRP cultivation for biofuel) and five economic scenarios (subsidy schemes) to explore the benefits of using the CRP. The environmental assessment revealed wide variation in potential impacts. Lignocellulosic feedstocks had the greatest potential to improve the environmental condition relative to row crops, but the most plausible impacts were considered to be neutral or slightly negative. Model simulations revealed that industry growth was much more sensitive to economic scenarios than land-use scenarios—similar volumes of biofuels could be produced with no CRP as with

100% utilization. The range of responses to economic policy was substantial, including long-term market stagnation at current levels of first-generation biofuels under minimal policy intervention, or RFS-scale quantities of biofuels if policy or market conditions were more favorable. In total, the combination of the environmental assessment and the supply chain model suggests that large-scale conversion of the CRP to row crops would likely incur a significant environmental cost, without a concomitant benefit in terms of biofuel production.

22. “The “Biomass Scenario Model Documentation: Data and References”

Y. Lin, E. Newes, B. Bush, S. Peterson, and D. Stright

May 2013
Document: Research Report
Document No.: NREL/TP-6A20-57831

http://www.osti.gov/bridge/servlets/purl/1082565/

The Biomass Scenario Model (BSM) is a system dynamics model that represents the entire biomass-to-biofuels supply chain, from feedstock to fuel use. The BSM is a complex model that has been used for extensive analyses; the model and its results can be better understood if input data used for initialization and calibration are well-characterized. It has been carefully validated and calibrated against the available data, with data gaps filled in using expert opinion and internally consistent assumed values. Most of the main data sources that feed into the model are recognized as baseline values by the industry. This report documents data sources and references in Version 2 of the BSM (BSM2), which only contains the ethanol pathway, although subsequent versions of the BSM contain multiple conversion pathways. The BSM2 contains over 12,000 total input values, with 506 distinct variables. Many of the variables are opportunities for the user to define scenarios, while others are simply used to initialize a stock, such as the initial number of biorefineries. However, around 35% of the distinct variables are defined by external sources, such as models or reports. The focus of this report is to provide insight into which sources are most influential in each area of the supply chain. We find that data based on POLYSYS datasets and U.S. Department of Agriculture baseline projections are the most utilized sources in the feedstock sector, whereas the conversion module relies heavily on data found in National Renewable Energy Laboratory technical reports dealing with the techno-economic characteristics of different technologies. The distribution, dispensing, and fuel use modules utilize data on gasoline stations from the National Association of Convenience Stores.

23. “International Trade of Wood Pellets”

National Renewable Energy Laboratory

May 2013
Document: Fact Sheet

Document No.: NREL/BR-6A20-56791

http://www.osti.gov/bridge/servlets/purl/1079729/

The production of wood pellets has increased dramatically in recent years due in large part to aggressive emissions policy in the European Union; the main markets that currently supply the European market are North America and Russia. However, current market circumstances and trade dynamics could change depending on the development of emerging markets, foreign exchange rates, and the evolution of carbon policies. This fact sheet outlines the existing and potential participants in the wood pellets market, along with historical data on production, trade, and prices.

24. "International Trade of Biofuels"

National Renewable Energy Laboratory

May 2013
Document: Fact Sheet
Document No.: BR-6A20-56792
http://www.osti.gov/bridge/servlets/purl/1079733/

In recent years, the production and trade of biofuels has increased to meet global demand for renewable fuels. Ethanol and biodiesel contribute much of this trade because they are the most established biofuels. Their growth has been aided through a variety of policies, especially in the European Union, Brazil, and the United States, but ethanol trade and production have faced more targeted policies and tariffs than biodiesel. This fact sheet contains a summary of the trade of biofuels among nations, including historical data on production, consumption, and trade.

25. "Applications of the Biomass Scenario Model"

B. Bush

March 2013
Document: Presentation

http://www.eia.gov/biofuels/workshop/presentations/2013/pdf/presentation-14-032013.pdf

U.S. policy targets 36 billion gallons per year of biofuels utilization by 2022, under the renewable fuels standard provisions of the Energy Independence and Security Act of 2007. Achieving such large scale biofuels adoption requires substantial development of new infrastructure, markets, and related systems. The U.S. Department of Energy is employing a system dynamics model, the Biomass Scenario Model (BSM), to represent the primary system effects and dependencies in the biomass-to-biofuels supply chain and to provide a framework for developing scenarios and conducting biofuels policy analysis. This approach is designed to help focus government action by determining which supply chain changes would have the greatest potential to accelerate the deployment of biofuels. Modeling the integration of all aspects of the supply chain from growing the feedstock through harvest, collection, transport, conversion, distribution of fuel and finally consumption of the fuel in applicable vehicles (including the availability of these vehicles) is critical to understanding where government funds might be utilized most effectively. This presentation provides an overview of the status of the BSM and a summary of recent results from system analysis based on it. We find that policies which are coordinated across the whole supply chain have significant impact in fostering the growth of the biofuels industry.

26. "Modeling biofuel expansion effects on land use change dynamics"

E. Warner, D. Inman, B. Kunstman, B. Bush, L. Vimmerstedt, S. Peterson, J. Macknick, and Y. Zhang,

January 2013
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Document No.: JA-6A20-56291

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Increasing demand for crop-based biofuels, in addition to other human drivers of land use, induces direct and indirect land use changes (LUC). Our system dynamics tool is intended to complement existing LUC modeling approaches and to improve the understanding of global LUC drivers and dynamics by allowing examination of global LUC under diverse scenarios and varying model assumptions. We report on a small subset of such analyses. This model provides insights into the drivers and dynamic interactions of LUC (e.g., dietary choices and biofuel policy) and is not intended to assert improvement in numerical results relative to other works. Demand for food commodities are mostly met in high food and high crop-based biofuel demand scenarios, but cropland must expand substantially. Meeting roughly 25% of global transportation fuel demand by 2050 with biofuels requires >2 times the land used to meet food demands under a presumed 40% increase in per capita food demand. In comparison, the high food demand scenario requires greater pastureland for meat production, leading to larger overall expansion into forest and grassland. Our results indicate that, in all scenarios, there is a potential for supply shortfalls, and associated upward pressure on prices, of food commodities requiring higher land use intensity (e.g., beef) which biofuels could exacerbate.

27. "Biomass Resource Allocation among Competing End Uses"

E. Newes, B. Bush, D. Inman, Y. Lin, T. Mai, A. Martinez, D. Mulcahy, W. Short, T. Simpkins, C. Uriarte, and C. Peck

May 2012
Document: Research Report
Document No.: TP-6A20-54217

http://www.osti.gov/bridge/servlets/purl/1041351/

The Biomass Scenario Model (BSM) is a system dynamics model developed by the U.S. Department of Energy as a tool to better understand the interaction of complex policies and their potential effects on the biofuels industry in the United States. However, it does not currently have the capability to account for allocation of biomass resources among the various end uses, which limits its utilization in analysis of policies that target biomass uses outside the biofuels industry. This report provides a more holistic understanding of the dynamics surrounding the allocation of biomass among uses that include traditional use, wood pellet exports, bio-based products and bioproducts, biopower, and biofuels by (1) highlighting the methods used in existing models' treatments of competition for biomass resources; (2) identifying coverage and gaps in industry data regarding the competing end uses; and (3) exploring options for developing models of biomass allocation that could be integrated with the BSM to actively exchange and incorporate relevant information.

28. "Ethanol Distribution, Dispensing, and Use: Analysis of a Portion of the Biomass-to-Biofuels Supply Chain Using System Dynamics"

L. J. Vimmerstedt, B. Bush, and S. Peterson

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May 2012
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Document No.: JA-6A2-47590

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The Energy Independence and Security Act of 2007 targets use of 36 billion gallons of biofuels per year by 2022. Achieving this may require substantial changes to current transportation fuel systems for distribution, dispensing, and use in vehicles. The U.S. Department of Energy and the National Renewable Energy Laboratory designed a system dynamics approach to help focus government action by determining what supply chain changes would have the greatest potential to accelerate biofuels deployment. The National Renewable Energy Laboratory developed the Biomass Scenario Model, a system dynamics model which represents the primary system effects and dependencies in the biomass-to-biofuels supply chain. The model provides a framework for developing scenarios and conducting biofuels policy analysis. This paper focuses on the downstream portion of the supply chain–represented in the distribution logistics, dispensing station, and fuel utilization, and vehicle modules of the Biomass Scenario Model. This model initially focused on ethanol, but has since been expanded to include other biofuels. Some portions of this system are represented dynamically with major interactions and feedbacks, especially those related to a dispensing station owner's decision whether to offer ethanol fuel and a consumer's choice whether to purchase that fuel. Other portions of the system are modeled with little or no dynamics; the vehicle choices of consumers are represented as discrete scenarios. This paper explores conditions needed to sustain an ethanol fuel market and identifies implications of these findings for program and policy goals. A large, economically sustainable ethanol fuel market (or other biofuel market) requires low end-user fuel price relative to gasoline and sufficient producer payment, which are difficult to achieve simultaneously. Other requirements (different for ethanol vs. other biofuel markets) include the need for infrastructure for distribution and dispensing and widespread use of high ethanol blends in flexible-fuel vehicles.

29. "Understanding the Developing Cellulosic Biofuels Industry through Dynamic Modeling"

E. Newes, D. Inman, and B. Bush

In *Economic Effects of Biofuel Production*, M. A. dos Santos Bernardes, Ed. Rijeka, Croatia: InTech, 2011, pp. 373–404.

August 2011
Document: Book Chapter
Document No.: CH-6A20-50782

http://www.intechopen.com/books/economic-effects-of-biofuel-production/understanding-the-developing-cellulosic-biofuels-industry-through-dynamic-modeling

Biofuels are promoted in the United States through aggressive legislation, as one part of an overall strategy to lessen dependence on imported energy as well as to reduce the emissions of greenhouse gases (Office of the Biomass Program and Energy Efficiency and Renewable Energy, 2008). For example, the Energy Independence and Security Act of 2007 (EISA) mandates 36 billion gallons of renewable liquid transportation fuel in the U.S. marketplace by the year 2022 (U.S. Government, 2007). Meeting such large volumetric targets has prompted an unprecedented increase in funding for biofuels research. Language in the EISA legislation limits the amount of renewable fuel derived from starch-based feedstocks (which are already established and feed the commercially viable ethanol industry in the United States); therefore, much of the current research is focused on producing ethanol—but from cellulosic feedstocks. These feedstocks, such as agricultural and forestry residues, perennial grasses, woody crops, and municipal solid wastes, are advantageous because they do not necessarily compete directly with food, feed, and fiber production and are envisaged to require fewer inputs (e.g., water, nutrients, and land) as compared to corn and other commodity crops. In order to help propel the biofuels industry in general and the cellulosic ethanol industry in particular, the U.S. government has enacted subsidies, fixed capital investment grants, loan guarantees, vehicle choice credits, and aggressive corporate average fuel economy standards as incentives. However, the effect of these policies on the cellulosic ethanol industry over time is not well understood. Policies such as those enacted in the United States, that are intended to incentivize the industry and promote industrial expansion, can have profound long-term effects on growth and industry takeoff as well as interact with other policies in unforeseen ways (both negative and positive). Qualifying the relative efficacies of incentive strategies could potentially lead to faster industry growth as well as optimize the government's investment in policies to promote renewable fuels. The purpose of this chapter is to discuss a system dynamics model called the Biomass Scenario Model (BSM), which is being developed by the U.S. Department of Energy as a tool to better understand the interaction of complex policies and their potential effects on the burgeoning cellulosic biofuels industry in the United States. The model has also recently been expanded to include advanced conversion technologies and biofuels (i.e., conversion pathways that yield biomass-based gasoline, diesel, jet fuel, and butanol), but we focus on cellulosic ethanol conversion pathways here. The BSM uses a system dynamics modeling approach (Bush et al., 2008) built on the STELLA software platform (isee systems, 2010) to model the entire biomass-to-biofuels supply chain. Key components of the BSM are shown in Figure 1. In addition to describing the underpinnings of this model, we will share insights that have been gleaned from a myriad of scenario- and policy-driven model runs. These insights will focus on how roadblocks, bottlenecks, and incentives all work in concert to have profound effects on the future of the industry.

Earlier publications may be found here:
https://www.zotero.org/groups/209264/bsm_publications/items.