Bioenergy Supply, Land Use, and Environmental Implications

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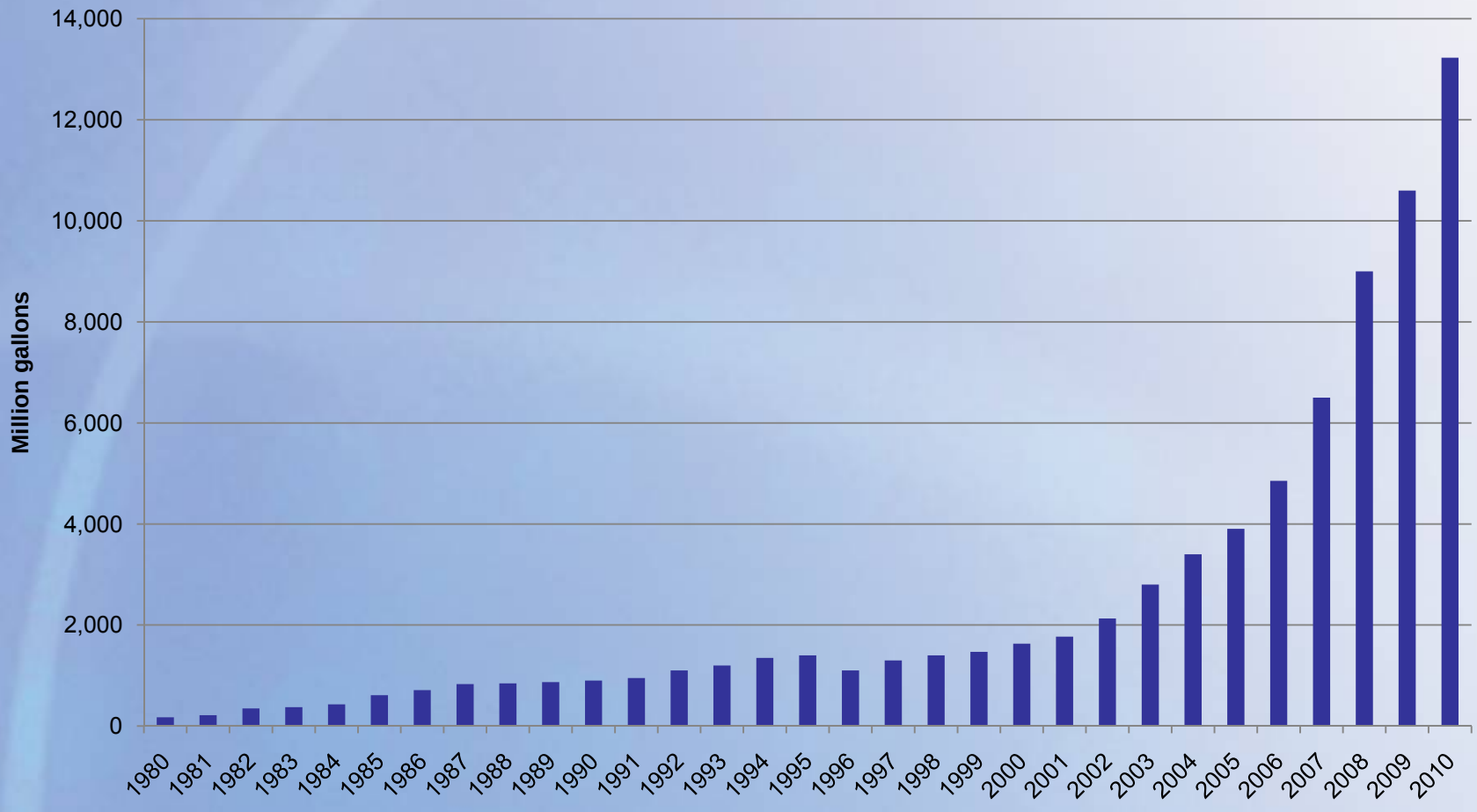
Introduction

- Forestry and agricultural activities widely recognized as potential near-term low-cost greenhouse gas mitigation options
- Mitigation is available through
  - Reducing emissions (e.g., soil management)
  - Enhancing sinks (e.g., afforestation)
  - Providing feedstocks for bioenergy production
- However, level of mitigation achieved is dynamic and can vary substantially over time and space due to differences in market and policy incentives that influence land use
- In addition, increased competition for agricultural outputs will impact production practices, crop mix, commodity markets, land use, and net GHG emissions

Bioenergy

- Potential reductions in GHG emissions along with domestic energy security have been drivers of rapid global bioenergy expansion
- Relatively little concern regarding potential negative impacts of biofuels prior to efforts to expand volumes
  - Details emerged and studies followed pointing out issues of land use change, water use, agricultural commodity prices (food vs. fuel), and net GHG impacts with full life cycle accounting
  - Similarly, concerns about sustainability and environmental impacts of forest biomass to energy have led to challenges across the US
    - Study for MA suggesting forest biomass could have greater emissions than coal through 2050
    - Challenges over smoke, toxics, forest cover, biodiversity, etc
- Important to consider land use change and other market-induced effects in assessing net impacts on GHG emissions

US Ethanol Production, 1980-2010



Key US Bioenergy Policies

- Existing
  - Energy Independence and Security Act of 2007
  - State-level Renewable Portfolio Standards
  - 2008 Farm Bill
    - Multiple programs encouraging and providing funding for renewable energy development
  - American Recovery and Reinvestment Act of 2009
    - Funding for clean energy
- Potential Future Policies
  - National Renewable Electricity Standard or Clean Electricity Standard
  - GHG mitigation policies

Energy Independence and Security Act of 2007

- Revisions to the U.S. National Renewable Fuel Standard program (RFS)
  - Increases in required volumes of biofuels
  - Expand beyond gasoline to transportation fuels more broadly
  - Specific volume standards for cellulosic biofuels, biomass-based diesel, advanced biofuels, and total renewable fuels used in transportation
  - New definitions and criteria for renewable fuels, including minimum GHG reduction thresholds

RFS2 Volume Requirements (billion gallons)

Year	Cellulosic biofuels	Biomass-based diesel	Advanced biofuels	Total renewable fuels
2008	n/a	n/a	n/a	9.0
2009	n/a	0.50	0.60	11.10
2010	0.10 (6.5 mgy)	0.65	0.95	12.95
2011	0.25 (5.0-17.1 mgy)	0.80	1.35	13.95
2012	0.50 (3.45-12.9 mgy)	1.00	2.00	15.00
2014	1.75	TBD, ≥1.00	3.75	18.15
2016	4.25	TBD, ≥1.00	7.25	22.25
2018	7.00	TBD, ≥1.00	11.00	26.00
2020	10.50	TBD, ≥1.00	15.00	30.00
2022	16.00	TBD, ≥1.00	21.00	36.00

Share of Gasoline or Diesel Volume, 2012

Renewable Fuel Category	Standards for 2011	Proposed Standards for 2012
Renewable fuel	7.95%	9.21%
Advanced biofuel	0.77%	1.21%
Biomass-based diesel	0.68%	0.91%
Cellulosic biofuel	0.004%-0.015%	0.002%-0.010%

Notes:

Percentage requirements are based on RFS2 volume requirements as a share of EIA gasoline and diesel volume projections. These percentages represent the minimum fraction of each refiner's or importer's gasoline and diesel volume that must fall into each renewable fuel category.

EISA Lifecycle GHG Reduction Thresholds

Renewable Fuel Category	Minimum GHG Reduction Threshold Relative to 2005 Petroleum Baseline
Renewable fuel[a]	20%
Advanced biofuel	50%[b]
Biomass-based diesel	50%
Cellulosic biofuel	60%

Notes:

[a]The 20% reduction level generally applies to renewable fuel produced by new facilities that commenced construction after December 19, 2007. Existing facilities are not subject to this requirement.

[b]EISA provisions permit the EPA administrator to adjust these thresholds by up to 10 percentage points, i.e., if this option is exercised, then the advanced biofuels threshold can be as low as a 40% reduction in net GHG emissions.

State Renewable Portfolio Standards

- 27 States plus the District of Columbia have RPS, another 4 states have an alternative energy portfolio standard, and 7 have voluntary goals (the other 12 states have no renewable energy standards or goals)
- Standards range from 8% to 33% when fully phased in, with full requirement taking effect in years between 2013 and 2030 across states
- Generally do not require biomass energy specifically, but seen as a likely major source in many states

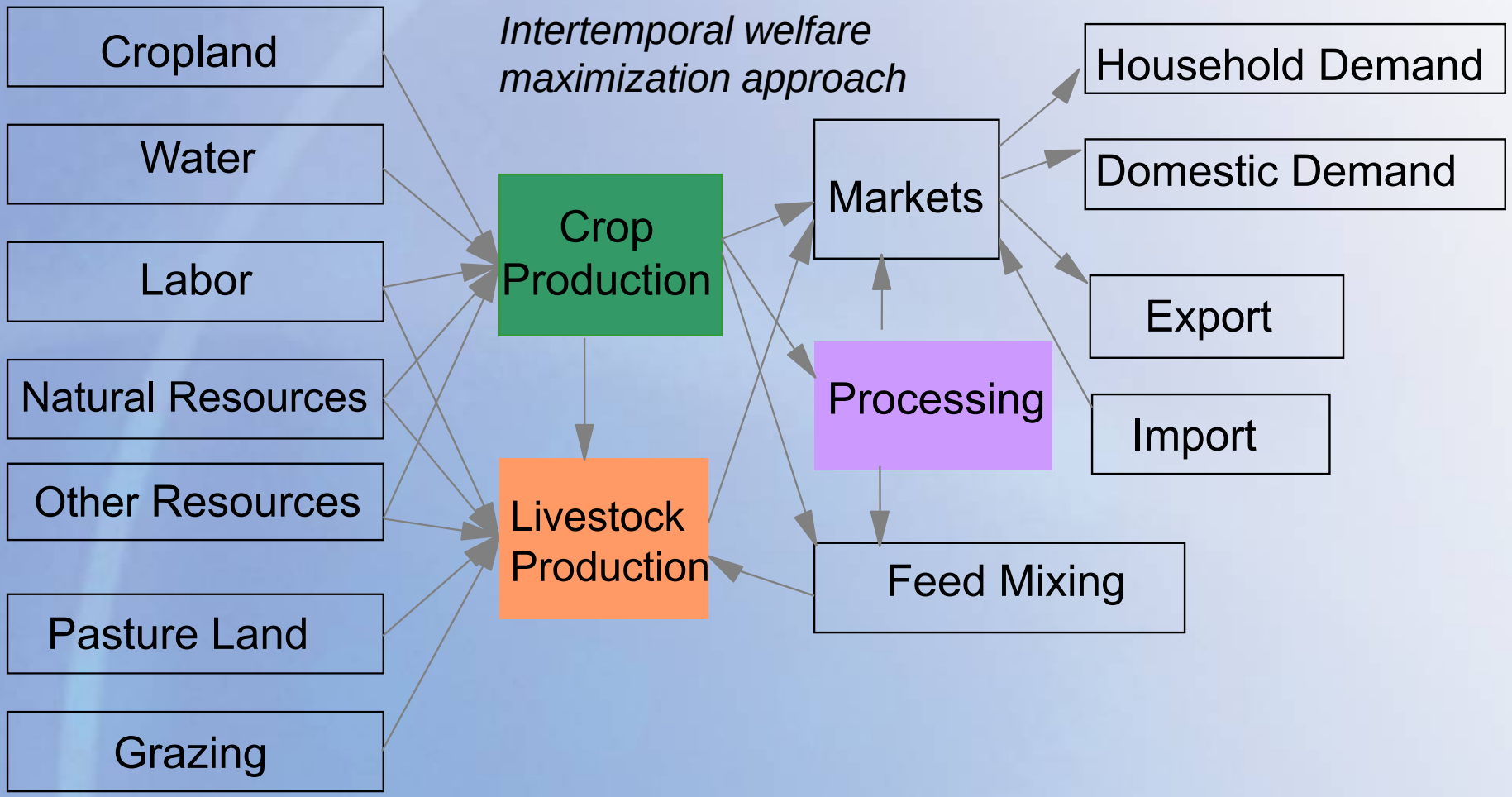
US Clean (or Renewable) Electricity Standard

- Currently about 10% of US electricity produced from renewable sources
- Recent studies have generally concluded that the bulk of the increase in renewable energy would come from:
  - Wind generation in the west and plains
  - Biomass feedstocks in the southeast
- Studies looking at 20%-25% CES or RES estimated increases in biomass generation of 14-410 billion kWh by 2030 or 2035 depending on the study and policy specification
- This is up to about 418 million dry tons of biomass

FASOM Model Structure

- Objective: Welfare Maximization
  - Land is allocated between activities (and combined with other inputs) based on relative rents (including GHG payments) and suitability to maximize intertemporal welfare
- Both Forestry and Agriculture, 10 Land Types
  - Forest – approximately 80 products from private timberland
  - Agriculture – crops and pasture
    - Over 70 primary and about 60 processed commodities, 20 processed feeds
  - Developed – Tracks conversion of forest, crop, and pastureland for development
- 3 GHGs — CO_2, N_2O, CH_4
  - Stocks and flows of GHGs for more than 50 sources and sinks
- 63 US regions (11 market regions) and international trade with 37 major trading partners
- Detailed Bioenergy Market
  - Forestry & agricultural dedicated and residue feedstocks
  - Tracks production of starch- and sugar-based ethanol, cellulosic ethanol, biodiesel, and bioelectricity

FASOM Agricultural Sector



FASOM Regions

Mitigation Possibilities in FASOM

Source/Sink	Category of Potential Mitigation	CO_2	CH_4	N_2O
Forestry				
Afforestation	Sequestration	X		
Reforestation	Sequestration	X		
Timberland management	Sequestration	X		
Harvested wood products	Sequestration	X		
Agriculture				
Manure management	Emission		X	X
Crop mix alteration	Emission, Sequestration	X		X
Crop fertilization alter.	Emission, Sequestration	X		X
Crop input alteration	Emission	X		X
Crop tillage alteration	Emission, Sequestration	X		X
Grassland conversion	Sequestration	X		
Irrigated/dryland mix	Emission	X		X
Rice acreage	Emission	X	X	X
Enteric fermentation	Emission		X	
Livestock herd size	Emission		X	X
Livestock system change	Emission		X	X
Bioenergy				
Conventional ethanol	Fossil Fuel Substitution	X	X	X
Cellulosic ethanol	Fossil Fuel Substitution	X	X	X
Biodiesel	Fossil Fuel Substitution	X	X	X
Bioelectricity	Fossil Fuel Substitution	X	X	X
Development				
Carbon on developed land	Sequestration	X		

Major categories of source/sinks:

1. Forest Management
2. Afforestation
3. Ag Soil C Seq.
4. Other Ag CH4 & N2O
5. Biofuels (FF Sub.)
6. Fuel for Production
7. Developed Land C Seq.

Total of 50 GHG sources and sinks

Full eligibility assumes all categories eligible for carbon payments

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Selected Key Assumptions

- Average national corn yield of ~ 186 bu/acre by 2022 (1.6% average annual increase)
- Corn ethanol yields of 2.71 gallons/bu for dry mill process and 2.50 gallons/bu for wet mill process
- 17 lbs of dried distillers grains (DDG) produced per bu of corn (dry milling) or 15.9 lbs DDG and 0.1439 gallons corn oil with fractionation or 15.5 lbs DDG and 0.1929 gallons corn oil with extraction
- 13.5 lbs of gluten feed, 2.5 lbs of gluten meal, and 0.2078 gallons of corn oil produced per bu of corn (wet milling)
- 1 lb of DDG substitutes for 1 lb total of corn and soybean meal initially, increasing to 1.196 total lbs. by 2017 for cattle
- Cellulosic ethanol yields reach 92.3-101.5 gallons per dry ton by 2022
- 32 million acres of land remain in Conservation Reserve Program

Renewable Fuel Production by Feedstock (MGY)

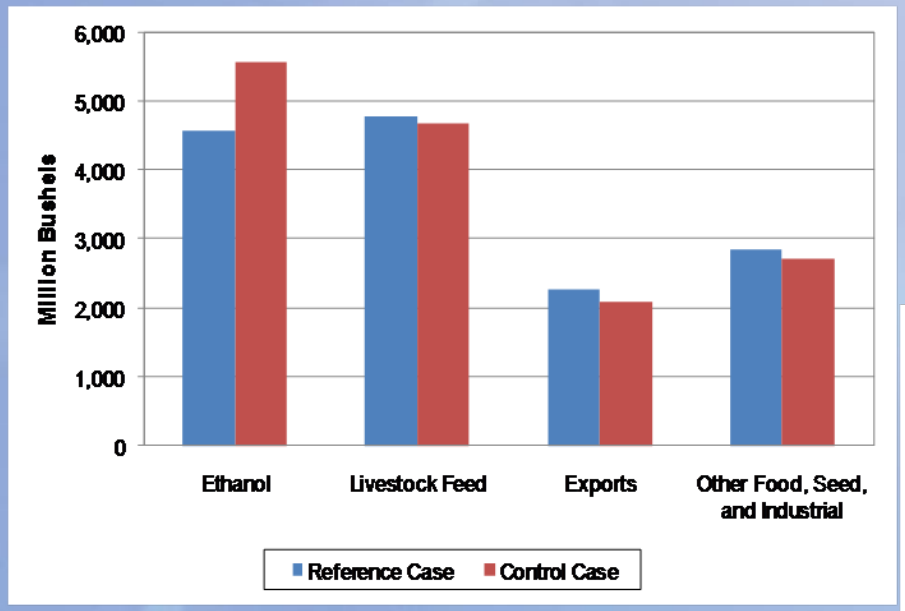
Feedstock	2017		2022	
	Reference Case	Control Case	Reference Case	Control Case
Biodiesel				
Corn oil (nonfood grade)	0	542	0	681
Edible tallow	23	23	24	24
Lard	16	53	23	55
Nonedible tallow	46	47	48	48
Soybean oil	104	659	120	659
Cellulosic ethanol				
Bagasse	185	581	229	614
Corn residue	0	0	0	4,871
Hardwood logging residue	0	75	0	73
Softwood logging residue	0	33	0	36
Sweet sorghum pulp	65	107	22	110
Switchgrass	0	3,879	0	7,912
Wheat residue	0	42	0	77
Starch-based ethanol				
Sorghum	3	0	16	0
Corn (wet milling process)	1,281	1,391	1,311	1,391
Corn (dry milling process)	10,009	13,594	10,969	13,594
Sweet sorghum	18	30	6	30
Total ethanol	11,562	19,729	12,553	28,728
Total biodiesel	189	1,324	214	1,467
Total renewable fuels from agricultural feedstocks in FASOM	11,750	21,053	12,766	30,195

Acreage, Production, and Price of Corn and Soybeans

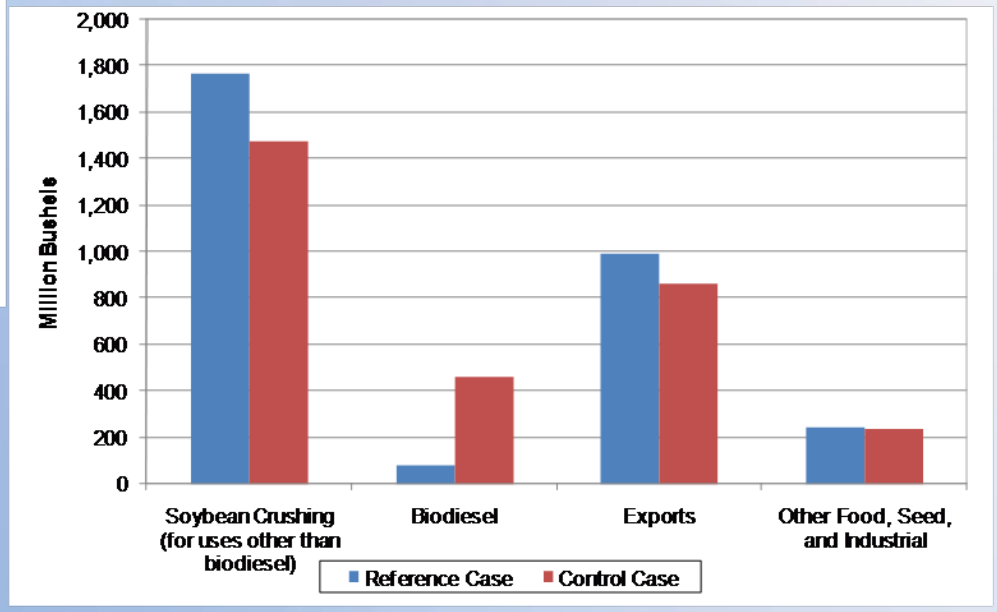
Crop	2017			2022		
	Reference Case	Control Case	Change	Reference Case	Control Case	Change
Corn						
Acreage (million acres)	78.7	83.6	4.9	77.9	81.5	3.6
Price ($2007/bushel)	$3.45	$3.74	$0.29	$3.32	$3.60	$0.27
Production (million bushels)	13,812.1	14,586.1	774.0	14,511.7	15,079.2	567.5
Soybeans						
Acreage (million acres)	67.3	67.2	-0.1	68.1	66.6	-1.4
Price ($2007/bushel)	$10.02	$10.97	$0.95	$9.85	$10.87	$1.02
Production (million bushels)	2,988.7	2,966.2	-22.5	3,080.5	3,028.1	-52.4

Distribution of Corn and Soybean Usage, 2022

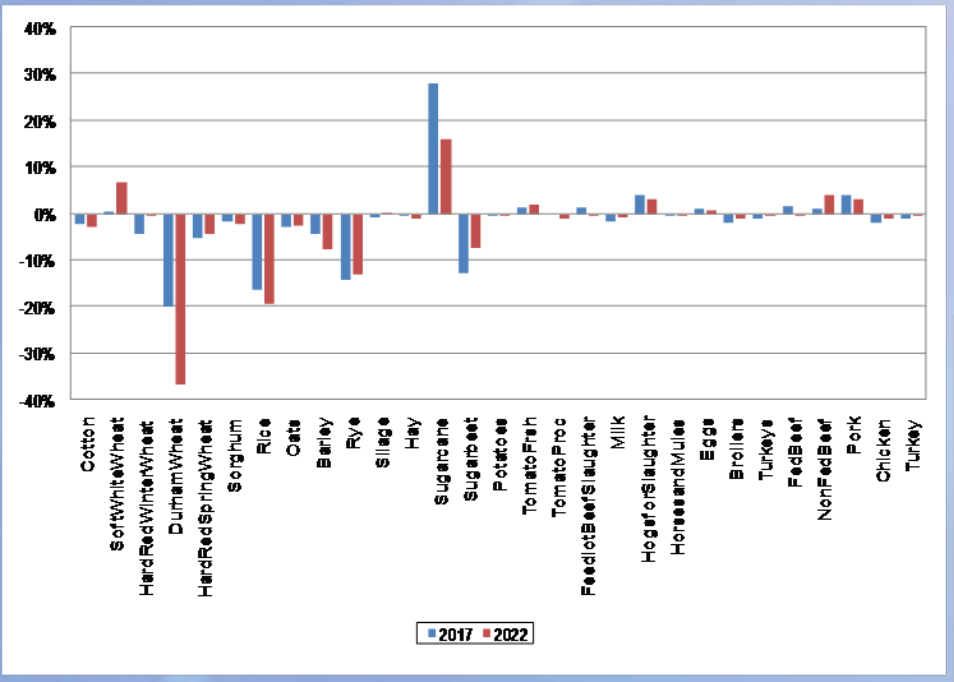
U.S. Corn Use



U.S. Soybean Use

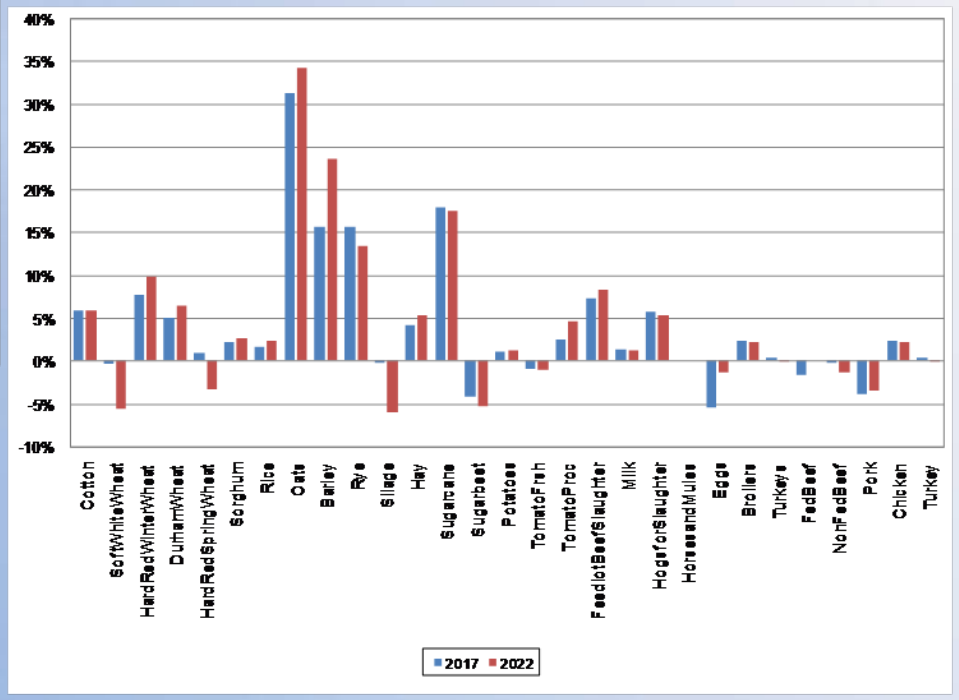


Changes in Commodity Production and Prices, 2022



% Change Commodity Production

% Change Commodity Price



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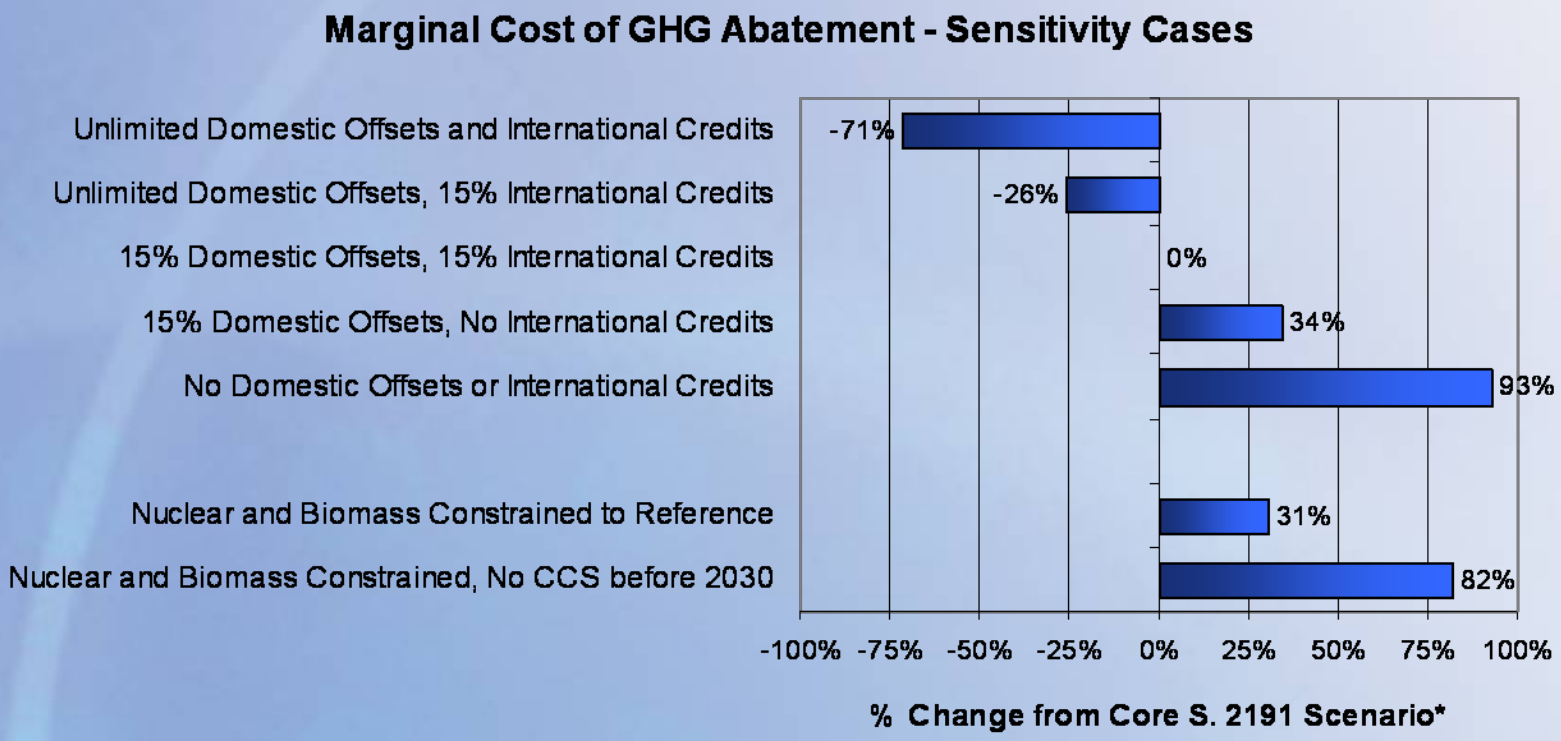
U.S. Land Use Change – RFS2

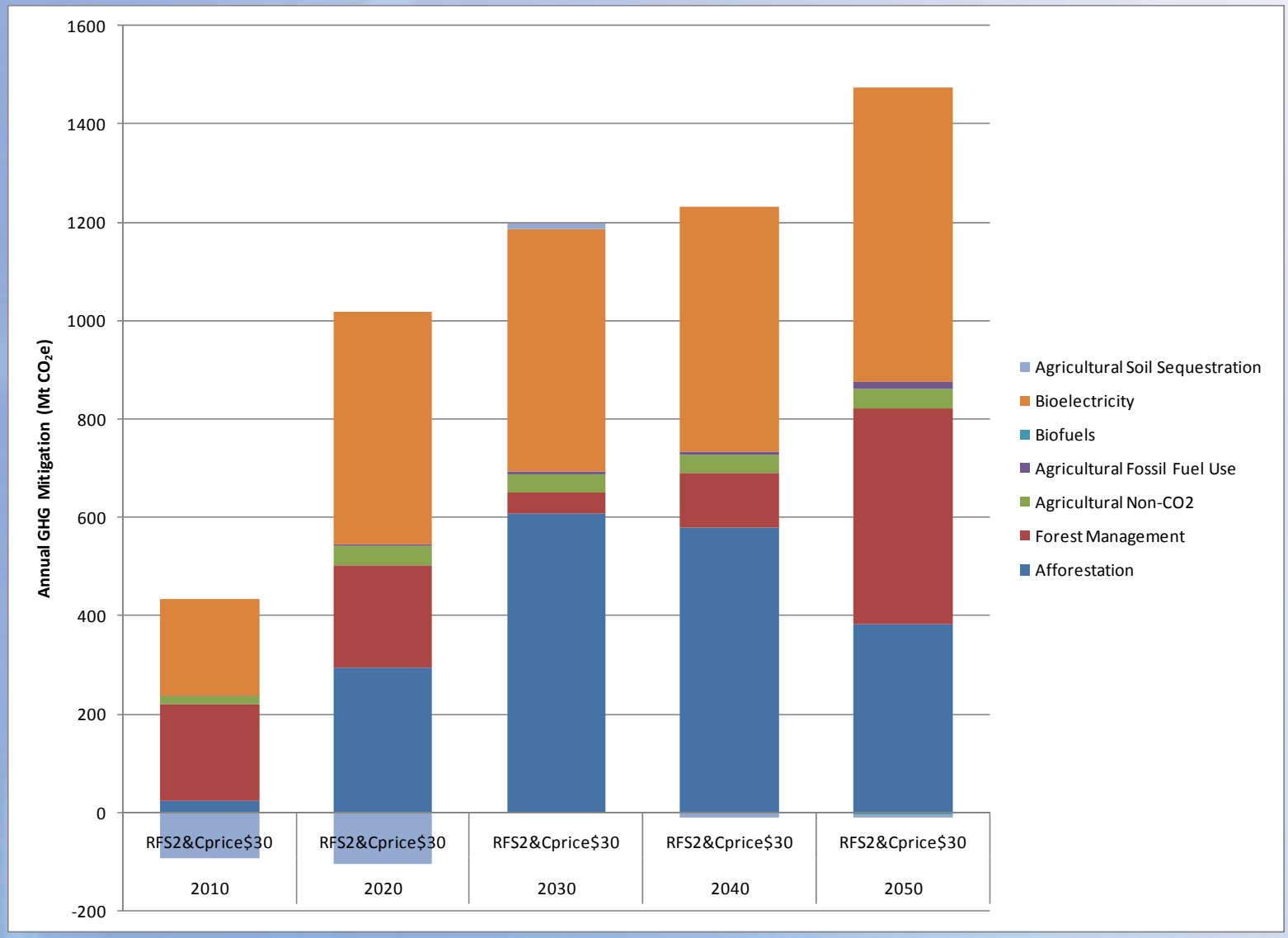
- Total U.S. cropland in production increases by about 0.6 million acres between 2017 and 2022 under the baseline
- RFS2 volumes increase cropland area in production by 4.6 million acres in 2017 and 8.1 million acres in 2022 relative to the baseline
- Pasture in use increases by 11.0 million acres in 2017 and 3.1 million acres in 2022 relative to baseline
- Increases in cropland and pasture in use come primarily from idle pastureland and private forestland

Offsets in U.S. Climate Policy Analysis

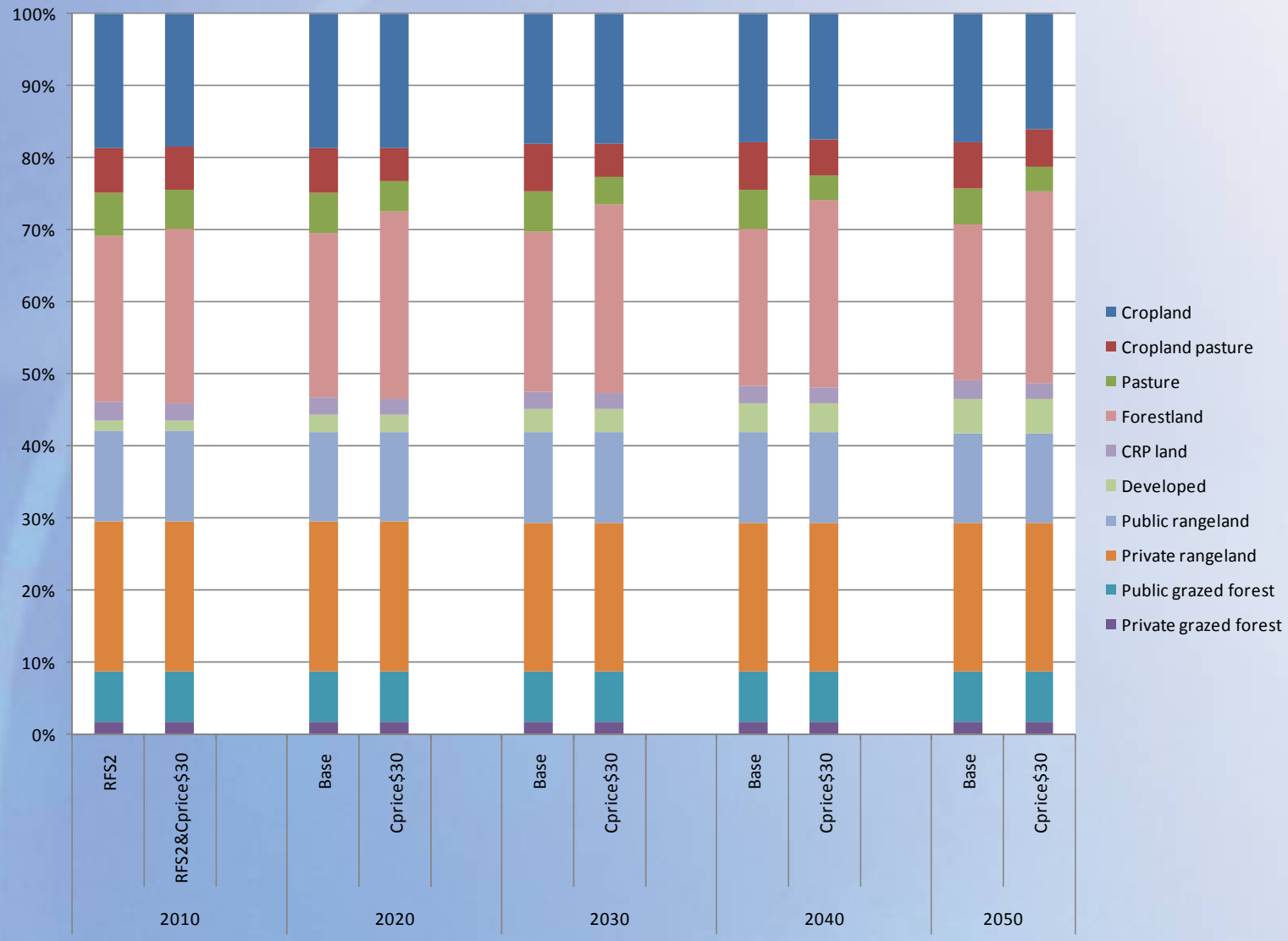


Source: EPA's analysis of the Lieberman-Warner Climate Security Act of 2008 (S. 2191), http://www.epa.gov/climatechange/economics/economicanalyses.html

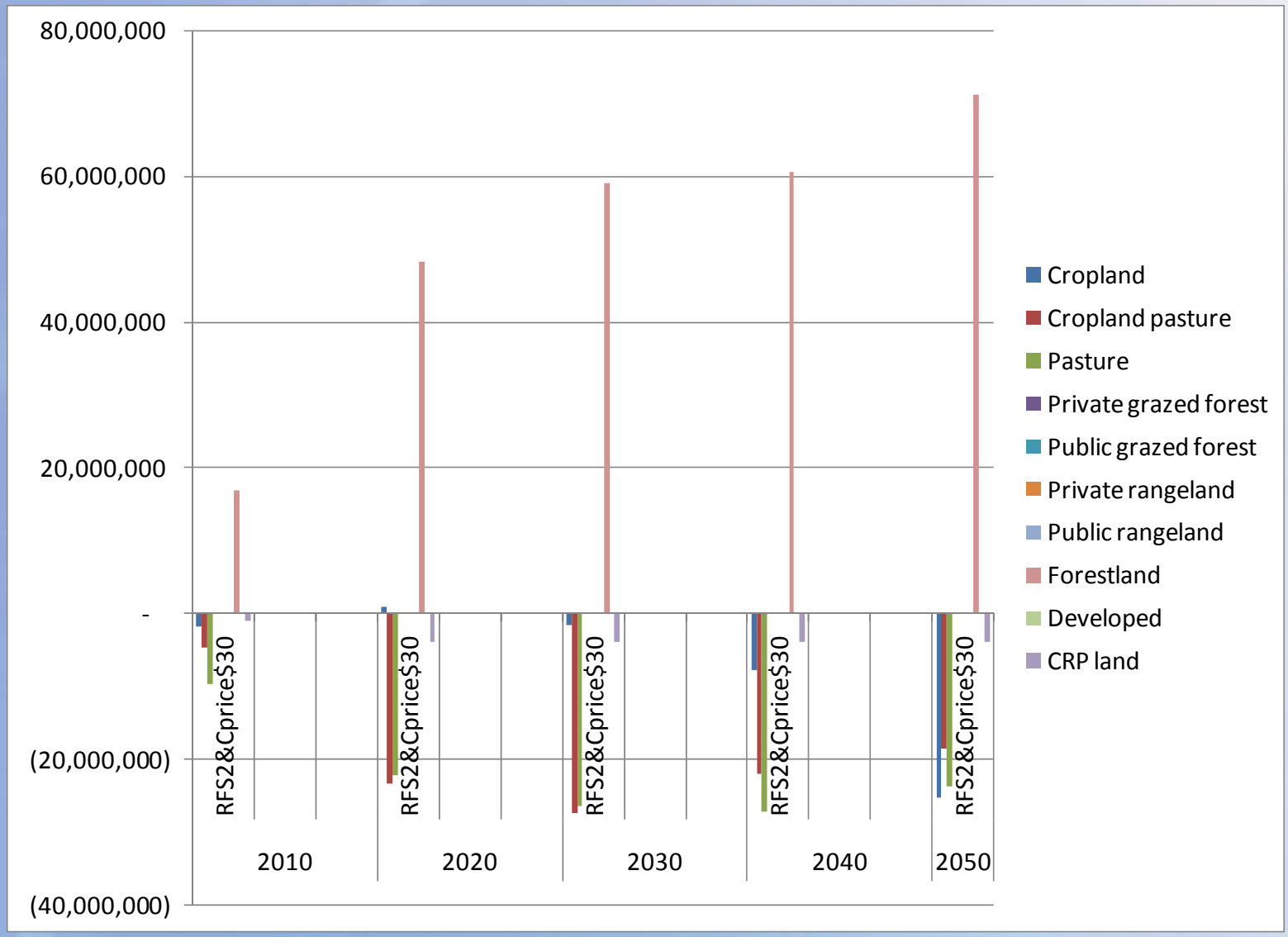
GHG Mitigation Potential (tCO_2e/year)



Land Use Chart



Change in Land Use at $30/tCO2e



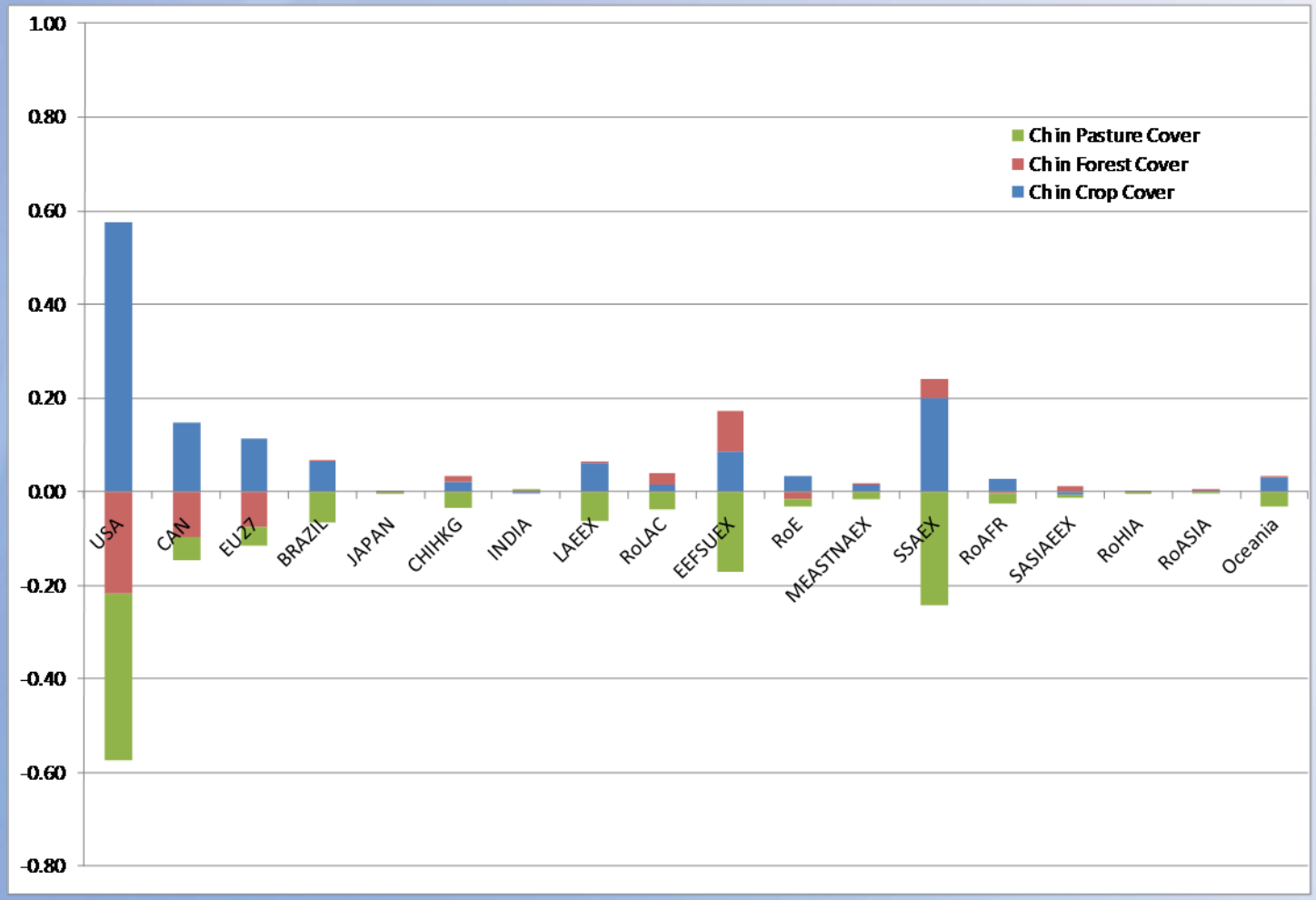
GTAP Model

- Widely used multi-region global CGE model
- CGE models enable simulation of economy-wide impacts, enabling examination of factors such as:
  - Food security
  - International trade
  - Environment and natural resources
- We apply modified version of the model that expands treatment of biofuels (GTAP-BIO)

U.S. biofuel scenarios implemented in GTAP

	Billion gallons		
	Corn-Ethanol	Biodiesel	Sugar-Ethanol
2006 baseline	4.252	0.140	0.303
Corn-ethanol Experiment:	**+2.00** *(47.04%)*	0.140	0.303
Biodiesel Experiment:	4.252	**+1.00** *(714.29%)*	0.303

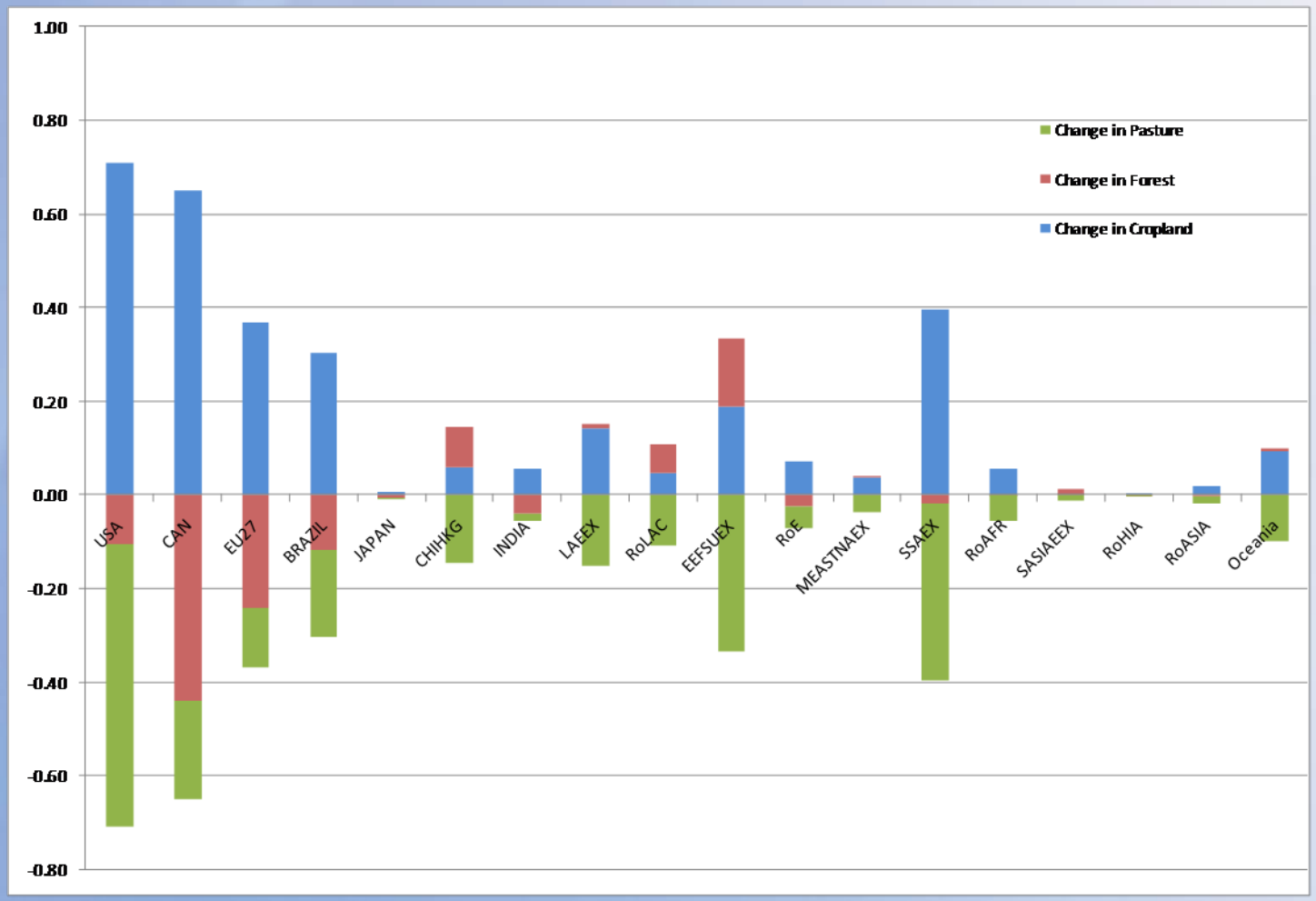
Land cover change for corn ethanol case (million acres)



Change in commodity prices for U.S. corn ethanol case

Sectors	*Market Price*				*World Price*
	USA	Canada	EU-27	Brazil	
Cereal Grains	1.95	0.21	0.08	0.17	0.48
Other Grains	0.43	0.17	0.08	0.13	0.07
Oilseeds	0.80	0.25	0.12	0.16	0.25
Sugarcane	1.08	0.24	0.06	0.07	0.12
Other Agri	0.35	0.12	0.04	0.07	0.08
Proc Livestock	0.11	0.05	0.00	0.01	0.03
Ethanol1	0.98	-3.42	-0.04	0.01	0.80
DDGS	-0.22	12.95	0.41	0.17	0.09
Biodiesel	0.53	0.11	0.10	0.06	0.21
Oil_Cake	0.06	0.05	0.01	0.03	0.03
Ethanol2	-0.03	-0.09	-0.08	0.00	-1.18
Coal	0.06	0.04	0.05	0.04	0.03
Oil	-0.87	-0.75	-0.66	-0.64	-0.70
Gas	-0.04	-0.06	-0.04	-0.08	-0.05
Oil_Pcts	-0.64	-0.61	-0.58	-0.53	-0.58
Electricity	-0.02	-0.02	-0.02	-0.05	-0.06

Land cover change for U.S. biodiesel case (million acres)



Change in commodity prices for U.S. biodiesel case

Sectors	*Market Price*				*World Price*
	USA	EU-27	Brazil	Canada	
Paddy_Rice	0.35	0.20	0.58	-0.02	0.14
Wheat	-0.09	0.31	0.33	0.10	0.15
CrGrains	0.27	0.51	0.44	0.11	0.22
Oilseeds	3.58	1.34	1.02	1.23	1.44
Sugar_Crop	0.60	0.41	0.48	0.34	0.28
OthAgri	0.43	0.36	0.47	0.21	0.23
Proc_Dairy	-0.88	0.00	0.09	-0.23	-0.25
Proc_Rum	-1.18	-0.05	0.11	-0.33	-0.44
proc_NonRum	-1.29	-0.13	0.07	-0.29	-0.36
Proc_Feed	-10.44	-0.70	0.15	-1.91	-2.71
Ethanol1	-0.94	-0.04	0.08	0.00	-0.88
DDGS	0.21	0.79	0.79	0.15	0.28
Cveg_Oil1	110.89	6.98	2.28	16.42	16.53
VOBP	-50.89	-12.02	-0.24	-15.11	-22.07
Biodiesel	56.44	5.44	0.40	2.77	28.57
Ethanol2	0.02	-0.02	0.13	-0.01	-0.69
Coal	-0.13	-0.02	-0.03	-0.04	-0.05
Oil	-0.35	-0.20	-0.18	-0.27	-0.23
Gas	-0.03	-0.02	-0.02	-0.05	-0.02
Oil_Pcts	-0.24	-0.16	-0.14	-0.19	-0.17
Electricity	-0.04	-0.02	-0.01	-0.03	-0.03

Future Research

- Additional exploration of interactions between energy policies promoting bioenergy consumption and GHG mitigation policies
- Incorporation of more detailed modeling of bioelectricity demand for biomass feedstocks due to state-level renewable portfolio standards
- Simultaneous modeling of climate impacts and mitigation potential and costs
- Continued development of GTAP and ADAGE CGE models (additional work on cellulosic feedstocks, more detailed GHG accounting, etc.) and linkages to FASOM

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