



United States Department of Agriculture, Economic Research Service

Bio-electricity and Land Use in the Future Agricultural Resources Model

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Contributors to FARM Project

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Brief History of FARM

- Legacy FARM
 - The first version of the Future Agricultural Resources Model (FARM) was constructed in the early 1990s by Roy Darwin and others at the Economic Research Service
 - By partitioning land into land classes, this model provided a unique capability among CGE models to simulate land use on a global scale
- FARM
 - Adds a time dimension for analysis of alternative climate policies
 - Tracks energy consumption and greenhouse gas emissions
 - Expansion of agricultural products to handle land use and AgMIP scenarios
- Participation in international multi-model comparison studies during 2011-13 (all timed to be available for IPCC AR5)
 - EMF-24: US greenhouse gas mitigation and technology scenarios
 - EMF-27: Global greenhouse gas mitigation and technology scenarios
 - EMF-28: European Union greenhouse gas mitigation scenarios
 - AgMIP: Global reference scenario and climate impacts



CGE Framework

- New FARM uses Tom Rutherford's GTAP in GAMS code as a starting point
 - Comparative-static global CGE model
 - Armington trade between world regions
 - Constant-elasticity-of-substitution (CES) production and utility functions
 - Fully compatible with GTAP 7 social accounts
- Major extensions for new FARM
 - Conversion from comparative-static to dynamic-recursive framework
 - Started with 10-year time steps; now runs with 5-year time steps beginning with GTAP 7 base year of 2004
 - Conversion of consumer demand from CES to Linear Expenditure System (LES)
 - Production system allows joint products
 - Introduction of land classes for agricultural and forestry production
 - Introduction of electricity generating technologies

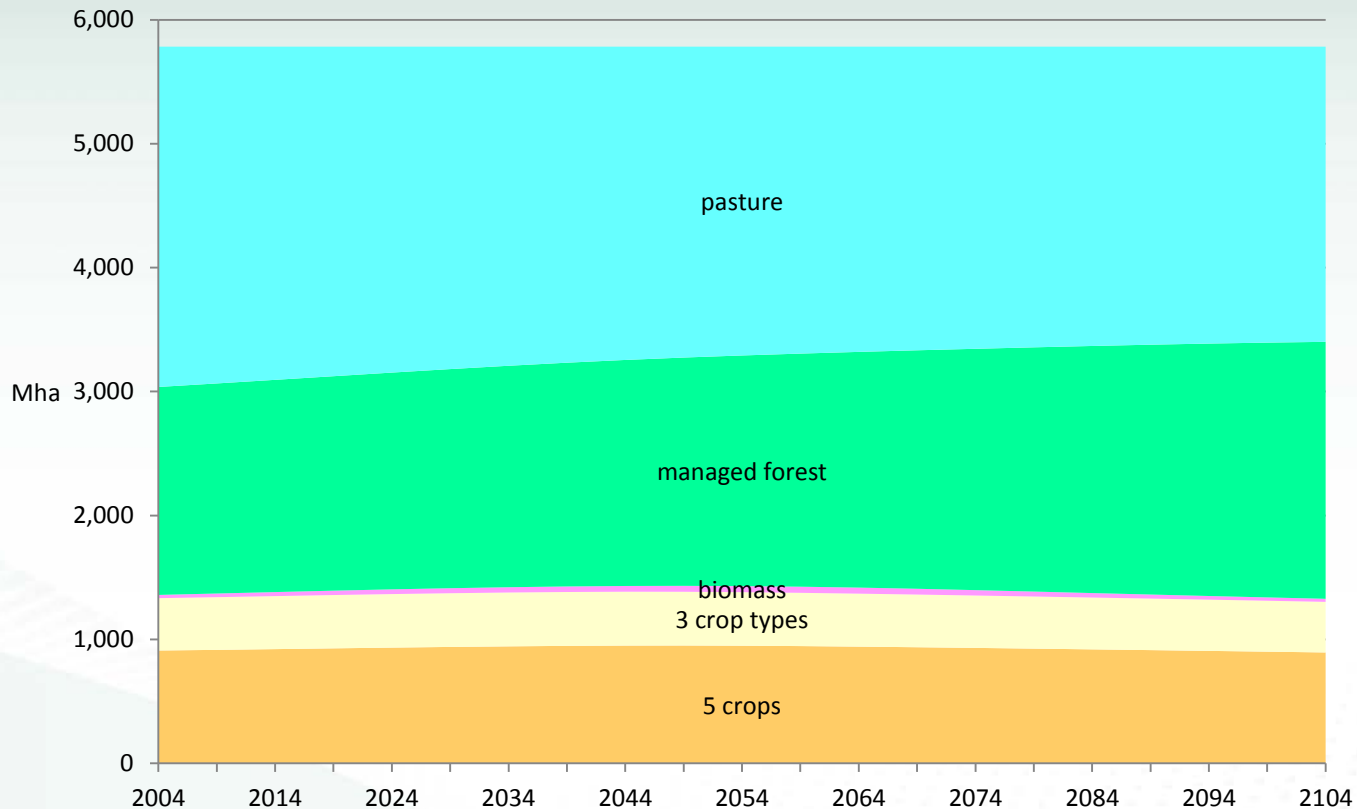


Global Scenarios

- Reference scenario
 - Time horizon to 2100
 - Drivers
 - Population
 - Growth in per-capita income
 - Agricultural productivity
 - Energy efficiency
 - Structure
 - 13 to 20 world regions
 - Five-year time steps
 - 38 production sectors covering agricultural and energy systems
 - Key outputs
 - CO₂ price and emissions
 - Land use for crops and biomass
- Technology scenarios (Energy Modeling Forum)
- Environmental policy (Energy Modeling Forum)
 - Greenhouse gas cap-and-trade
 - Renewable Portfolio Standards in electricity generation
- Climate impacts and economic adaptation (AgMIP)
- Combinations of the above



World Agricultural Land Use Reference Scenario G01



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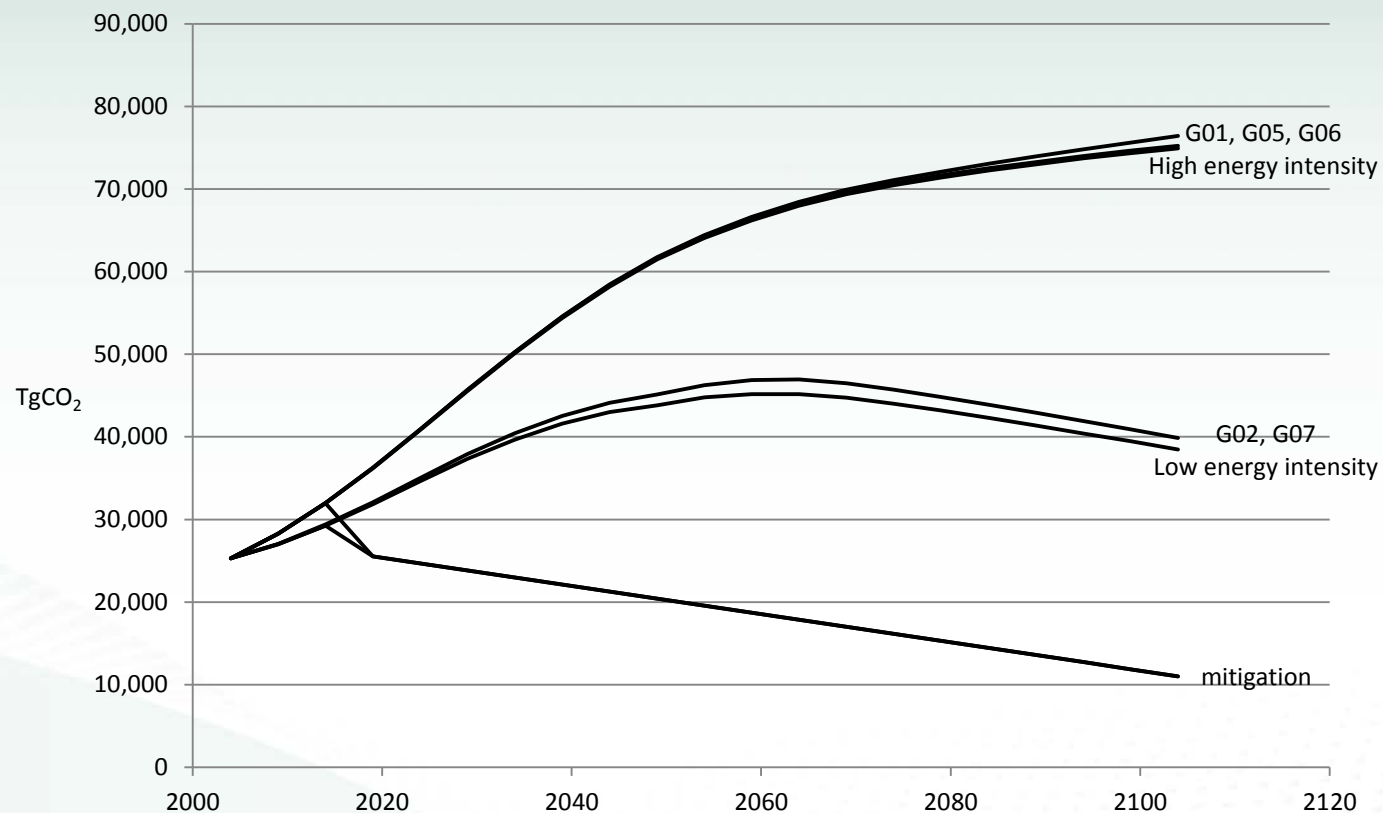
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FARM Scenario Matrix (EMF-27)

Technology Dimension								
	Default	“All Good”	Single Technology Sensitivities				Conventional vs. Renewable	
Energy Intensity	High	Low	High	High	High	High	High	Low
CCS	On	On	Off	On	On	On	On	Off
Nuclear	On	On	On	Off	On	On	On	Off
Wind and Solar	Adv	Adv	Adv	Adv	Cons	Adv	Cons	Adv
Bioenergy potential	High	High	High	High	High	Low	Low	High
Policy Dimension								
Reference	G01	G02				G05	G06	G07
550 ppm CO ₂ -eq	G17	G18	G19			G22	G23	G24
Fragmented Policy	G28							



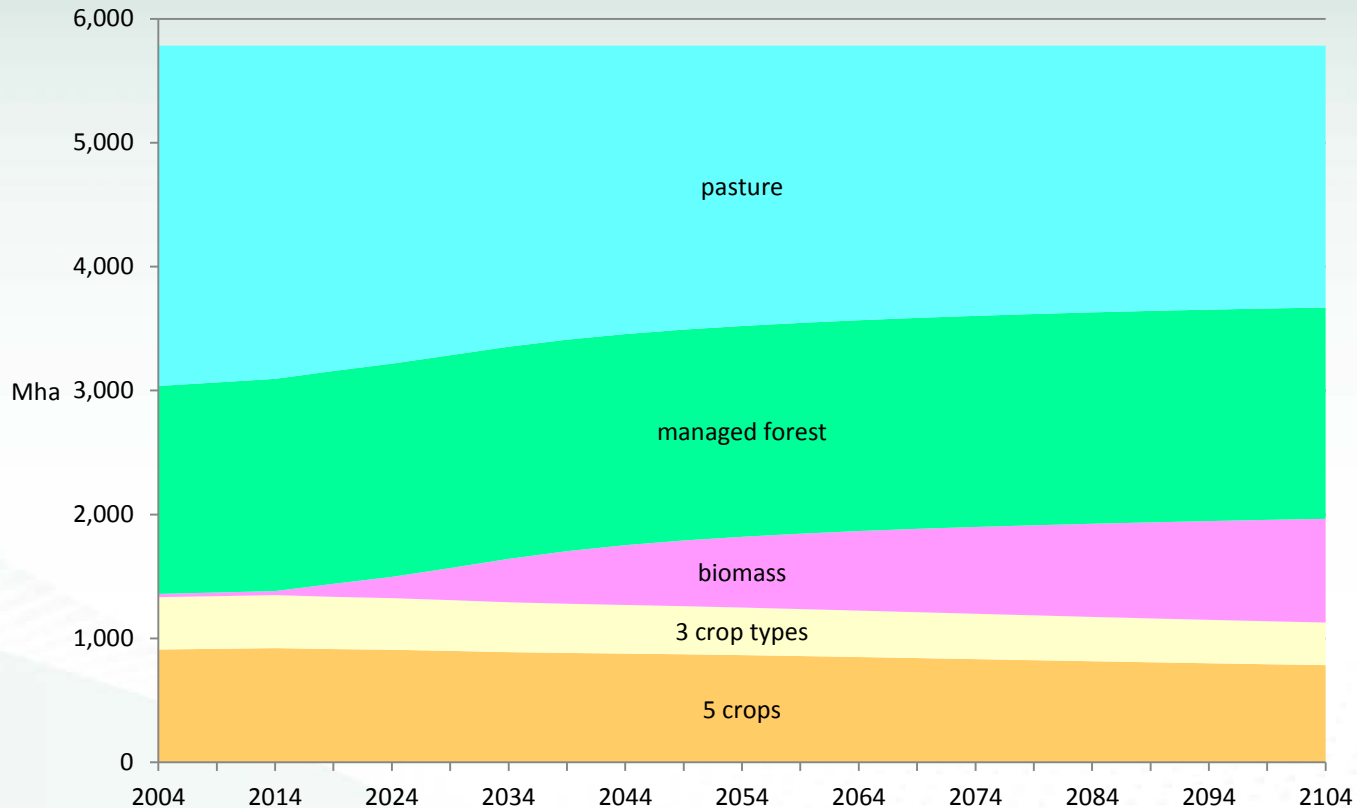
Reference Scenarios of Global CO₂ Emissions



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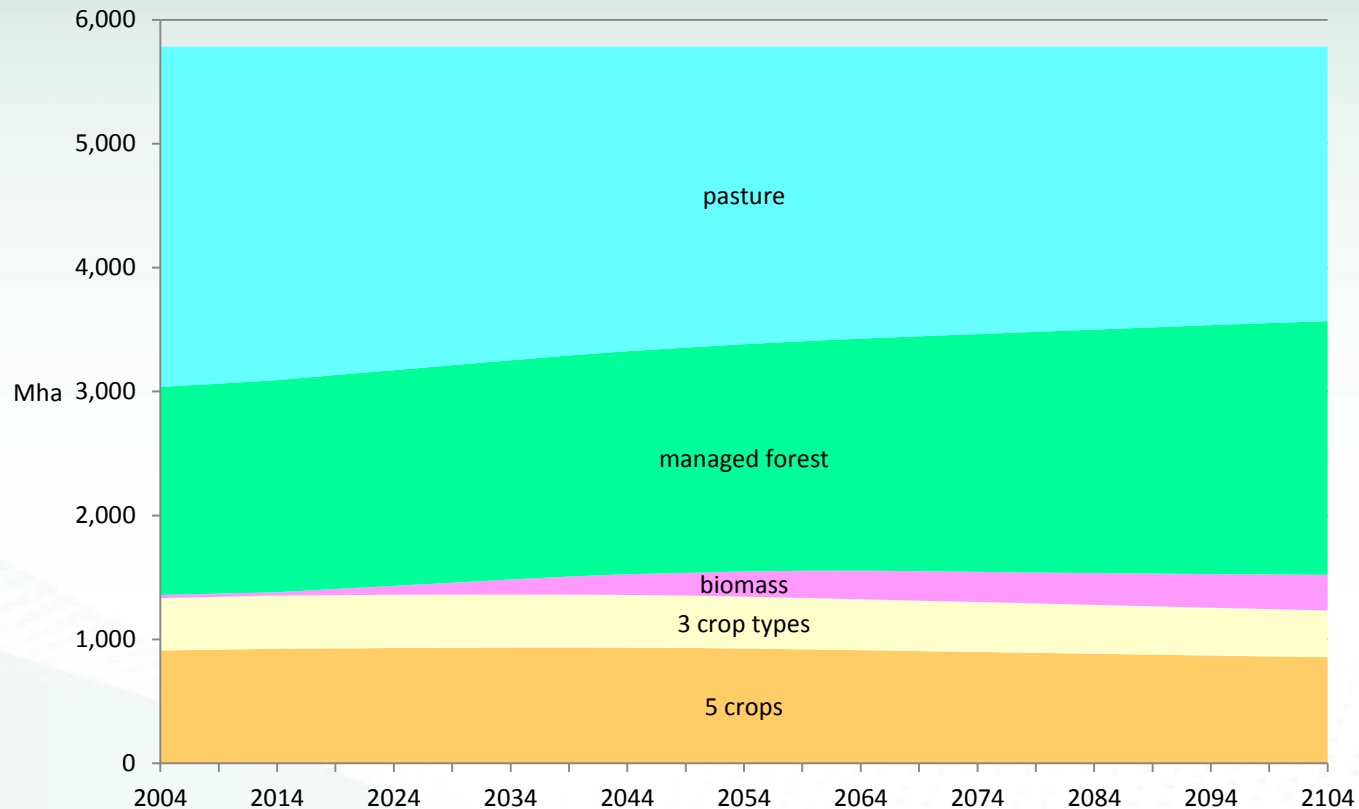
World Agricultural Land Use High Energy Intensity (G17 mitigation)



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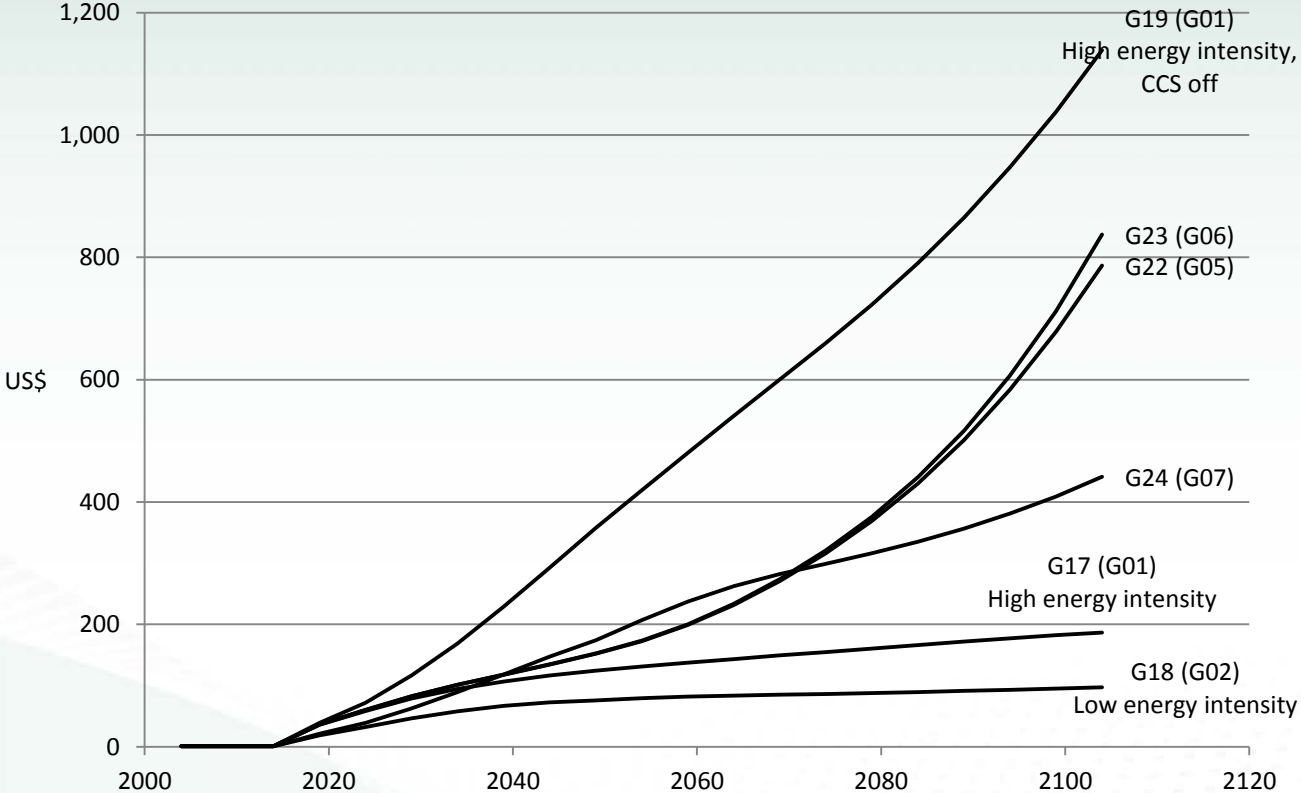
World Agricultural Land Use Low Energy Intensity (G18 mitigation)



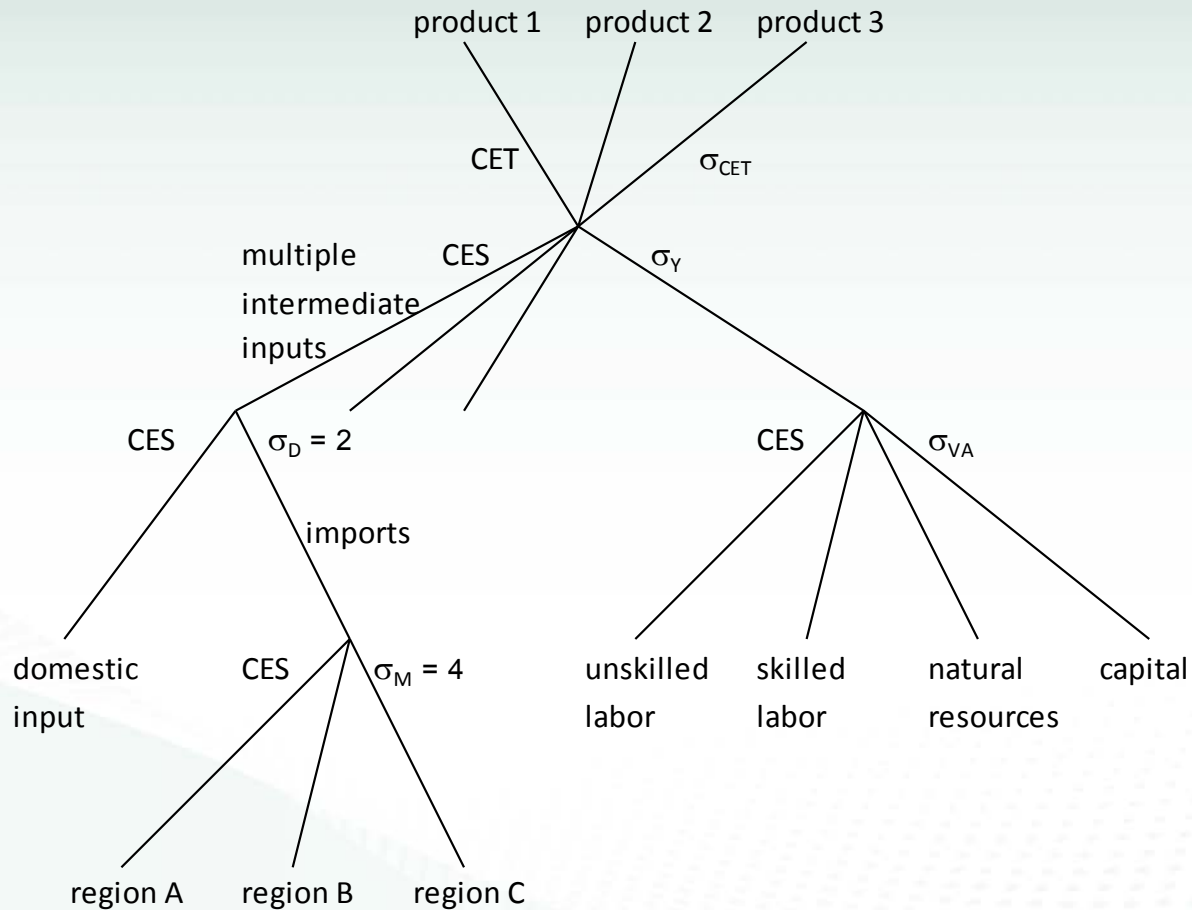
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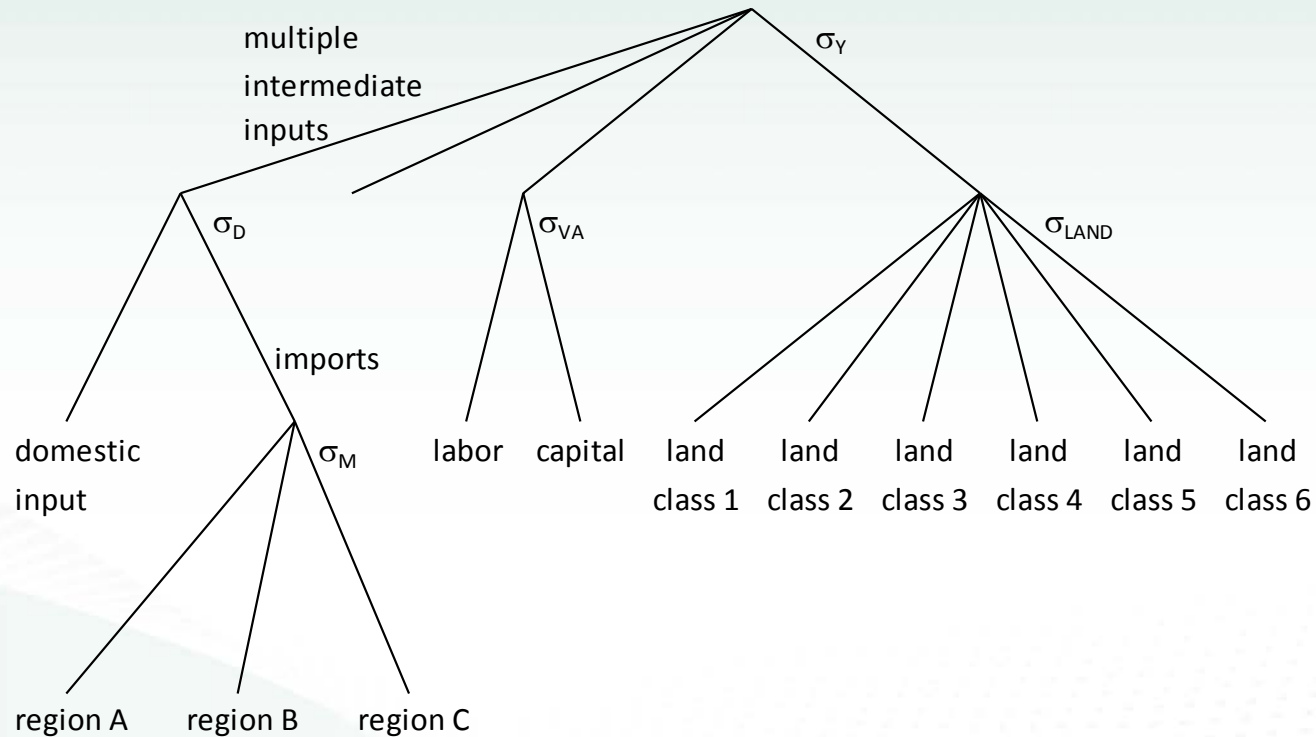
CO₂ Prices across 550 ppm Mitigation Scenarios



Generic Production Structure in FARM

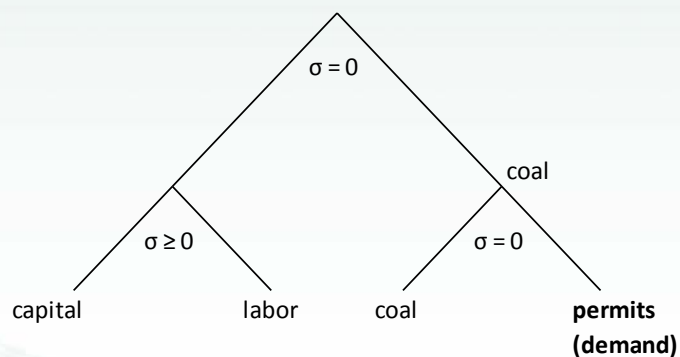


Nesting Structure for Crops and Forestry

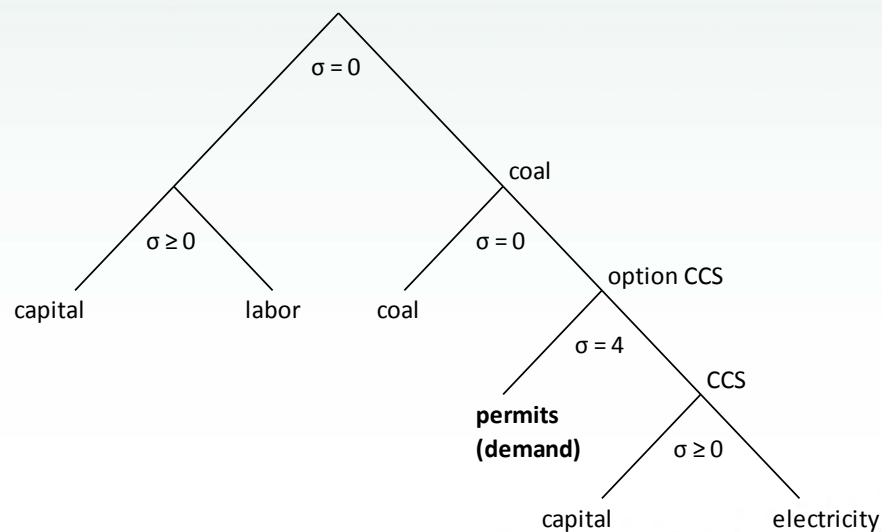


Nesting for Electricity Generation using Coal

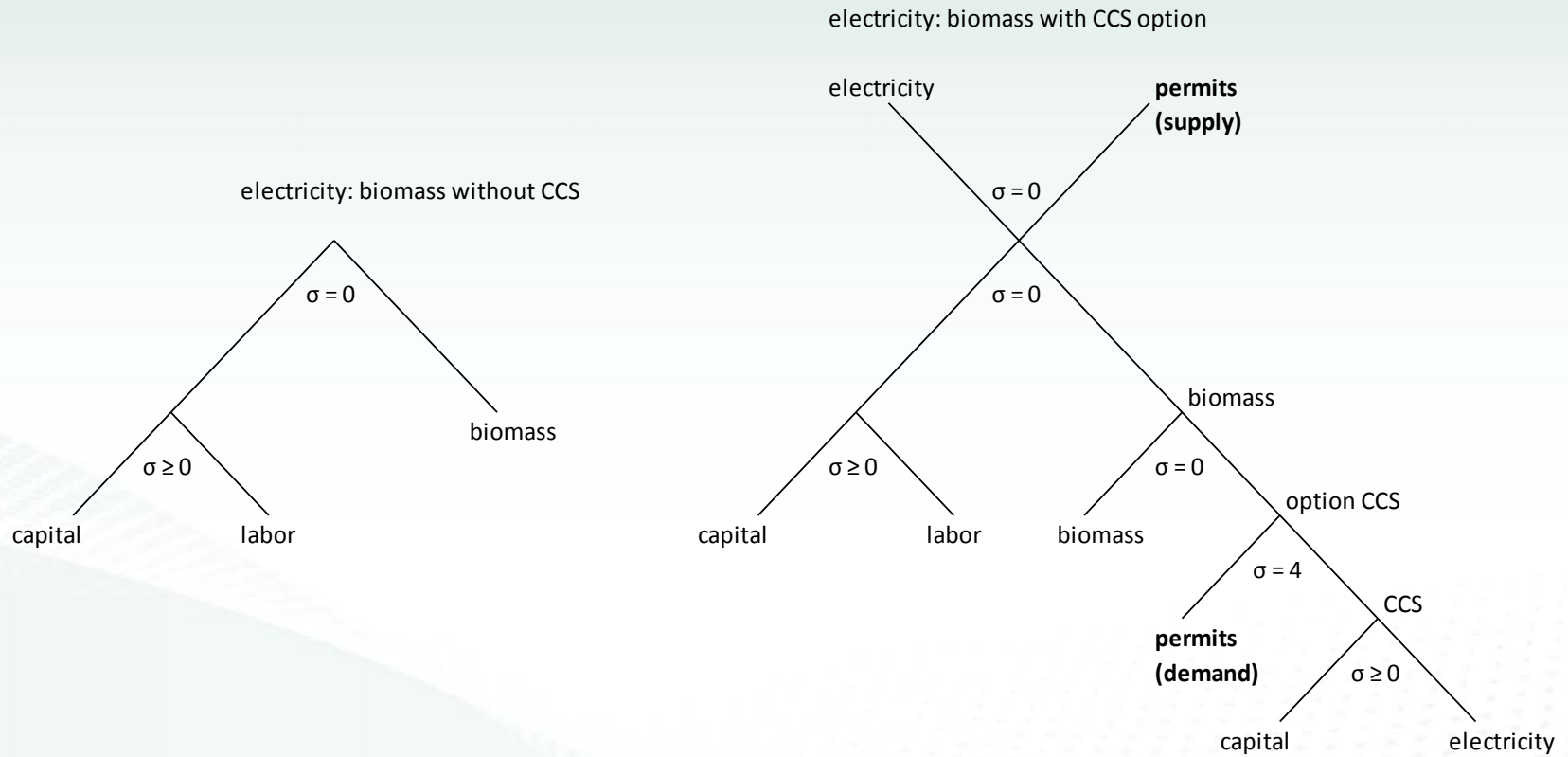
electricity: coal without CCS



electricity: coal with CCS option

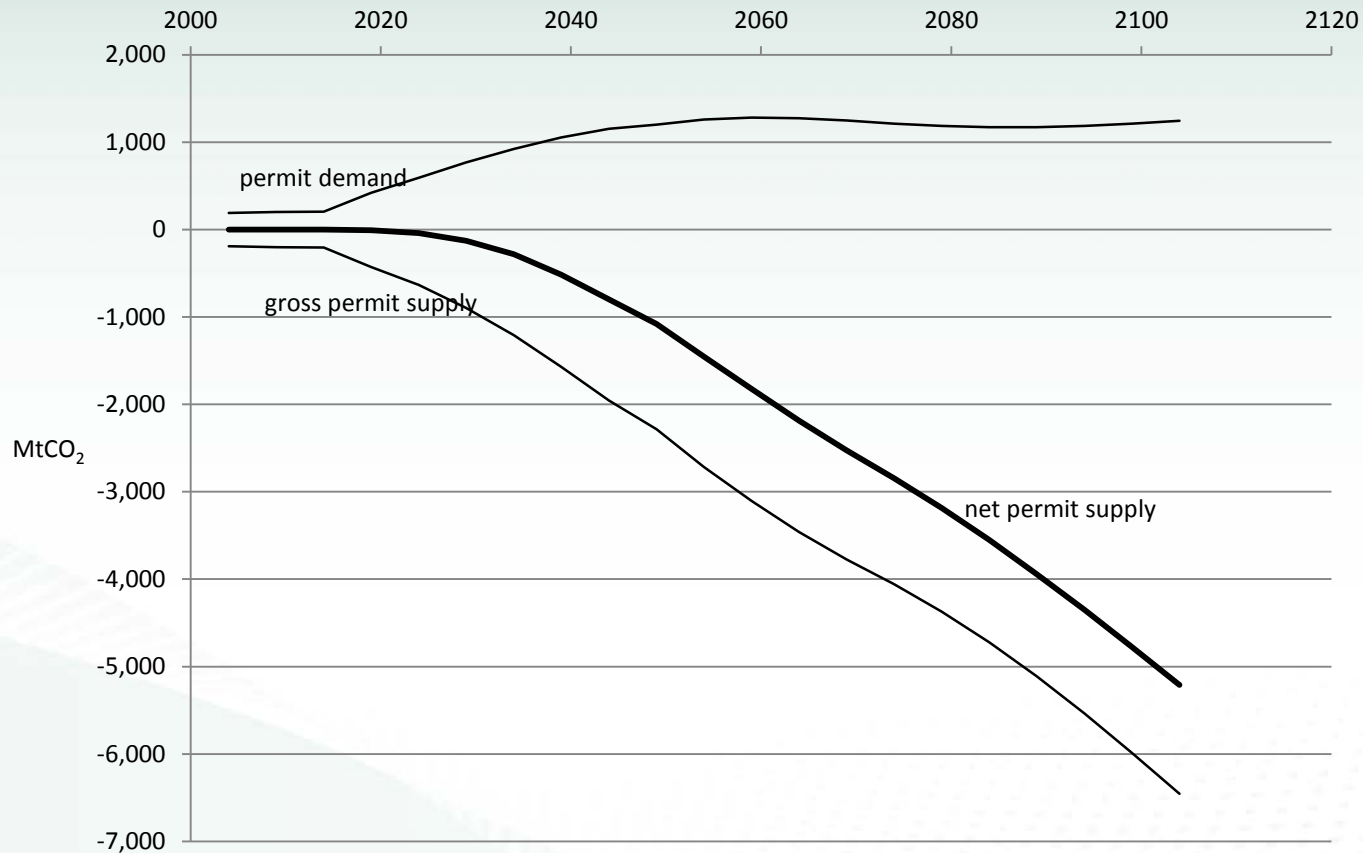


Nesting for Electricity Generation using Biomass



Bio-electricity with CCS

Low Energy Intensity (G18 mitigation)



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Conclusions

- Biomass with CCS can be a negative emissions technology
- Placing biomass with CCS in a computable general equilibrium model was not easy
 - Joint products of electricity and sequestered C
 - CCS switches on or off depending on CO₂ price
 - Rents accrue to landowners depending on CO₂ price and cost of C sequestration
- Further model development
 - Improve land allocation methods
 - Greater spatial resolution
 - Water as a constraint to crop and biomass expansion
 - Regional C sequestration availability
 - Introduce competing biofuel pathways
 - Introduce forest dynamics and joint products from forests
 - Wood production
 - Biomass production
 - C sequestration in standing forests
 - Improve representation of future food demand, especially with rising per-capita incomes (AgMIP)

