US Greenhouse Gas Emission Scenarios to 2050

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Global Challenges Toward a Low-Carbon Economy:
Country-Specific Scenario Analysis

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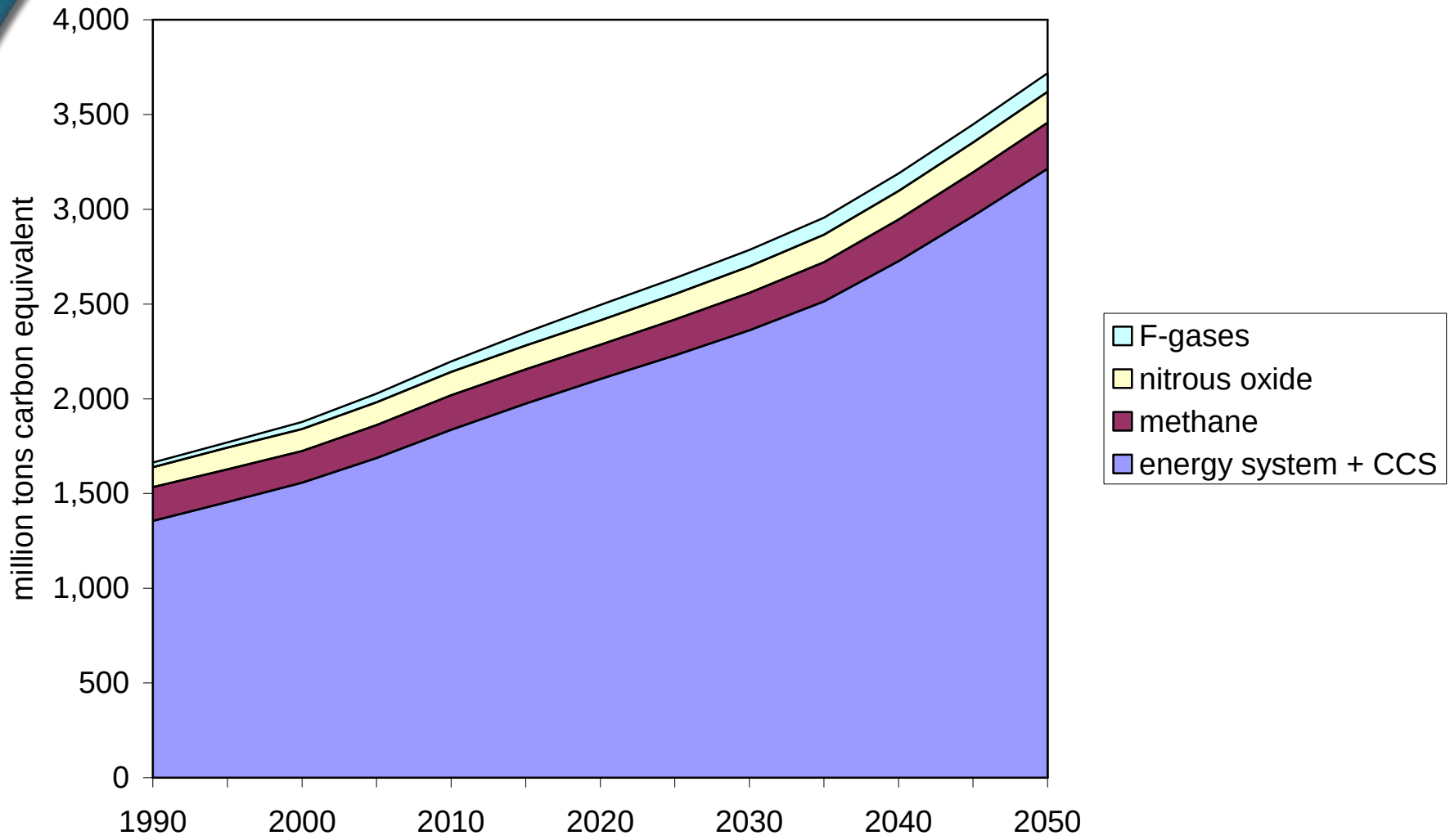
Introduction

- Results for the United States from Energy Modeling Forum study (EMF-21)
- Goals
  - Provide policy-relevant analysis (not policy prescriptive)
  - Economic comparison of major classes of greenhouse gas (GHG) mitigation options
- Classes of Mitigation Options
  - Energy efficiency improvements
  - Fuel switching
  - Carbon dioxide capture and storage (CCS)
  - Non-CO_2 GHGs
  - Terrestrial options (biofuels, carbon in soils, carbon in trees)
- Main Conclusions
  - No single model can represent all relevant processes
  - Each type of mitigation option contributes significant fraction of total

Models

- Energy System and Geologic Storage
  - CO_2 emissions from energy combustion, carbon dioxide capture and storage from electricity generation
  - Battelle Second Generation Model
- Non-CO_2 Greenhouse Gases
  - Methane, Nitrous Oxide, F-gases
  - Energy Modeling Forum (EMF-21) baselines and marginal abatement cost curves
- Agricultural Offsets
  - Soil sequestration, Afforestation, Biofuel Offsets
  - Agricultural Sector Model (McCarl, B.A. and Schneider, U.A. 2001. "Greenhouse Gas Mitigation in U.S. Agriculture and Forestry." *Science* **294**, 2481-2482.)

U.S. Carbon Equivalent Emissions (baseline)



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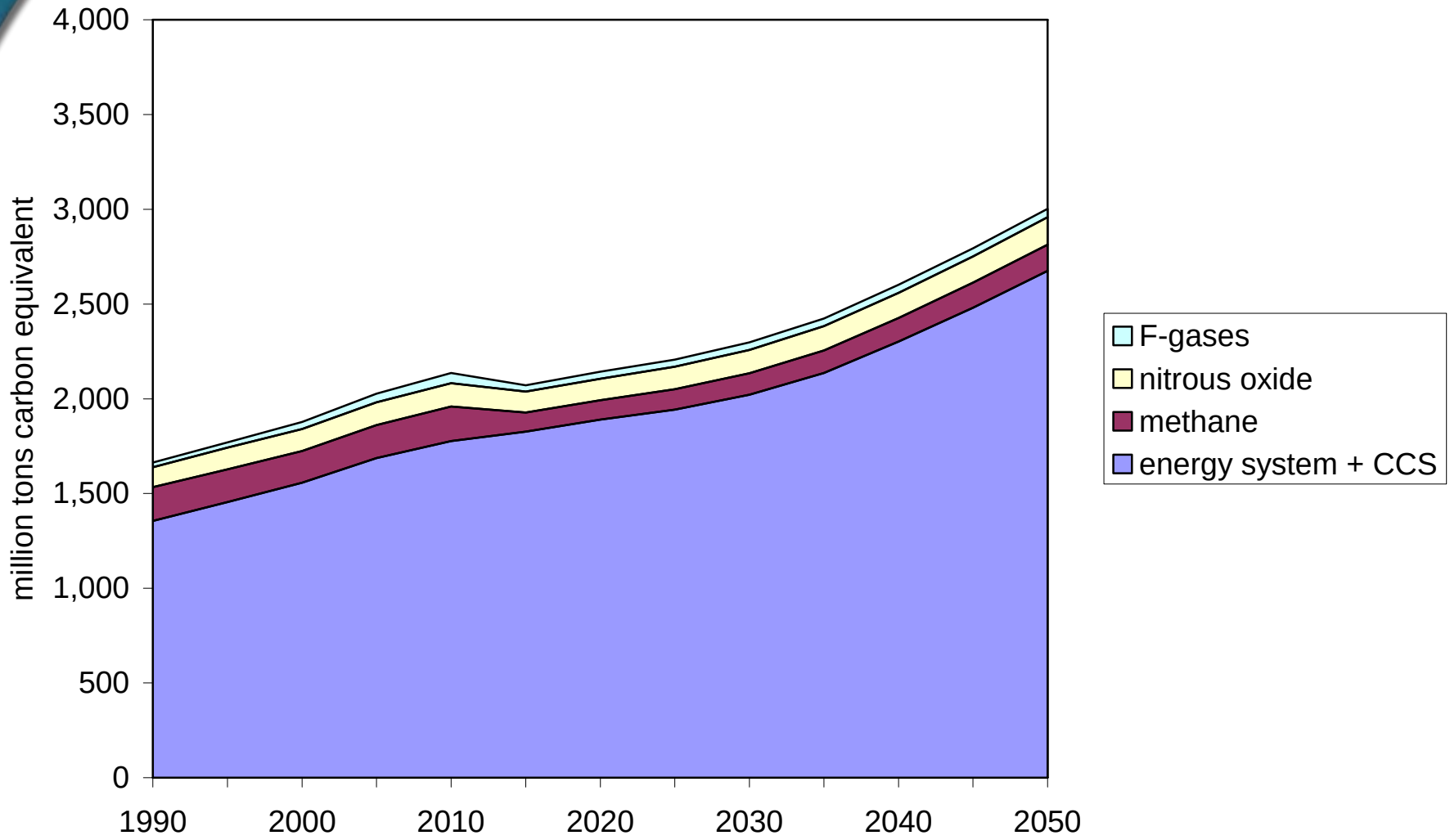
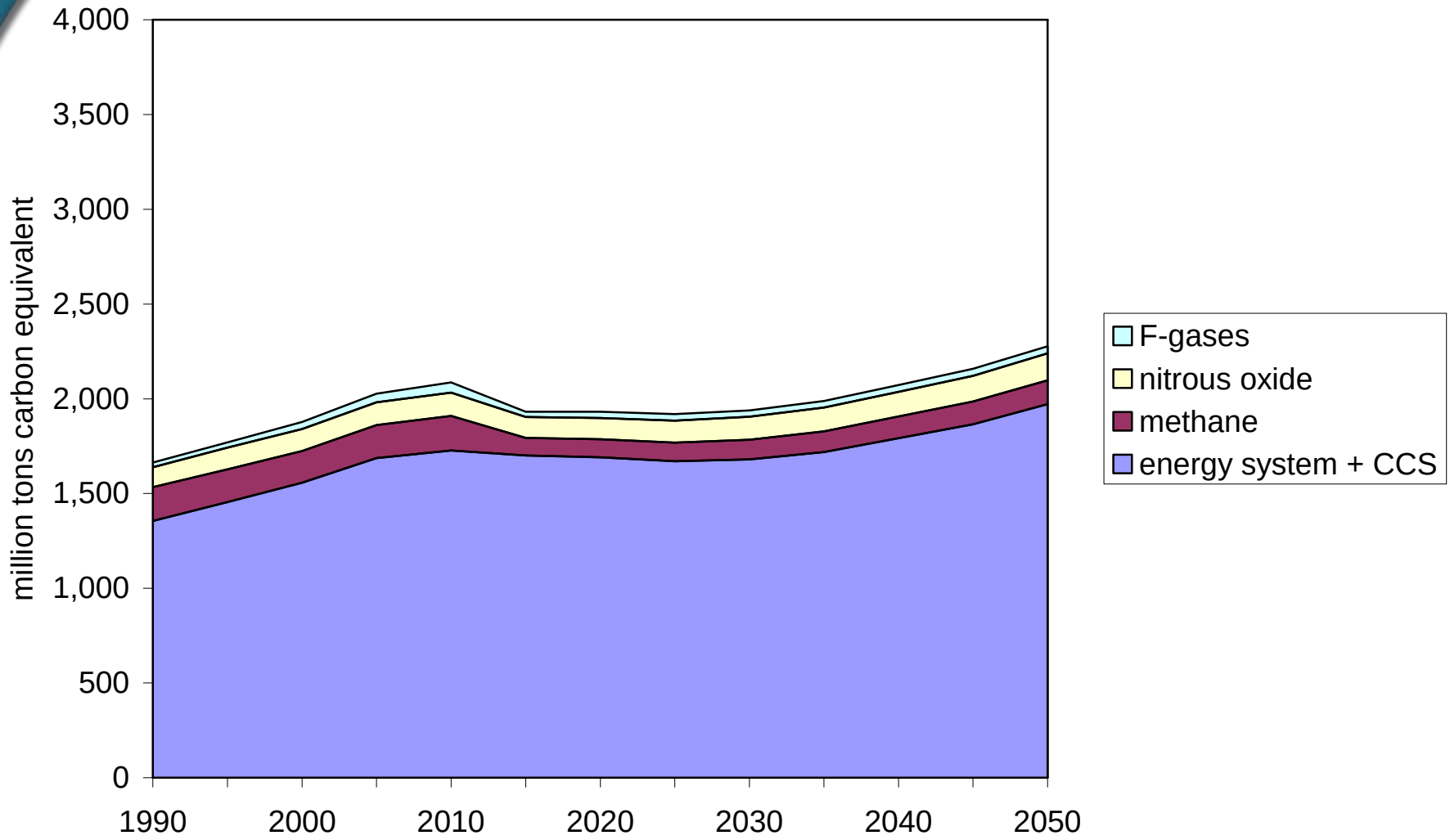
U.S. Carbon Equivalent Emissions ($100 constant)



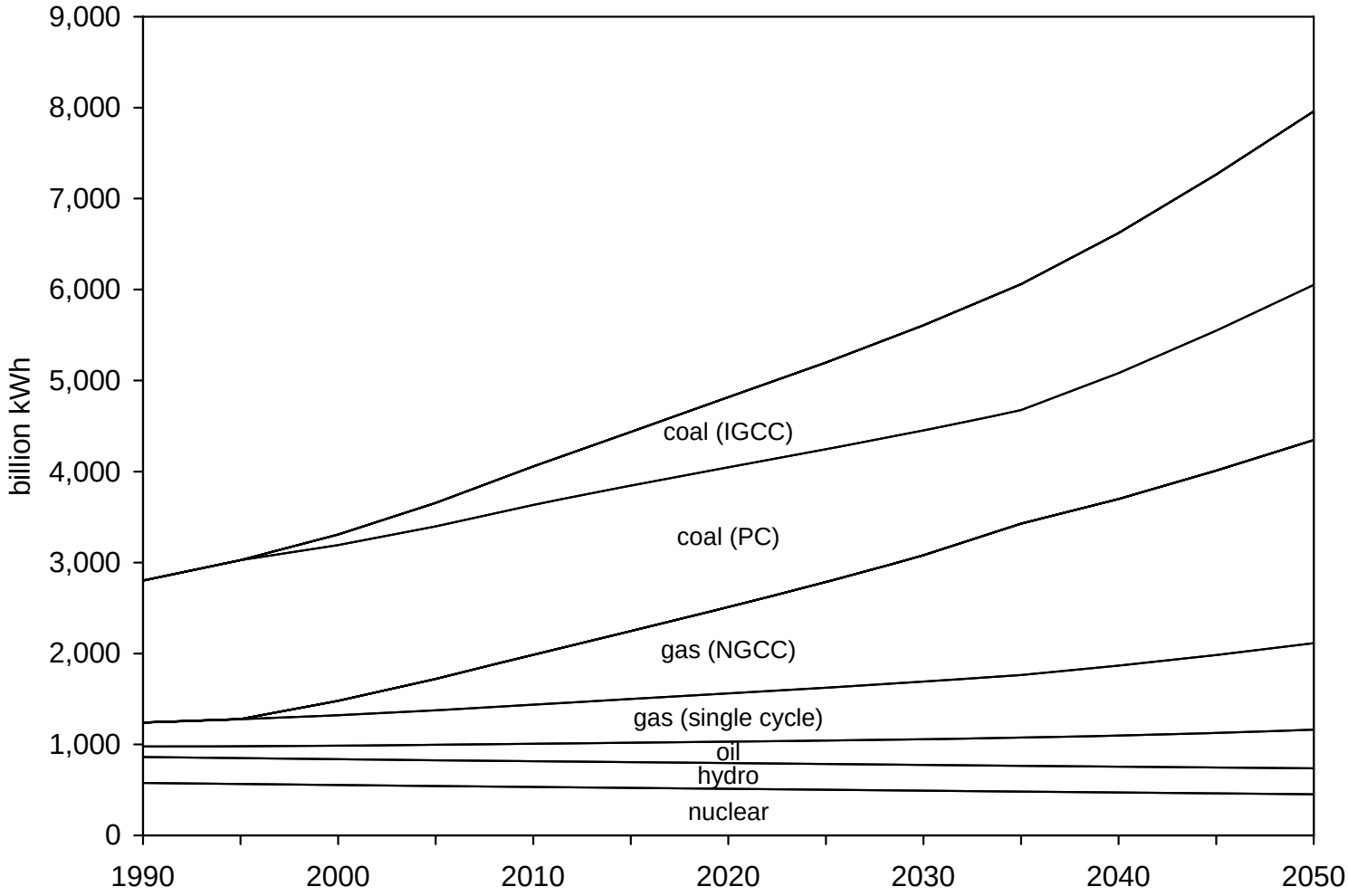
U.S. Carbon Equivalent Emissions ($200 constant)



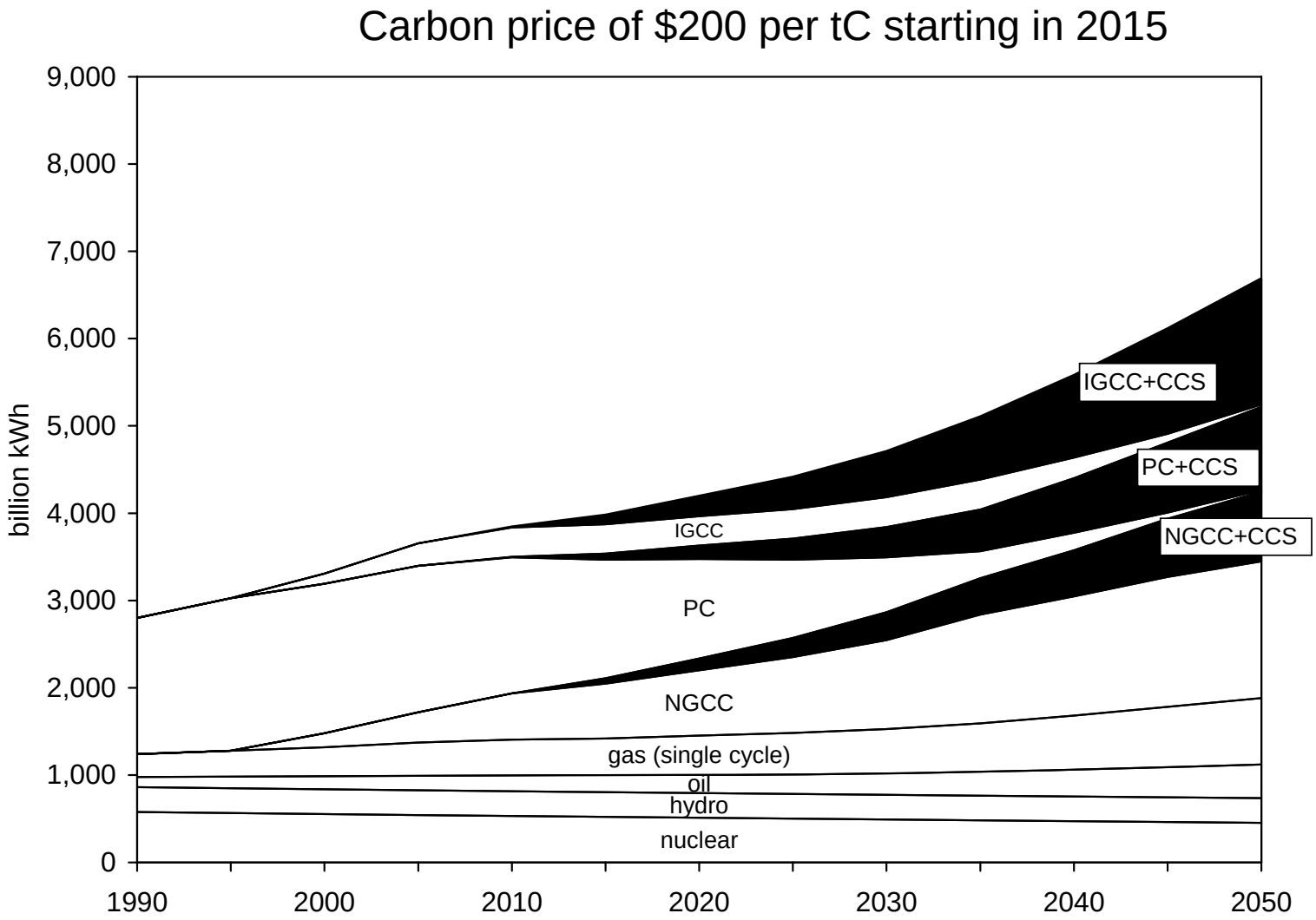
Carbon Dioxide Capture and Storage (CCS)

- Carbon Dioxide Capture from Electric Power Generation
  - Technologies with and without CCS
    - Coal integrated gasification combined cycle (IGCC)
    - Natural gas combined cycle (NGCC)
  - Engineering cost model for capture process from David and Herzog, 2000, “The Cost of Carbon Capture,” Proceedings of the Fifth International Conference on Greenhouse Gas Control Technologies
- Geologic Storage
  - Cost of storage assumed constant ($40 per tC)
  - Ongoing work at Battelle to construct storage supply curves for the US and other countries

U.S. Electricity Baseline Scenario

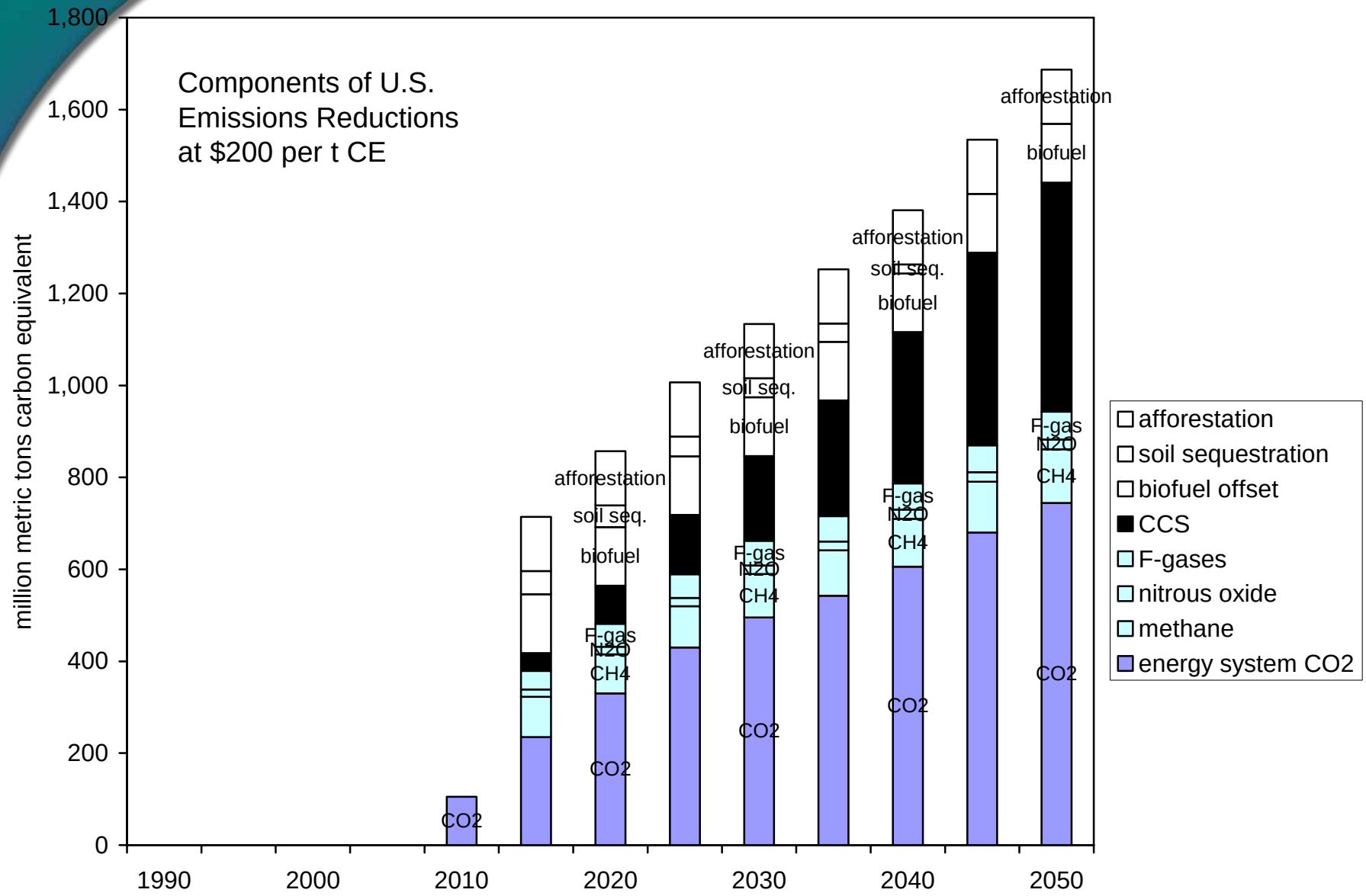


Constant-Carbon-Price Scenario

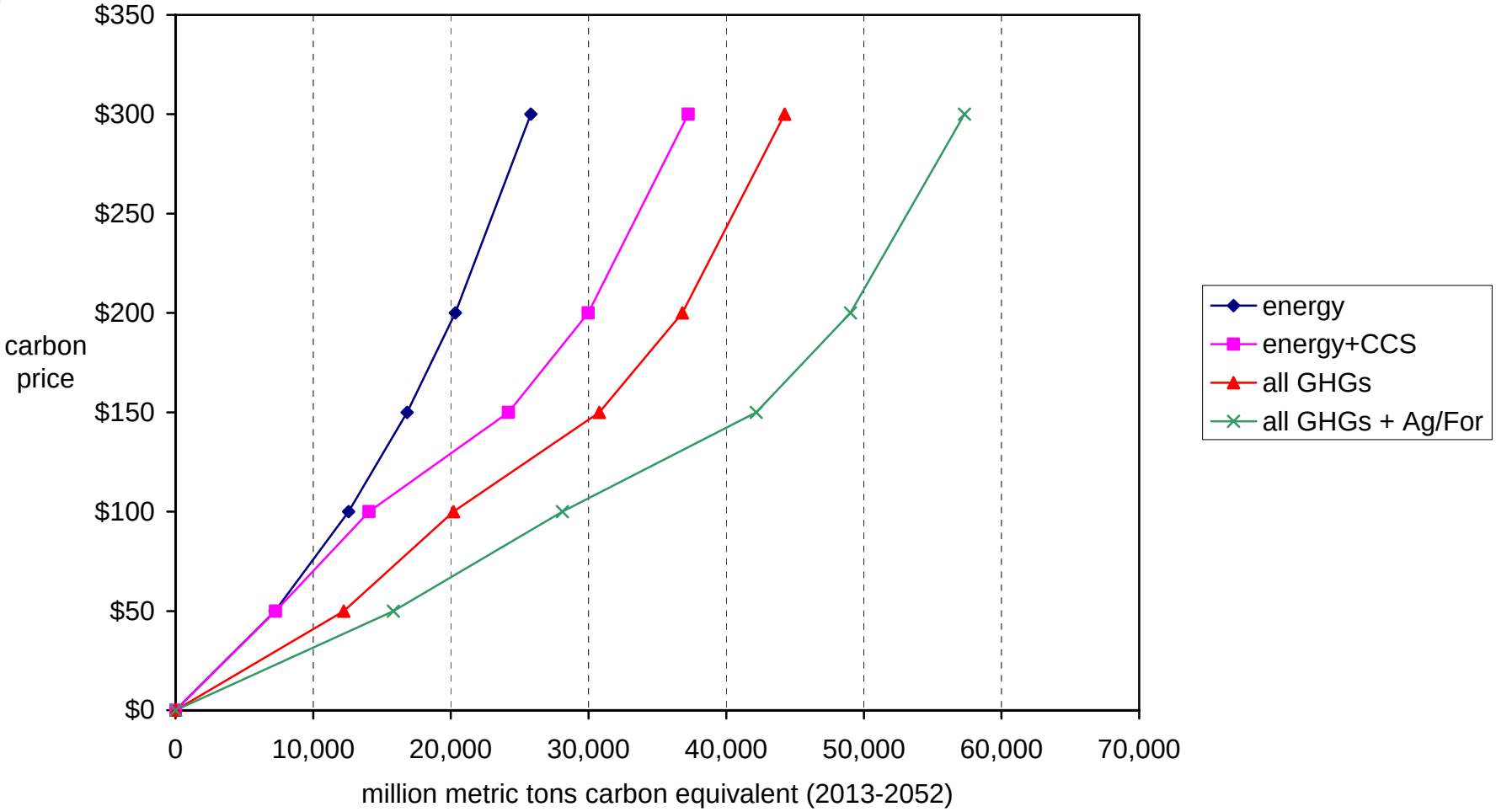


Economic Comparison of Mitigation Options

- View 1: Components of US emission reductions relative to baseline over time
  - Constant carbon price of $200 per t C-eq
  - Components
    - Energy system CO_2
    - Carbon dioxide capture and storage
    - Non-CO_2 GHGs (methane, nitrous oxide, F-gases)
    - Terrestrial options (soil carbon, afforestation, biofuels)
- View 2: Cumulative emission reductions over a range of carbon prices
  - Results derived from a set of constant-carbon-price experiments
  - Carbon prices up to $300 per t C-eq
  - Expressed as cumulative marginal abatement cost curves
  - Cumulative emissions reductions over 40 years


Components of U.S. Emissions Reductions at $200 per t CE
million metric tons carbon equivalent
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1990
2000
2010
2020
2030
2040
2050
CO2
afforestation
soil seq.
biofuel
F-gas
N2O
CH4
CO2
afforestation
soil seq.
biofuel
F-gas
N2O
CH4
CO2
afforestation
soil seq.
biofuel
F-gas
N2O
CH4
CO2
afforestation
soil seq.
biofuel
F-gas
N2O
CH4
CO2
afforestation
biofuel
F-gas
N2O
CH4
CO2
afforestation
soil sequestration
biofuel offset
CCS
F-gases
nitrous oxide
methane
energy system CO2

U.S. Cumulative Emissions Reductions (40 years with constant carbon price)



Conclusions

- No single model can represent all relevant processes
  - Bottom-up: specialized analysis or models by sector
    - Agriculture / Forestry
    - Buildings
    - Industry
    - Transportation
    - Electricity generation
  - Top-down: combine results across sectors
- Each type of mitigation option contributes significant fraction of total
  - Energy efficiency improvements
  - Fuel switching
  - CO_2 capture and storage
  - Non-CO_2 greenhouse gases
  - Terrestrial storage and biofuels
- Potential of each mitigation option varies across countries