DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

Biofuels National Strategic Benefits Analysis

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Strategic Analysis and Sustainability

Principal Investigator: Paul Leiby (ORNL)

Co-Investigators:

Rocio Uria-Martinez (ORNL)and Maxwell Brown (Colo. Sch. Of Mines)

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY

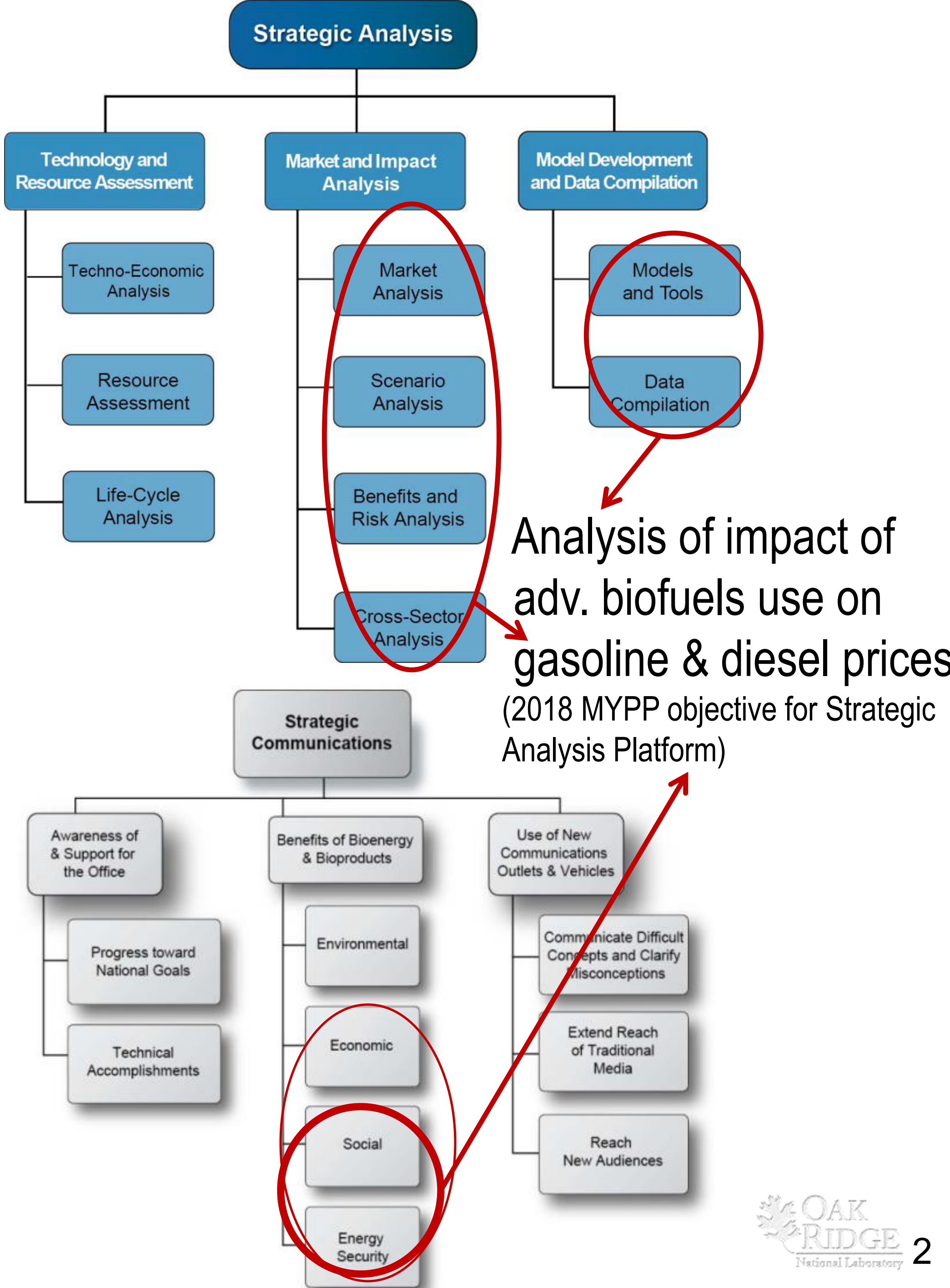
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Goal Statement

- To assess, quantify and explain potential **fuel market impacts** and overall **economic and security benefits** associated with biofuels

Relevance and tangible outcomes for the U.S.:

- Evaluating the benefits, costs and resilience of alternative biofuel supply chain configurations
- Provides insight on pathways to effectively achieve *economically sustainable* advanced biofuel industry
- Understand role and implications of biofuels in changing oil markets



Quad Chart Overview

Timeline

- Project start date: 12/15/2011
- Project end date: 09/30/ 2018
- Percent complete: 37%

Budget

	Total Costs FY 10 – FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date)
DOE Funded	$125K	$326K	$154K	$1050K
Project Cost Share (Comp.)*	0	0	0	0

Barriers

- Barriers addressed (from MYPP, Nov 2014)
  - St-A: Scientific Consensus on Bioenergy Sustainability
  - St-F: Systems Approach to Bioenergy Sustainability
  - At-B: Analytical Tools and Capabilities for System-Level Analysis
  - Ct-A: Lack of Acceptance and Awareness of Biofuels as a Viable Alternative Fuel

Partners

- Partners
  - Maxwell Brown (CO School of Mines)
  - NREL/INL for RIN analysis tasks
  - NREL/ANL for RSP task
- Other interactions/collaborations
  - NREL (for model scenario comparisons, data sharing and benchmarking)

1 - Project Overview

- **Context:**
  - Oil price volatility, Regulatory uncertainty (RFS-2), Blend wall
- **History:**
  - Past alt-fuel transitional analysis work (e.g., TAFV, HyTrans)
    - viewed as insightful for other EERE alternative fuel technical programs
  - Leverage models/data on biofuel supply chain segments (e.g., Billion Ton Study, BLM, TEA reports on conversion pathways)
    - how do they interact within biofuel supply chain and across the entire fuel market?
  - Prior oil security work for DOE, EPA can be brought to bear on biofuels
- **High level objectives of the project:**
  - Evaluating biofuels potential supply & demand under various market and policy contexts
  - Quantify costs & benefits of advanced biofuel penetration, with an emphasis on energy security and fuel market outcomes

2 – Approach (Technical)

Major challenges	Critical success factors
1. Understand likely extent/speed/cost of transition to advanced biofuels	• Develop/maintain biofuels market transition model: BioTrans* • Represent dynamic investment decisions and fuel/vehicle choice decisions (while imposing market equilibrium conditions)
2. Assess impact of biofuels on fuel market price levels and volatility	• Econometric analysis of past ethanol & gasoline market data (price levels and volatilities) • Identify triggers that disrupt the relationship (e.g., RIN constraints)
3. Define, measure and communicate energy security impacts of biofuels	• Energy security metric development and application to model scenarios

*See supplementary slides for diagram

2 – Approach (Management)

Major challenges	Critical success factors and Management
1. Model Validation	• Best practices on code version control, code structure & testing • Benchmarking choice, other parameters based on historical data • Testing/evaluating via Paired cases with BSM
2. Relating to Other Models/Analysis in the Same Space	• Data and soft-linkages to related models • PolySys, NEMS, VISION, ADOPT, MA3T, BSM, TEAs • Participate/Co-organize 2014 BioEnergy Modeling Workshop • Keep abreast of literature and findings from other researchers, BETO team communication
3. Establish Effective Model Scale and Scope	• Identify strengths/limitations, and focus of model • Periodically discuss key questions with BETO • BioTrans focus: national, downstream portion of supply chain, interactions between petroleum fuel market and biofuel market

3 – Technical Accomplishments/ Progress/Results

Tasks	Milestones
Task A: Development and Application of BioTrans for Improved Economic/Security Metrics	Report outlining methodological approach for improved economic/security benefits metrics and application to compare metrics for various portfolios of biofuel supply pathways
Task B: Assess Potential for Renewable Super Premium	Configure BioTrans for RSP scenarios (contributes top separate Multi-lab project)
Task C: Examine Influence of Risk Uncertainty on Biofuels Development	BioTrans model cases and presentation slides comparing biorefinery and retail infrastructure investment patterns under complete versus limited foresight, with uncertain future markets
Task D: Examine Effects of Biofuels on Fuel Price Volatility and Energy Security	Empirical analysis of historical ethanol and fuel market data testing for evidence of past biofuels influence on fossil fuel price volatility
Task E: RIN Market Analysis	RIN market regulatory and data analysis (Multi-lab task – presented by INL)

Task B: Assessing Market Potential for Renewable Super Premium

Could a high-octane, mid-level ethanol blend paired with an optimized engine be more successfully adopted than E15 and E85 have? Why? Under which conditions?

Literature Review (NREL/ORNL)

Scarce literature on RSP but

Lessons learned from other alternative fuels

Info on value of vehicle and fuel attributes

Interviews (NREL)

14 organizations representing

- OEMs
- Drivers
- Retailers
- Fuel providers

Identifying hurdles (and potential resolutions) to RSP adoption

Fuel Market Data Analysis (ORNL)

Demand for premium grade gasoline as a proxy for demand for high-octane fuels

Historical cost differential of various gasoline grades

Modeling (NREL/ORNL)

Inputs from other RSP team groups

- RSP vehicle sales projections
- RSP mileage penalties/gains
- Retail infrastructure compatibility & costs

Scenario analysis

- BSM (NREL)
- BioTrans (ORNL)

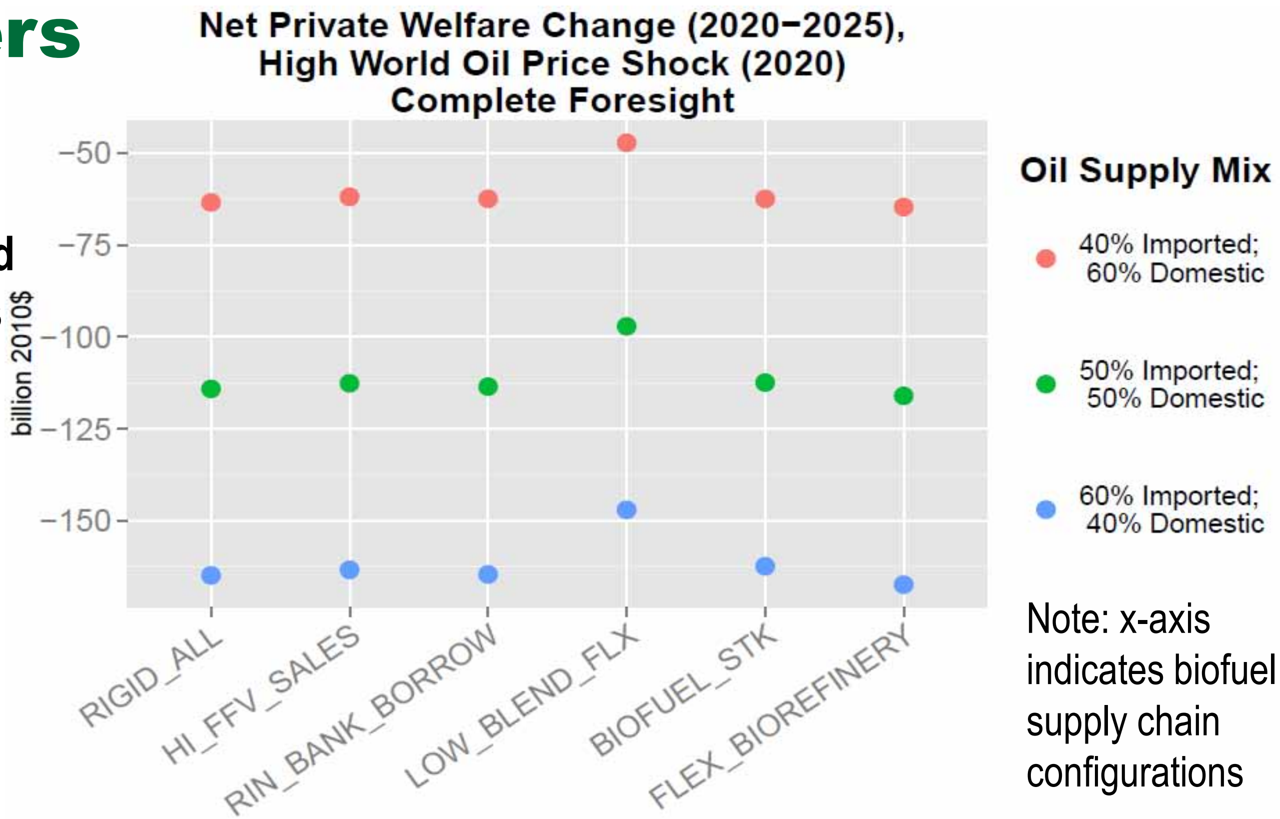
Task A Review and discussion identified 4 system attributes promoting Energy Security. Indicates metrics to (partially) quantify benefits.

1. Supply stability (concern for ΔS)	• "Resilience" of energy-feedstock supply (oil or substitute) • Supply-chain stability (incl. production and delivery infrastructure) • Domestic-origin of supply
2. Energy price stability (concern for ΔP_e, often due to ΔS)	• Short-run buffer supply availability (surge supply, stocks, spare capacity) • Flexibility of demand (through reduction or substitution)
3. Economic security (related to energy) (concern for C_e, ΔGDP)	• Lower/acceptable energy cost burden ($C_e = P_e*D_e$) • Income stability/reliability for producers (farmers, fuel producers) • Lower GDP sensitivity to energy price shocks • Lower security premium (expected marginal social cost)
4. Reduced importance of energy for National Security/Foreign Policy	• Military energy security: reliable military fuels at acceptable cost • Foreign–policy and National-security independence from energy

Task A: Shock Cost Comparisons offer Insights on Economic Security & Effectiveness of Flexibility Levers

BioTrans **simulations of shocked vs. unshocked** market conditions yield estimates of change in:

- Fuel supply mix & price (ES attributes #1&2)
- Surplus for fuel and biofuel market participants (ES attribute #3)

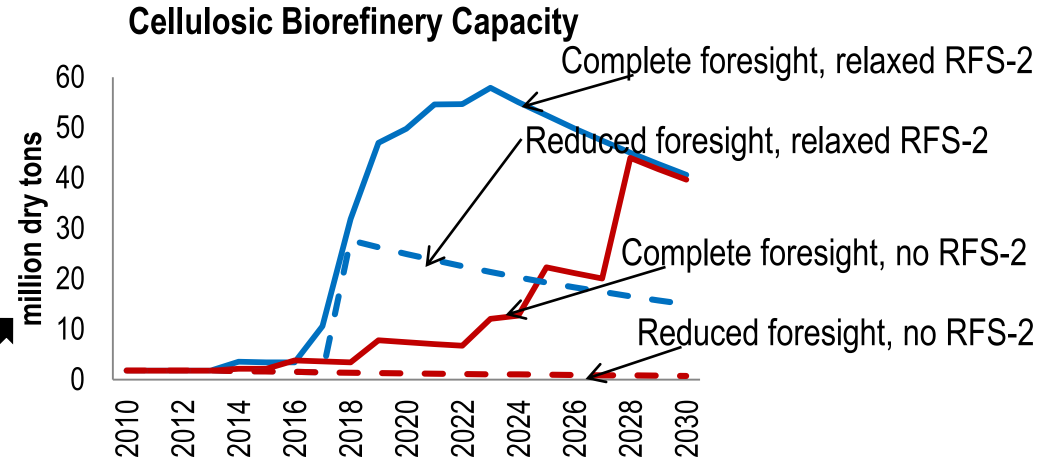


Note: x-axis indicates biofuel supply chain configurations

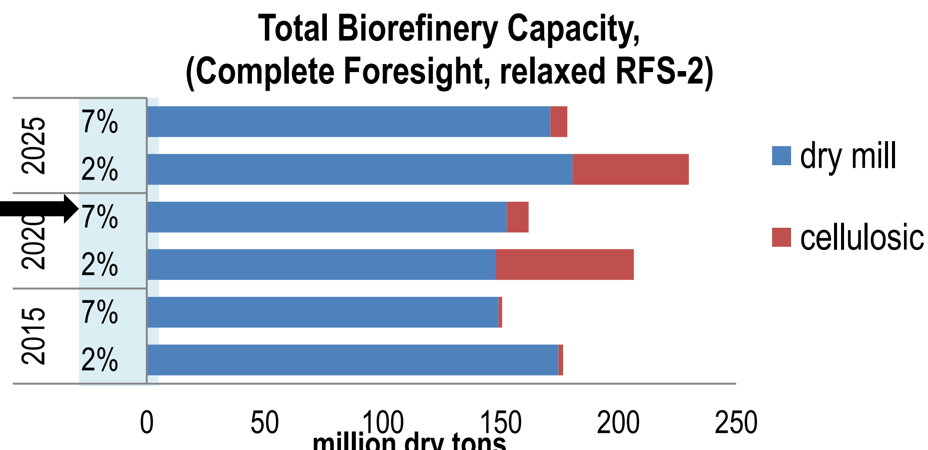
- **Imported oil fraction** has a large effect on net welfare change in response to world oil price shocks
- Low-cost blend adjustments in E05-E15 range (LOW_BLEND_FLX) appear as the most effective lever *for **either direction** of a short-lived oil price shock*
- Even with higher FFV sales (HI_FFV_SALES), FFV market share is small & E85 availability remains limited
- Levers that offer flexibility ***within*** the biofuel supply chain (e.g., ability to switch feedstocks in a biorefinery, FLEX_BIOREFINERY) do not offer much value in the case of oil shocks
- Estimated shock cost is limited to bio&petro-fuel market(**rest-of-economy effects** are out of model scope)

Task C: Examining the Influence of Risk Uncertainty on Industry Investment Decisions is Key to Capture Observed Slow Pace of Advanced Biofuel Commercialization

- **Motivation: Understanding response of market actors to risk and uncertainty**
  - Simulated *smooth* investment patterns under complete foresight are inconsistent with observed behavior
  - Without a depiction of risk, the model may *overestimate* investment levels
- **Approaches:**
  - Implement reduced foresight version of BioTrans
  - Risk-adjusted discount rate or risk premium in costs
- **Next step:**
  - Combine shocks & depiction of risk in the comparison of energy security metrics across supply chain configurations



With no regulatory constraint, investment in cellulosic biorefineries only happens under complete foresight

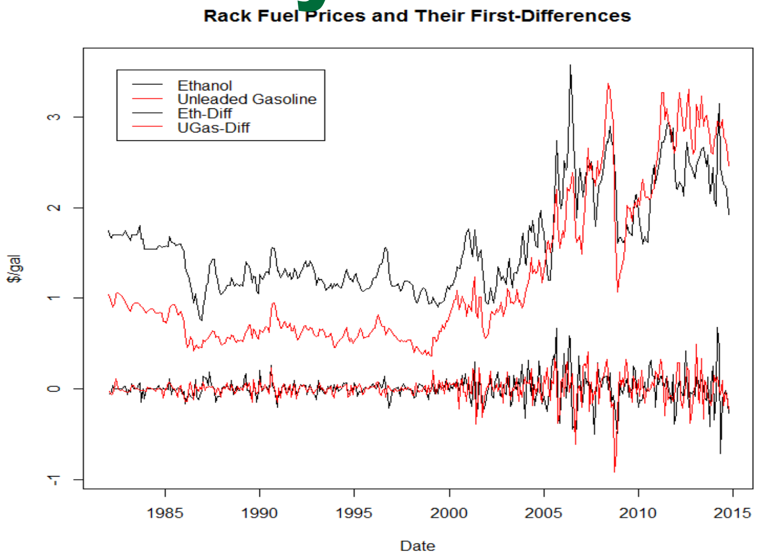


Higher discount rate results in shift towards technologies with lower CapEx (dry mill instead of cellulosic biorefineries) and lower total biorefinery capacity

Data Analysis Task D: Examine implications of Biofuels for Price Volatility, Energy Security

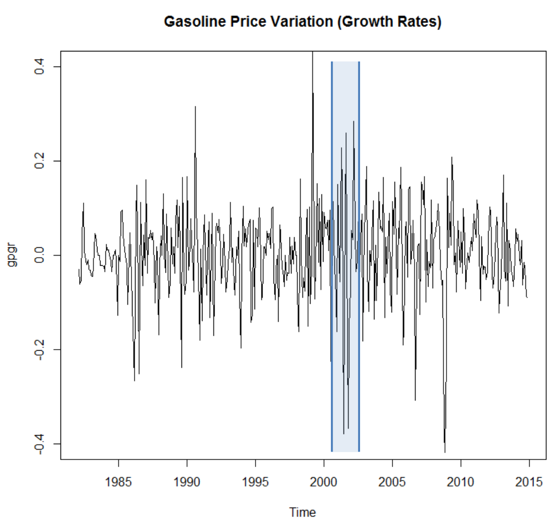
- Biofuels can affect price *levels*, but fuel price *volatility* also matters
  - Important for economic stability (viability of biofuels industry), energy security
  - Influential on economic costs (e.g. Ferderer 1996, Auerbach and Sauter 2006, Hamilton 20XX)
- Investigating implications of biofuels for fuel price volatility
  - Q: How do fuel volatilities change over time with market conditions and fuel interactions?
  - Q: Are there "portfolio diversification" benefits from biofuels, (reducing overall volatility)?
- Connection to BioTrans system modeling:
  - Benchmark fuel price interactions, capture shorter-run fluctuations, represent RIN market
- Approach: Empirical models of volatility (variance) and "volatility clustering"
  - An extended literature review indicated:
    - Findings re volatility transmission (biofuels to gasoline or vice-versa) mixed (Serra 2012, Serra and Zilberman 2013)
    - The transmission of price level and volatility from one market to another depends in part on whether the biofuels mandate, or blendwall, is strictly binding (e.g. Thompson, Meyer and Westhoff 2009)

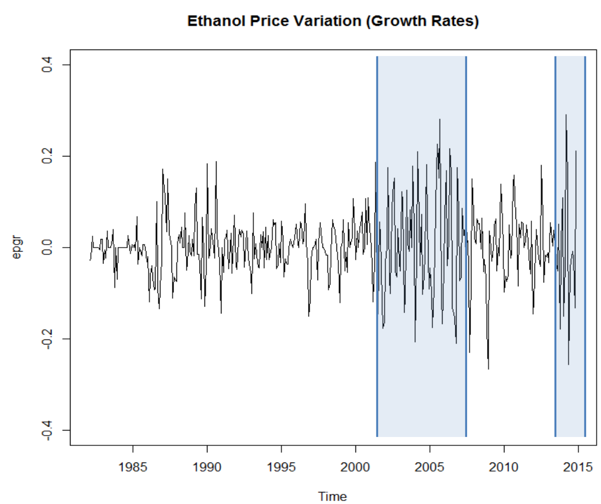
Task D: Price Volatility analysis suggests potential for portfolio benefits. Cross-fuel volatility interactions need further study

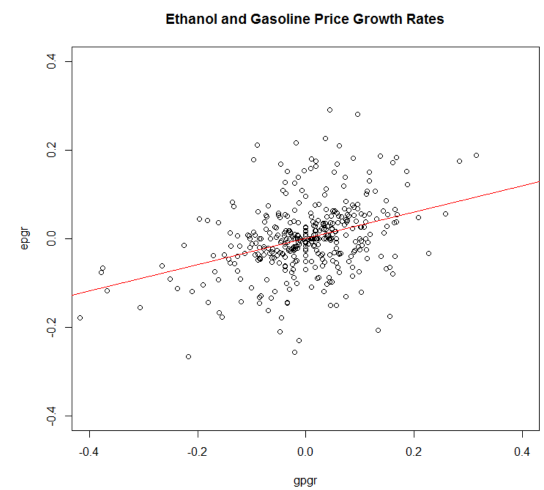


- **Progress:**
  - Empirical data were assembled for biofuel and petroleum markets, and RIN markets.
  - Estimated GARCH models of volatility (separately, for each fuel) showed significant variation of ethanol and gasoline price volatility over time (trend and autocorrelation)
  - Now modeling volatility interactions and response to market conditions

Prospects for portfolio benefits (per Bailis et al 2013): Specific patterns, and magnitude, of volatility differ. Price correlation positive but modest.





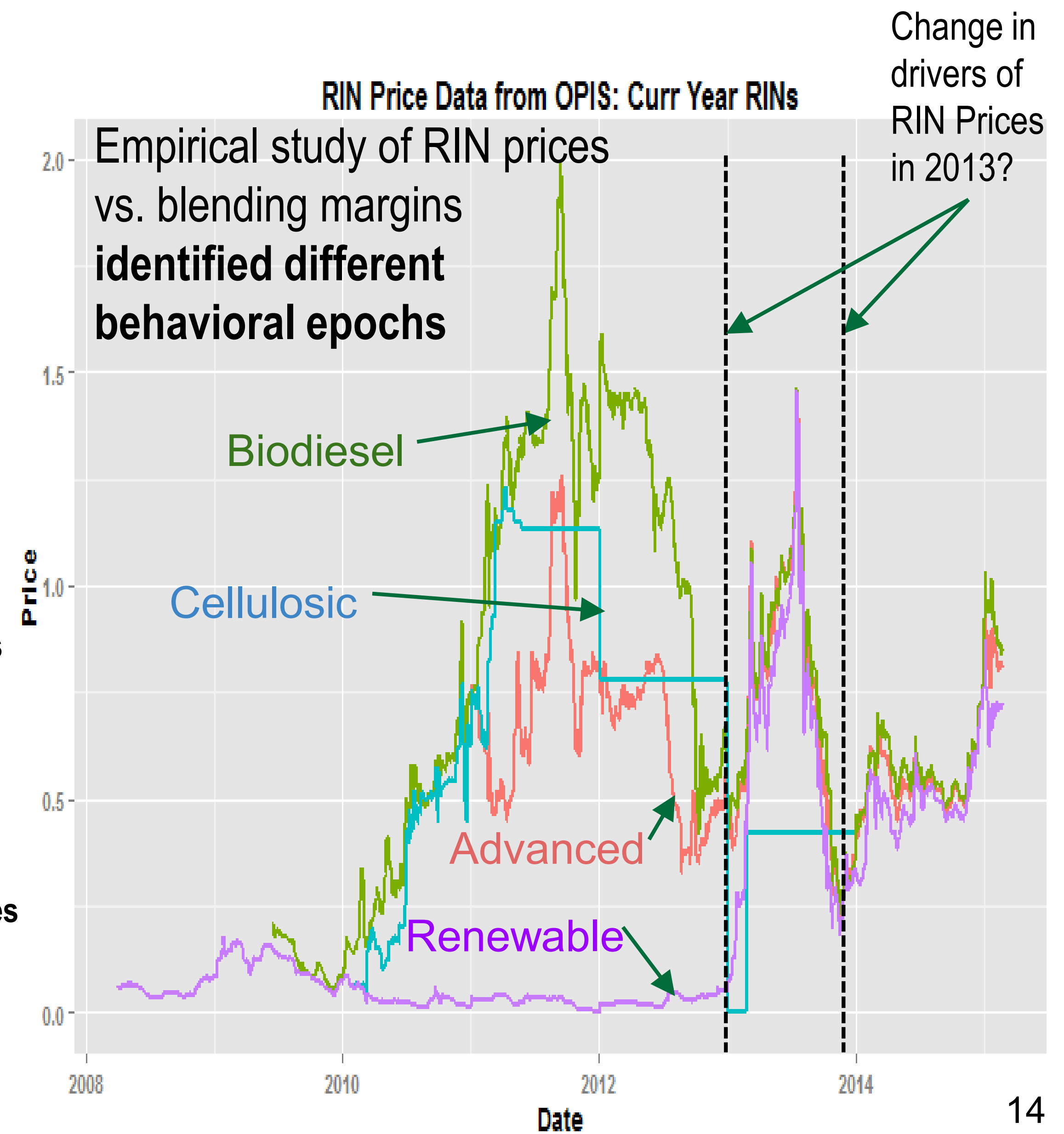


Task E- RIN Market Analysis (Conceptual and Empirical)

- **Improving understanding of RIN prices – a key incentive for biofuel**
- **Joint task with INL, NREL** (will be reported by J. Jacobson)
- **RIN prices endogenous to BioTrans (& BSM) models**

RIN Markets Are Complex

- Interactions of 4 changing, overlapping mandates
- Reflect marginal cost of RFS compliance
  - Sensitive to blendwall, RFS volume and blending limit regs
- Economic context alters RIN prices
  - fluctuating petroleum prices, feedstock supplies
  - (changing) other policies, tax/credits
- Trading and intertemporal flexibility:
  - embody transaction costs, expectations



4 – Relevance

- Project outcome directly contributes to DOE Strategic Analysis Goals and Key Milestones
  - "provide context and justification for decisions at all levels by establishing the basis of quantitative metrics"
  - "Develop and maintain analytical tools, models, methods, and datasets to advance the understanding of bioenergy and its related impacts"
  - "By 2018, complete analysis on impact of advanced biofuels use on gasoline and diesel prices" [MYPP Nov 2014 p. 2-118]
- Radical changes in petroleum, biofuel, supply and prices since 2007:
  - Continued importance of uncertainty, price shocks, volatility
  - Relevant for biofuels benefits and for economic sustainability for industry
- Energy security and resilience are founding objectives for biofuels
  - Project seeks to define energy security metrics and assess them for alternative configurations of the biofuel system to help guide biofuels strategic planning
- Understanding consumer behavior and market introduction prospects under different scenarios is important for BETO's MYPP goal of attaining commercial viability of advanced biofuels
  - MYPP objective : $3/GGE for various biofuel pathways
  - Is the resulting price per gallon at the pump attractive for consumers?

5 – Future Work – FY2015

- Focus on new context of increased oil domestic production and lower/variable oil prices: Explore the viability and role of biofuels
  - Milestone (FY15Q2): Briefing on a survey of biofuels-relevant issues arising from the expanding US oil and gas supply
  - Milestone (FY15Q4): Draft report on the effective role for biofuels in evolving liquid fuels markets, quantifying its role in adding to fuel supply and energy security. (Revise estimate of security premium and other metrics)
- Integrate vehicle choice module (MA3T) with BioTrans to capture the feedbacks between fuel market and vehicle market
  - Combine consumer choice, vehicle manufacturer incentives, retailing decisions
- Evaluate alternative RFS-2 futures, including the impact of EPA upcoming decision regarding the future of RFS-2
  - Milestone (FY15Q3): Short technical note on alternative biofuel blending mandate futures (compare total biofuel production, biorefinery capacity mix, RIN prices, fuel prices and benefits for at least 3 alternative RFS-2 futures)

Summary

- **Overview:**
  - Benefits and costs of alternative configurations of the biofuels system
  - At national level, with a special focus on energy security and resilience, price effects
- **Approach**
  - Combines partial equilibrium modeling of markets and policies with selected empirical analysis of historical market data, and development of useful energy security metrics
- **Technical Accomplishments/Progress/Results**
  - Substantial improvement in ability to explore impacts of oil, biomass, or biofuel supply shocks
    - Suite of "flexibility measures" developed and incorporated
    - Novel representations of uncertainty and *varying degrees of foresight* by firms and consumers
      - This is a substantial extension of prior smooth market conditions and provides greater realism than complete foresight or no foresight, in normal markets or shocks
  - Energy security concepts reviewed and new metrics identified.
- **Relevance**
  - To measuring and communicating economic and social benefits (also potential risks) of further penetration of biofuels under various market and policy futures
  - To assessing impacts of biofuels on petroleum fuel price
- **Future work:**
  - Apply framework to estimate energy security impacts for range of system configurations
  - Extended focus on oil market changes, implications for biofuels role and benefits

Supplemental Slides

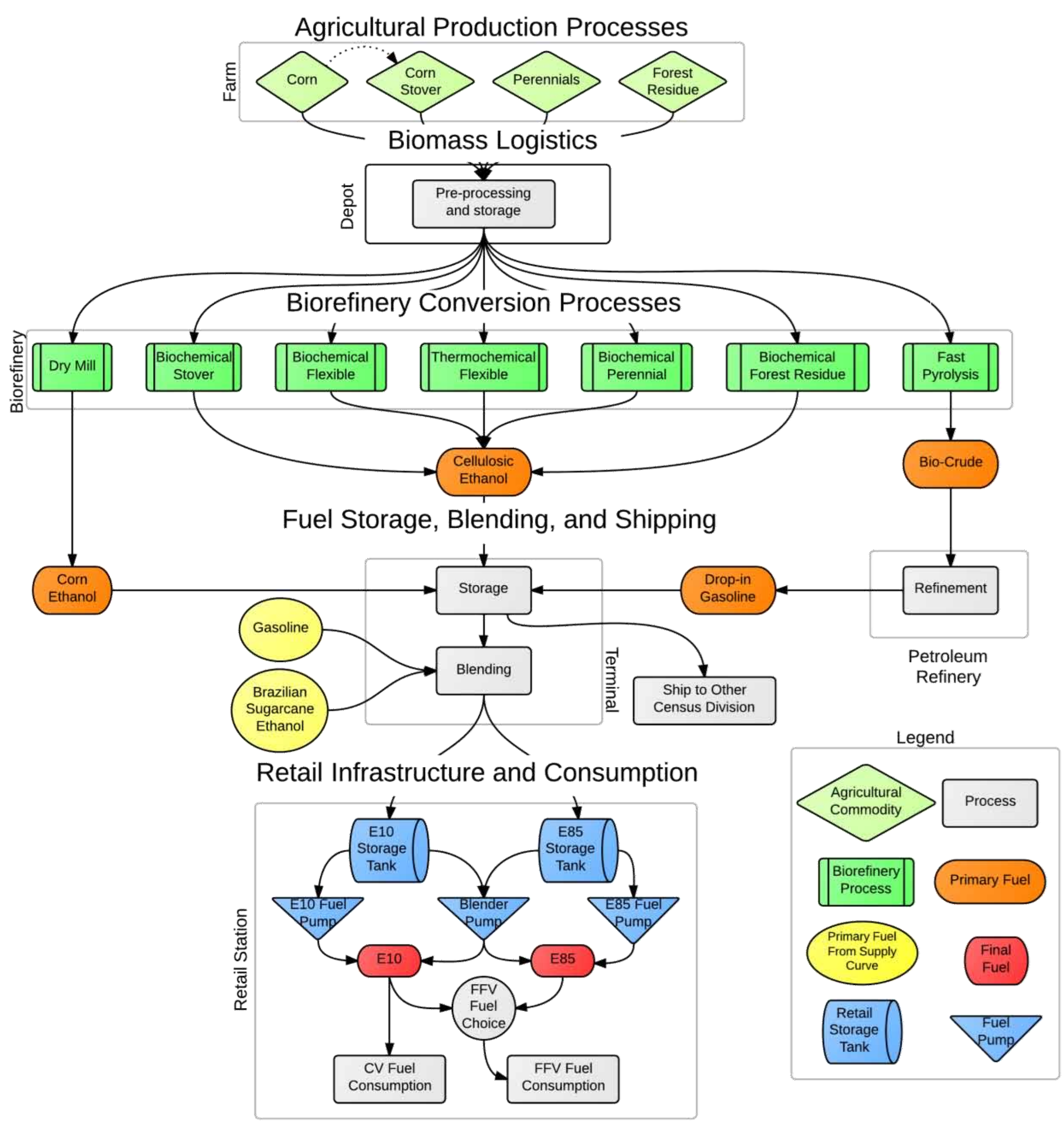
Responses to Previous Reviewers' Comments

- **Comment #1**: "The project's focus on and analysis of the US energy and economic security results of various biofuel portfolios is important work. It could be further augmented with additional national security community dialogue to refine terminology and solicit interagency policy questions on this topic"
- Response:
  - We have worked to broaden and clarify energy security metrics, reviewing literature and canvassing experts (see summary table below)
  - Organized and chaired special session on "Energy Security and Transportation Energy" at Transportation Research Board Jan 2014 Meeting.
- **Comment #2**: "One concern is that the modeling work builds on other modeling results. Uncertainties of the GTAP-based and AEO-based model results that seem to serve as input in this project are being propagated in the models developed in this project".
- Response:
  - As strategies to mitigate the problem of error propagation, we will state explicitly all our assumptions and information sources, keep input values updated and monitor confidence levels, and be careful about how we present results (e.g., design bounding scenarios to get ranges for the central metrics in the model, and work to represent uncertainty.)

Publications, Patents, Presentations, Awards, and Commercialization

- A. Levine, E. Warner, J. Jacobson, P. Leiby 2014. "The Legal and Regulatory Context of the Renewable Fuel Standard Program," Paper submitted for review at *Journal of Energy and Natural Resources Law.*
- Uria-Martinez, R., P. Leiby and M. Brown (2014). "Technical Note on Deployment Costs and Blending Levels of Renewable Super Premium." Draft Report. March, 2014.
- E. Warner, A. Levine, B. Bush, J. Jacobson, P. Leiby 2014. *Renewable Identification Number (RIN) Market Assessment and Retrospective* , Technical Report, NREL/TP-6A20-61813, Oct.
- C. Johnson, E. Newes, A. Brooker, R. McCormick, S. Peterson, P. Leiby, U. Martinez, G. Oladosu, M. Brown 2014. *Renewable Super Premium Market Assessment, Technical Report* , Draft Report. November 2014.

BioTrans Model Structure



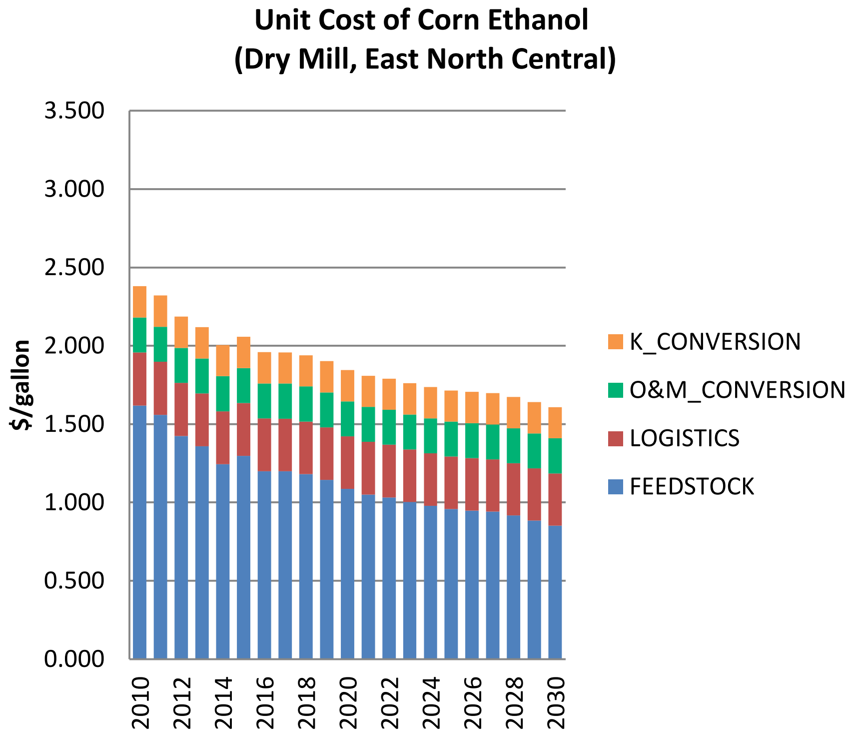
- Classical economic model (nonlinear programming optimization, partial equilibrium)
  - Market clearing quantity-price combinations throughout the supply chain
  - Spatial and intertemporal equilibrium conditions are satisfied
- National scope, 30 years
  - Depicts transitions that depend on long-lived investments, expectations
- Regional disaggregation at census-division level
- Includes representative set of feedstocks and conversion processes, logistics, fuel retail, and fuel choice

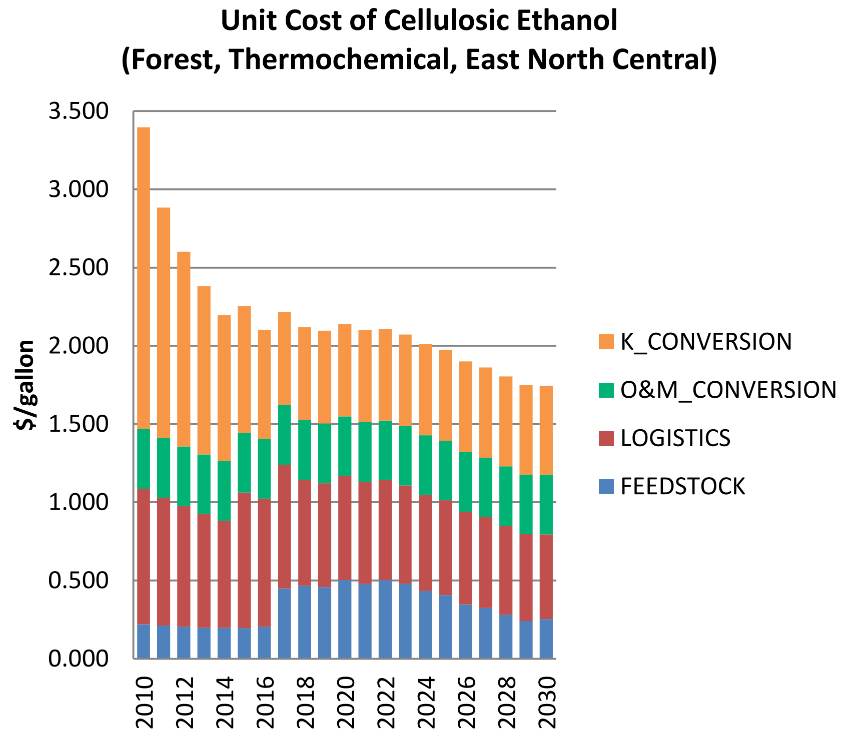
Task A. Matrix of “Factors promoting energy security” vs. “Energy Security Attributes,” based on info from experts, stakeholders

Energy Security Attributes and Factors Revision: 2/20/2014

	Identified Attributes of Energy Security										
	Supply stability (avoid supply volatility or loss, resulting price spikes) (concern for DS)			Energy price stability (concern for ΔPe, often due to ΔS)		Economic security (related to energy) (Ce, ΔY, ΔGDP)				Reduced importance of energy for National Security/Foreign Policy	
Factors/Actions	“Resilience” of energy-feedstock supply (oil or substitute)	Supply-chain stability	Domestic-origin of supply	Short-run buffer supply availability	Flexibility of demand (through reduction or substitution [8])	Lower/acceptable energy cost burden ($Ce = Pe*De$)	Income stability for farmers	Economic stability/ market reliability for fuel producers	Lower GDP sensitivity to price shocks [3,8]	Military energy security: reliable military fuels at acceptable cost	Foreign–policy and National-security independence from energy [12]
o Fossil fuel/petroleum consumption displacement [3,5,8]	X			X					X		x
Seek substitute fuel with more stable supply and lower price volatility [5a Kiefer]		X				X					
o Energy import reduction									X		
Oil import reduction			X								
Other fuel import reduction (including biofuels imports)			X								
o Expanded fuel choice options for consumers at pump (e.g. petroleum fuels and biofuels)		X			X				X		
o Energy crop supply resilience, hardy energy crops		X					X	X			
Crop stress tolerance: drought tolerance; heat tolerance; salt tolerance [1]		X					X	X			
Low input (water or fertilizer) crops [1]		X					X				
High yield crops		X					X	X			
Crops suitable for an extended range of lands		X						X			
Feedstock and policy that is resilient in face of climate/weather variability and risk		X									
o Non-food crop based fuels avoiding volatile interactions with food markets						X		X			
o Conversion process modularity and flexibility	X	X									
o Storage/Inventories to smooth supply/demand variations				X							
Cost-effective storage (store-ability) of biomass				X							
Ability to store as stand in field or forest across seasons1				X							
Ability to store more cheaply/longer given preprocessing				X							
o Fuel supply chains resistant to disasters (weather; natural; political)	X	X					X	X			
o Reduction of economic sensitivity to energy price shocks											
Reduction of oil use (cost share in economy, or activity)						X			X		
Diversification of sources, limiting budget exposure											
Biorefinery flexibility in terms of outputs (co-products)								X			
o Energy infrastructure reliability		X									
o Greater flexibility and price stability through fuel compatibility with existing infrastructure [10,2]											
o Flexibility and price stability through flexible policy incentives (avoid regulatory risk)								X			
o Supply stability through policy stability [8,12]		X						X			

Cellulosic fuels are higher capital cost.
Task C Finding: Uncertainty regarding future reduction in capital cost can inhibit investment in cellulosic pathways





- **Reducing the period for which investors have good-quality information (from 20 years to 4-5 years) causes a shift in biorefinery investment mix from technologies with high CapEx and low CapEx (e.g., cellulosic) to technologies with low CapEx and high OpEx (e.g., dry mills)**

Task D. Results indicate pattern of significant variation of ethanol and gasoline price volatility over time (trend and autocorrelation)

- **Model of variance:**

  Variance(t) = omega + alpha1* e(t) + beta1 Var(t-1)

  - omega - the constant coefficient of the variance equation
  - alpha - the value or vector of autoregressive coefficients
  - beta - the value or vector of variance coefficients

For Ethanol Price variance

	Estimate	Std. Err	t value	Pr(>|t|)
omega	0.0001523	7.652e-05	1.991	0.046534 *
alpha1	0.1675	4.667e-02	3.590	0.000331 ***
beta1	0.8247	4.518e-02	18.253	< 2e-16 ***

For Gasoline Price variance

	Estimate	Std. Err	t value	Pr(>|t|)
omega	0.0005754	0.0003187	1.805	0.071006 .
alpha1	0.1719849	0.0490508	3.506	0.000454 ***
beta1	0.7849576	0.0556737	14.099	< 2e-16 ***