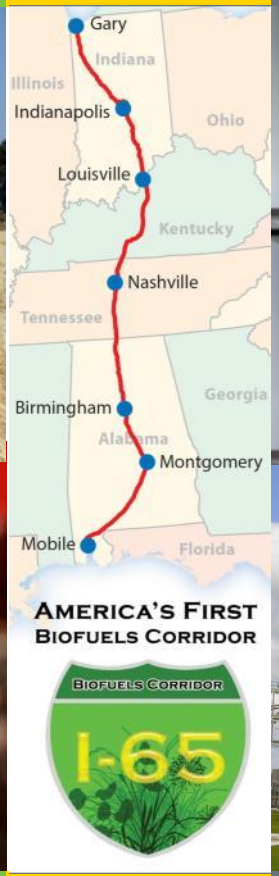
2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



GCAM Bioenergy and Land Use Modeling

May 21, 2013 Principal Investigator: Marshall Wise

Technology Area Review: Analysis and Sustainability

Organization: PNNL

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Goal Statement

- The main objective is to model and study the long-term global potential and role of bioenergy using the PNNL Global Change Assessment Model (GCAM)
  - Project supports BETO Analysis and Sustainability goals of providing an integrated context for analysis
  - Project provides analysis within a global economic context of bioenergy systems, technologies, and policies that considers the entire energy and agriculture systems
- Context: the GCAM modeling project is an established, multi-client effort ongoing for over two decades
  - This BETO project is able to leverage this effort and focus on improving modeling capabilities, data, and analysis in key areas related to bioenergy production and use
  - This project helps maintain GCAM at the state of the art for representing bioenergy in a global integrated assessment model

Quad Chart Overview

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Timeline

- Project start date: March 2010
- Project end date: September 2017
- Percent complete: 35%

Budget

- Funding for FY11: $200K
- Funding for FY12: $200K
- Funding for FY13: $100K
- Project funded for 4 years/ average annual funding of $175K

Barriers

- Barriers addressed
  - At-A. Lack of Comparable, Transparent, and Reproducible Analysis
  - At-B. Limitations of analytical tools and capabilities for system-level analysis
  - St-F: Systems Approach to Bioenergy Sustainability

Partners

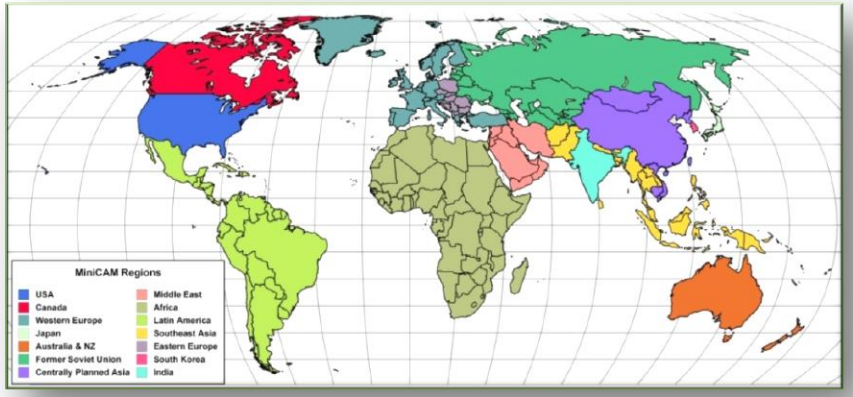
- GCAM Modeling Team
- Joint Global Change Research Institute (JGCRI)
- Project Management:
  - Quarterly reporting with milestones for model development analysis.
  - End of FY formal report of new analysis, to be considered for journal submission

Project Overview

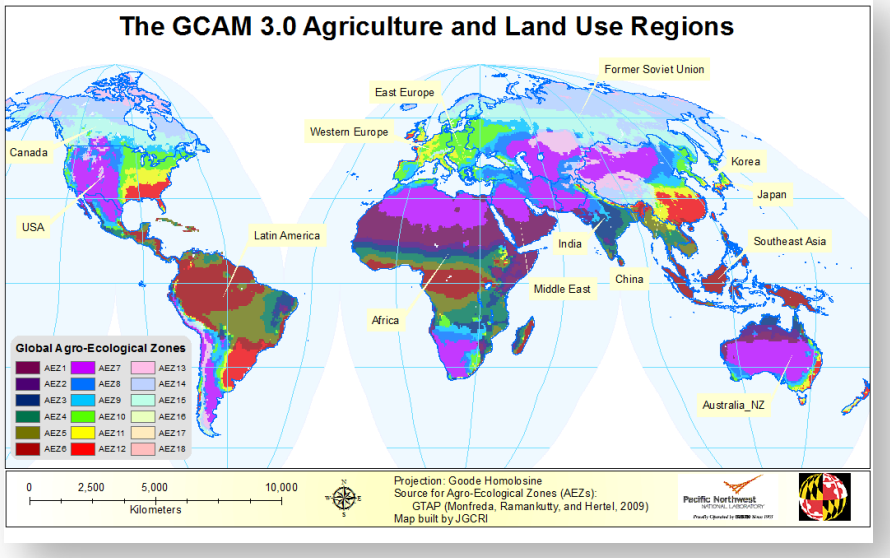
- GCAM has been used and funded for research and analysis by many offices of DOE (Office of Science, Policy and International, Fossil Energy, Nuclear Energy, EERE), EPA, and for private industry
  - Participates in IPCC, Energy Modeling Forum (EMF)
  - Available as a community model
- This project is 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
- Efforts conducted for BETO have included –
  - Modeling/data for bioenergy crops and technologies globally
  - Integrated economic analysis of biofuels and biopower
  - Current: incorporation of water demand into biorefining

Global Change Assessment Model

- **14 Energy/Economy Regions**



- **151 Agriculture/Land Use Regions**



- GCAM is a long-term, global Integrated Assessment Model (IAM)
- GCAM links Economic, Energy, Agriculture, Land-use, and Climate systems
- GCAM is a community model developed and led by PNNL
- Economic and physical interactions of technology and policy on energy, agriculture and land-use, and climate

1 - Approach

Technical Approach

- Upgrade the GCAM representation, and parameterization of biomass production and use by investigating current and potential biomass crops, resources, and transformation technologies
- Leverage capabilities developed in concurrent GCAM modeling efforts for other sponsors
- Leverage BETO efforts by incorporating key resources, technologies, life-cycle analysis, and techno-economic analysis into GCAM
- Provide timely reports and analysis on bioenergy issues that are relevant and document progress

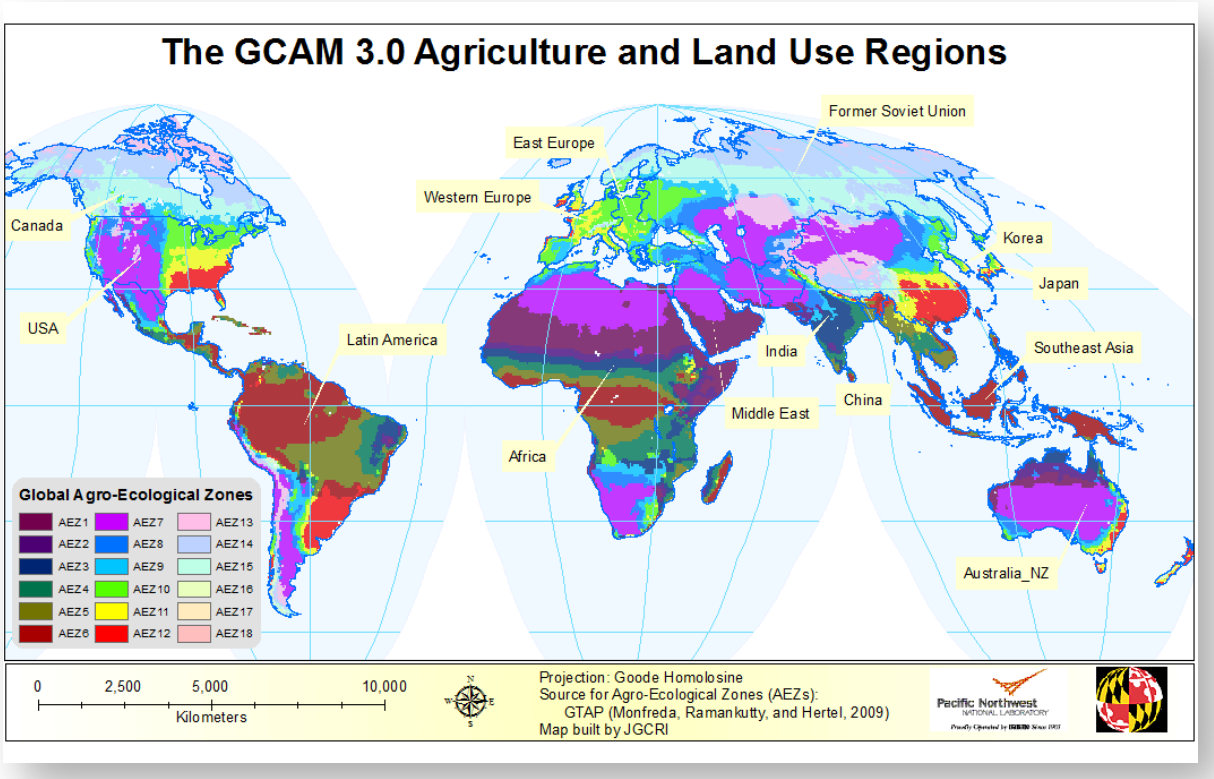
Management Approach

- Annual Statements of Work with quarterly milestones
- Formal quarterly progress reports to BETO
- Clear all model and data development through formal review process with PNNL GCAM Core Model Management Committee

Outline of Technical Accomplishments Presentation

- Part 1. Completion of GCAM bioenergy and agricultural modeling at the agro-ecological zone (AEZ) subregional level (in progress during FY11 Peer Review)
  - Paper on impacts of representative expanded global biofuels policies currently in peer review
- Part 2. Studied role of bioenergy and Carbon Dioxide Capture and Storage (CCS) in long-term global policies
  - Work done under DOE Office of Science that is enhanced by the model development funded by BETO
- Part 3. Incorporation of GCAM water modeling and bioenergy
  - Also leverages an ongoing effort funded by DOE Office of Science

Part 1. Modeling of Bioenergy Globally at AEZ subregions



- Crop yields, forests, pasture, terrestrial carbon, and other economic and physical land characteristics with data specific to each of 151 land regions
- Bioenergy crops and residue resources are modeled in each region where viable and are produced based on economics and policy

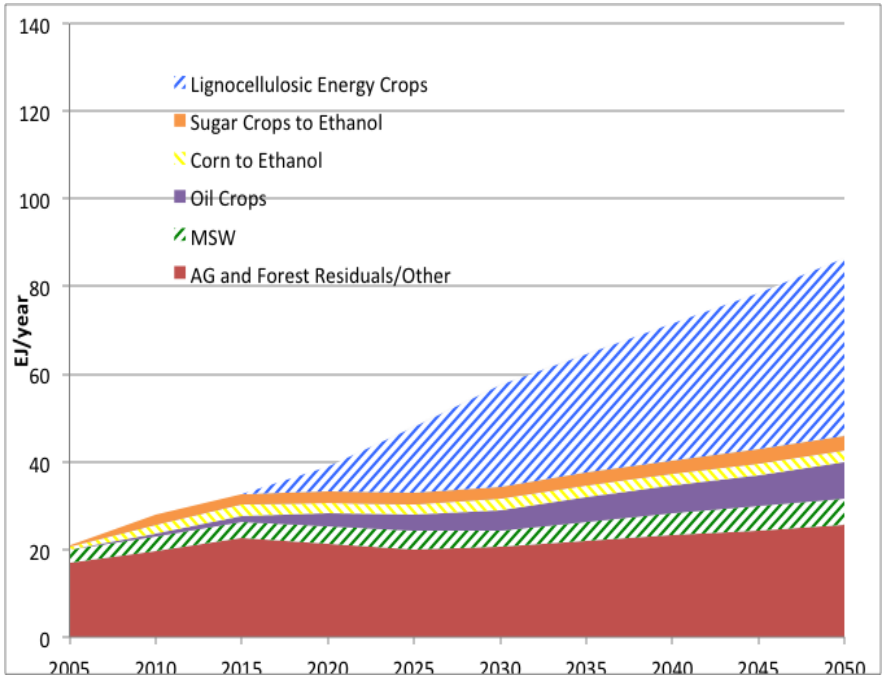
Part 1. Modeling of Bioenergy Globally at AEZ subregions

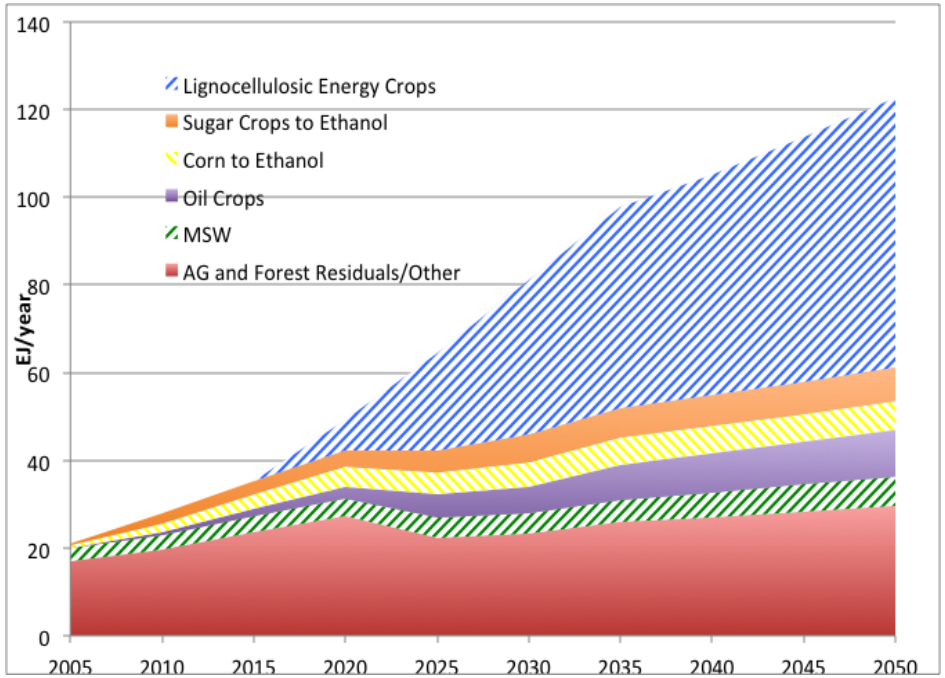
- Completed study and submitted paper (currently in review) studying impact on energy and agriculture of scenarios of current and *hypothetical* expansion of biofuels policies around the world

	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%

Part 1. Modeling of Bioenergy Globally (results from paper)

- Most of the global bioenergy increase is from dedicated cellulosic crops, but residue sources (from agriculture and forestry) remain significant

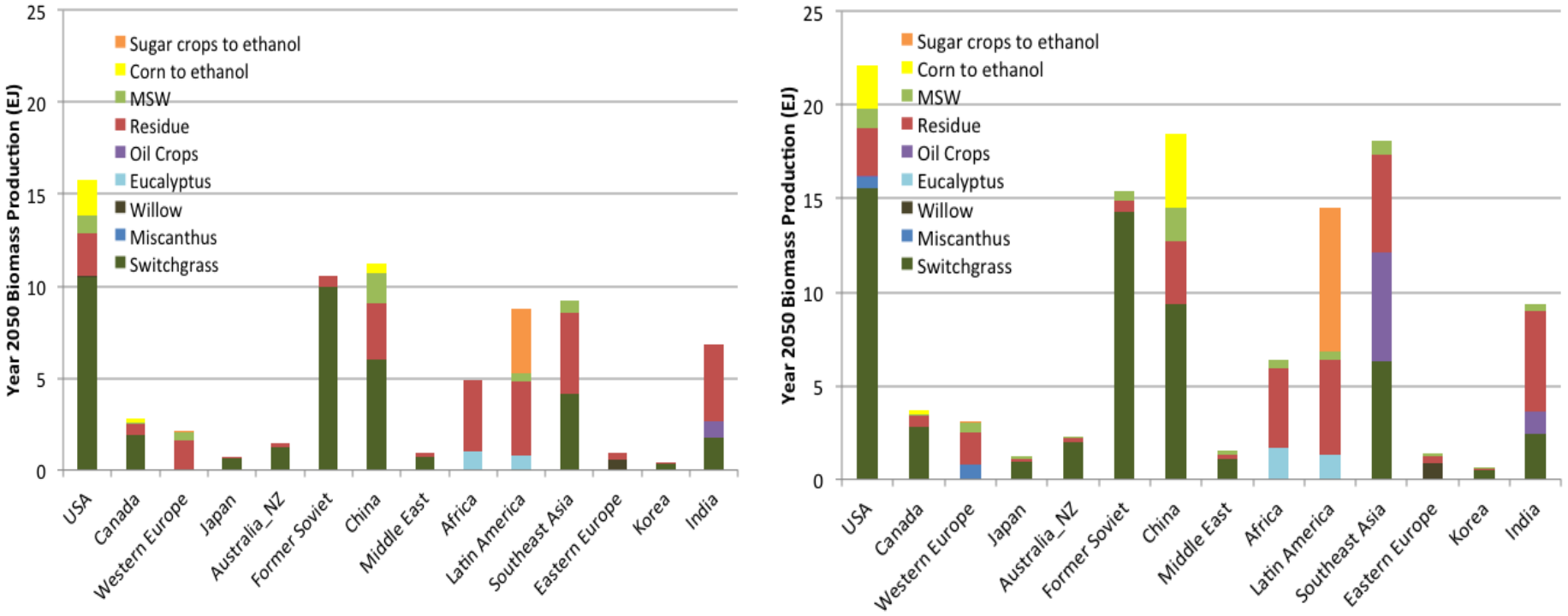




Global biomass production (for use in all energy sectors) by type, baseline (left panel) and high biofuels scenario (right panel), primary energy equivalent (EJ/year)

Part 1. Modeling of Bioenergy Globally (results from paper)

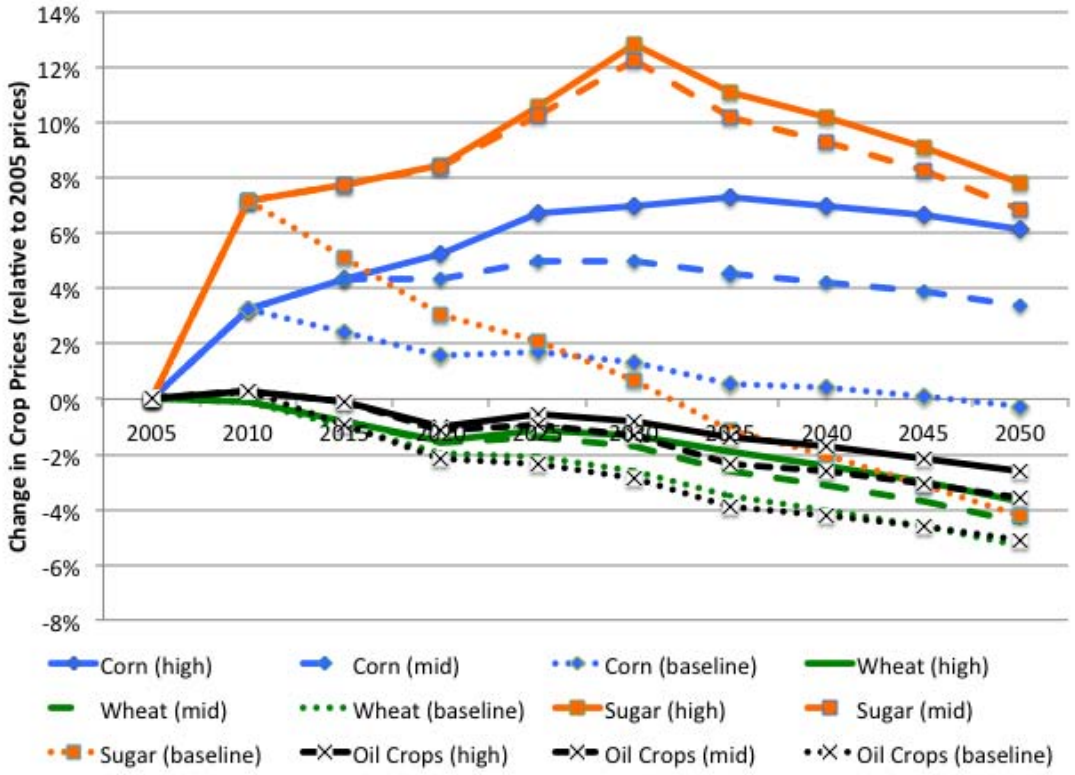
- Most of the increase is from baseline to high is from switchgrass, except for sugar in South America and oil crops in Southeast Asia



Year 2050 bioenergy production by region, primary energy equivalent of the feedstocks, baseline scenario (left panel) and high biofuels scenario (right panel) (EJ/yr)

Part 1. Modeling of Bioenergy Globally (results from paper)

- 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



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

Part 2. Role of Bioenergy and CCS in long-term Global Policies

- Study published for a special issue of *Climatic Change*
- This is a typical example of research done outside of the BETO project but benefits from our model development efforts through the BETO project
- Paper demonstrates impact of bioenergy and CCS in reducing the cost of achieving a strict climate mitigation target

Climatic Change
DOI 10.1007/s10584-012-0678-z

Can radiative forcing be limited to 2.6 Wm^{-2} without negative emissions from bioenergy AND CO_2 capture and storage?

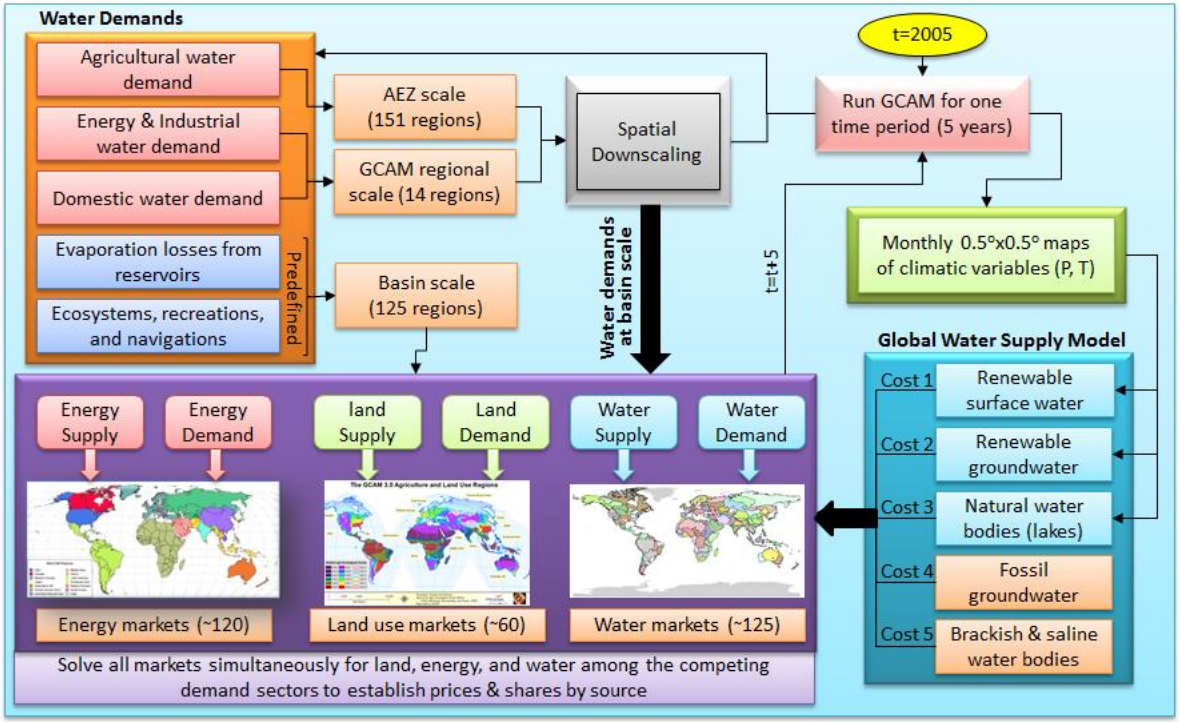
James Edmonds · Patrick Luckow · Katherine Calvin · Marshall Wise · Jim Dooley · Page Kyle · Son H. Kim · Pralit Patel · Leon Clarke

Received: 23 February 2012 / Accepted: 23 December 2012

Abstract Combining bioenergy and carbon dioxide (CO_2) capture and storage (CCS) technologies (BECCS) has the potential to remove CO_2 from the atmosphere while producing useful energy. BECCS has played a central role in scenarios that reduce climate forcing to low levels such as 2.6 Wm^{-2}. In this paper we consider whether BECCS is essential to limiting radiative forcing (RF) to 2.6 Wm^{-2} by 2100 using the Global Change Assessment Model, a closely coupled model of biogeophysical and human Earth systems. We show that BECCS can potentially reduce the cost of limiting RF to 2.6 Wm^{-2} by 2100 but that a variety of technology combinations that do not include BECCS can also achieve this goal, under appropriate emissions mitigation policies. We note that with appropriate supporting land-use policies terrestrial sequestration could deliver carbon storage ranging from 200 to 700 $PgCO_2$-equiavalent over the 21st century. We explore substantial delays in participation by some geopolitical regions. We find that the value of BECCS is substantially higher under delay and that delay results in higher transient RF and climate change. However, when major regions postponed mitigation indefinitely, it was impossible to return RF to 2.6 Wm^{-2} by 2100. Neither finite land resources nor finite potential geologic storage capacity represented a meaningful technical limit on the ability of BECCS to contribute to emissions mitigation in the numerical experiments reported in this paper.

Part 3. Incorporation of GCAM Water Modeling and Bioenergy

- Current FY effort – develop and implement water demand parameters for bioenergy refining based on LCA and other analysis from BETO projects
- Future planned efforts – water demands for bioenergy crops as part of long-term development of GCAM modeling of agriculture water demands



Water Modeling in GCAM

Milestones/Metrics and Progress:

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Title/Description	Due Date	Completed
Global Bioenergy Crops Modeling	Dec -11	✓
Incorporating UN Protected Lands in GCAM	Mar-12	✓
Analysis and report of data and modeling requirements for incorporating algae ponds in GCAM	Jun-12	✓
Summary report of FY12 achievements	Sep-12	✓
50% completion of GCAM data collection for water input parameters for bioenergy refining techs	Dec-12	✓
Completion of GCAM data collection for water input parameters for bioenergy refining techs	Mar-13	✓
GCAM modeling scenarios of water inputs for bioenergy refining technologies	Jun-13	In progress
Technical report of modeling scenarios exploring bioenergy refining and water	Sep-13	

3 - Relevance

- Provides a dynamic, long-term integrated context to supplement LCA analysis of specific sustainability metrics (Barrier: St-F – Systems Approach to Bioenergy Sustainability)
  - GCAM is a consumer of BETO LCA analyses
  - Integrated analysis of energy land, emissions, food, water.
- GCAM is available as a community model, and participates in several international multi-model analysis efforts such as the IPCC and EMF (Barrier: At-B Limitations of Analytical Tools and Capabilities for System-Level Analysis)
- Provides a systems, economic, multi-sector, policy, and international context for bioenergy (Barrier: At-C Inaccessibility and Unavailability of Data)
  - Provides scenarios of future bioenergy demand in the context of energy and environmental policies and other fuels, technologies, and sources of energy

4 - Critical Success Factors

- In order to project long term impacts GCAM needs to maintain state of the art for modeling and analysis of bioenergy production and use in a global, integrated assessment model
  - Must be current with regards to technologies, markets, and policies that affect bioenergy
- GCAM continues to provide integrated analysis of bioenergy that considers the potential interactions and trade-offs among different sustainability goals
  - Continue to explicitly model impacts on economics, environment, and food prices
  - Develop more capability to consider water
  - Explicitly models the global agriculture and energy systems and their impacts on the U.S.

5. Future Work

- FY 13 end of year milestone: report showing global scenario modeling and analysis of water requirements for refining bioenergy into liquid fuels considering the trade-offs among different processes and technologies.
  - Incorporates data obtained collaboratively from BETO-funded efforts at Argonne National Laboratory (May Wu et al.)

- For FY 14 and 15, main project effort will be to develop modeling capability to explore elements of lifecycle water implications for bioenergy globally, understanding the implications of key factors such as:
  - Choices between irrigation and other practices, and the competition for water among all crops in all parts of the world
  - Climate change impacts on water requirements and yields more generally
  - This effort strongly leverages the ongoing GCAM water modeling project

GANTT CHART

ML or DL or Go/No Go	Description	FY13 Q3	FY13 Q4	FY14 Q1	FY14 Q2	FY14 Q3	FY14 Q4
ML	Run Scenarios of Bio Refining and Water						
DL	Technical Report/Paper						
ML	Collect Data on Water Inputs for BioCrops						
ML	Continue Data and Construct Model Structures						
ML	Run Model Scenarios						
DL	Technical Report/Paper						

Summary

1) Approach: analyze bioenergy in an integrated economic model of land use, agriculture, and energy systems.
2) Technical accomplishments: integrated analysis of bioenergy sources and technologies in a global modeling framework.
3) Relevance: supports several barriers in the BETO multi-year plan for Strategic Analysis and Sustainability.
4) Critical Success factors and challenges: continue to provide current and relevant integrated analysis of bioenergy.
5) Future Work: bioenergy water requirements into modeling of global agriculture water modeling.
6) Technology transfer: GCAM is a community model, freely available and used around the world.

Additional Slides

Responses to Previous Reviewers' Comments

- Need more specific statement of milestones.
  - As this project is highly leveraged, we have taken care to define perform specific model development and analysis tasks for BETO with quarterly milestones.
  - Intra-FY milestones involve model and data development. End of FY milestones are reporting and papers on analysis.
  - Since last Peer Review milestones met include the following:
    - GCAM modeling of bioenergy crops and resources globally (FY11).
    - A report and submitted paper of impact of potential international biofuels (FY11).
    - Incorporation of UN Protected Lands GIS data into GCAM. Report, future paper (FY12).
    - Scoping model development and report on what steps would be required to model algae ponds into GCAM (FY12).
    - Current FY13: GCAM model and data structures for water for refining biofuels.
- Assumptions about uncertain future parameters and structures need to be open and peer reviewed.
  - Model is available as a community model, documentation on the internet, annual community users meeting.
  - One of the goals is to allow exploration of the impact of changing uncertain parameters.
  - Participation in several international intermodel exercises (e.g., Stanford Energy Modeling Forum, IPCC, Potsdam Institute ROSE project).

Publications, Presentations, and Commercialization

- 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. Elsevier.

- With additional model development funding from the DOE Office of Science