

# Advanced Electric Generating Technologies in a Computable General Equilibrium Model

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# Overview

- ▶ Why change model framework?
  - Work with sector specialists
  - Need for modularity suggests object-oriented framework
- ▶ SGM review
- ▶ Class diagrams
- ▶ Example: Electricity Generation
  - Advanced technologies
  - Engineering cost model
  - Generation without carbon capture and carbon prices at {\$0, \$100, \$200}
  - Generation with carbon capture and carbon prices at {\$0, \$100, \$200, \$300}
- ▶ Modeling activities

# Second Generation Model

- ▶ 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

# SGM Regions

## ▶ Annex I

- United States
- Canada
- Western Europe
- Japan
- Australia
- Former Soviet Union
- Eastern Europe

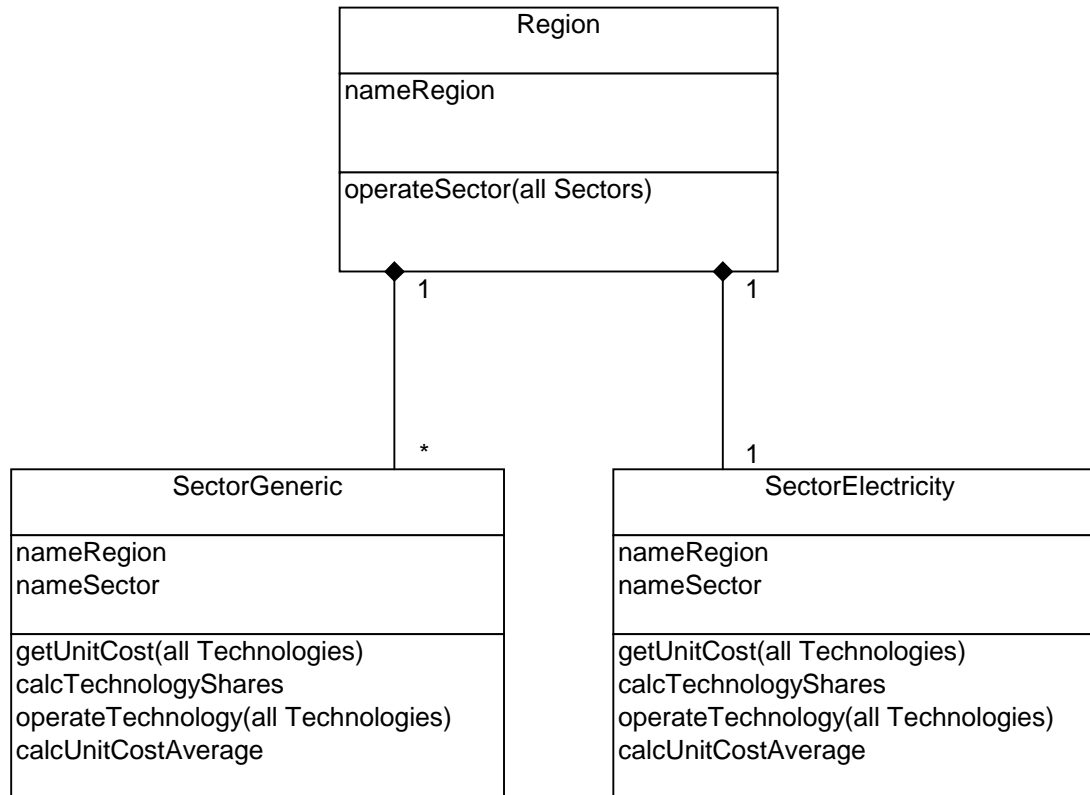
## ▶ Non Annex I

- China
- India
- Brazil
- Middle East
- Mexico
- South Korea
- Rest of World

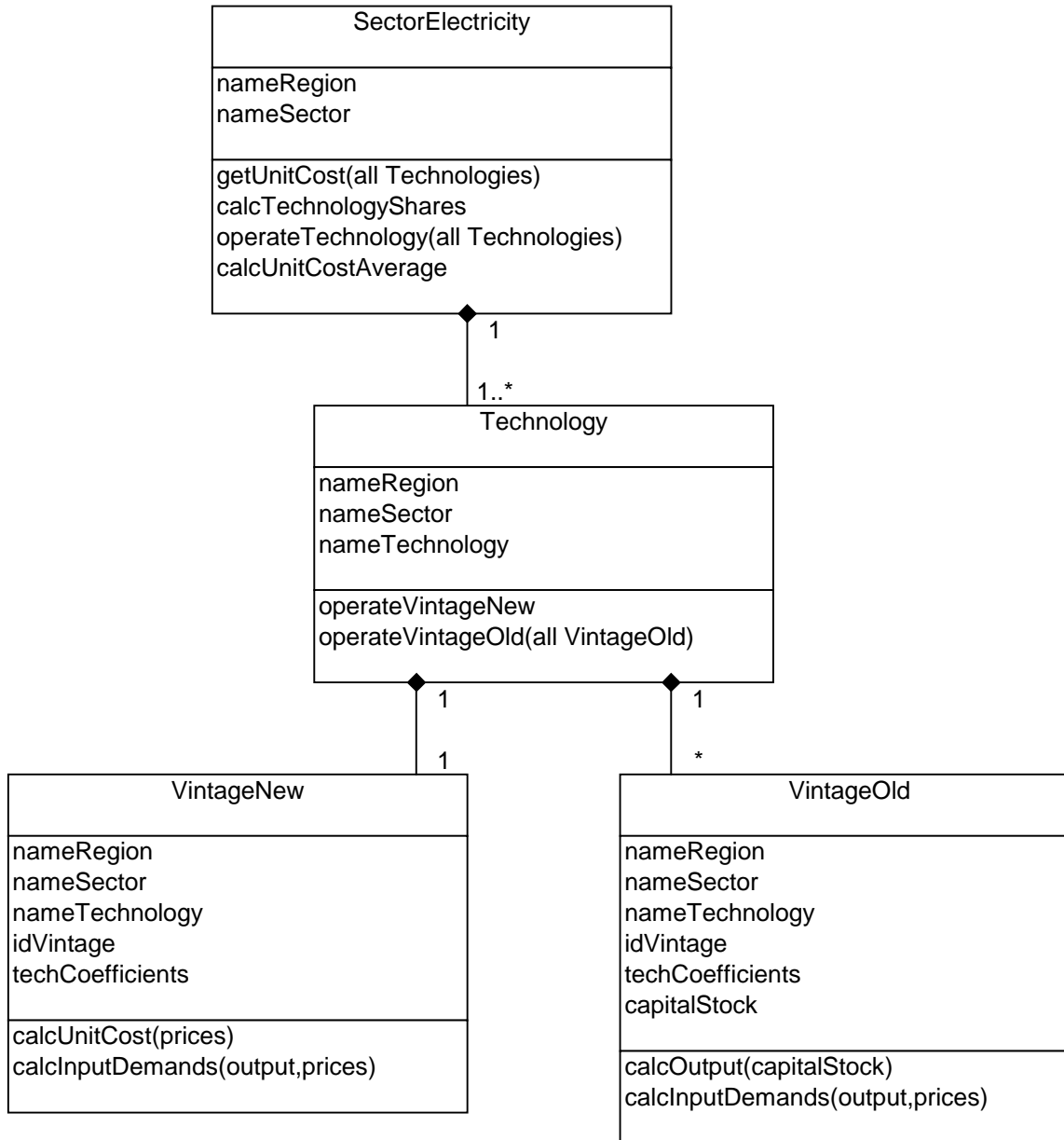
# Production Sectors in SGM

- 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

# Class Diagram: Sector Level and Above

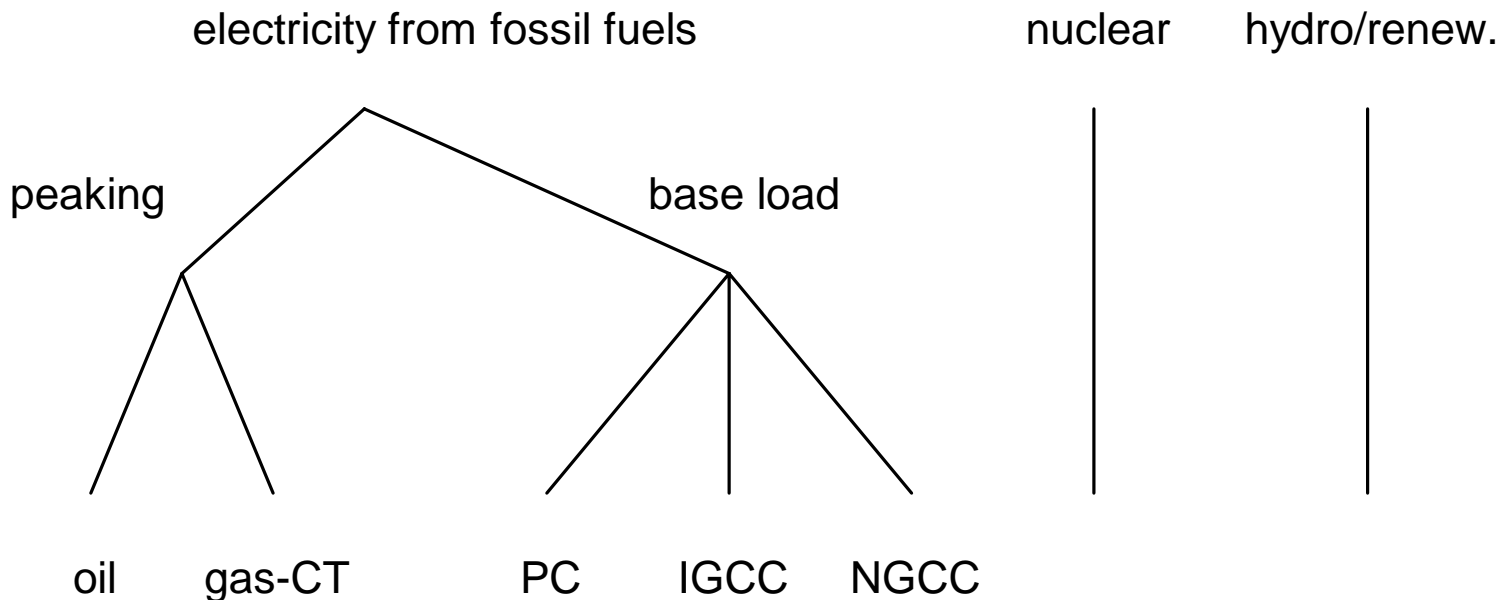


# Class Diagram: Sector Level and Below



# Electricity Sector

- ▶ All production sectors other than electricity represented by CES production function
- ▶ Each electric generating technology represented by fixed-coefficient production function
- ▶ Electricity sector uses a nested logit structure to allocate new investment to generating technologies





# Engineering Cost Model

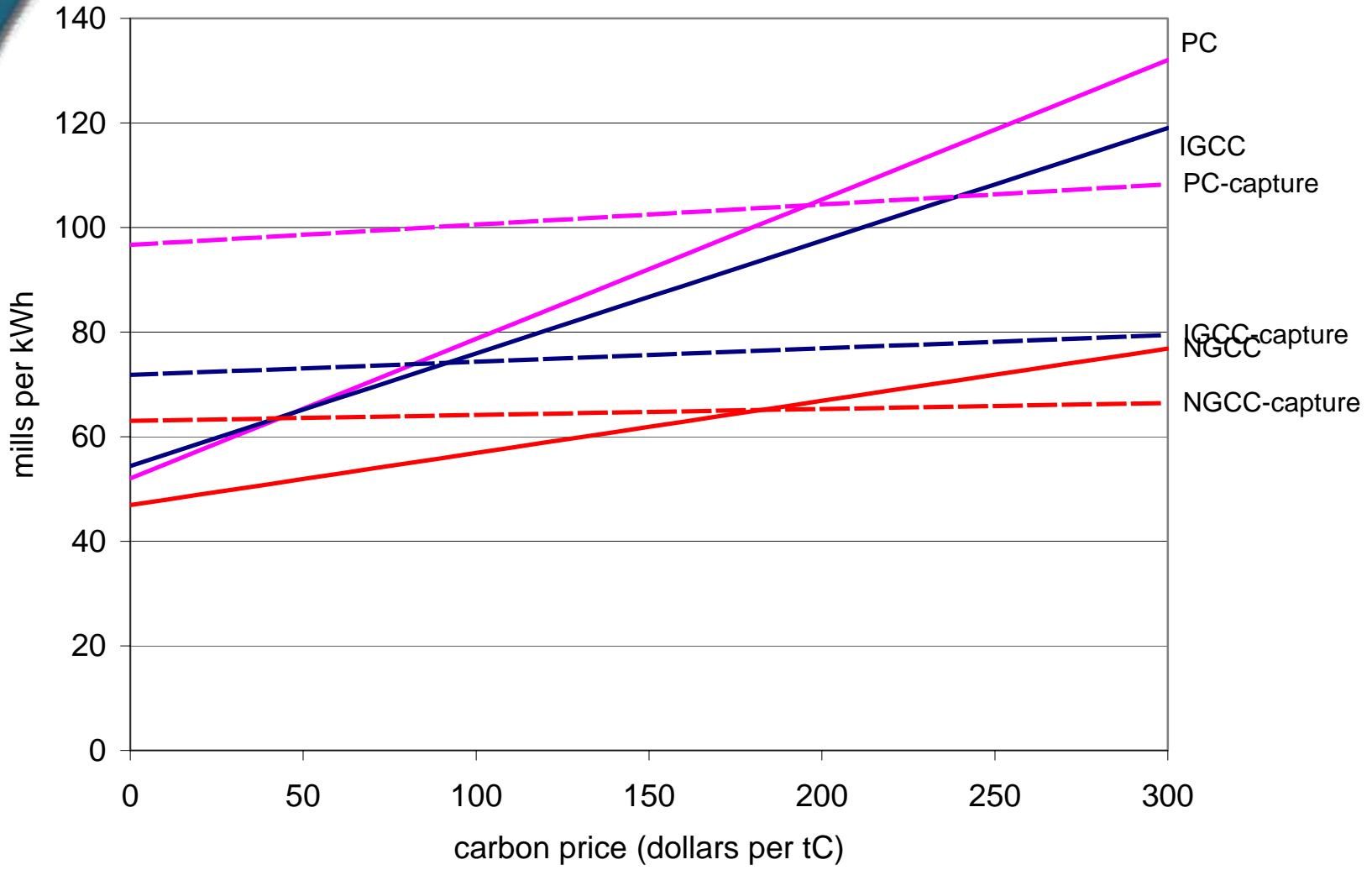
- ▶ Electricity Generation (hypothetical plant)
  - First cost of capital (\$ per kW)
  - Interest rate
  - Equipment lifetime (years)
  - Heat rate (efficiency)
  - Operation and maintenance (mills per kWh)
  - Price of fuel (\$ per GJ)
  - Carbon emissions coefficient (kg C per GJ)
- ▶ Capture Process
  - Fraction of CO<sub>2</sub> captured (efficiency)
  - Capital Cost (\$ per kg CO<sub>2</sub> per hour)
  - Operation and Maintenance (mills per kg CO<sub>2</sub>)
  - Energy required (kWh per kg CO<sub>2</sub>)
- ▶ Calculate total cost per kWh (mills per kWh) with and without capture for each generating technology

# Cost Comparison

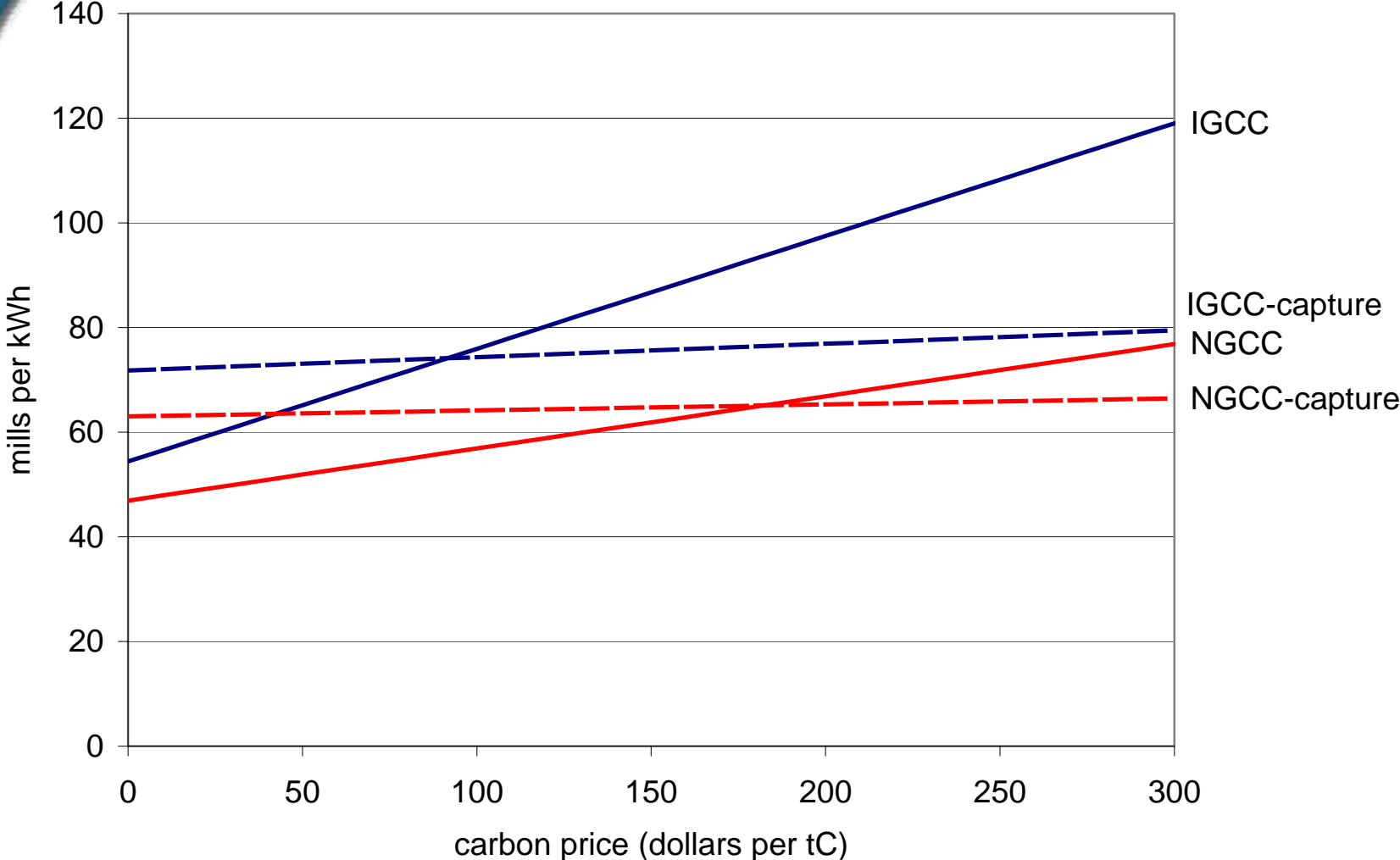
	reference mills/kWh	with capture mills/kWh	\$/ton C
Pulverized Coal	45.5	84.4	189
Coal IGCC	50.6	68.8	96
NGCC	36.8	53.3	187

Note: Cost per ton of carbon avoided is for capture only and does not include sequestration cost.

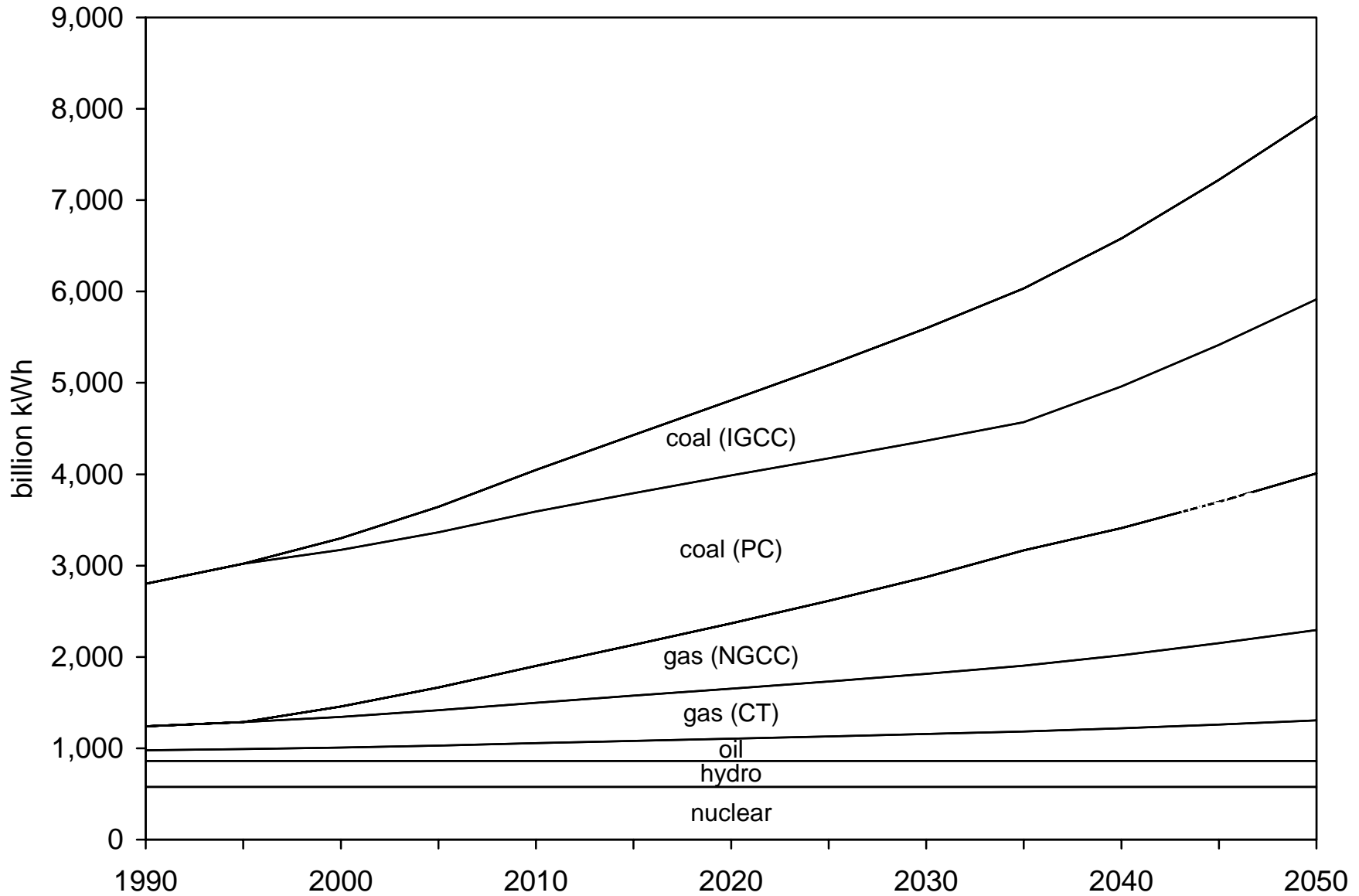
# Electricity Cost as a Function of Carbon Price



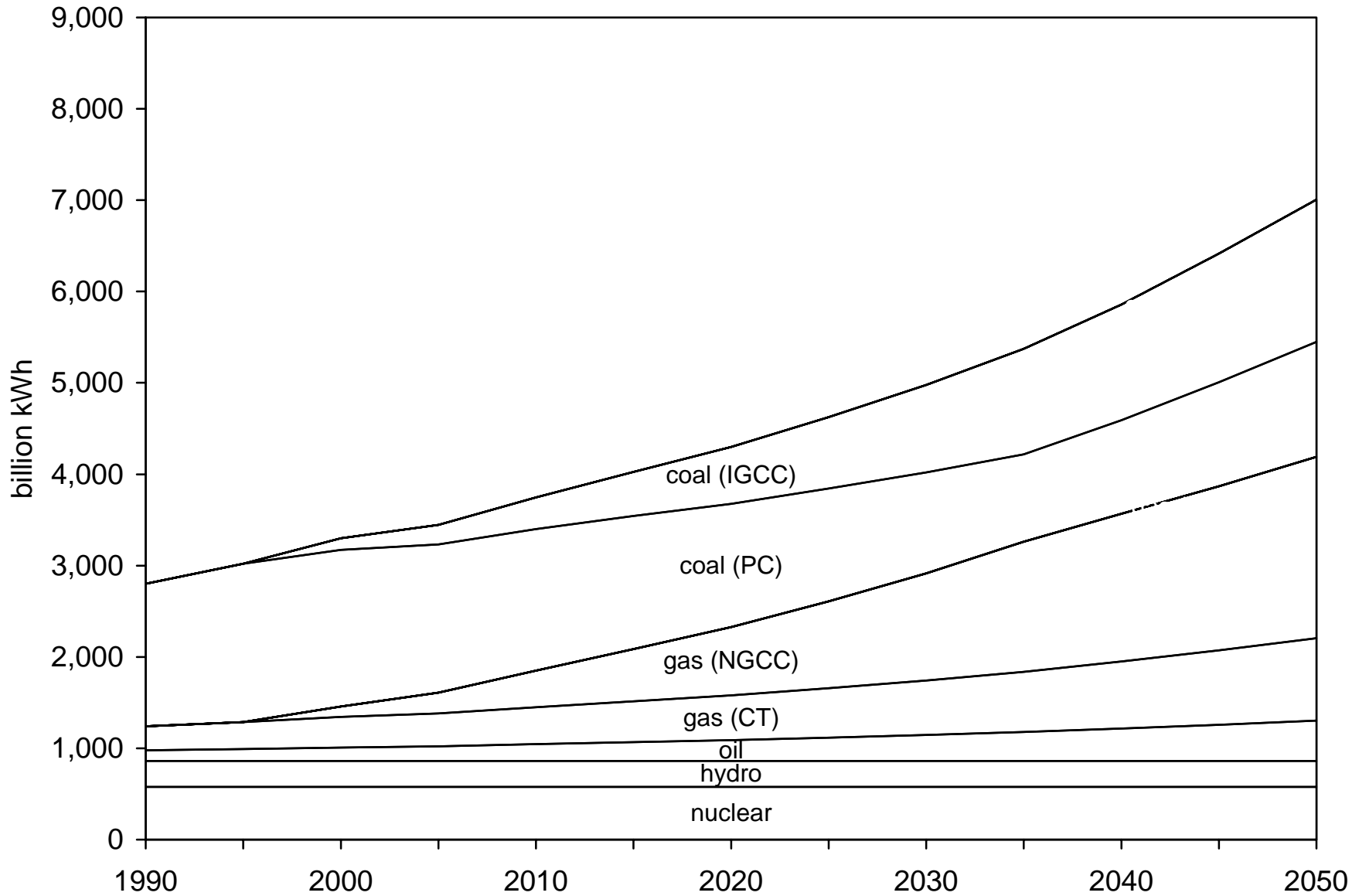
# Electricity Cost as a Function of Carbon Price



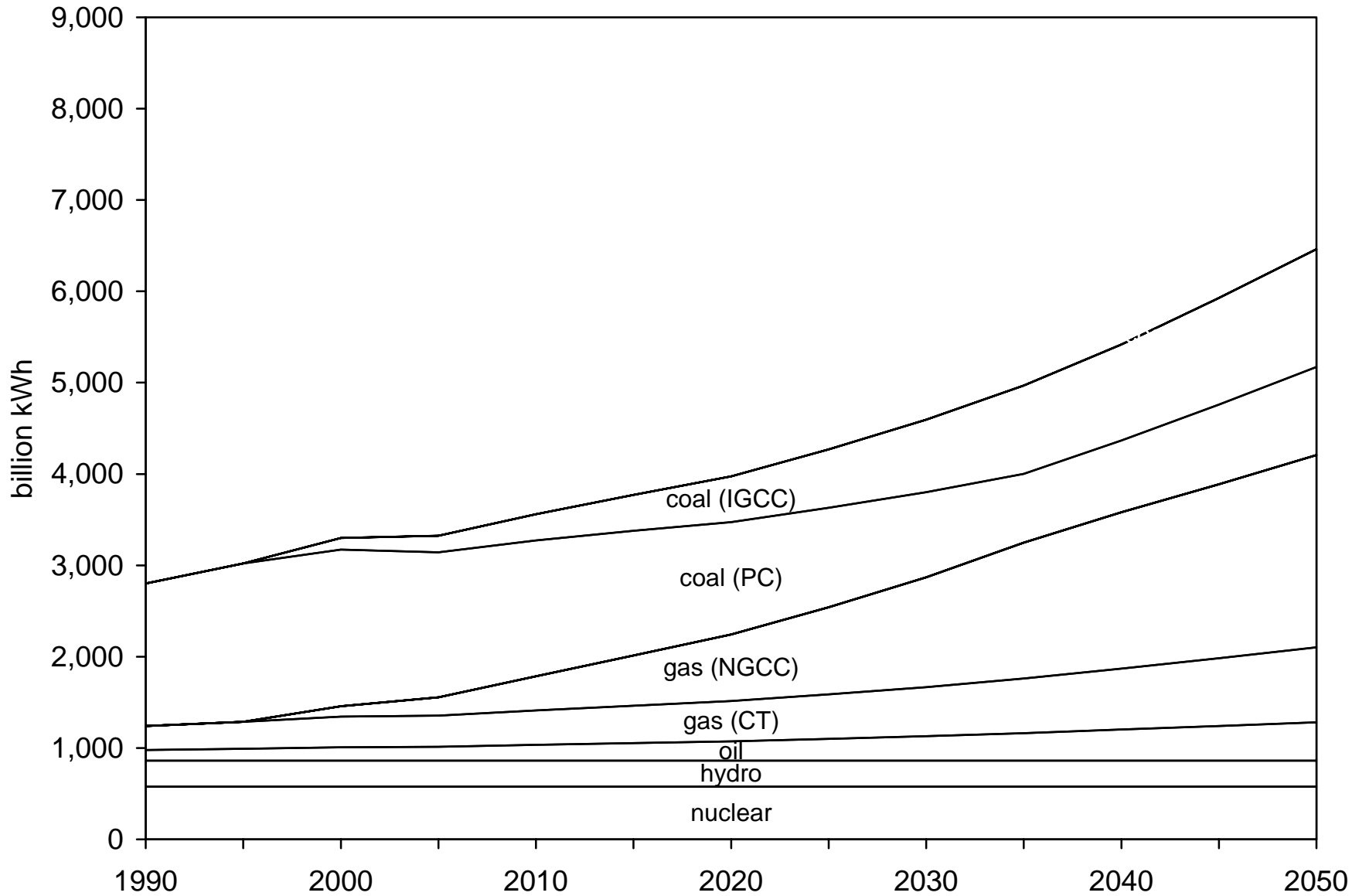
# SGM-USA Electricity Generation (\$0 per tC)



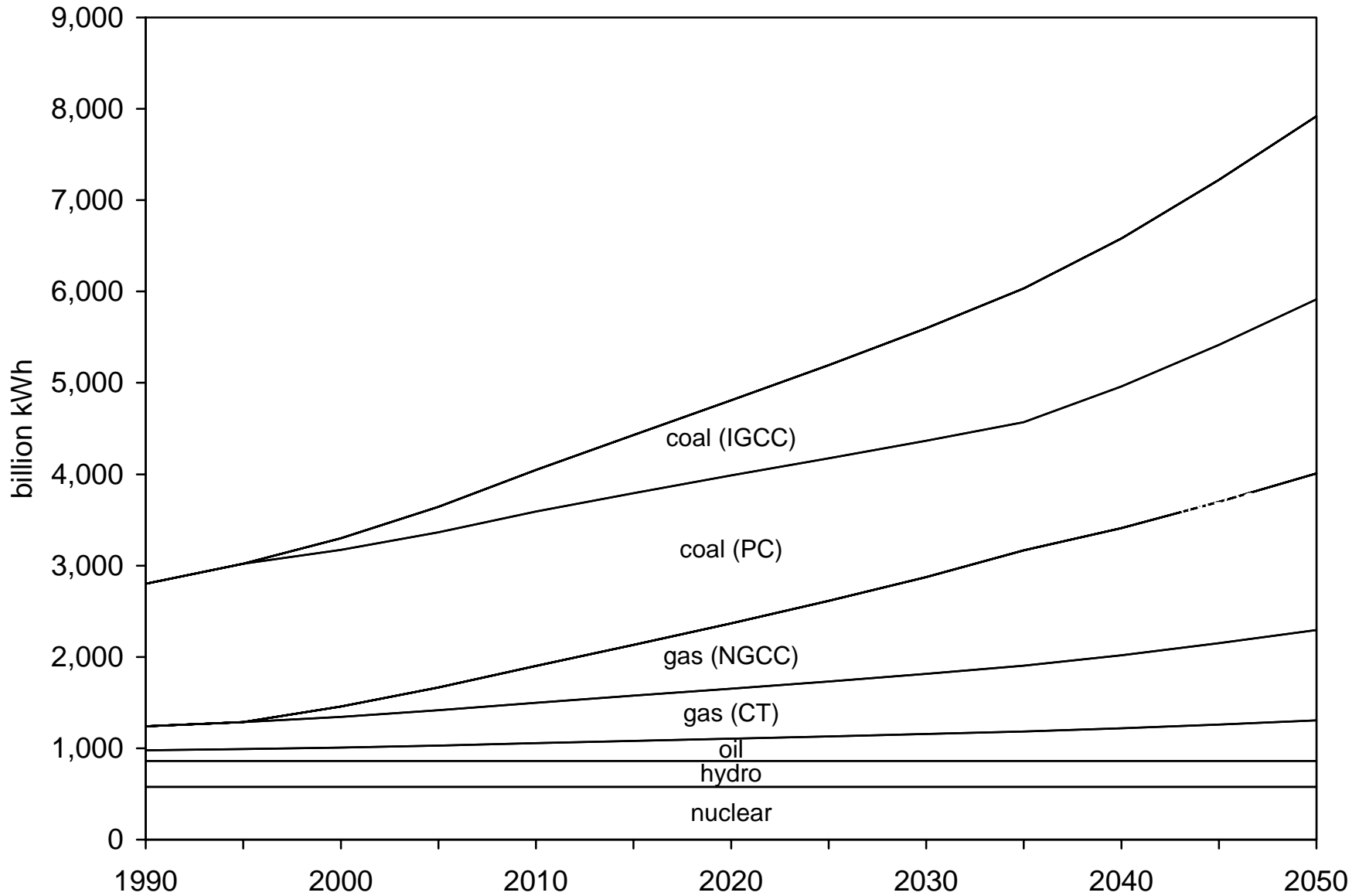
# SGM-USA Electricity Generation (\$100 per tC)



# SGM-USA Electricity Generation (\$200 per tC)

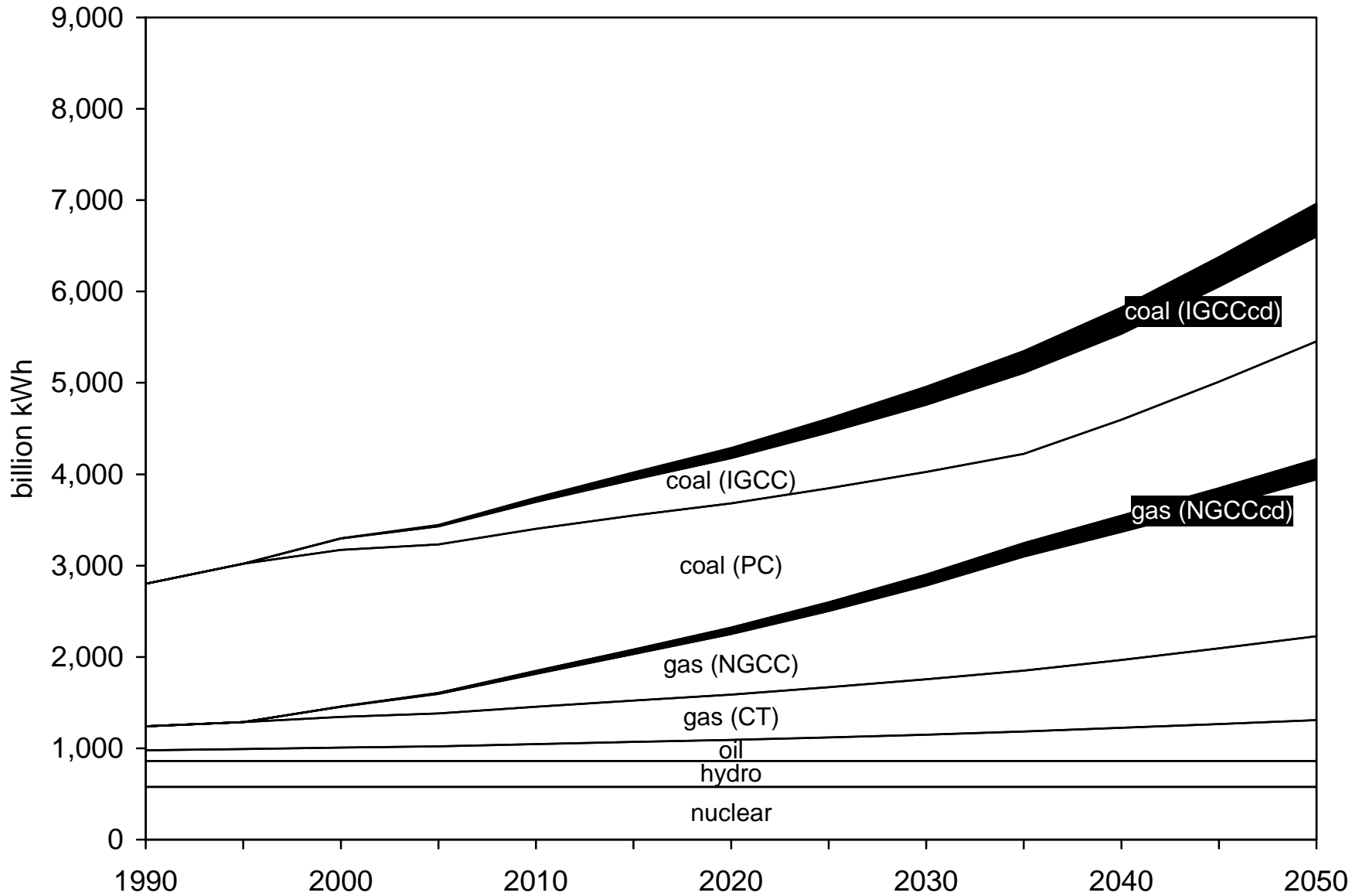


# SGM-USA Electricity Generation (\$0 per tC)

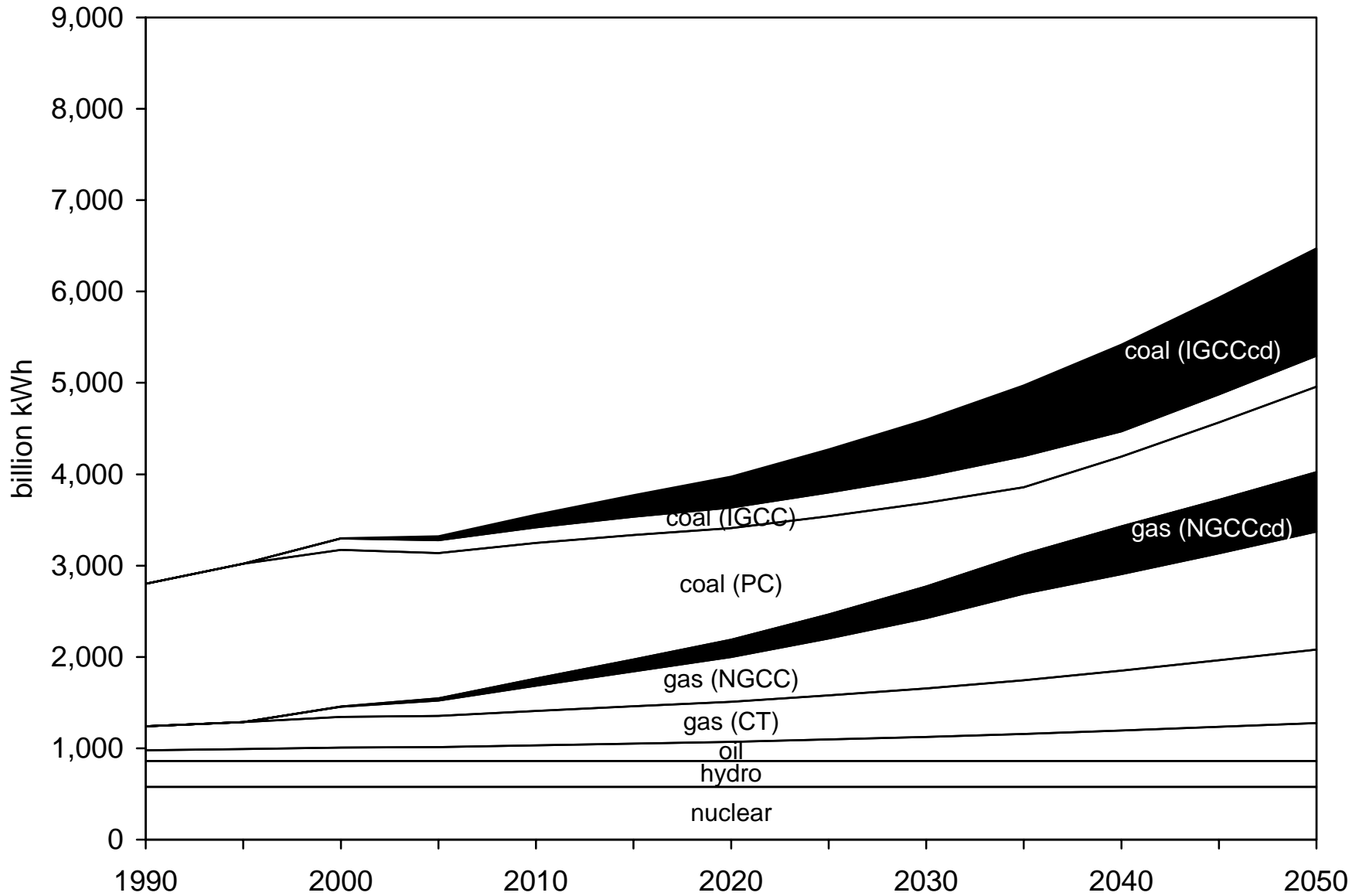




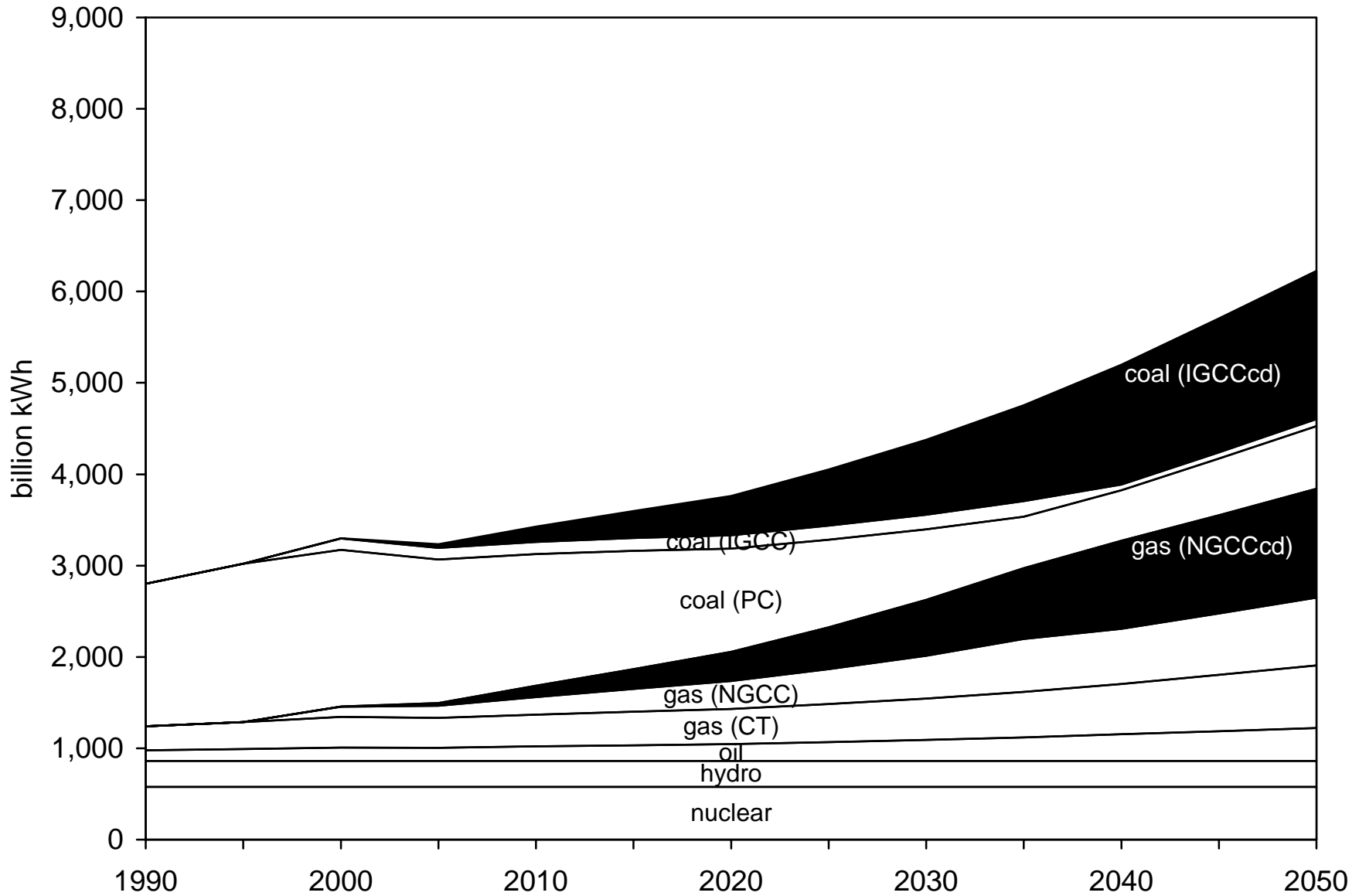
# SGM-USA Electricity Generation (\$100 per tC)



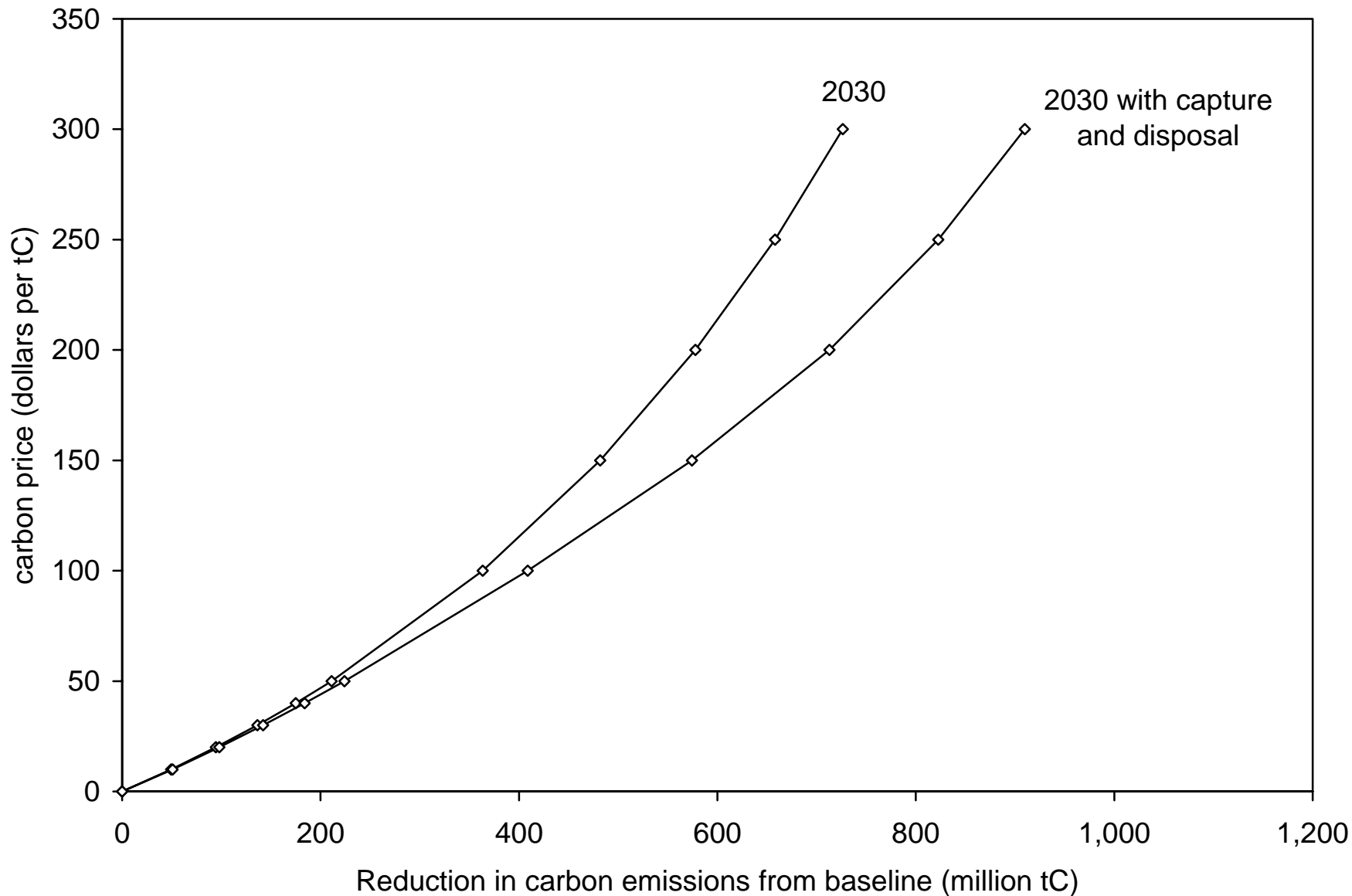
# SGM-USA Electricity Generation (\$200 per tC)



# SGM-USA Electricity Generation (\$300 per tC)



# SGM-USA Marginal Abatement Cost Curves in 2030



# Current Modeling Activities

- ▶ Prototypes for SGM-USA and SGM-Germany
- ▶ Object version of Agriculture and Land Use (AgLU) model
- ▶ Extend to other SGM regions
- ▶ Questions
  - Could we have done this in GAMS or GEMPACK?
  - C++ or Java?