Top-Down Economic Modeling of Developing Countries

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Overview

- Second Generation Model
  - Motivation for model development
  - SGM regions and partner institutions
  - Model structure
- Typical Analysis
  - Energy Modeling Forum
  - Single-country studies
- Special Considerations for Developing Countries
  - Currency conversion
  - Expand agricultural sector
- Current Activities

Top-Down Economic Models

- Project baseline carbon emissions over time for a country or group of countries
- Find the least-cost way to meet any particular emissions constraint
  - Energy system
  - CO_2 capture and storage
  - Non-CO_2 greenhouse gases
  - Terrestrial sequestration and biofuel offsets
- Provide a measure of the carbon price, in dollars per metric ton
- Provide some measure of the overall cost of meeting an emissions target

Second Generation Model

- SGM characteristics
  - Collection of computable-general-equilibrium (CGE) models for 14 world regions
  - Five-year time steps from 1990 through 2050
  - Capital stocks are industry specific with a new vintage for each model time step
- Marginal abatement cost curves for carbon
  - Generated using constant-carbon-price experiments
  - Outward shift (to the right) over time as economy grows and capital stocks turn over

Brief History of SGM

- Development began in 1991
- Cost of reducing carbon emissions in the U.S. and other countries
- Design
  - Top-down with broad economic coverage
  - Computable general equilibrium
  - Joint development with international partners
  - Local data used whenever possible
    - Model constructed in local currency
    - Input-output tables
    - Energy balance tables

SGM Regions

- Annex I
  - United States
  - Canada
  - Western Europe
  - Japan
  - Australia
  - Former Soviet Union
  - Eastern Europe
- Non Annex I
  - China
  - India
  - Brazil
  - Middle East
  - Mexico
  - South Korea
  - Rest of World

Partner Institutions

- India
  - Indian Institute of Management, Ahmedabad
- China
  - Energy Research Institute
- Brazil
  - Federal University of Rio de Janeiro
- South Korea
  - Korea Energy Economics Institute
- Mexico
  - Instituto Mexicano del Petroleo

Typical Set of SGM Production Sectors

1 agriculture
2 everything else (including services)
3 crude oil production
4 natural gas production
5 coal production
6 coke
7 electricity generation
8 oil refining
9 distributed gas
10 paper and pulp
11 chemicals
12 non-metallic minerals
13 primary metals
14 food processing
15 other industry and construction (including other mining)
16 rail and land transport
17 other transport

Input-Output Table

	production activities	C G I X M
intermediate inputs	interindustry flows	final demand
primary factors	value added	

Energy Balance Table

energy inputs (fuels)

production imports exports	sources
electricity generation oil refining coking	energy transformation
agriculture industry transport residential buildings commercial buildings	final consumption

Engineering Cost Model

- Electricity Generation (hypothetical plant)
  - First cost of capital ($ per kW)
  - Interest rate
  - Equipment lifetime (years)
  - Heat rate (efficiency)
  - Operation and maintenance (mills per kWh)
  - Price of fuel ($ per GJ)
  - Carbon emissions coefficient (kg C per GJ)
- Calculate levelized cost per kWh for each generating technology

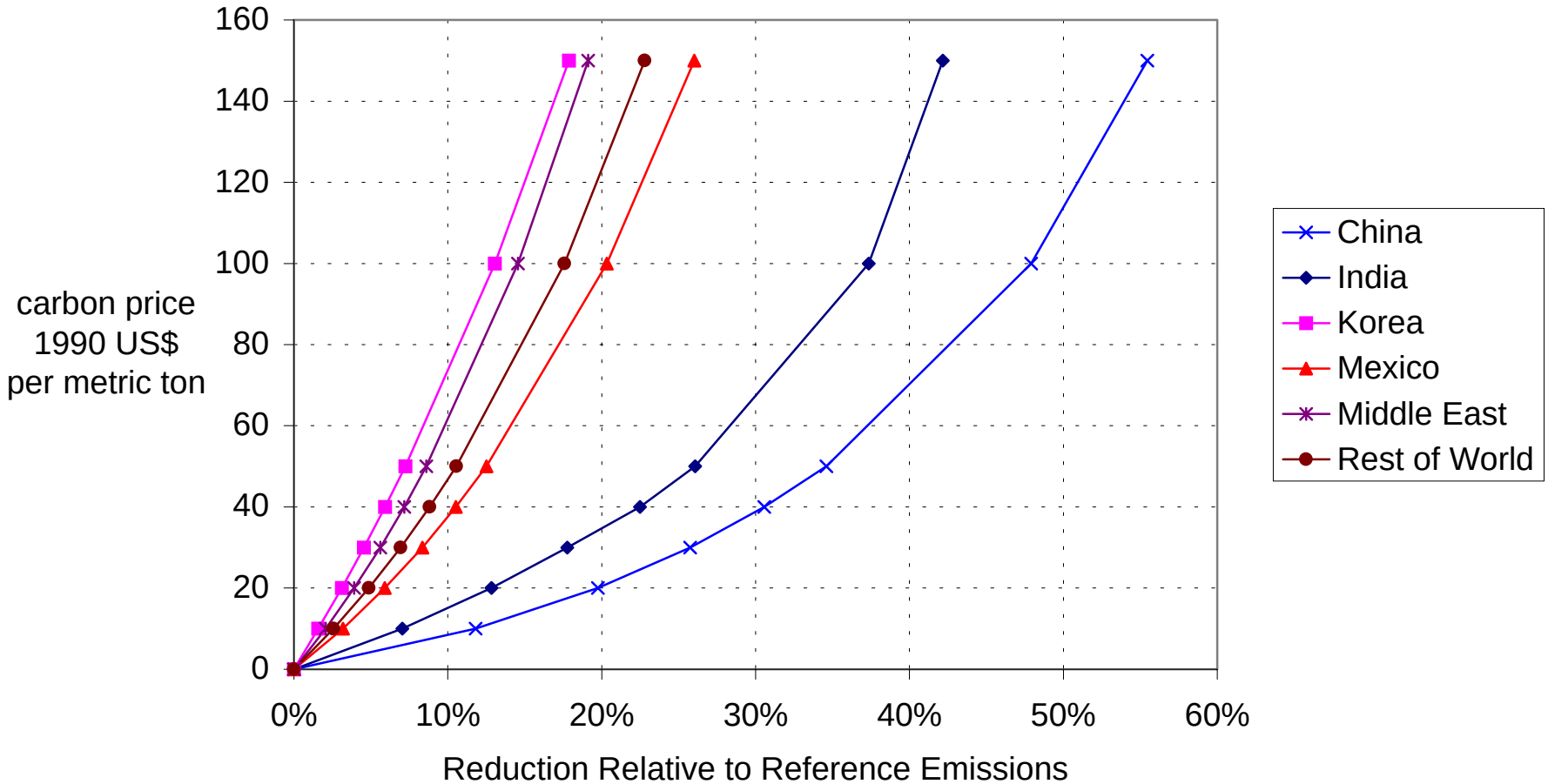
Typical Analysis

- Participation in Energy Modeling Forum
  - Global economic models
  - Emissions trading with alternative targets and technology options
- Single-country studies
  - Evolution of economy and energy system over time
  - Response to carbon policy

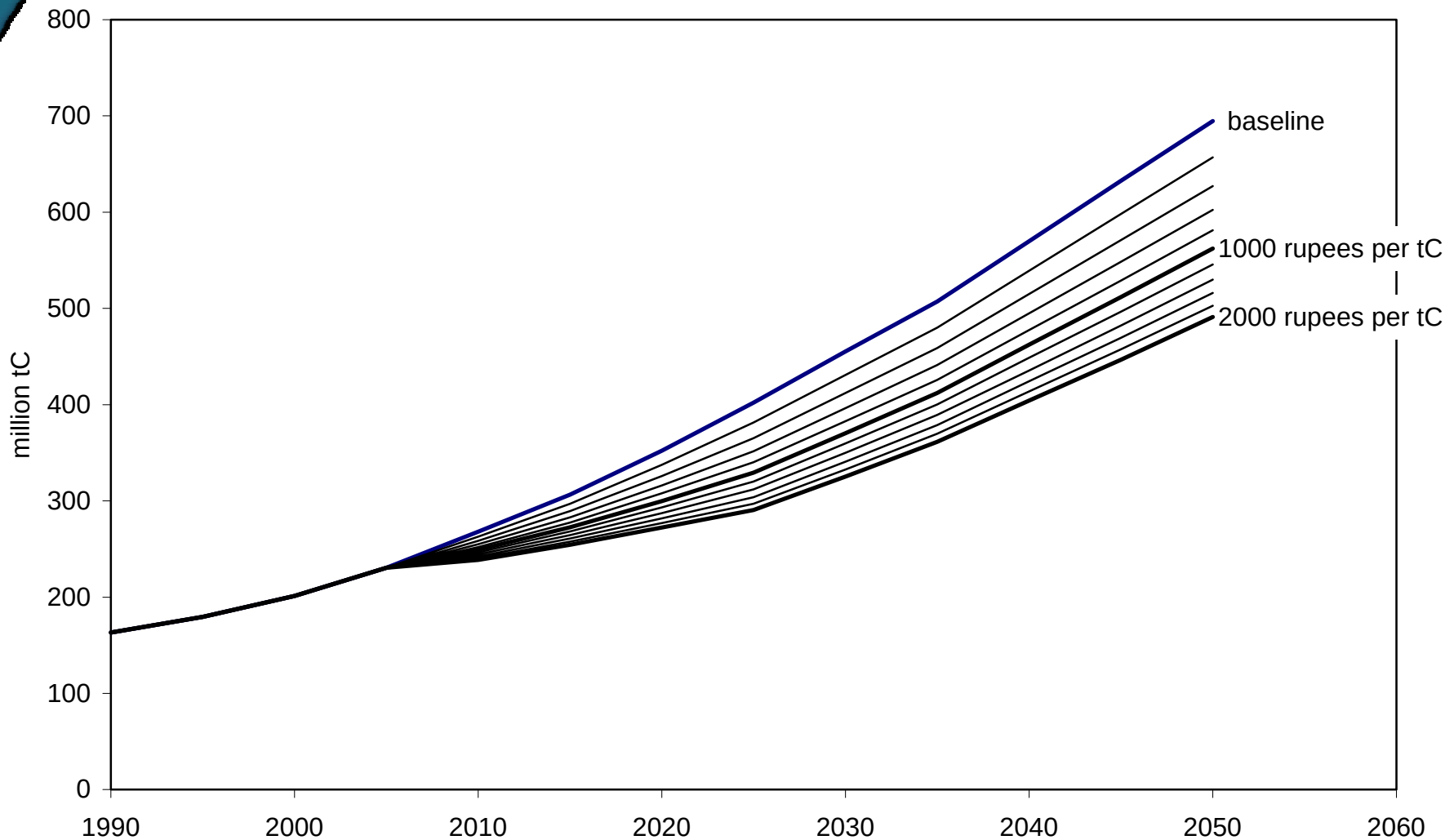
Energy Modeling Forum Studies

- EMF-14
  - Stabilize concentrations of CO_2
- EMF-16
  - Cost of meeting Kyoto targets
- EMF-19
  - Role of advanced energy technologies
- EMF-21
  - Non-CO_2 greenhouse gases and carbon sinks

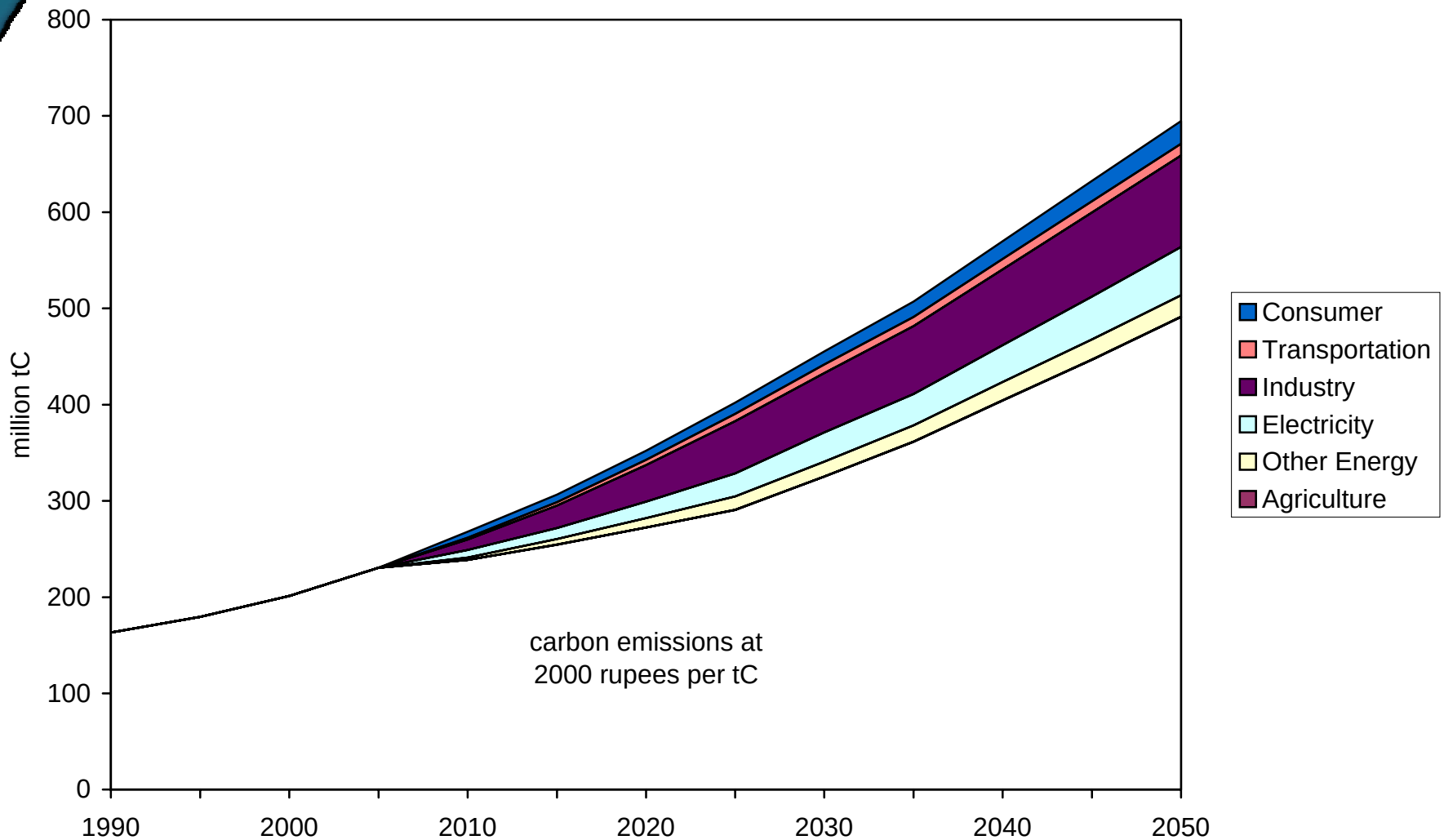
Marginal Abatement Curves for Non-Annex I Regions



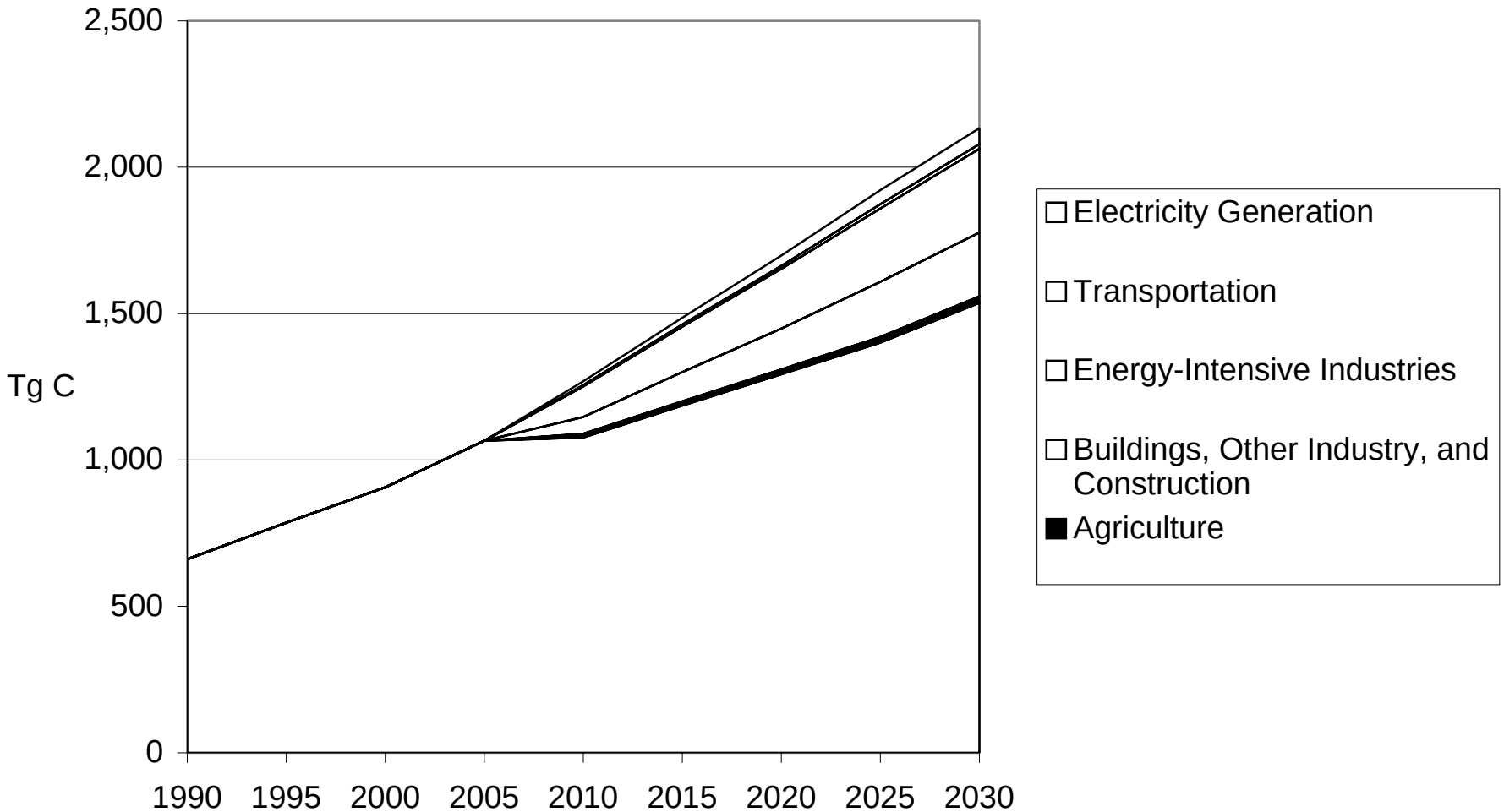
SGM-India Carbon Emissions



SGM-India: Components of Emissions Reduction



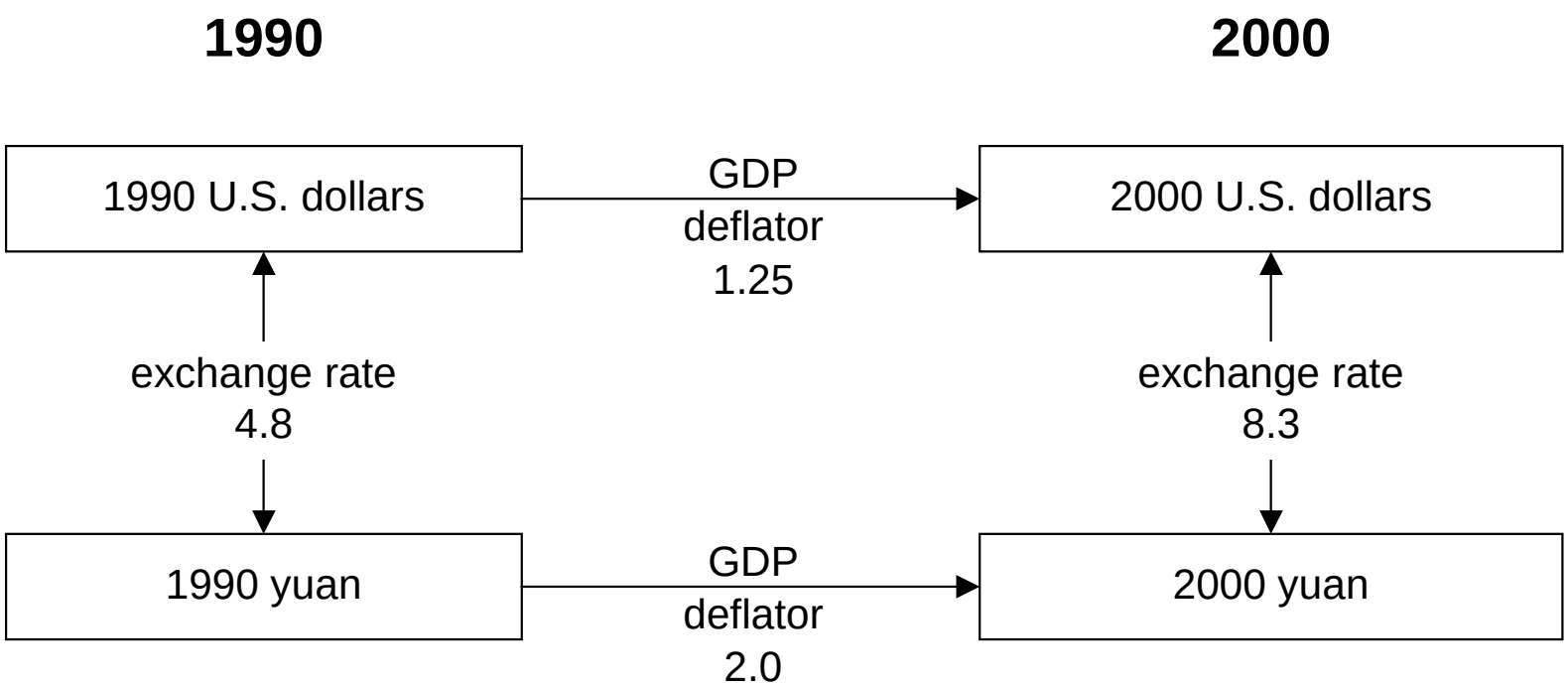
SGM-China Carbon Emissions
Response to 300 yuan per ton carbon price in 2010



Special Considerations

- Currency Conversion
  - What exchange rate should be used for international trade in carbon emissions rights?
- Expand Agricultural Sector
  - Large part of economy in developing countries
  - Source of methane and nitrous oxide emissions
  - Source of carbon emissions from land use change
  - Potential for carbon sequestration in forests and agricultural soils
  - Potential for commercial biofuels
  - Competition for land
  - Climate impacts

Currency Conversion



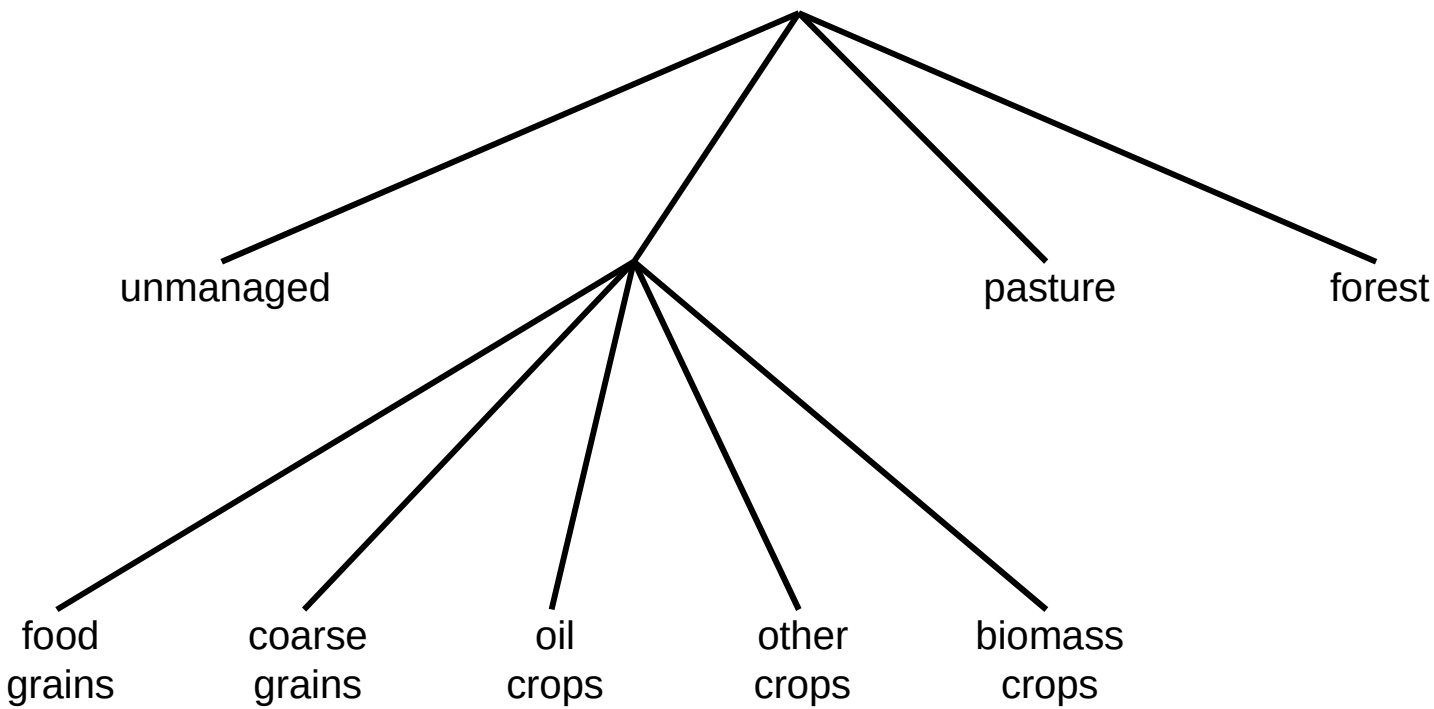
Agriculture and Land Use (AgLU) Model

- First version completed in 1996
- Design
  - Top-down
  - Partial equilibrium
  - 14 world regions
- Studies
  - Role of biomass in carbon policy
  - Impact of ENSO on North America
  - U.S. climate impacts

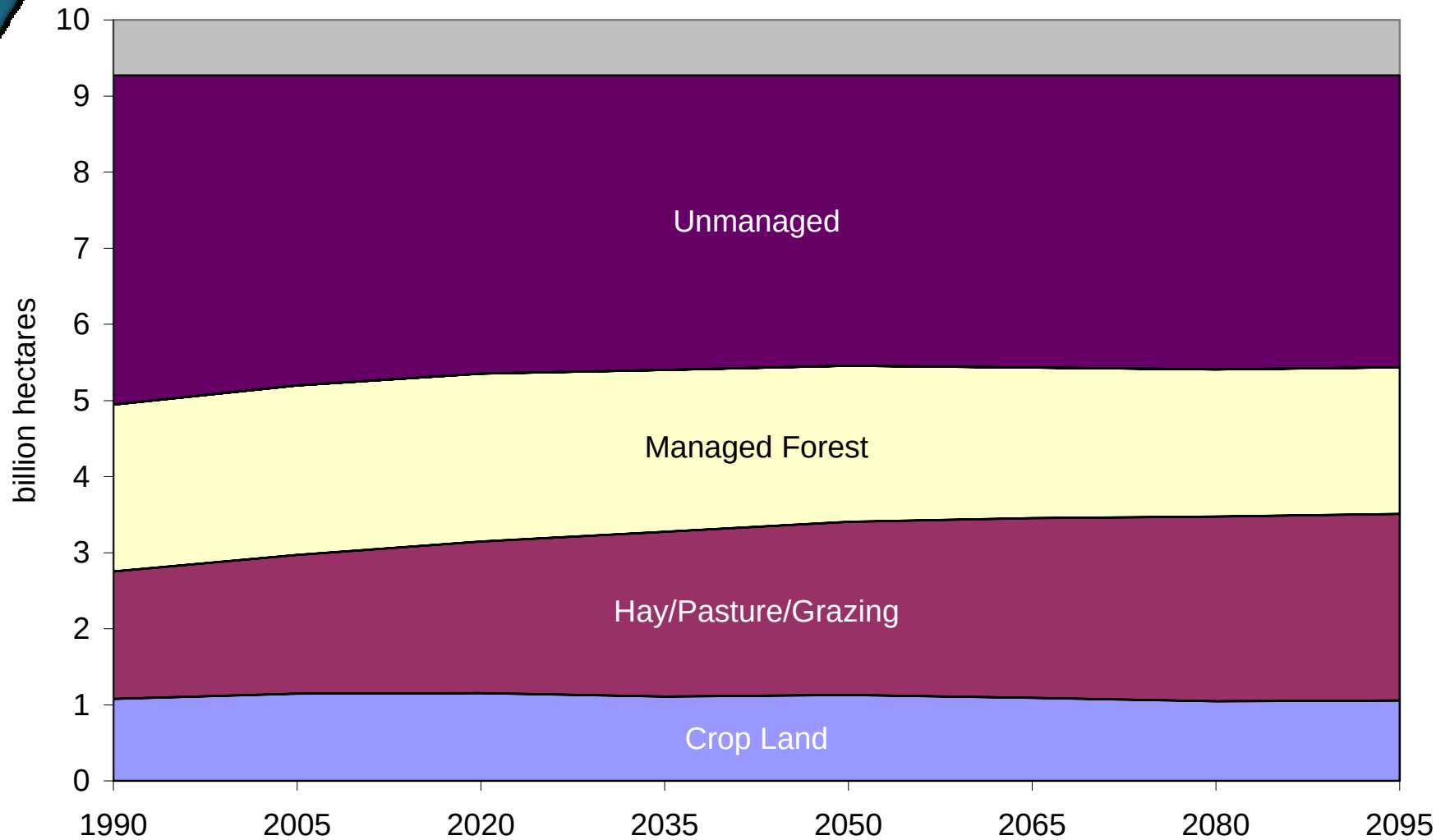
Methodology Highlights

- 15-year Time Steps from 1990 through 2095
- Land Allocation
  - Land owners compare economic returns across crops, biomass, pasture, and future trees
  - Underlying probability distribution of yields per hectare
- Forest Dynamics
  - Trees in AgLU grow for 45 years
  - Two forest markets (current and future) needed for model stability

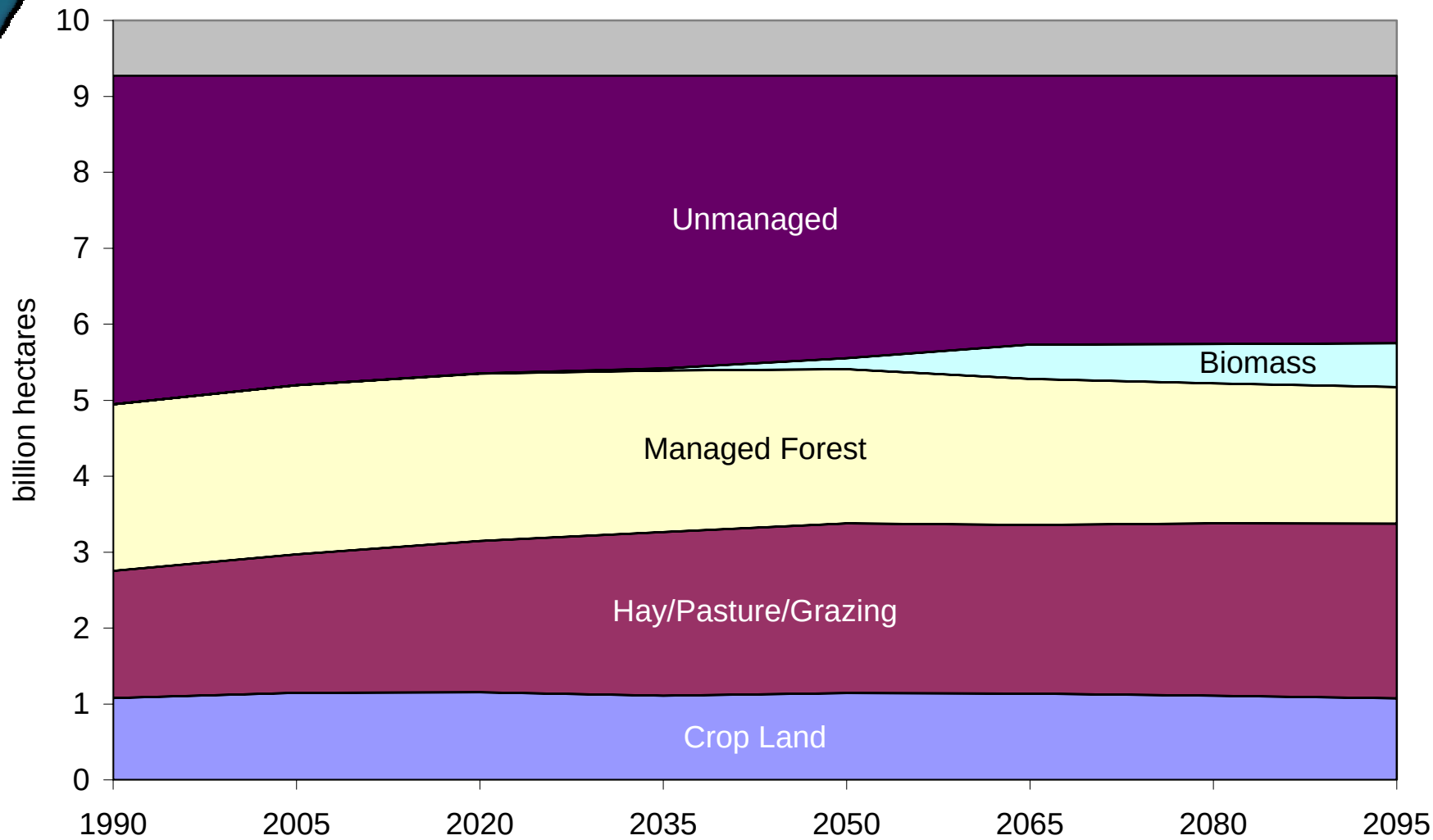
AgLU Land Allocation



Global Land Use (baseline)



Global Land Use (cap on carbon price at $150 per t C)



Current Activities

- Non-CO_2 greenhouse gases (methane, nitrous oxide, F-gases)
  - Baseline
  - Marginal abatement cost curves
  - EMF-21 data supplied by U.S. Environmental Protection Agency
- Response of forests to a carbon policy
  - EMF-21 subgroup on terrestrial carbon sinks
- Potential for commercial biofuels in India and China
  - Battelle Global Energy Technology Strategy Project (GTSP)
  - Simulate in Battelle Agriculture and Land Use model