Global Biofuels Modeling and Land Use

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DOE Bioenergy Technologies Office (BETO)

2015 Project Peer Review

Strategic Analysis & Cross-cutting Sustainability

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U.S. DEPARTMENT OF ENERGY

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OAK RIDGE NATIONAL LABORATORY
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GOAL STATEMENT

- Primary goal of the project is to demonstrate the viability of biofuels in the context of the national/global economy.
- Metrics include:
  - **Cost effectiveness***:* meeting US liquid transportation fuel needs competitively under future economic and policy scenarios
  - **Energy security and external trade***:* reduce dependence on foreign oil and improving the balance of trade
  - **Land and water resources**: minimizing the land use impacts of biofuels
  - **Greenhouse gas emissions**: reducing GHG emissions and climate impacts
  - **Social well-being***:* economic growth, food security, employment, etc.
- Contributes to meeting BETO's strategic goal to demonstrate:
  - *"the positive economic, social, and environmental effects and reducing the potential negative impacts of bioenergy production activities"* (MYPP, 2014)

1 - PROJECT OVERVIEW: QUAD CHART

Timeline

- Project start date: FY09
- Project end date: FY15
- Project complete: 85%

Barriers addressed

- At-B. Analytical Tools and Capabilities for System-Level Analysis
- At-C. Data Availability
- Ct-C. Inconsistent and Unpredictable Policy Landscape and Priorities

Budget

	Total Costs FY 10 – FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date
DOE ($K) Funded	463	308	182	150
Project Cost Share (Comp.)	0%	0%	0%	0%

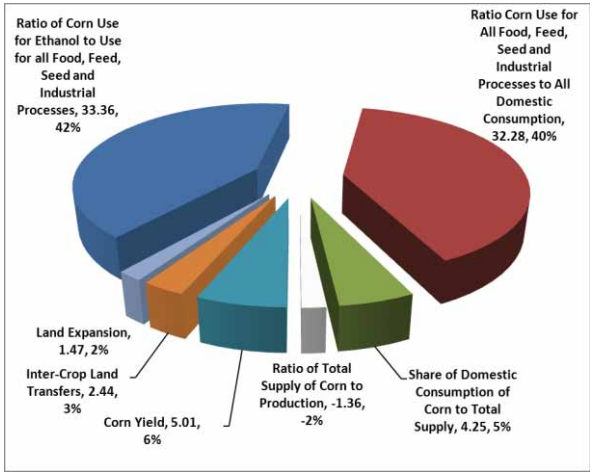
Partners

- National Renewable Energy Laboratory (NREL)
- Argonne National Laboratory (ANL)
- International Food & Policy Research Institute (IFPRI)
- Private industry (e.g. Biodiesel Board, California Air Resources Board, Corn Growers Association)

1 – PROJECT OVERVIEW: BACKGROUND

- **Many critical drivers are outside the biofuel supply chain**
  - Transportation market: consumers have many options and are smart
  - Petroleum market: rapid changes in the oil market
  - Climate change: a primary driver of biofuel policy
  - Interactions between biofuels and other policies
  - National/global dimensions of land use change

Empirical analysis showed that corn use for ethanol production in the US largely from domestic market adjustments, production and yield change*

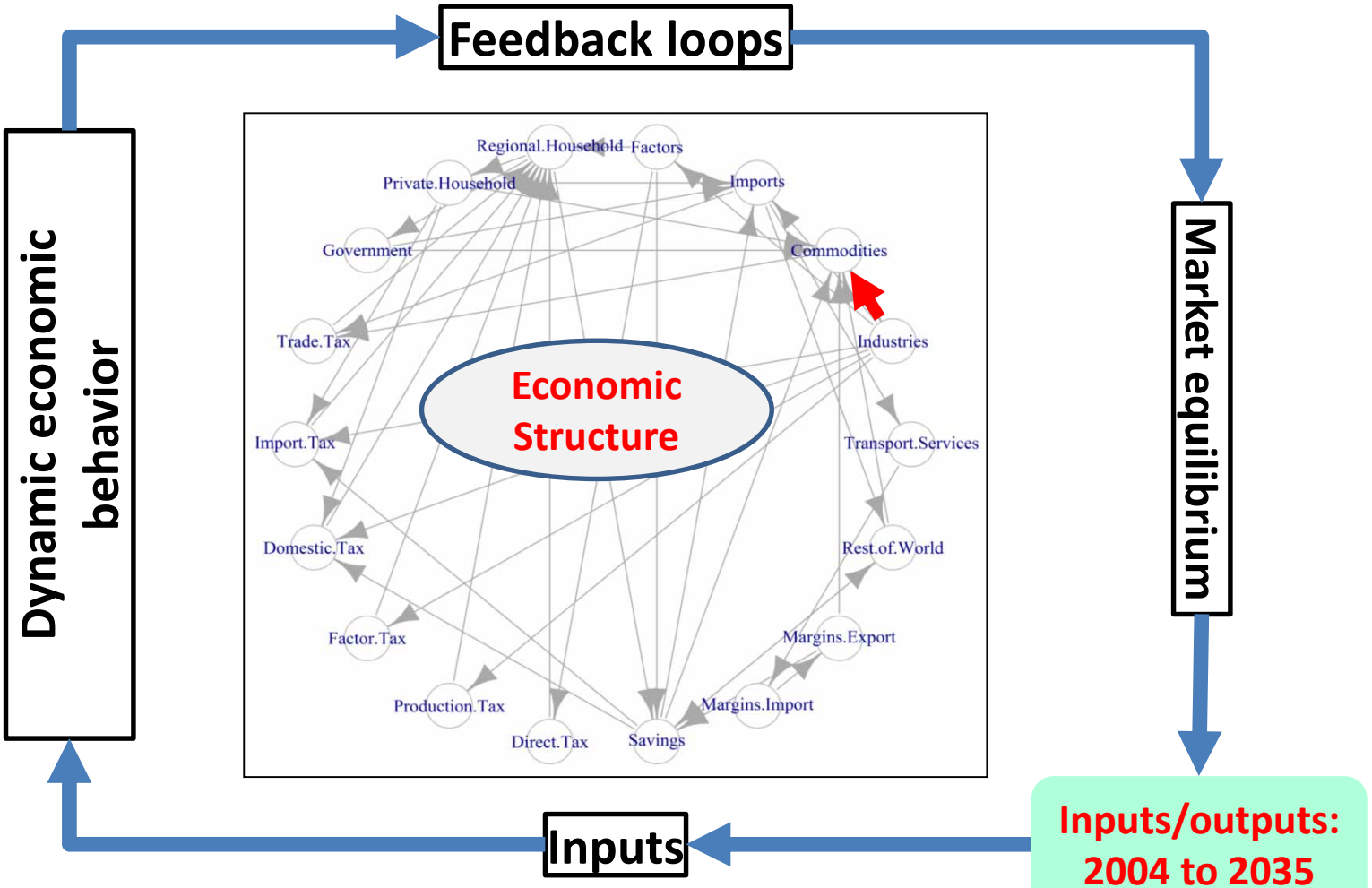


- **Project capabilities have been used to address the:**
  - Indirect land use change impacts (**initial motivation for the effort**)
  - Interactions of biofuels with other sectors of the economy
  - Impacts of biofuels on the U.S. economy and global GHG emissions

*Oladosu G., K. Kline, R. Uria-Martinez, and L. Eaton (2011) "Sources of Corn for Ethanol Production in the United States: A Decomposition Analysis of the Empirical Data", Biofuels, Bioproducts & Biorefining (BioFPR) Journal 5:640-653(2011) DOI:10.1002/bbb.305

2 - APPROACH: TECHNICAL Primary analytical tool is the Energy Policy in General Equilibrium (EPGE) Model*

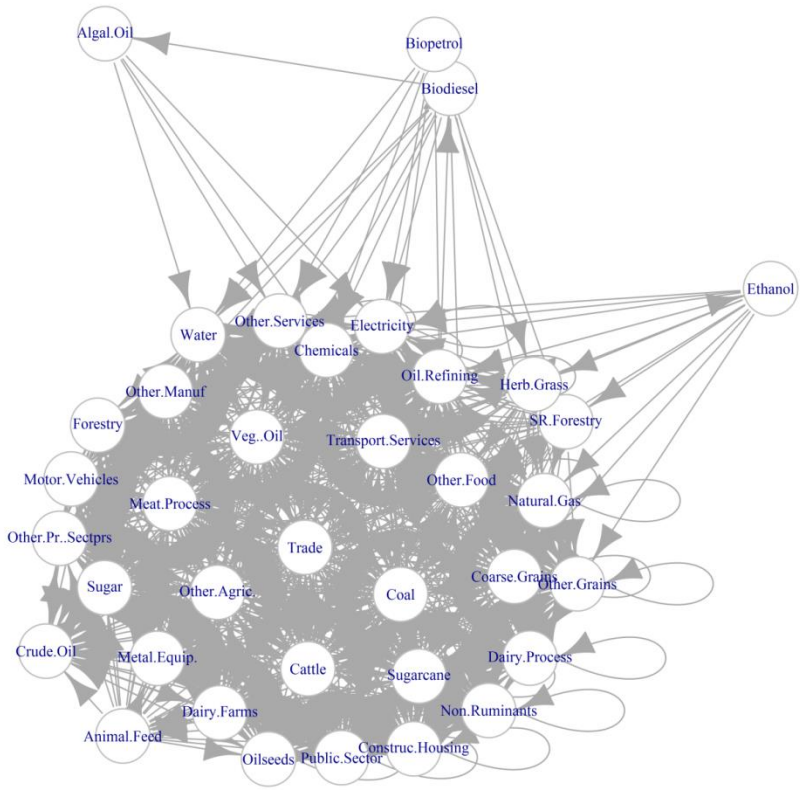
- General equilibrium models have an economy-wide scope
  - comprehensively captures drivers outside the biofuel supply chain



*Previously known as the **GTAP-DEPS:GTAP for Dynamic Energy Policy Simulations** (see Oladosu, 2012; Oladosu et al, 2012).

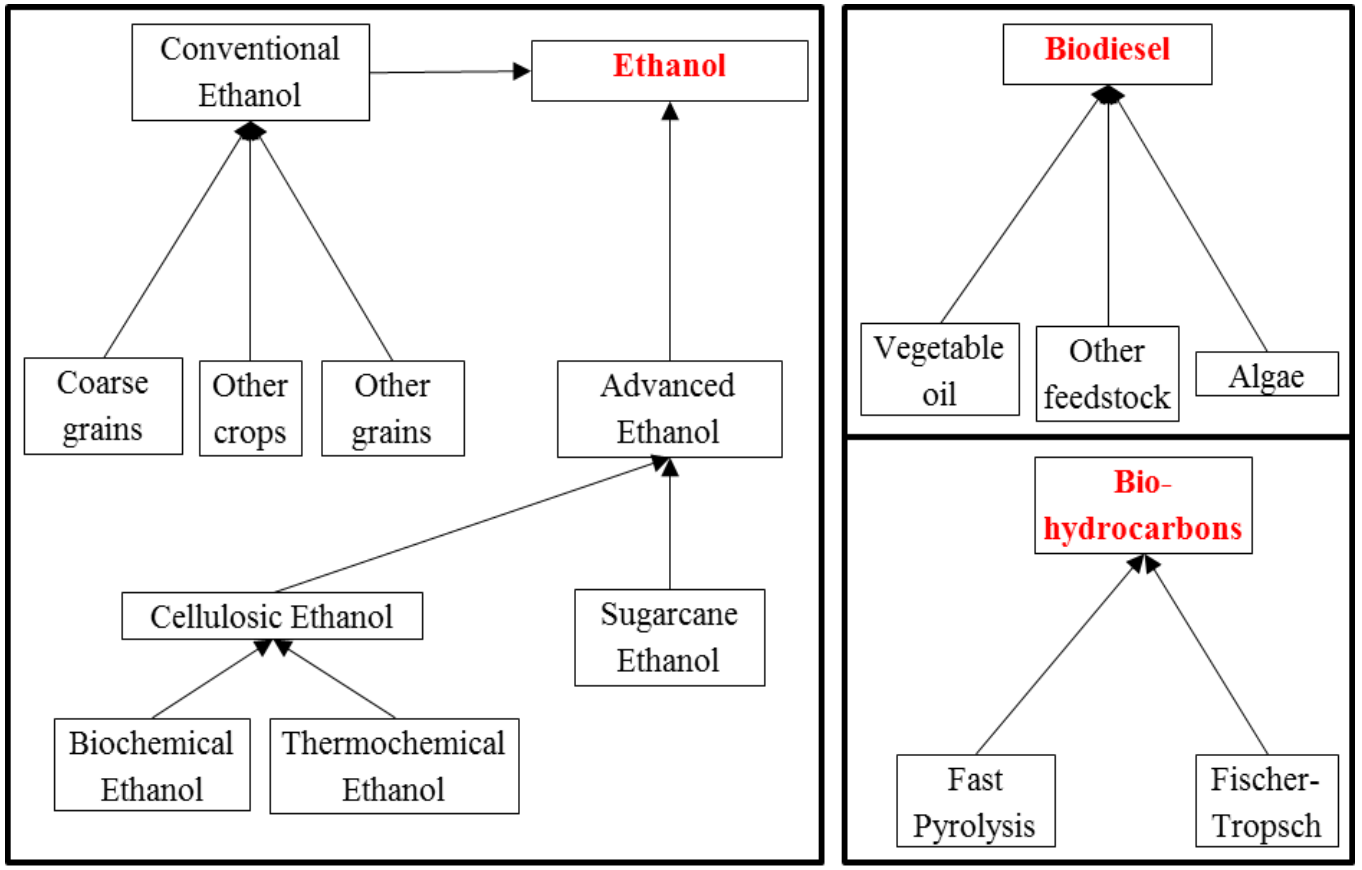
2- APPROACH: TECHNICAL EPGE incorporates connections across non-agricultural and agricultural sectors of the economy

Non-Agric Sectors		Agric. Sectors
Coal		Coarse Grains
Crude Oil		Other Grains
Natural Gas		Other Agric.
Other Manuf		Oilseeds
Oil Refining		Sugarcane
Chemicals		Cattle
Motor Vehicles		Non-Ruminants
Metal Equip.		Dairy Farms
Electricity		Forestry
Water		SR-Forestry
Construc/Housing		Herb-Grass
Trade		Meat Process
Transport Services		Veg. Oil
Other Services		Dairy Process
Public Sector		Sugar
Ethanol		Other Food
Biodiesel		Animal Feed
Biopetrol		
Other Pr. Sectors		
Algal Oil		



- "Forest" of input-output (I-O) links emphasize the comprehensive nature of economic transactions included in general equilibrium models
  - **Oil, natural gas and coal supply curves** are explicitly modeled to capture their crucial role in the future prospects of the biofuel industry

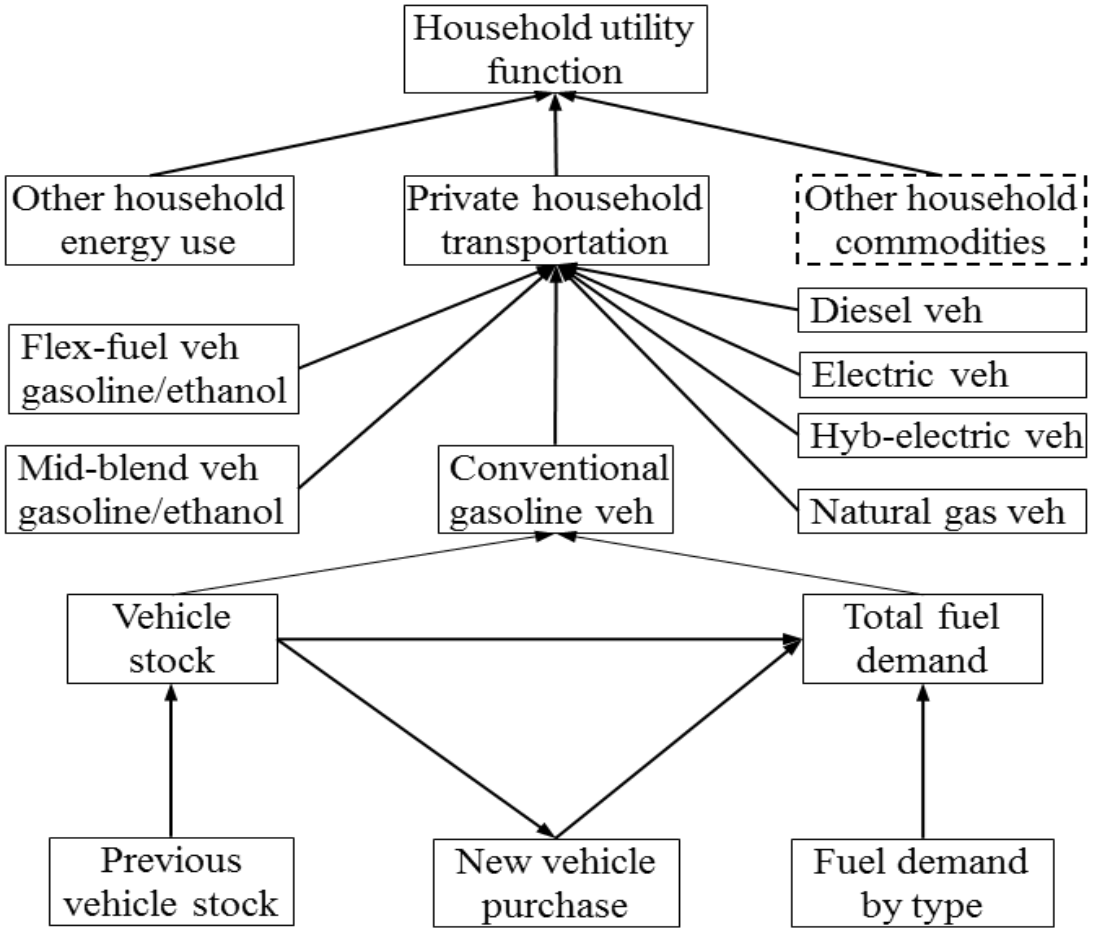
2 – APPROACH: TECHNICAL Technology-focused approach enables flexible introduction of new advanced biofuel technologies



- **Critical Success Factor**: State of the technology has crucial implications for the impacts of programs/policy options to promote biofuel market development

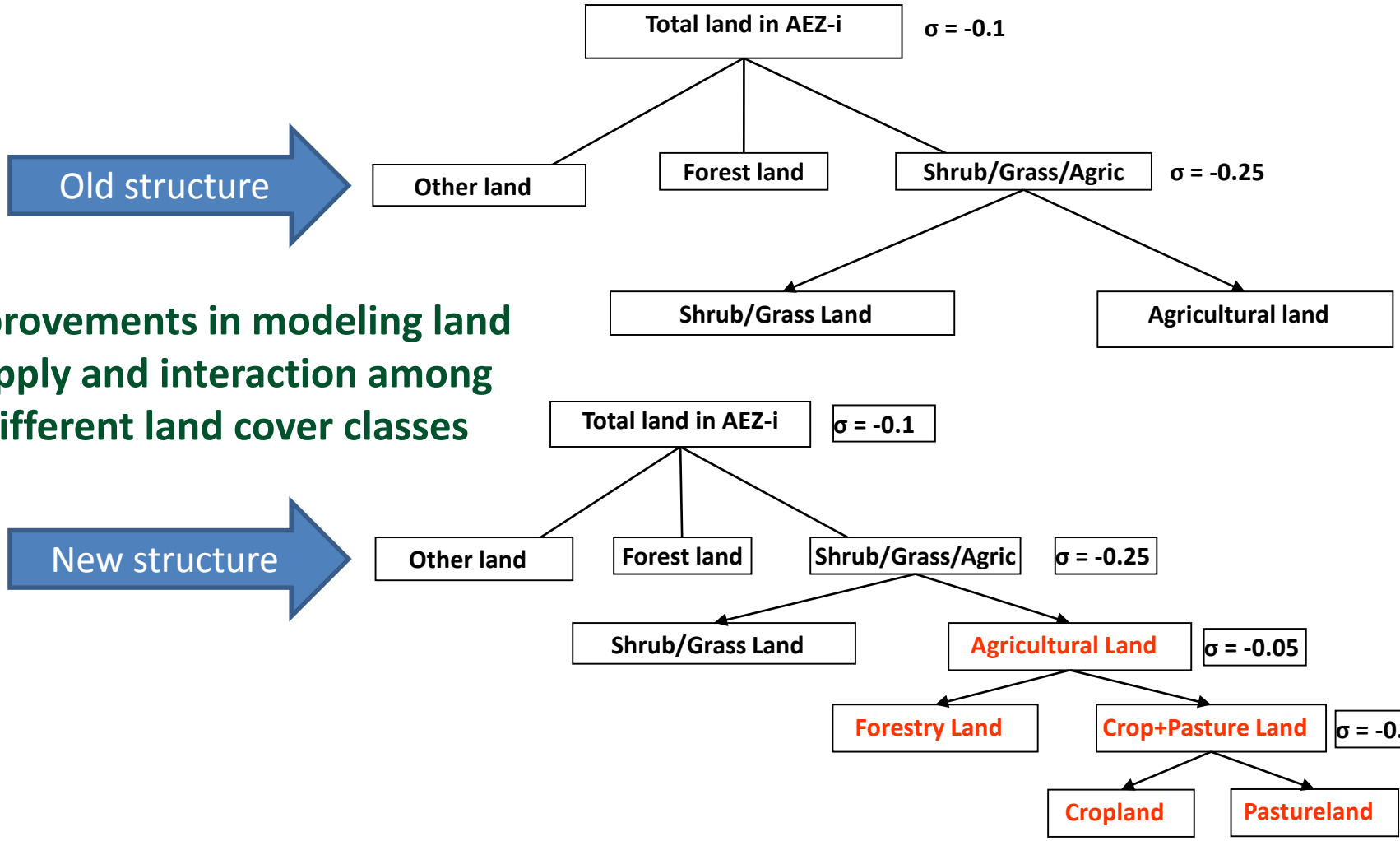
APPROACH - TECHNICAL EPGE explicitly accounts for consumer choices in the vehicle/fuel market

Purchase and fuel-choice decisions are modeled for 7 vehicle classes



- **Critical Success Factor**: Future supply/use of biofuels depends on how consumers respond in the transportation market.

2 – APPROACH: TECHNICAL Continuing efforts to address uncertainties in estimates of the land use change impacts of biofuels



- **Critical Success Factor**: Uncertainty about land use change emissions remain an important regulatory hurdle for biofuels

2 – APPROACH: MANAGEMENT

- Project implemented primarily by the PI
  - Joint authorship with others on project publications

- Scheduled interactions with BETO lead:
  - Monthly update reports
  - Quarterly milestone completion reports
  - Quarterly check-in calls

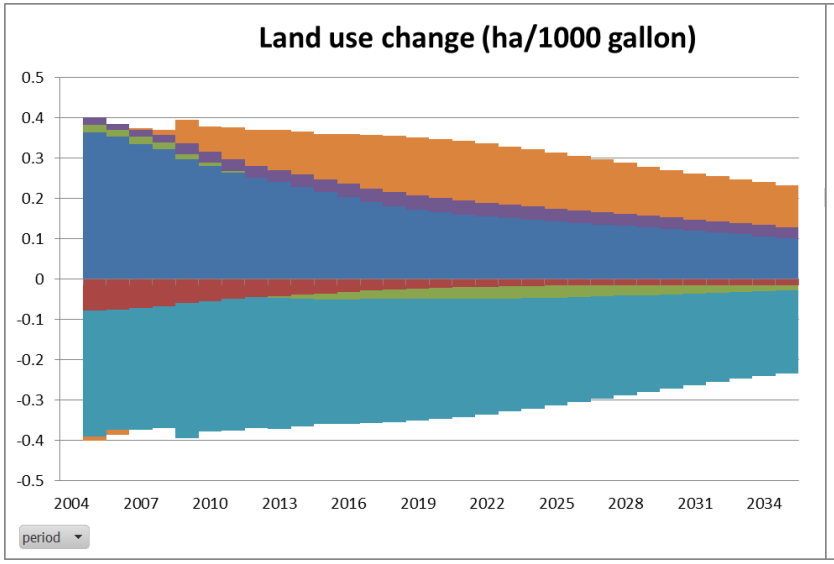
- Interactions with other BETO supported efforts:
  - Feedstock analysis (ORNL, INL)
  - Techno-economic analysis (NREL, PNNL)
  - Land use change emissions (ANL)

- Ad-hoc conference calls
  - As needed with organizations working in this area

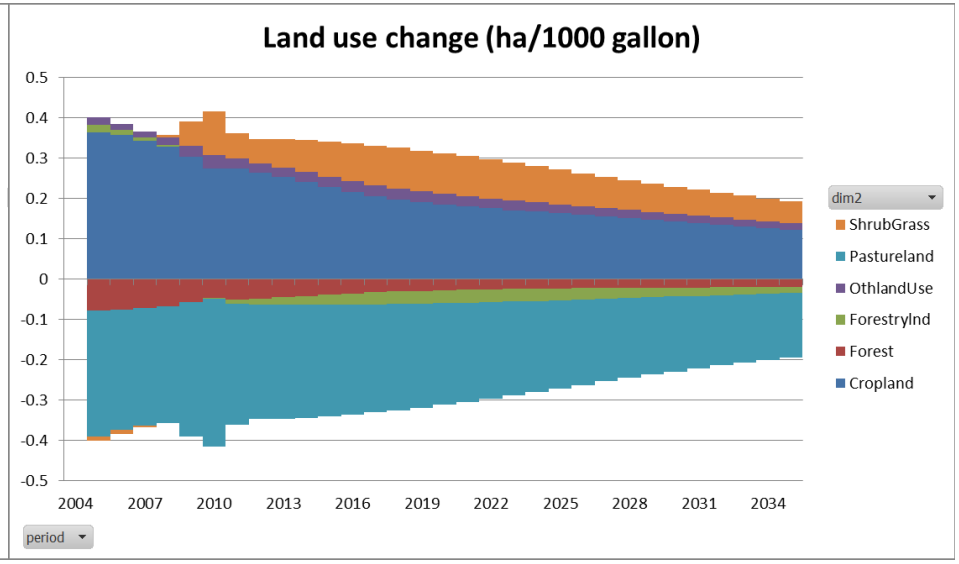
3 - TECHNICAL ACCOMPLISHMENTS

Qtr	2014: Milestones, Deliverables, or Go/No-Go Decision	Status
Q1	Brief technical note (attached to the Quarterly Report) to BETO on state of model changes and data to support evaluation of options for the future evolution of the US biofuel industry.	100%
Q2	Delivery of data on land conversions categorized by AEZ in the 19 regions of the world from 2010 to 2030 needed to estimate the GHG implications of conventional biofuels pathways simulations performed with the GTAP-DEPS model to ANL PI Michael Wang.	100% Simulations with previous version of the model complete.
Q3	Improved internal representation of land cover in the GTAP-DEPS model, and a detailed global land allocation sub-mode.	100% Completed estimation of the sub-model
Q4	Delivery of data on land conversions categorized by AEZ in the 19 regions of the world, 2010-2030] needed to estimate the GHG implications of advanced biofuels pathways simulations performed with the GTAP-DEPS model to ANL. PI Michael Wang.	100% Completed. Simulations with updated version of the EPGE model used to generate land use change impacts for conventional and advanced biofuels
Q4	Draft report on the relative potentials of alternative options (flexible vehicles, drop-in fuels, super renewable premium fuels) to increase the deployment of biofuels in the United States.	100% Completed. Draft paper forwarded to the BETO lead.

TECHNICAL ACCOMPLISHMENTS: Improved estimates of the land use impacts of conventional US biofuels production



Corn ethanol

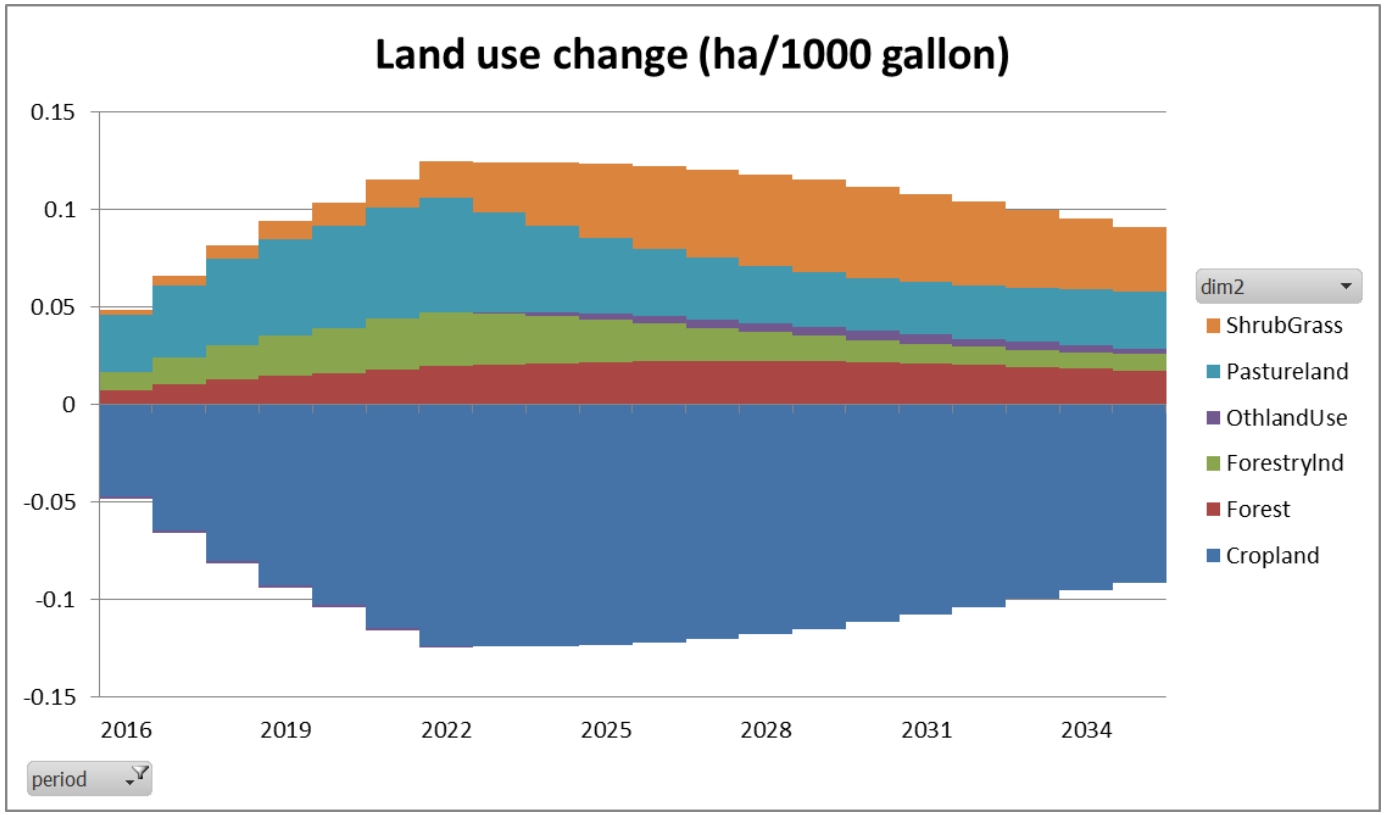


Biodiesel

- Global agricultural land (<u>cropland only</u>) change:
  - +0.10 to +0.36 ha/1000 gallons*
- <u>With pastureland</u> included in agricultural land:
  - Net agricultural land change would be: -0.13 to +0.04 ha/1000 gallons
- Conversion of pastureland should be part of emission calculations
  - …but far lower emission rates than other land cover types

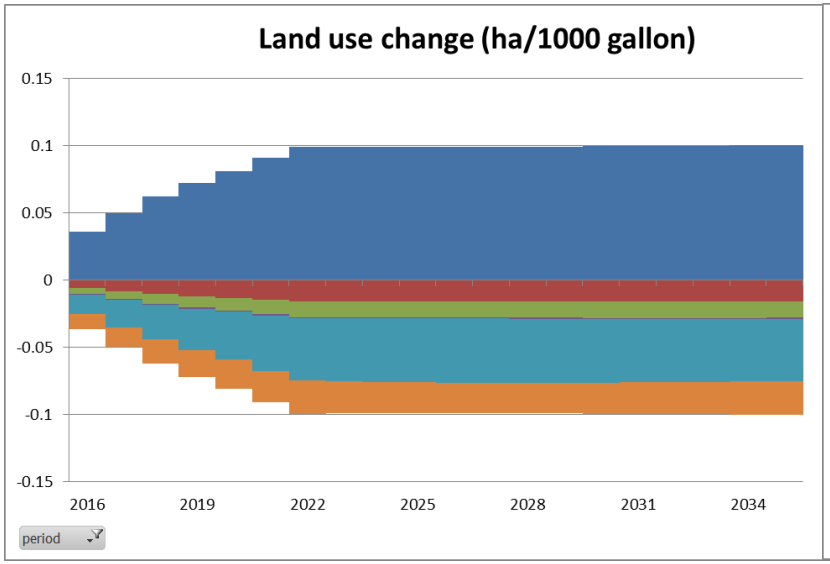
*An American football field is about ~0.54 ha

TECHNICAL ACCOMPLISHMENTS: Estimation of the land use impacts of advanced ethanol from residue feedstock

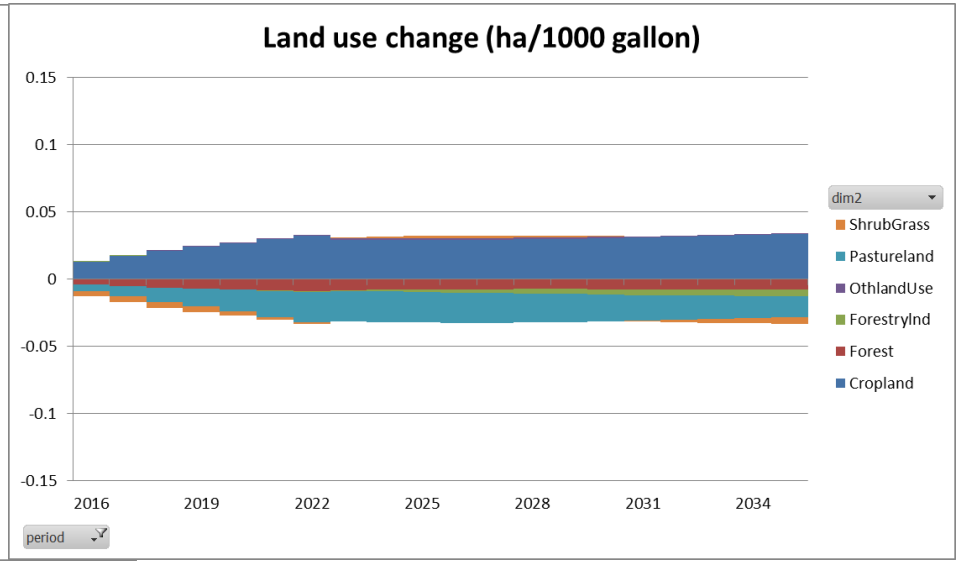


- No direct land use change effects
- Net indirect agricultural land (cropland) change is negative:
  - Due to the global market impacts of fossil fuel displacement
  - **Baseline for isolating the LUC effects of crop-based advanced biofuels**

TECHNICAL ACCOMPLISHMENTS: Estimation of the land use change impacts of advanced ethanol from crop feedstock



Herbaceous crops relative to residues

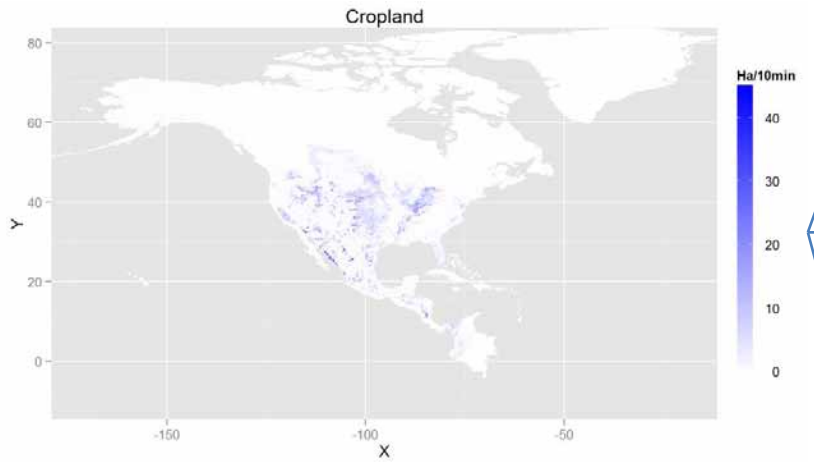


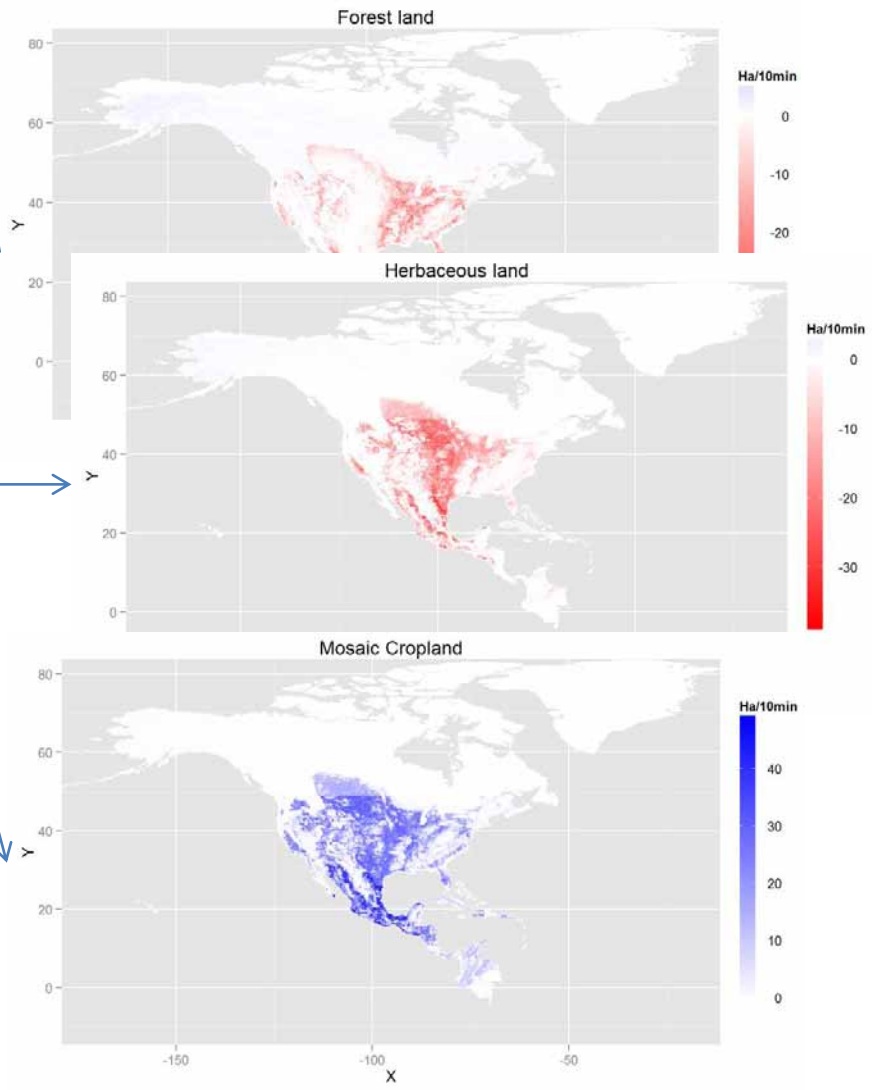
Short-rotation crops relative to residues

- Incremental agricultural (cropland) change relative to residues
  - Herbaceous crops: cropland change of +0.05 to +0.1 ha/1000 gallons
  - Short-rotation crops: cropland change of +0.01 to +0.03 ha/1000 gallons

TECHNICAL ACCOMPLISHMENTS: Detailed global allocation modeling for land cover type conversion

- Simulation of a 1% change in cropland in North America ~ 360,000 ha





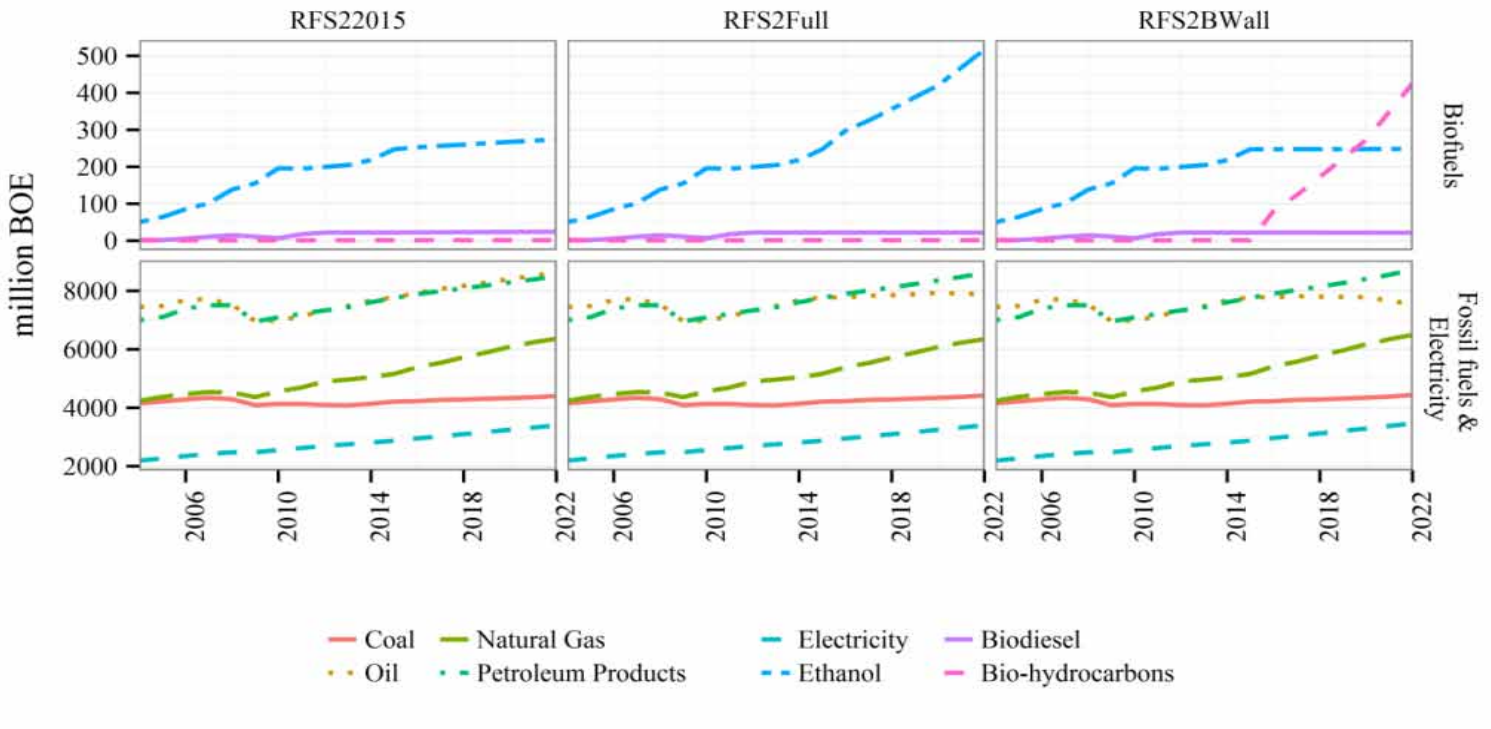
Allocation to 8 land cover categories driven by agricultural, population and bio-physical factors at grid-cell of ~34,000 ha*.

*Knoxville City, TN is ~25,000 ha & Knox County, TN is ~136,000 ha

TECHNICAL ACCOMPLISHMENTS: Evaluation of the prospects of biofuels under different technical and policy constraints

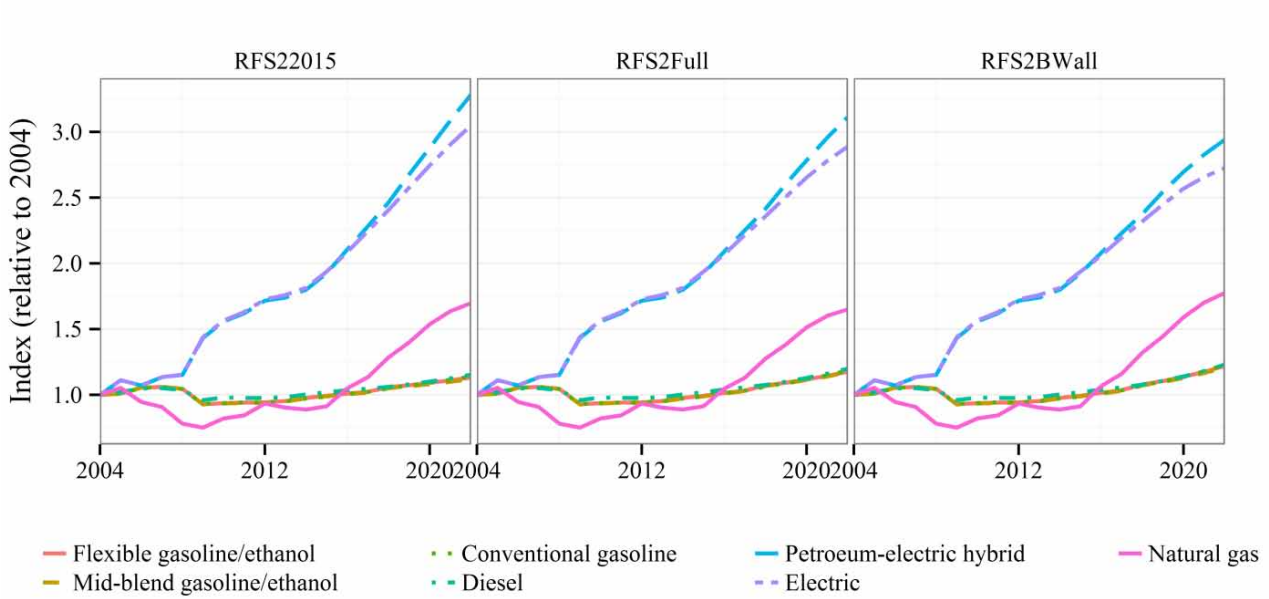
- Main scenarios:
  - **RFS22015** : No additional mandated biofuels beyond 2015
    - Mandate of ~15 billion gallons by 2015 (mostly conventional)
    - Beyond 2015: biofuel use is driven by market forces and existing blend levels
  - **RFS2Full**: Full implementation of RFS2 requirements under EISA
    - Mandate of 36 billion gallons by 2022 (15 conventional; 21 advanced)
  - **RFS2BWall**: Full implementation of RFS2 requirements under EISA
    - Mandate of 36 billion gallons by 2022 (15 conventional; 21 advanced)
    - With blend wall constraint on ethanol blending into gasoline

TECHNICAL ACCOMPLISHMENTS: RFS2 mandates are crucial to future increases in cellulosic biofuels

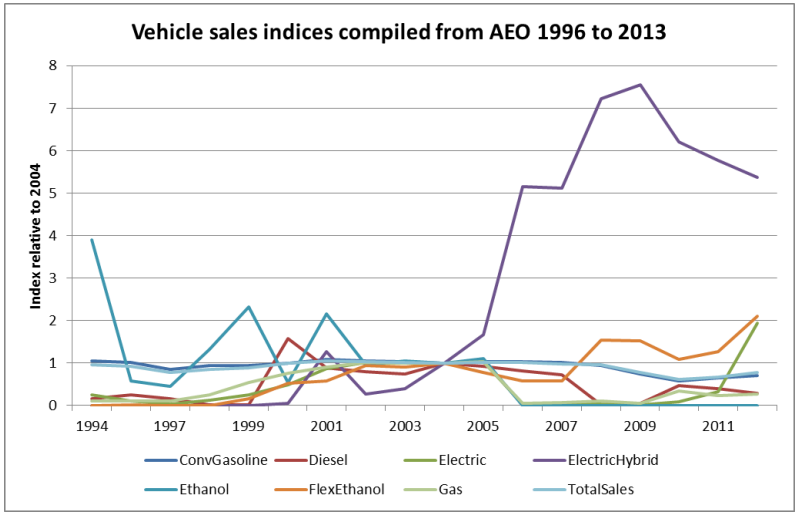


- Small increases in biofuels without the RFS2 mandates after 2015
- Blend wall leads to rapid increase in bio-hydrocarbons
  - Also leads to larger oil displacements

TECHNICAL ACCOMPLISHMENTS: Household vehicle choices do not change significantly across scenarios



- Electricity-using vehicles increase rapidly
- Natural gas vehicles increase after 2015
- Growth rates for other vehicle classes are similar to the average rate
  - Actual vehicle data 1994 to 2013 ➔➔



4 – RELEVANCE

- **The project provides metrics to support the strategic objectives of the BETO Multi-Year Program Plan to demonstrate:**
  - "the positive economic, social, and environmental effects and reducing the potential negative impacts of bioenergy production activities" (MYPP, 2014)
- **Project's analytical results inform regulators and other biofuel stakeholders on the:**
  - Indirect land use change impacts of biofuel policy
  - Interactions between biofuels and other sectors of the economy
  - Effects on the U.S. economy and reductions in global GHG emissions
- **Ongoing efforts help navigate uncertainties and risks to biofuels:**
  - Evaluating the impacts of barriers such as the blend wall on the costs/benefits of biofuel policy
  - Role of policy and technological options in the future biofuel market
  - Evaluating uncertainties around the land use change impacts of biofuels

5 – FUTURE WORK

- Complete structural and data updates to EPGE model:
  - Data updates to the underlying global economic database
  - Incorporate updated techno-economic data
    - Advanced biofuel/bioproducts (cellulosic and algae)
  - **Target date**: (March 30, 2015)
- Complete global land allocation model
  - Currently testing approaches to simulate the model
  - Will interact with KDF team on publishing to the server
  - **Target date**: (June 30, 2015)
- Complete and publish simulation results
  - Addressing future uncertainties and risks to the biofuels market
  - **Target date**: (September 30, 2015)
- Go/No-Go Decisions
  - Currently delaying data updates in order to incorporate newest version of GTAP economic database which will be released this month (for 2011)

SUMMARY

- Overview and Relevance: Project addresses critical drivers outside the biofuel supply chain within the context of the national/global economy, which are necessary to meeting BETO's goal to "develop commercially viable bioenergy and bioproduct technologies".
- Approach: The primary analytical tool under the project, EPGE, is a general equilibrium model designed to comprehensively model drivers beyond the biofuel supply chain including agricultural, transportation, petroleum and other markets, and their national and global dimensions. Empirical analysis of market data are also performed under the project.
- Technical Accomplishments: Results have demonstrated the indirect land use change impacts of biofuels, impacts of biofuels on the U.S. economy and global GHG emissions. Since the 2013 Peer Review the EPGE model has been significantly enhanced to better simulate the future prospects of biofuels.

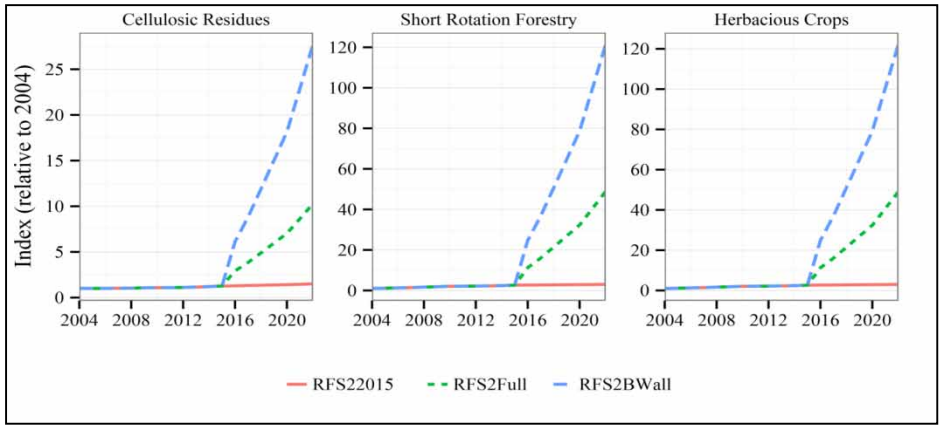
Future work: Update underlying global economic database, update advanced technology data, complete and publish simulation results with EPGE, and make available a detail global land allocation model.

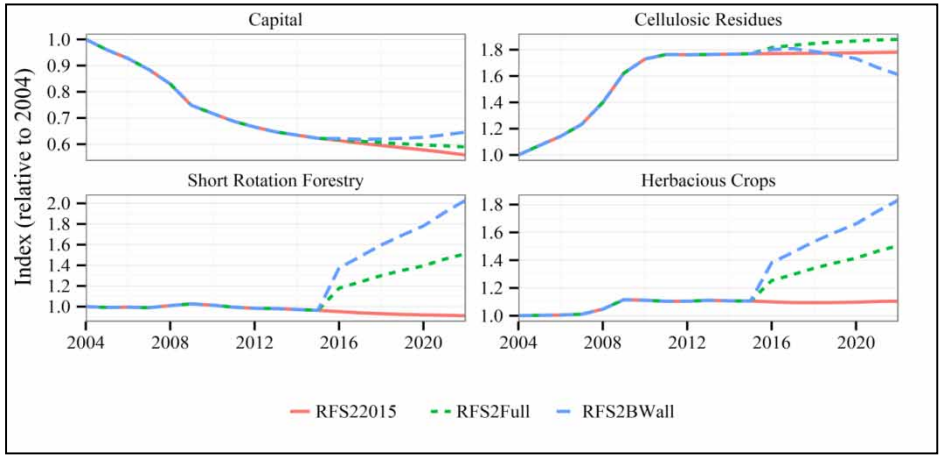
Additional Slides

Responses to Previous Reviewers' Comments

- Reviewer Comments: The high level presentation of the findings from this modified GTAP model point to negative shifts in land demand due to oil displacement in oil-producing countries. It is unclear what assumptions have been made to translate oil displacement into such large land use savings.
- Response To Reviewer Comments: We address the above comment by providing further clarification on the drivers of our results, and describing changes to the model since the 2013 Peer Review designed to address these issues.
- Drivers of model results on land use change:
  - Displacement of a portion of oil use by biofuels in the US leads to reductions in the US imports of oil, and reductions in the export of oil by exporters, as well as reduction in the global price of oil.
  - The reduction in incomes relative to the baseline, albeit small, implies a reduction in economic activities and the inputs into those activities, including land.
  - The magnitude of the implied percentage reduction in agricultural land use in these regions is about half (about -0.2%) of the increase in land use in the US (about 0.4%)
  - However, the small percentage reduction in land use translates into a significant reduction in hectares because yields in those regions are much lower than in the US. **Still, the global land use change remains below 5 million ha for the entire US biofuel target.**
- Project efforts to address other land use modeling issues:
  - The economic model used for the simulations has been modified to better represent interactions among land cover categories. Specifically, the supply of pastureland, combined with cropland into agricultural land in previous simulations, is now separate.
  - We have implemented a separate global land allocation model to estimate the conversion of land for agricultural purposes at a more detailed level.

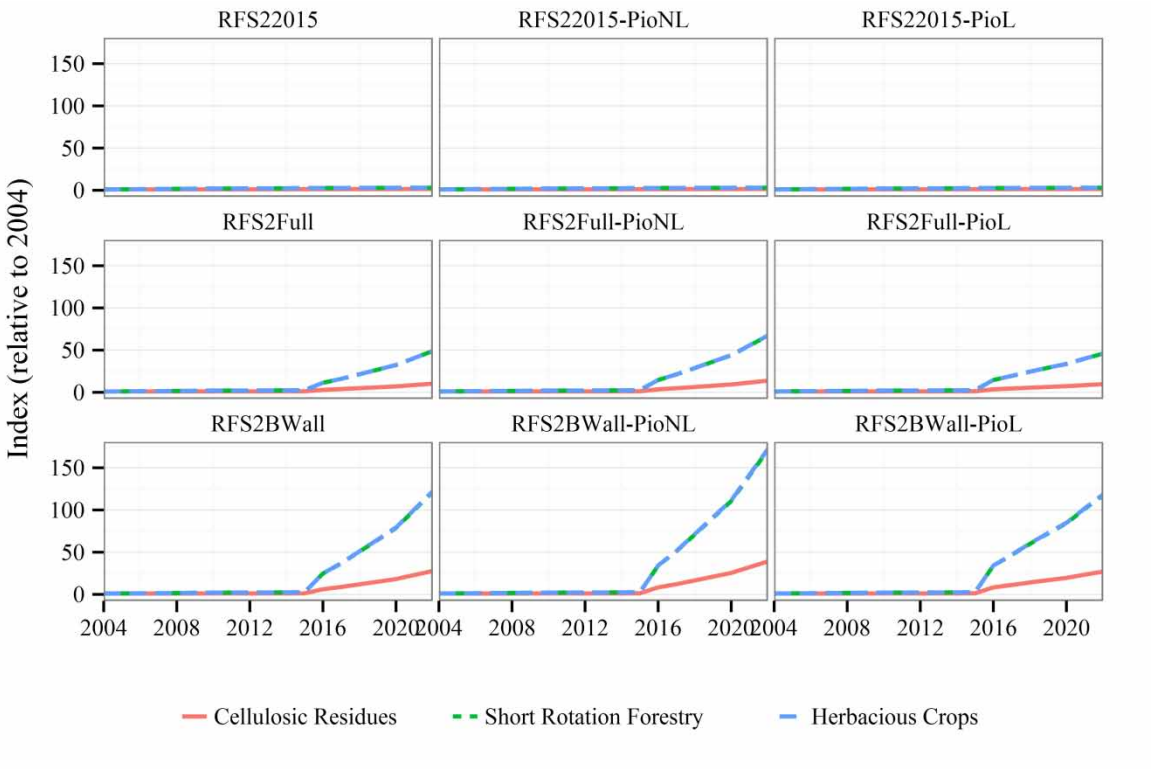
Input levels/costs for advanced biofuels in the USA (RFS2 scenarios with mature technologies)





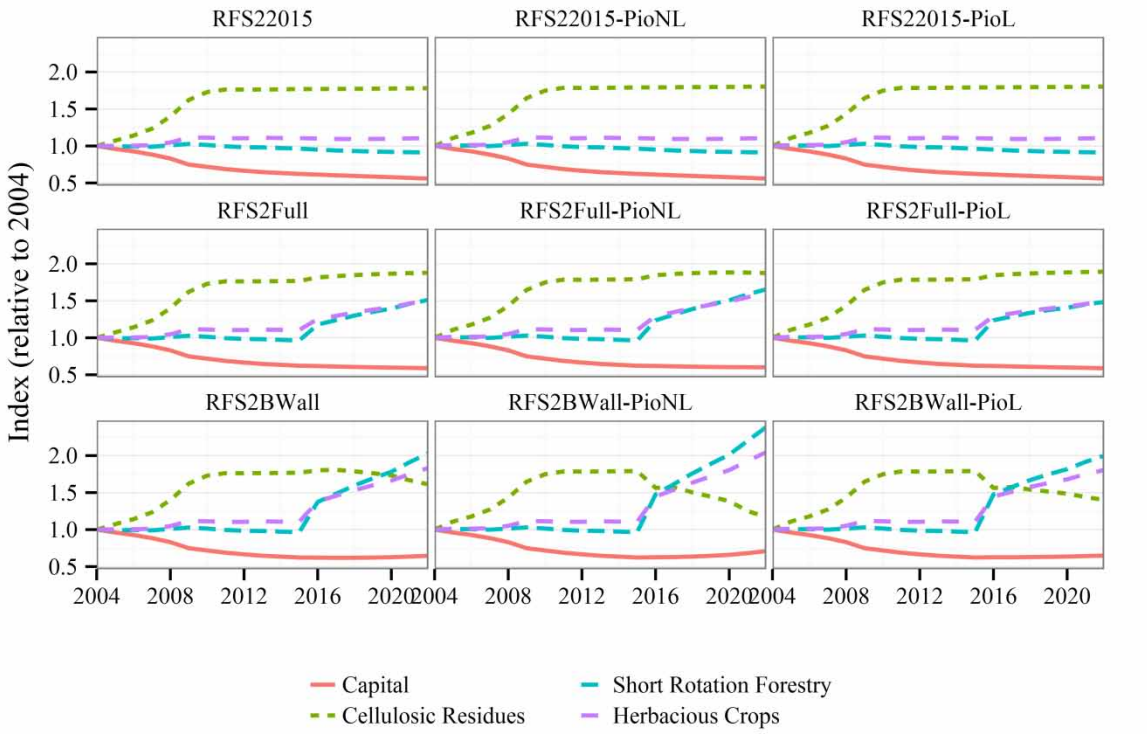
- Large increases in cellulosic materials are needed for advanced biofuel production
- Bio-hydrocarbons are currently feedstock inefficient: reflected in the production cost

Input levels for advanced biofuels in the USA (RFS2 scenarios with pioneer technologies)



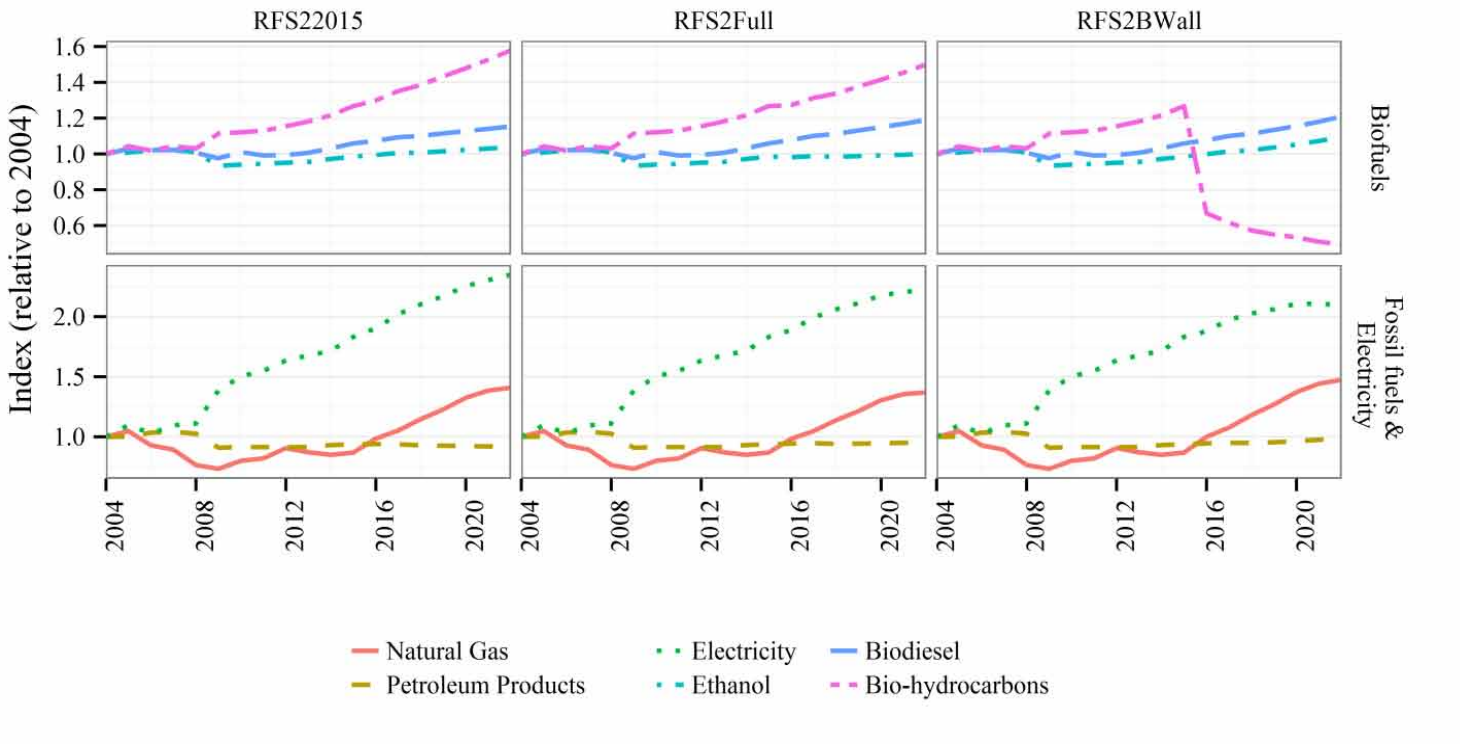
- Inputs increase significantly under the RFS2BWall case
  - Implies production at upper limits of cellulosic supply curves
  - Technology learning does not erase the effects

Input costs for advanced biofuels in the USA (RFS2 scenarios with pioneer technologies)



- Unit costs increase significantly only under the RFS2BWall case by 2022
- Dedicated energy crops serve as “backstop” for residues
  - Other sectors, namely electricity, give up residues at high prices
  - Electricity sector can use cheaper natural gas at higher residue prices

Household energy use for transportation in the USA: Demand for biofuels differ across scenarios



- Electricity and bio-hydrocarbons have the highest growth rates
- Direct purchases of ethanol by households are small

Selected Publications

- Oladosu, G., and S. Msangi. (2013) “Biofuel-Food Market Interactions: A Review of Modeling Approaches and Findings.” Agriculture 3.1: 53-71. http://www.mdpi.com/2077-0472/3/1/53/pdf
- Oladosu G., K Kline, P Leiby, R Uria-Martinez, M Davis, M Downing and L Eaton (2012) “Global Economic Effects of US Biofuel Policy and the Potential Contribution from the Advanced Biofuel Targets”, Future Science – Biofuels Journal 3(6)
- Oladosu G. (2012) “Estimates of the Global Indirect Energy-Use Emission Impacts of USA Biofuel Policy.” Applied Energy Journal 99: 85–96
- Oladosu G., K. Kline, R. Uria-Martinez, and L. Eaton (2011) “Sources of Corn for Ethanol Production in the United States: A Decomposition Analysis of the Empirical Data”, Biofuels, Bioproducts & Biorefining (BioFPR) Journal 5:640-653(2011) DOI:10.1002/bbb.305 http://onlinelibrary.wiley.com/doi/10.1002/bbb.305/abstract
- Oladosu GA and Kline KL 2010 “The Role Of Modeling Assumptions And Policy Instruments in Evaluating The Global Implications Of U.S. Biofuel Policies.” Proceedings of the 33rd International Association of Energy Economics International Conference “The Future of Energy: Global Challenges, Diverse Solutions” Rio de Janeiro, Brazil, June 6-9, 2010
- Oladosu G, K. Kline, P. Leiby, Rocio Uria-Martinez, Maggie Davis, Mark Downing and Laurence Eaton. (2012) “Evaluating the Potential Economic Effects of the US RFS2 Advanced Biofuel Targets”, 244th American Chemical Society National Meeting, Philadelphia.
- Oladosu G (2011) “Estimates of the Indirect Energy and Emission Effects from Biofuels”, Presented at the 30th USAEE/IAEE North American Conference: Changing Roles of Industry, Government and Research, Washington D.C., USA, October, 2011
- Oladosu GA and Kline KL “Empirical Analysis of the Sources of Corn Used for Ethanol Production in the United States: 2001-2009”, Presentation at the National Corn Growers Association (NCGA) AgEnergy Symposium, Nov. 4 2010, Washington, D.C.
- Carolyn Sarls and G Oladosu (2010) “A Comparison of Empirical and Theoretically Estimated Eucalyptus Yield in Brazil”, Poster Presentation, Oak Ridge National Laboratory
- G. Oladosu (2010) “Global Indirect Land Use Implications of U.S. Biofuel Policies: A Review of the Evidence”, University of Tennessee Department of Agricultural Economics Fall Seminar Series, Sept. 2010
- Oladosu, GA, and Kline KL “Land Use Impacts of Corn Ethanol: Reconciling Models, Empirical Data and Policy” at the National Corn Growers Association Conference on Land Use and Carbon Impacts of Corn-Based Ethanol, St. Louis, Missouri August 26 2009