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DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

GCAM Bioenergy and Land Use Modeling

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Analysis and Sustainability

PI: Marshall Wise
Pacific Northwest National Laboratory

- ▶ Support BETO Analysis and Sustainability goals by studying bioenergy production and use in a systems and economic context of US and global energy, agriculture, land use, and emissions.
 - MYPP goal: Develop and maintain analytical tools, models, methods, and datasets to advance the understanding of bioenergy and its related impacts.

- ▶ Maintain state-of-the-art representation of bioenergy as part of the GCAM core model used for DOE, EPA, energy firms, and international user community.
 - MYPP goal: Ensure high-quality, consistent, reproducible, peer-reviewed analysis.
 - Ensure bioenergy is considered comprehensively in GCAM analysis used in policy studies and in international efforts such as the Intergovernmental Panel on Climate Change (IPCC).

Quad Chart Overview

Timeline

- ▶ Project start date: March 2010
- ▶ Project end date: FY17
- ▶ Percent complete: 75%

Budget

	Total Costs FY 10 –FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date)
DOE Funded	600K	100K	150K	500K
Project Cost Share (Comp.)	0	0	0	0

Barriers

- ▶ Barriers addressed
 - St-B. Consistent and Science-Based Message on Bioenergy Sustainability
 - At-B. Limitations of analytical tools and capabilities for system-level analysis
 - St-F: Systems Approach to Bioenergy Sustainability

Partners

- PNNL Joint Global Change Research Institute (JGCRI)
- GCAM Modeling Team
- GCAM Core Model Committee
 - Formal management and peer review of model and data development before incorporation and release in core community model
- GCAM Community of Model Users

1 - Project Overview

- ▶ We have studied several issues related to bioenergy under this project with parallel additions to bioenergy modeling capability.
 - Modeling/data for bioenergy crops and technologies globally.
 - Integrated economic analysis of biofuels and biopower.
 - Incorporation of water demands for bioenergy production.

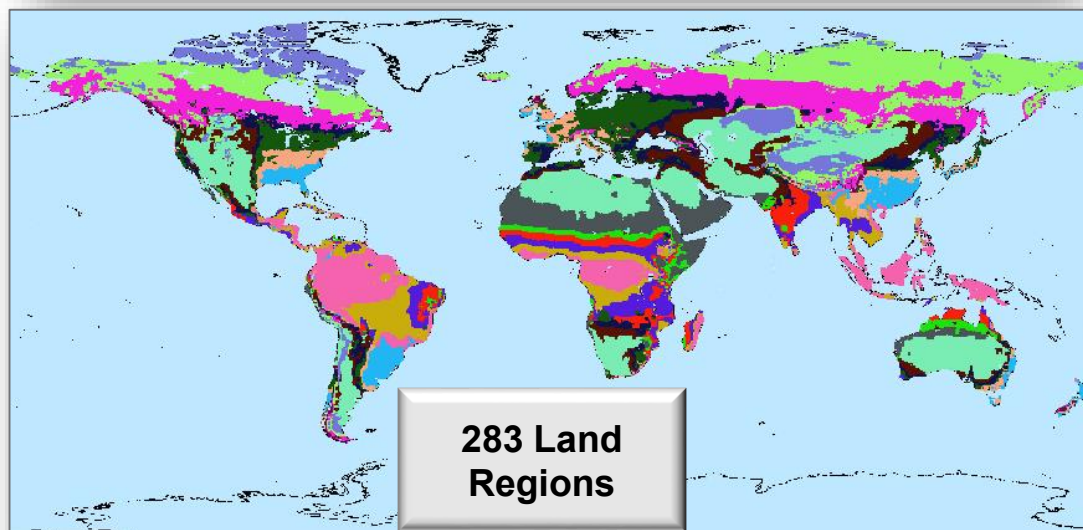
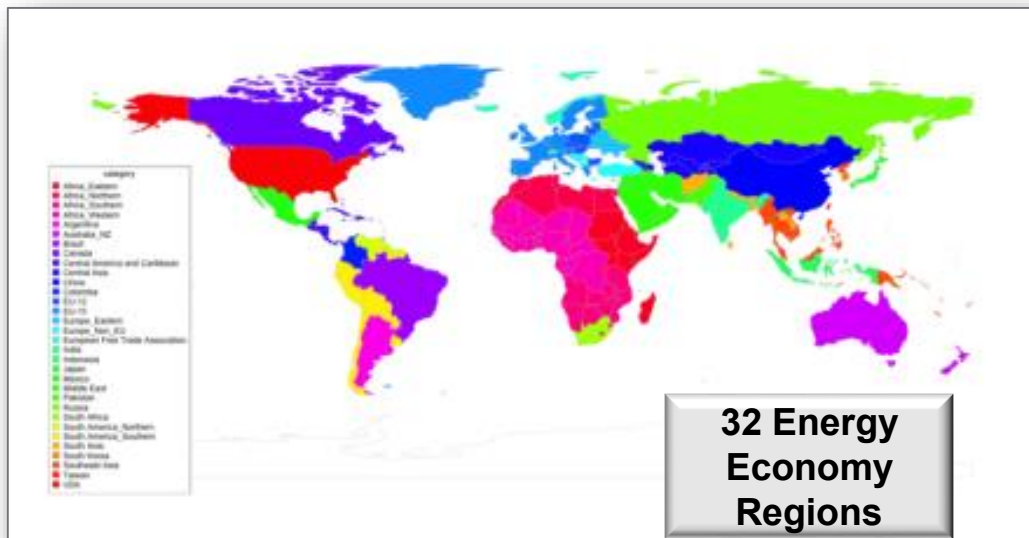
- ▶ BETO GCAM project is leveraged by the more than two decades of funding by DOE Office of Science - Biological and Environmental Research (BER), other DOE, EPA , and several other public and private organizations.

- ▶ GCAM participates in international forums and studies such as the IPCC and the Stanford Energy Modeling Forum (EMF)
 - Available as a community model with an international user group

Global Change Assessment Model 4.0

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- ▶ GCAM is a long-term (2100) Integrated Assessment Model linking Energy, Technology, Agriculture, Land-use, Emissions, and Climate.
- ▶ GCAM is a community model developed and led by PNNL.
- ▶ Ag/land use modeled in 283 regions defined by intersection of 32 energy/economy regions and GTAP Agro-Economic Zones (AEZs).
- ▶ Documentation available at: wiki.umd.edu/gcam.

2 – Approach (Technical)

- ▶ Define with BETO key bioenergy analysis and sustainability areas and guiding questions for which GCAM modeling can provide complementary insights to the other BETO tools and analyses.
 - Identify questions for which long-term, integrated analysis provides context to more focused life cycle, technology, and systems studies.

- ▶ Identify model developments needed to help address these questions.
 - Capture the key elements and system interactions rather than duplicate detail best suited to a more specifically focused model.
 - Maintain a balance between detail and complexity in representing bioenergy technologies and systems within a larger model.

- ▶ Ensure that these analyses are visible to policy makers and model developments are accessible to model users.
 - In addition to publishing papers and adding features to GCAM community model, use the bioenergy modeling capability for policy and technology analysis for DOE, EPA, IPCC, and other public and private organizations.

2 – Approach (Management)

- ▶ All efforts are clearly defined in agreement with BETO in annual proposals and Statements of Work with formal monitoring.
- ▶ Quarterly Milestones are defined in the Statement of Work with written reports or briefs delivered at the end of each quarter.
- ▶ Formal quarterly progress reports with financial updates and project progress updates are delivered to BETO.
- ▶ Opportunities for leveraging parallel GCAM developments are exploited when advantageous.
 - Plans must be done in close collaboration with other projects to keep task goals challenging yet achievable.
- ▶ All model and data development must be vetted and documented through a formal review process with PNNL GCAM Core Model Management Committee to become part of GCAM.

3 – Technical Accomplishments/ Progress/Results

- ▶ Progress and Accomplishments can be measured in terms of new analyses and the development of new analytical capabilities in support of new analyses.

- ▶ We have consistently published papers on bioenergy and its key role in the integrated assessment of global energy and agriculture.
 - GCAM work on analysis of bioenergy and land use change emissions featured prominently in the IPCC Special Report on Renewables.
 - In FY 14, published paper looking at potential impact of expanded global biofuels use on energy, agriculture, and emissions.

- ▶ Since last peer review, the major technical accomplishment was to incorporate water requirements for producing bioenergy crops in the context of GCAM agriculture and the economic modeling of irrigation.

- ▶ Among several MYPP barriers addressed by these accomplishments, perhaps the most directly relevant to these efforts is **St-B. Consistent and Science-Based Message on Bioenergy Sustainability.**

3 – Paper on Potential Impacts of Global Biofuels Expansion

► Used GCAM modeling to study impacts of expansion of global biofuels use through current and hypothetical future international biofuel policies.

► Explored impact on regional crop production, prices, and energy and LUC carbon emissions.

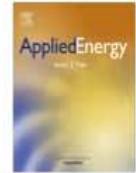
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Agriculture, land use, energy and carbon emission impacts of global biofuel mandates to mid-century



Marshall Wise ^{a,*}, James Dooley ^{a,1}, Patrick Luckow ^{a,b,2}, Katherine Calvin ^{a,3}, Page Kyle ^{a,4}

^a Pacific Northwest National Laboratory, Joint Global Change Research Institute, 5825 University Research Court, Suite 3500, College Park, MD 20740, USA

^b Synapse Energy Economics, 485 Massachusetts Ave., Suite 2, Cambridge, MA 02139, USA

HIGHLIGHTS

- Modeled impact of expanded global biofuels policies on energy and agriculture.
- GCAM integrated assessment model analysis of energy, land, and carbon emissions.
- Expanded biofuels policies reduce oil consumption with modest food price increases.
- Terrestrial carbon emissions eventually offset by reductions from energy system.

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ABSTRACT

Three potential future scenarios of expanded global biofuel production are presented here utilizing the GCAM integrated assessment model. These scenarios span a range that encompasses on the low end a continuation of existing biofuel production policies to two scenarios that would require an expansion of current targets as well as an extension of biofuels targets to other regions of the world. Conventional oil use is reduced by 4–8% in the expanded biofuel scenarios, which results in a decrease of in CO₂ emissions on the order of 1.2 GtCO₂ (base by mid-century) from the global transportation sector. The impact

3 – Published Paper on Impact of Global Biofuels Expansion (cont.)

The expansion of bioenergy production in these scenarios has some impact on the prices of sugar and corn and a small impact on food crops like wheat.

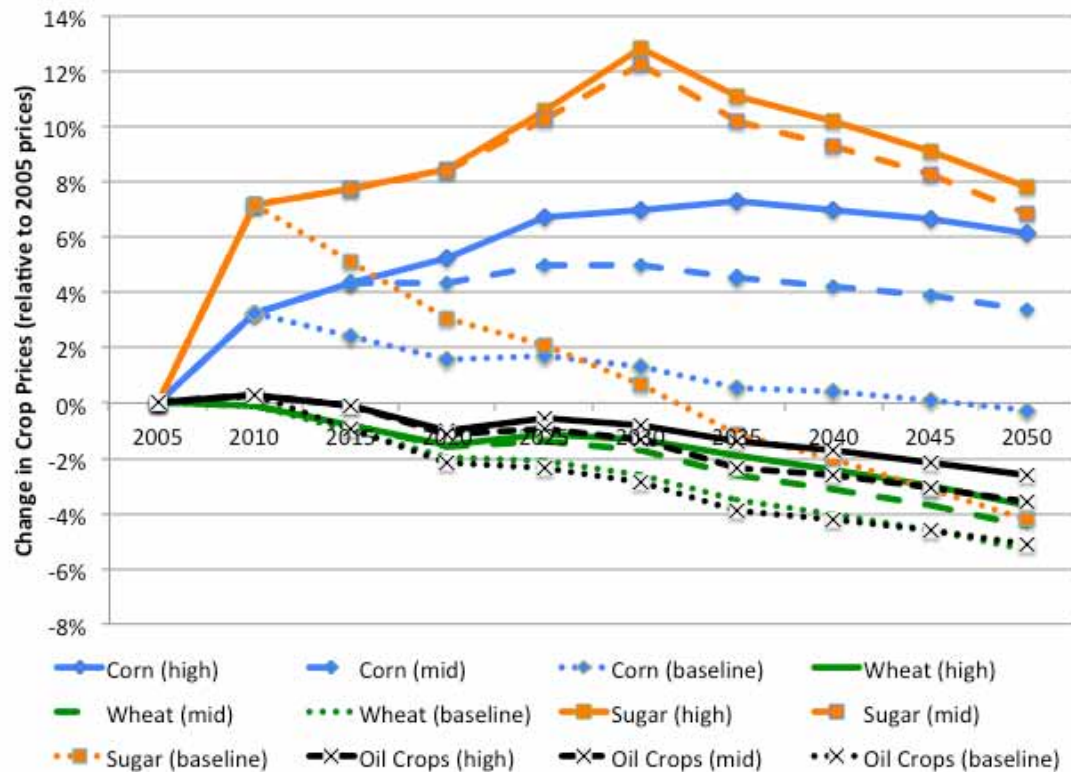


Figure: Change in long-term equilibrium food crop prices (producer prices) relative to 2005 (%).

3 – Published Paper on Impact of Global Biofuels Expansion (cont.)

Near-term increase in Land Use Change emissions is offset over time by reductions in energy system emissions.

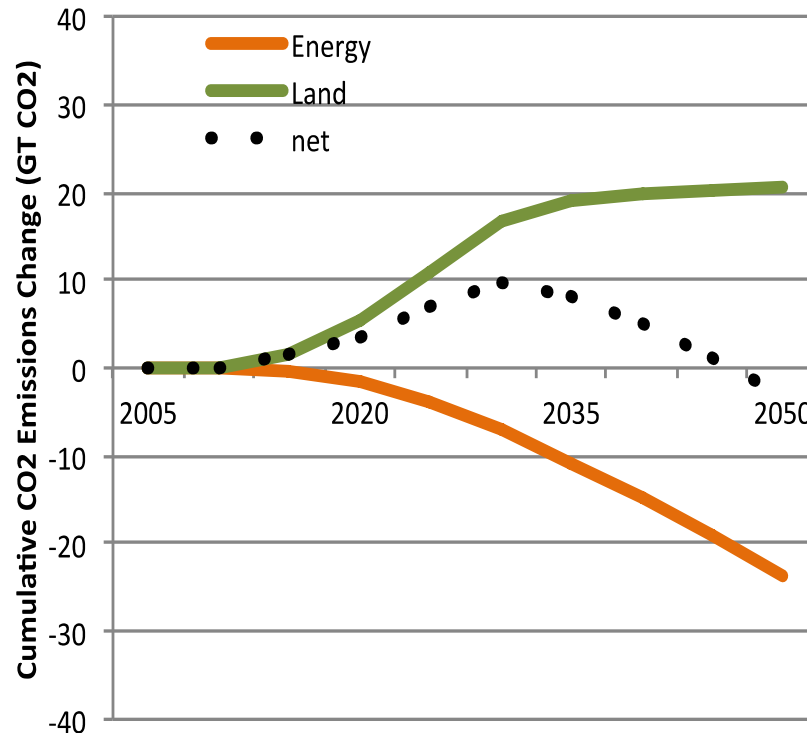
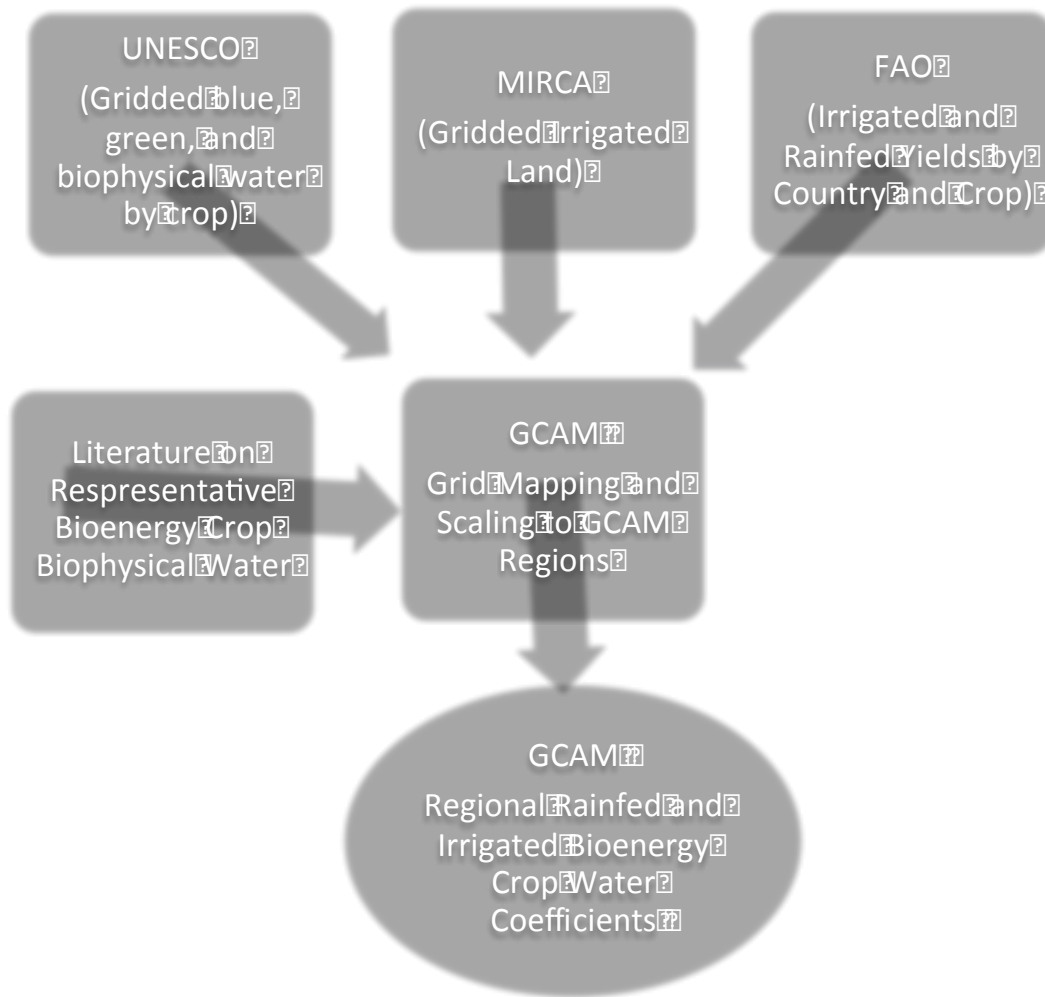


Figure: Net difference in ***cumulative*** emissions from land use change and energy system from the baseline scenario: Mid Biofuels scenario.

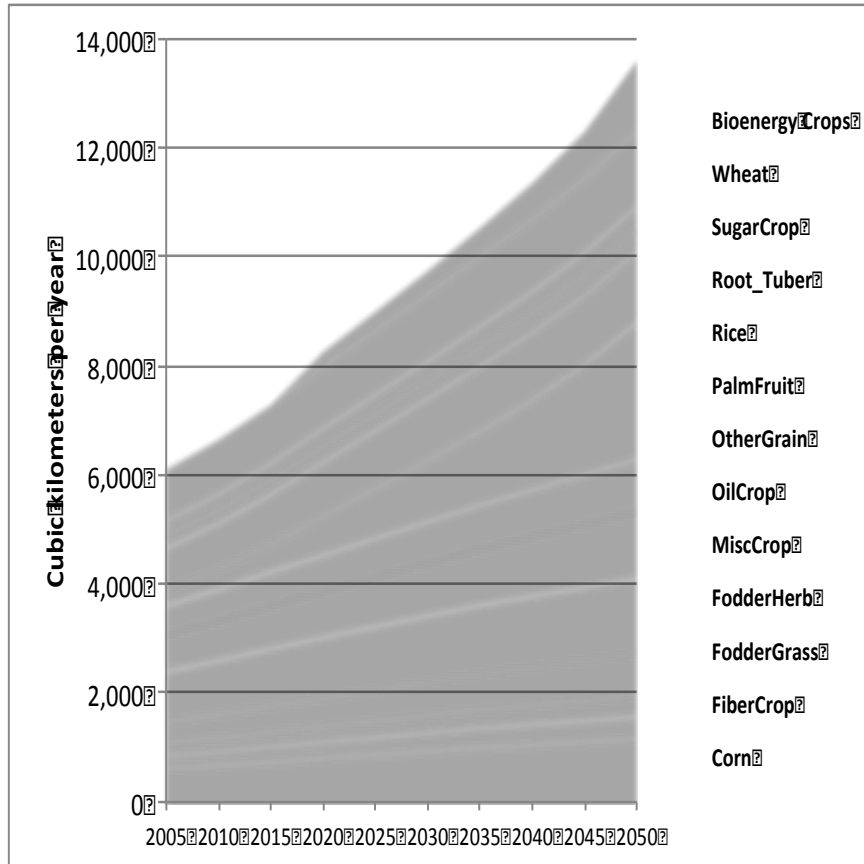
3 – Creating a Global Set of BioEnergy Crop Water Coefficients



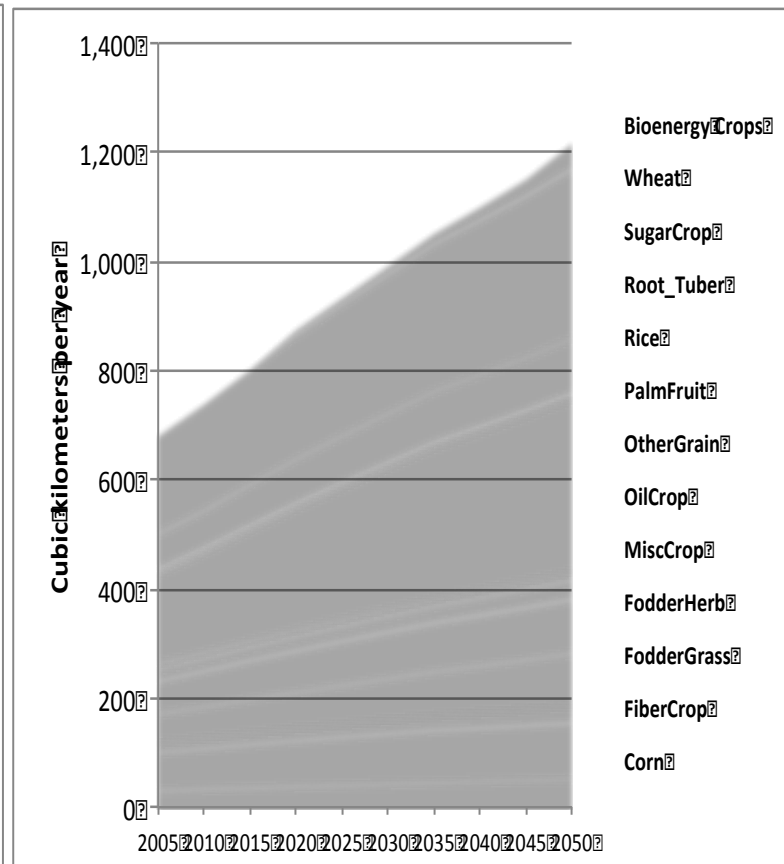
Multiple Sources of gridded land data, water coefficients, and country-level crop production data were necessary to create an internally-consistent data set for GCAM.

3 – Early GCAM Results: Water Consumption for Bioenergy Crops

Global Biophysical Water Consumption



Global Blue Water (Irrigation)



- ▶ Note: Biophysical water is total water: rainfed plus irrigation.
- ▶ This is a scenario with growing population and about 50 EJ of bioenergy crops per year by 2050.

4 – Relevance

- ▶ Provides a systems, economic, multi-sector, policy, and international context for bioenergy considering energy, agriculture, and emissions (Barriers St-F: Systems Approach to Bioenergy Sustainability, Mm-A: Lack of Understanding of Environmental/Energy Tradeoffs).
 - Complements LCA, techno-economic, and systems analyses by providing potential bioenergy scale and dynamics of drivers outside their scope.
 - Complements GTAP modeling of economic and trade impacts by focusing on long-term technology development and physical system details.

- ▶ Provides policymakers and industry with objective, quantitative analyses of sustainability issues such as land use change emissions, food prices, and water. (Barrier St-B: Consistent and Science-Based Message on Bioenergy Sustainability).
 - MYPP goal: Convey the results of analytical activities to a wide audience, including DOE management, Congress, the White House, industry, other researchers, other agencies, and the general public.

- ▶ Tech transfer: GCAM is open source and distributed as a community model (Barrier: At-C Inaccessibility and Unavailability of Data).

5 – Future Work

- ▶ Current and future tasks will turn the focus back to the energy system.
- ▶ FY 15 Scope: Analyze potential and impact of biofuels for US and global jet transportation
 - in the context of future scale of US and global demands for air transport,
 - in the context of other fuels and other demands for bioenergy,
 - in the context of agriculture and land use for bioenergy crops, and
 - considering the emissions impacts from the energy system and from land use when applicable.
- ▶ We have defined with BETO key framing questions and potential bio jet fuel pathways for analysis with GCAM.
- ▶ Key milestones include parameterization of bio jet fuel pathways and generation of scenarios and potential impact both nationally and globally over the next decades.

1. Overview - integrated analysis of bioenergy sources and technologies in a global modeling framework.
 2. Approach – Defined key bioenergy analysis and sustainability questions to guide analysis and model development efforts.
 3. Technical Accomplishments/Progress/Results - published papers of integrated analysis of bioenergy.
 4. Relevance – complements other tools and supports research in several areas of the BETO multi-year program plan.
 5. Future work – Integrated analysis of potential and impact of bio jet fuel production and use.
- ▶ Since 2013, published new study on the impact on agriculture, energy, and emissions of expanded global biofuels production and use. Implemented modeling of water demands for bioenergy production.



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Additional Slides

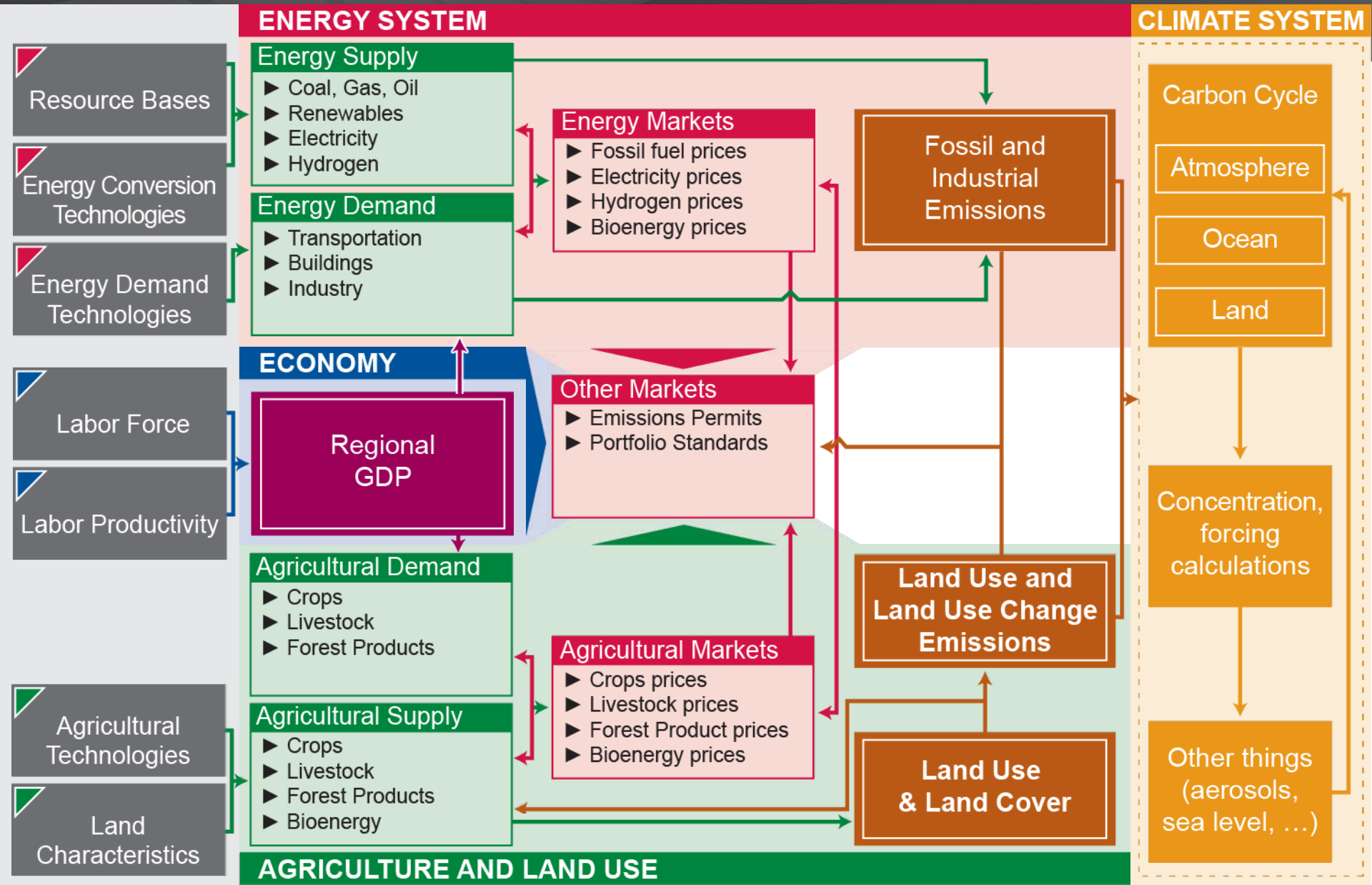
Responses to Previous Reviewers' Comments

- ▶ The common theme among 2013 peer reviewers' comments was not about the specific tasks in the project so much as the potential complexity and the inaccessibility of the modeling in general, along with inadequate explanation of the role of this modeling project in the context of the rest of BETO's analytical tools.
- ▶ These are fair criticisms that highlight the importance of communication of approach and analysis.
- ▶ In response, we have begun the statements of work each year with a clear statement of guiding questions that take clear advantage of the role of GCAM as a long-term, international, integrated model in complement to the other BETO tools.
- ▶ As to complexity and inaccessibility, GCAM is an open source, community model. We continue to hold annual GCAM workshops where we explain the theory and structure and train new users.

Publications, Patents, Presentations, Awards, and Commercialization

- ▶ Wise, M.A., J.J. Dooley, P. Luckow, K. Calvin, and P. Kyle. 2014. Agriculture, land use, energy and carbon emission impacts of global biofuel mandates to mid-century. *Applied Energy*. doi: 10.1016/j.apenergy.2013.08.042.
- ▶ Edmonds, James, Patrick Luckow, Katherine Calvin, Marshall Wise, Jim Dooley, Page Kyle, Son H. Kim, Pralit Patel, Leon Clarke. 2013. "Can radiative forcing be limited to 2.6 Wm⁻² without negative emissions from bioenergy and CO₂ capture and storage?" *Climatic Change*. Special Issue on "Carbon Dioxide Removal from the Atmosphere: Complementary Insights from Science and Modeling". doi:10.1007/s10584-012-0678-z.
- ▶ Luckow, Patrick, Marshall Wise, James Dooley, Son Kim. 2010. "Large Scale Utilization of Biomass Energy and Carbon Dioxide Capture and Storage in the Transport and Electricity Sectors under Stringent CO₂ Concentration Limit Scenarios." *The International Journal of Greenhouse Gas Control*. 4 (2010) pp 865-877.

GCAM Model Structure Schematic



Scenario Specifications for Applied Energy Paper

- Wise, Dooley et al 2014: Impact on energy and agriculture of scenarios of current and *hypothetical* expansion of biofuels policies around the world.

	Quantities or % of liquid fuels by Scenario phased in from now to 2050		
Region	Baseline (current levels)	Mid	High
USA	13 bgal	36 bgal (e.g., RFS 2)	53 bgal
Canada	5%	5%	5%
Latin America	12%	25%	25%
EU	5.75%	15%	25%
India	-	15%	25%
China	-	15%	25%
Southeast Asia	-	20%	25%
Africa	-	10%	20%
Former Soviet Union	-	10%	20%

References for Water Coefficient Parameterization

- ▶ Data from a number of gridded databases will be transformed in order to get water coefficients for crops consistent with GCAM's aggregation of crops and regions.
- ▶ Mekonnen and Hoekstra (2010) (for UNESCO) – gridded global source of “green” (rainfed) and “blue” (irrigated) water coefficients for all crops.
- ▶ MIRCA (Portmann et al 2010) – database of irrigated and rainfed land areas.
- ▶ FAO Aquastat (2005) – country by country yields of irrigated and rainfed crops consistent with FAO agriculture production.
 - GCAM is calibrated to FAO production and demand – so this step is required to ensure consistency.