THE IMPORTANCE OF TECHNOLOGICAL INNOVATION IN POLICY ASSESSMENTS OF CARBON CAPTURE AND STORAGE

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Motivation

- Computer models used to analyze climate policy scenarios typically treat technological change as an exogenous factor, or ignore it altogether
- Assumptions about technology cost and performance can have a strong influence on model results
- This study examines the importance of technological "learning" on the role of carbon capture and storage (CCS) systems as a mitigation strategy, under alternative climate-related policy scenarios

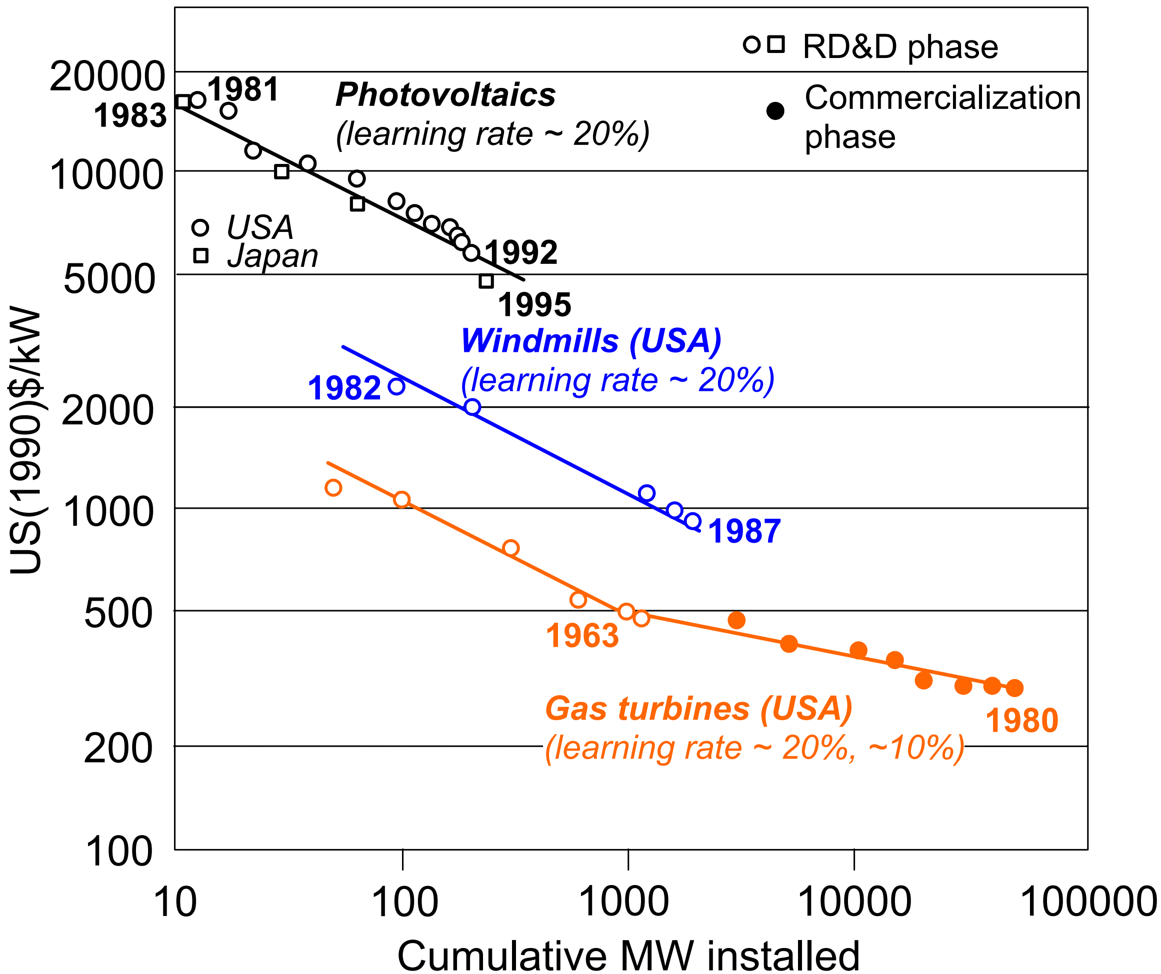
Approach

- Use historical studies to estimate rates of technological innovation for environmental technologies
- Incorporate these findings in a large-scale climate policy model to represent future cost trends for CCS systems
- Assess the policy implications of including technological “learning” for carbon sequestration technologies

Technological Innovation

- Future characteristics of a technology (e.g., costs) are not "autonomous;" they depend on intervening actions
- Improvements in technology are realized through investments in R&D, production, and deployment (resulting in learning-by-doing, and learning-by-using)
- For power generation technologies, cumulative installed capacity is the common proxy for accumulated knowledge

Learning Curves for Electricity Generation Technologies



Learning Curve Formulation

General equation:

$$y_i = a x_i^{-b}$$

where,

y_i = cost to produce i^{th} unit

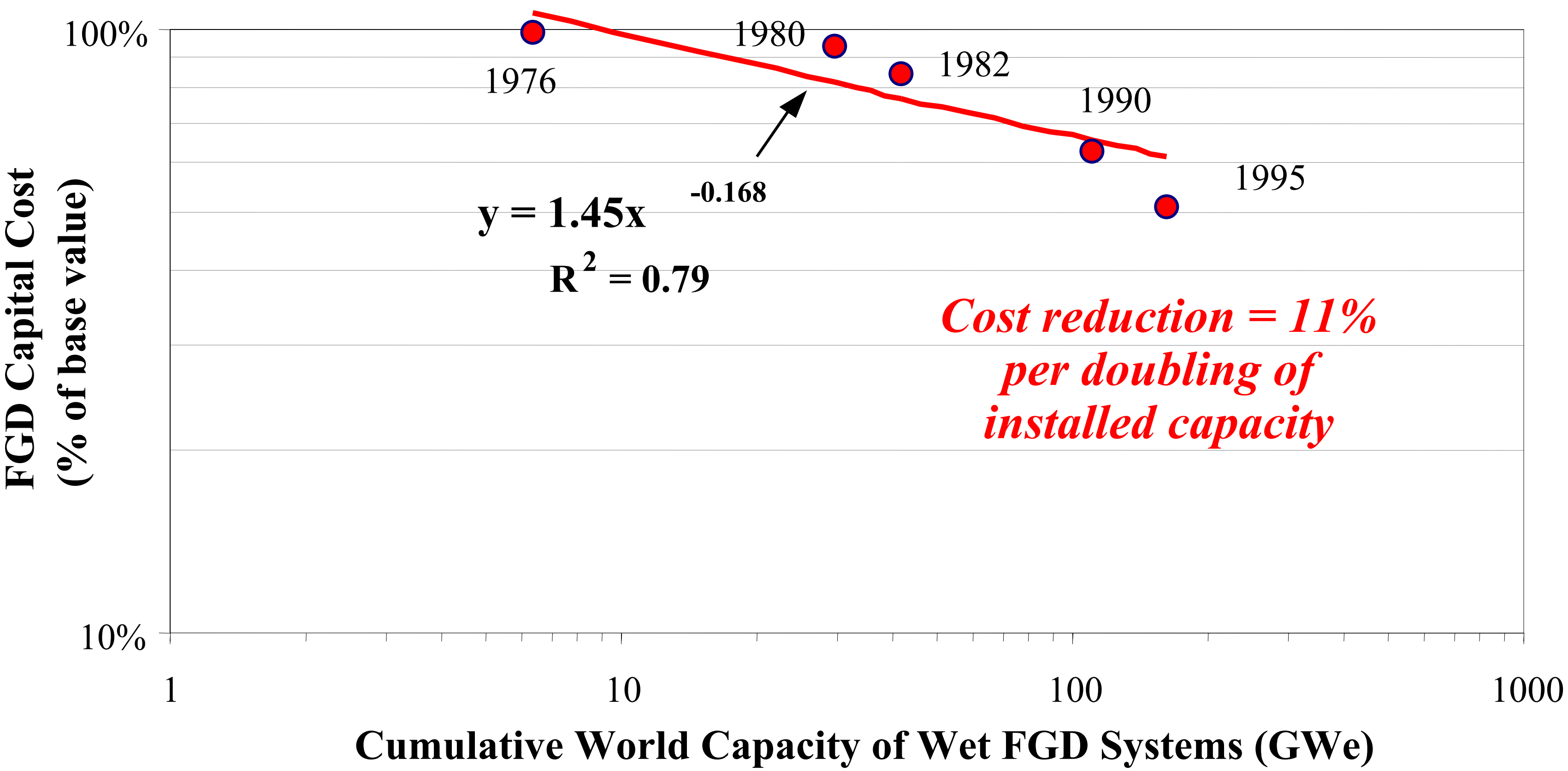
x_i = cumulative production thru period i

b = learning rate exponent

a = coefficient (constant)

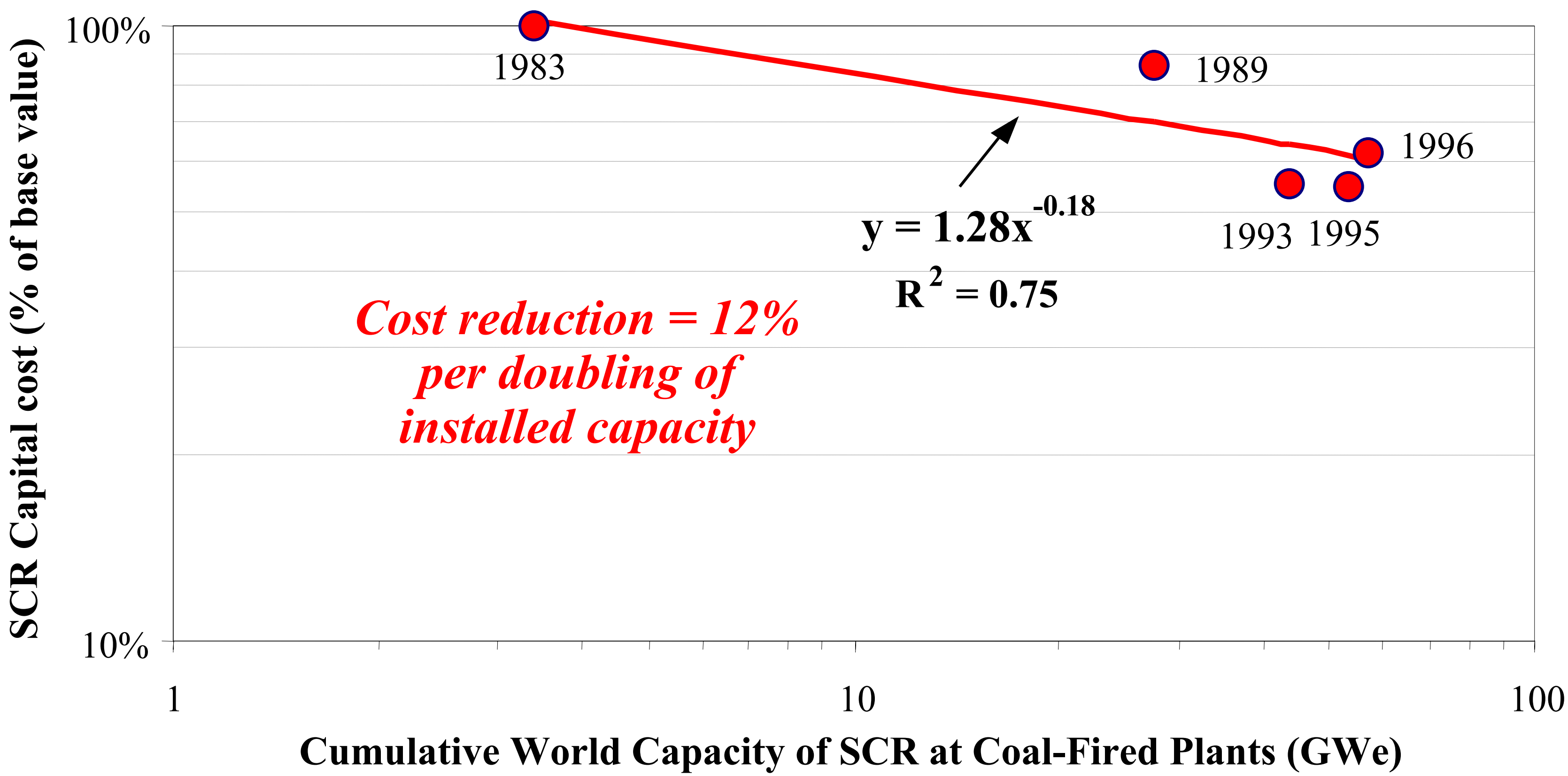
Percent cost reduction for a doubling of cumulative output is called the "learning rate" = $(1 - 2^{-b})$

Normalized Learning Curve for FGD Capital Cost



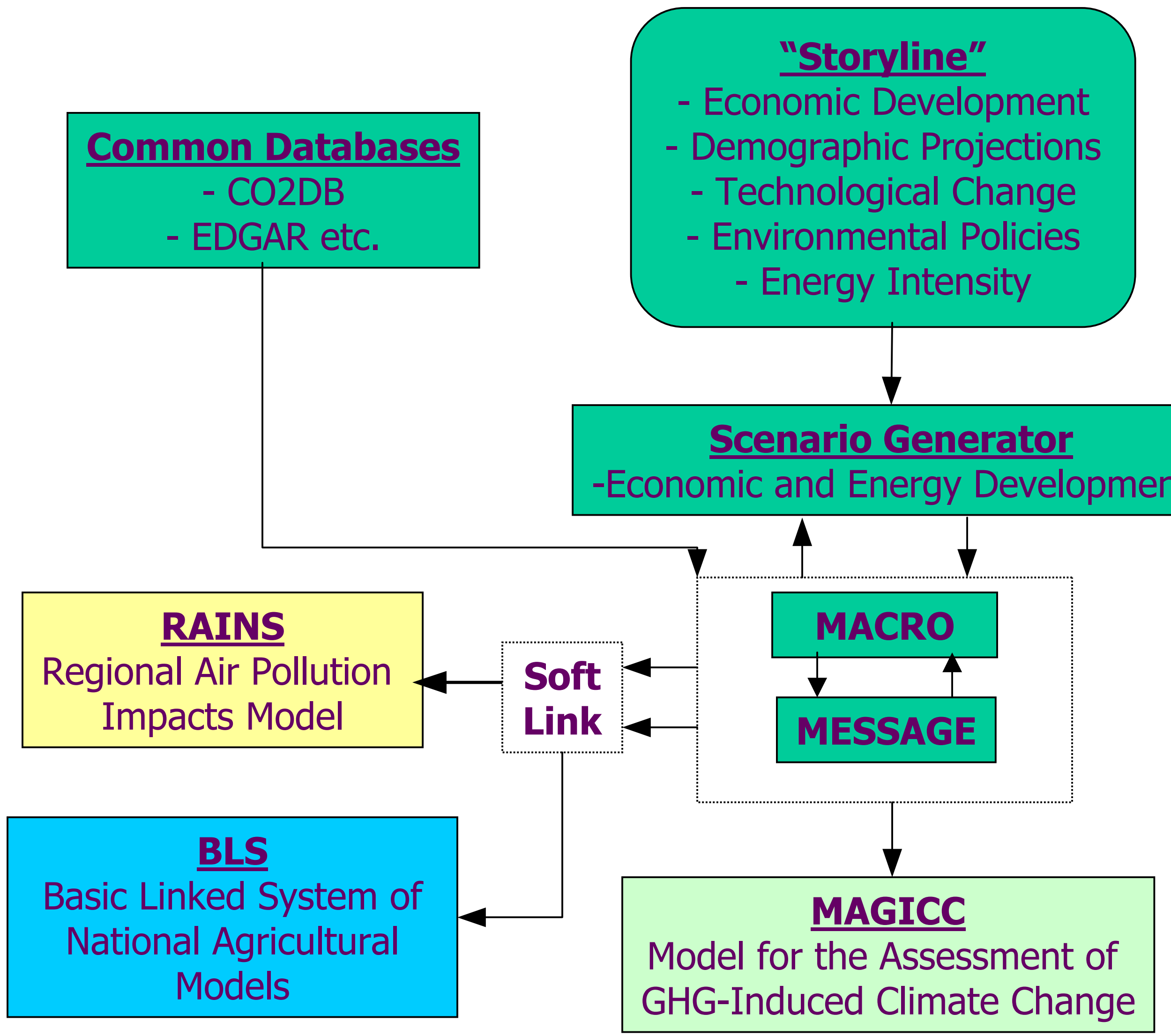
(Based on 90% SO_2 removal, 500 MW plant, 3.5%S coal)

Normalized Learning Curve for SCR Capital Cost

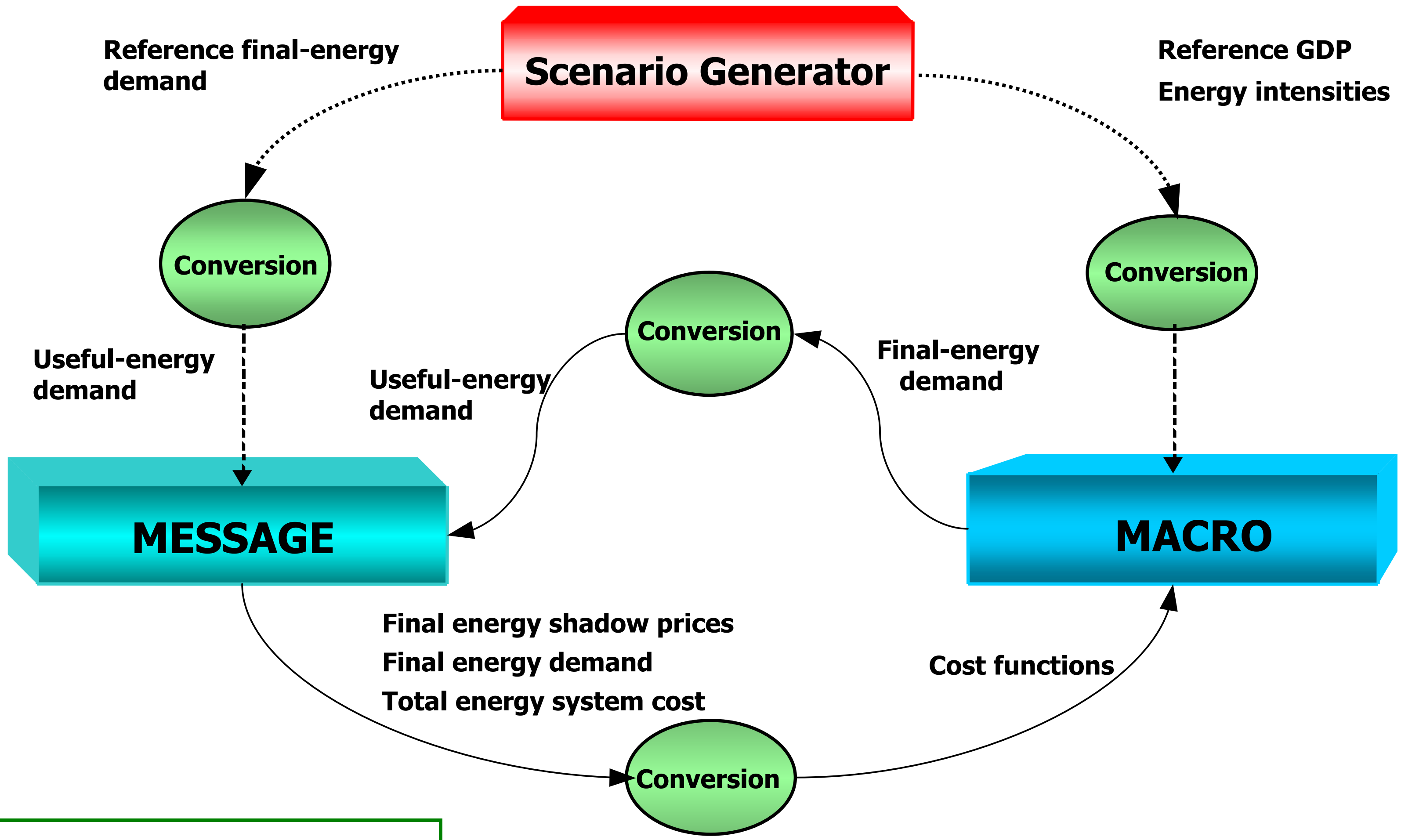


(Based on 80% NO_x removal, 500 MW plant, medium S coal)

The IIASA Modeling Framework

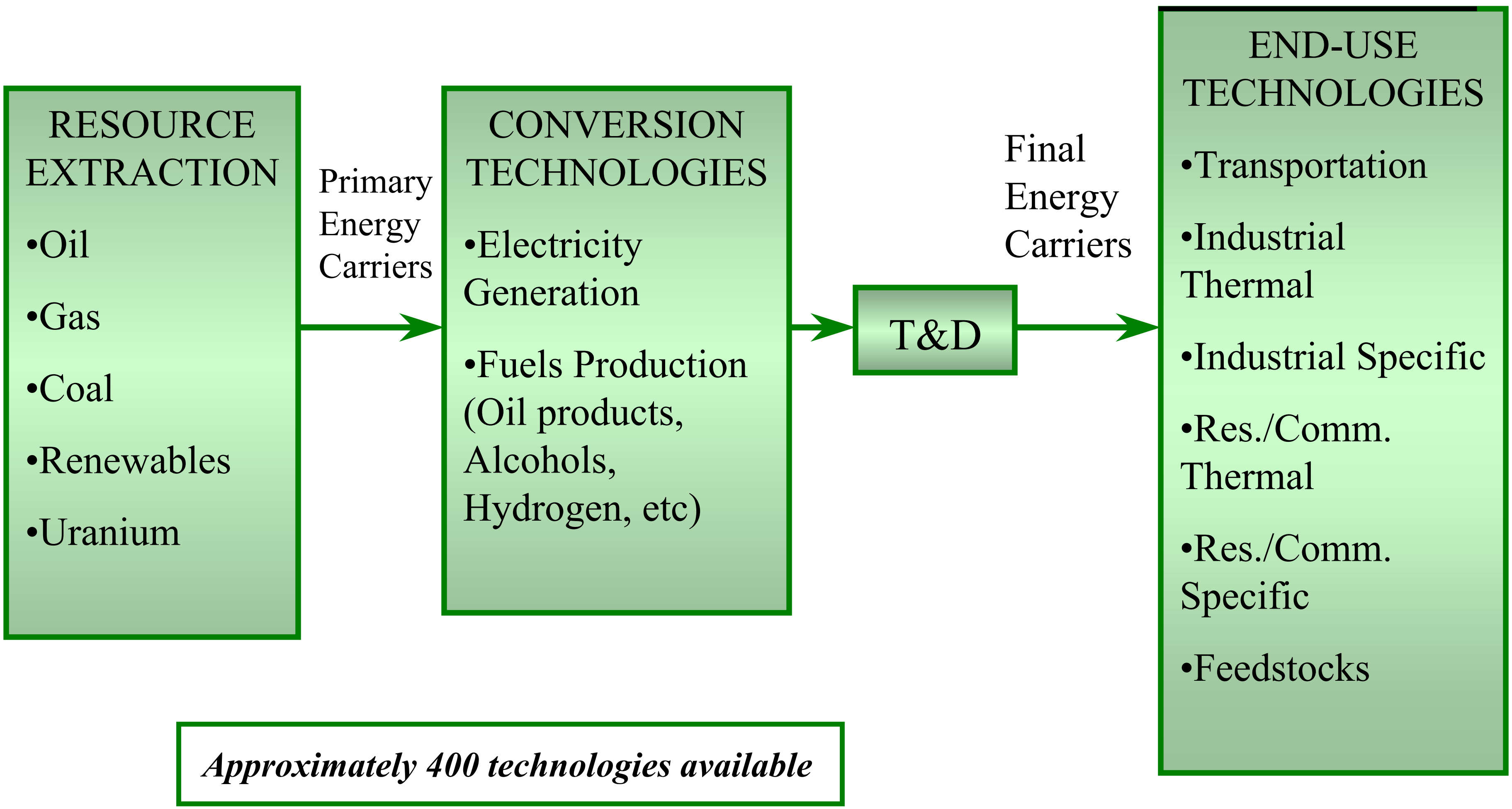


MESSAGE-MACRO



11 World Regions Modeled

Reference Energy System



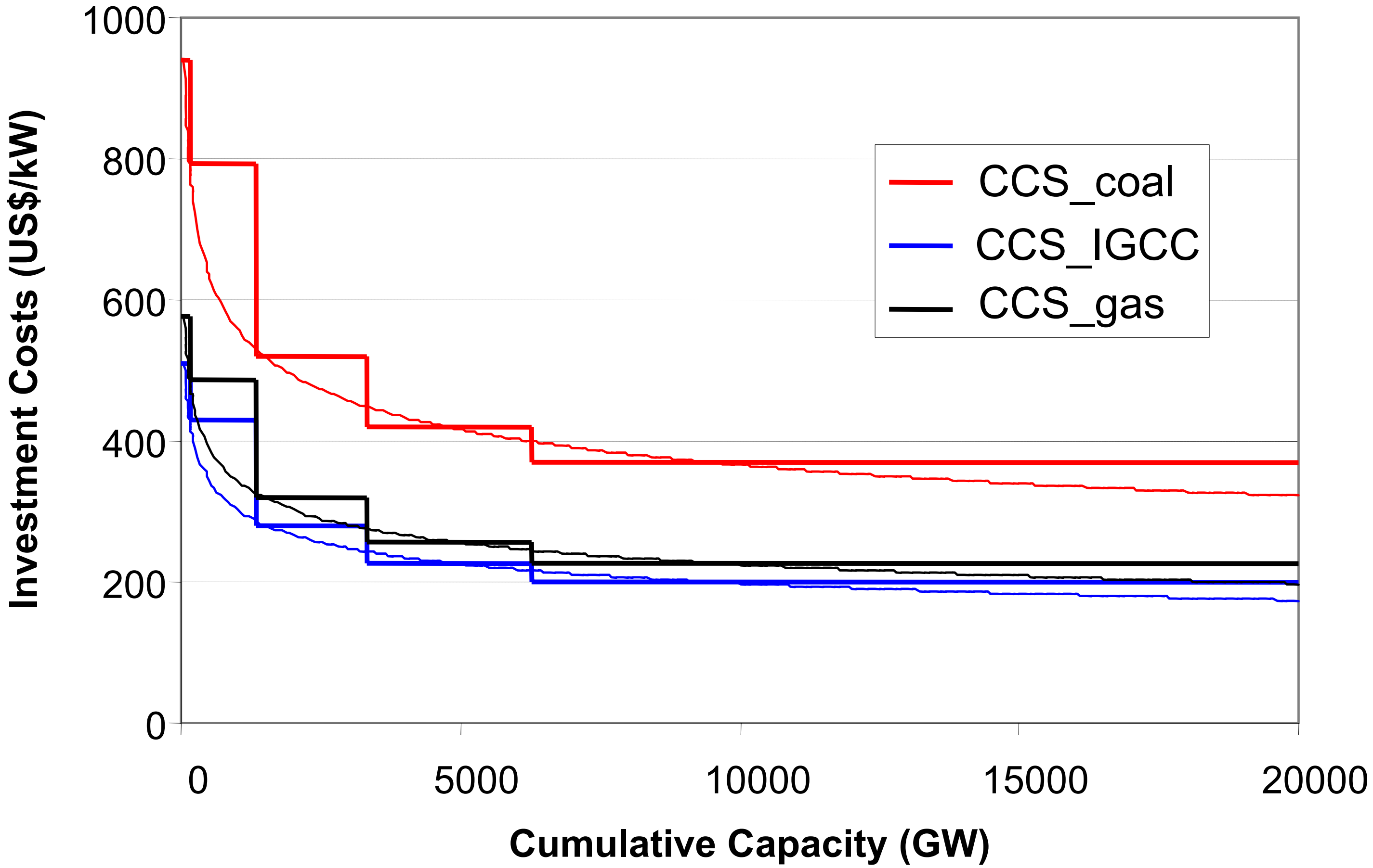
Carbon Capture Technologies in MESSAGE

- Electricity Sector
  - Natural gas (NGCC, GT)
  - Coal (PC, PFBC, etc.)
  - Coal IGCC
- Synthetic fuels production
  - Fossil-based methanol
  - Fossil-based hydrogen

Chemical separation processes (Natural gas, Coal)

Physical separation processes (Coal IGCC, Synthetic fuels production)

Endogenous Learning Curves for CCS Clusters



Climate Policy Scenarios

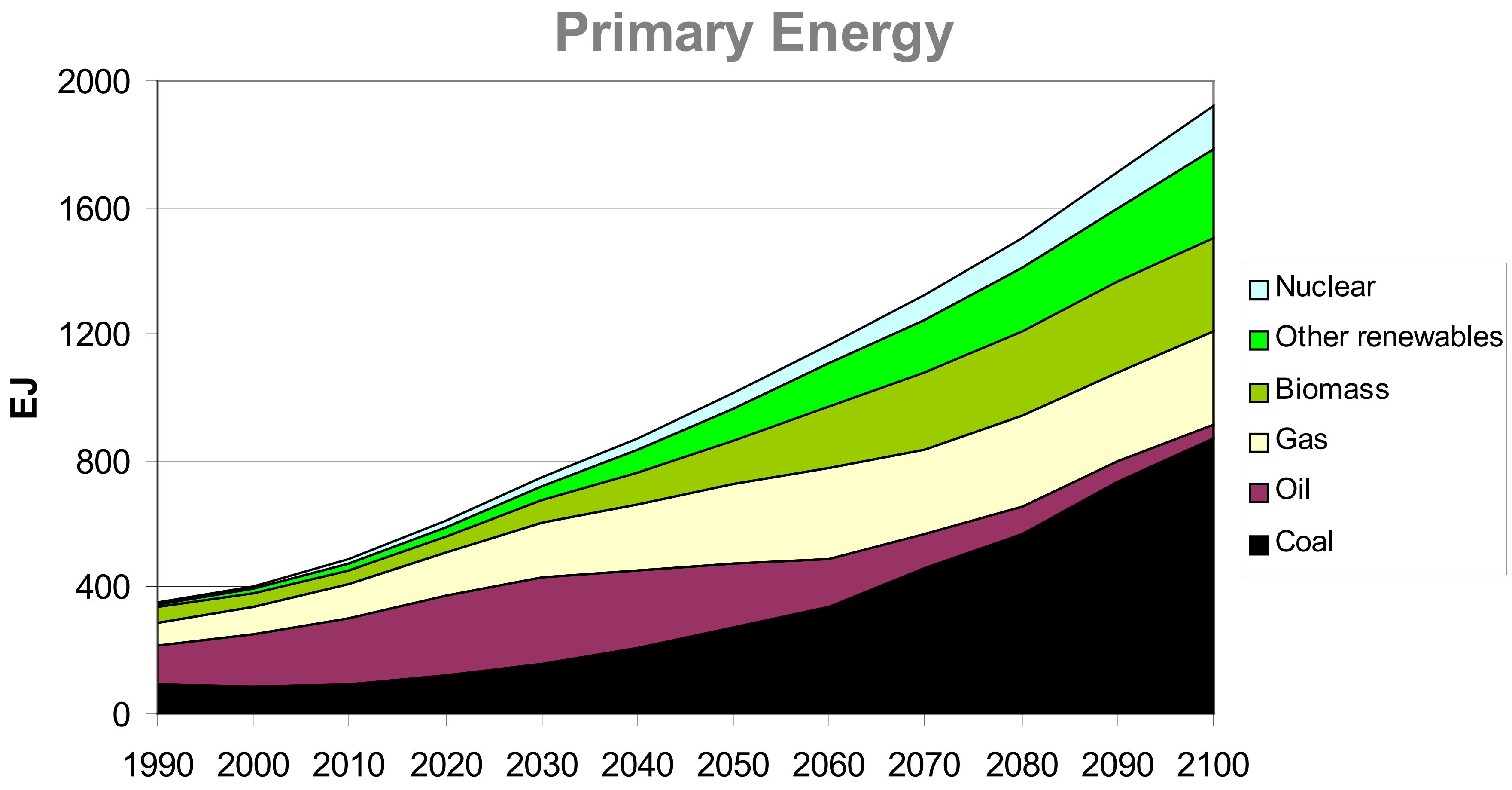
- Model the IPCC-SRES "A2" baseline scenario
  - with and without carbon constraints
  - with and without endogenous "learning" for CCS (assuming a 12% learning rate)
- Model two hypothetical policy scenarios:*
  - 550 ppmv CO_2 by 2100 (global optimization)
  - CCS required for power generation sector only (according to a scheduled phase-in)

*Scenario results are not directly comparable because of some differences in assumptions

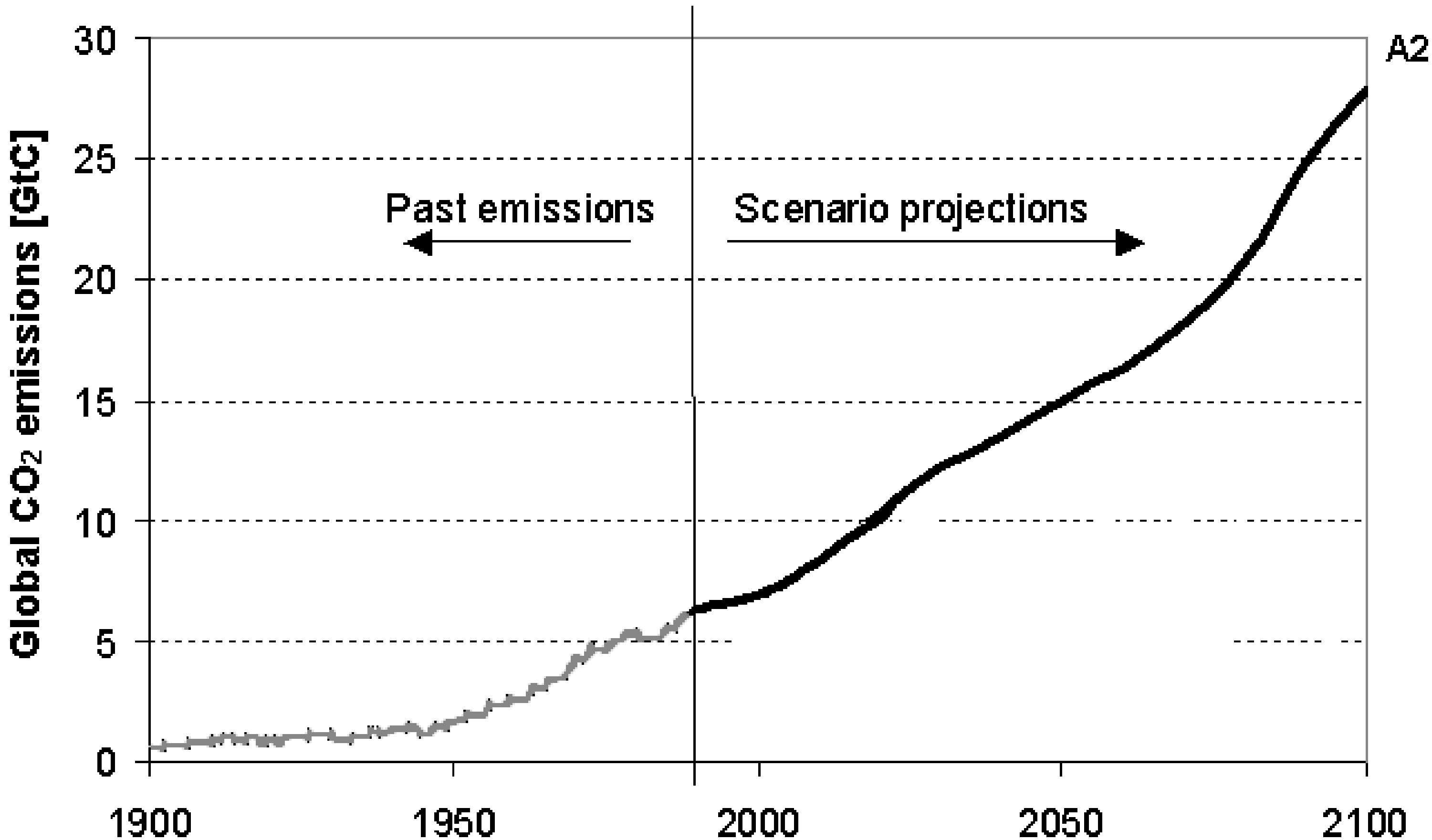
The A2 Baseline Scenario

Scenario Parameter	1990	2100
World Population (billion)	5.3	15.1
World GDP (trillion $1990)	20.9	243
Income Ratio (DEV/IND)	0.062	0.24
World Primary Energy (EJ)	352	1983
Cumulative CO_2 (GtC)	6.2	1761
Atmos. CO_2 Conc. (ppmv)	354	783

World Energy Use: Scenario A2



Energy-Related CO_2 Emissions



Results for the

550 ppm stabilization

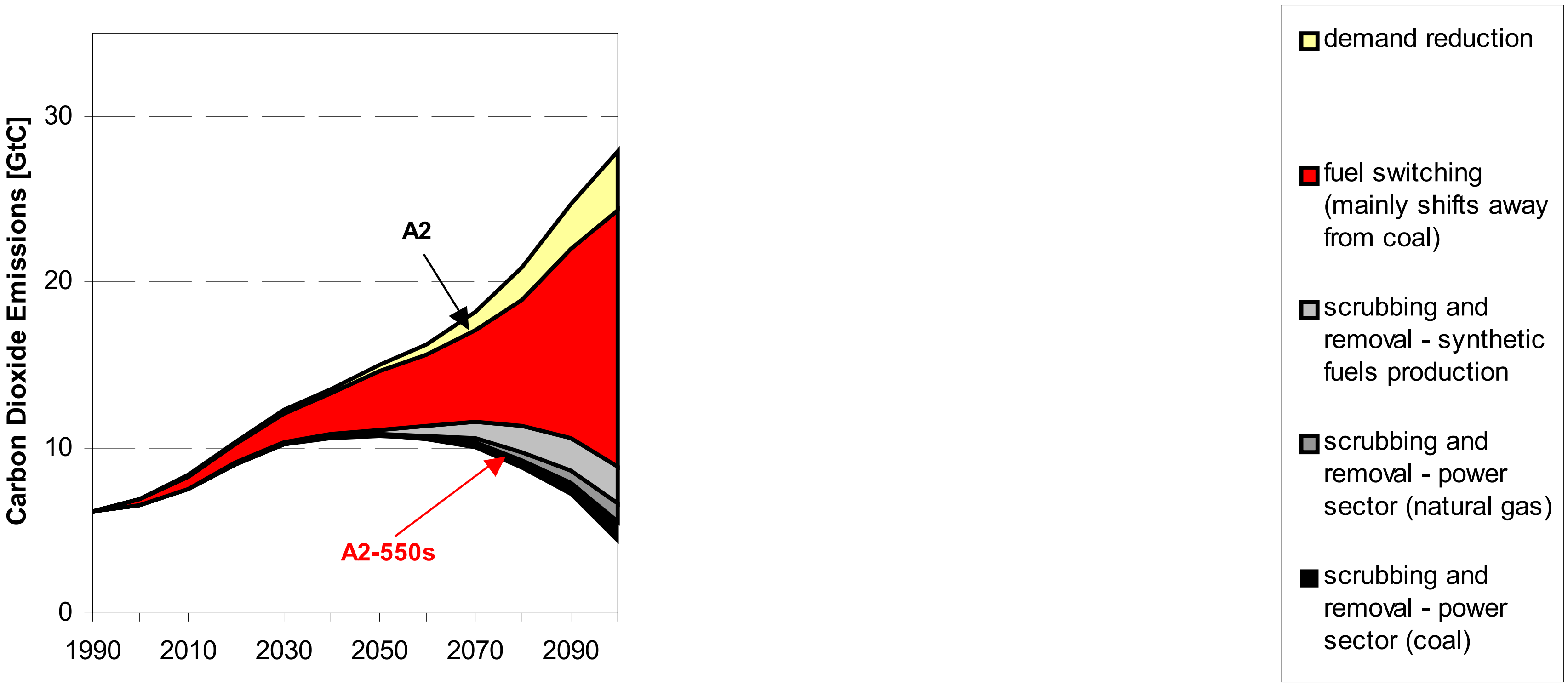
scenario

(global optimization)

Main Mitigation Measures

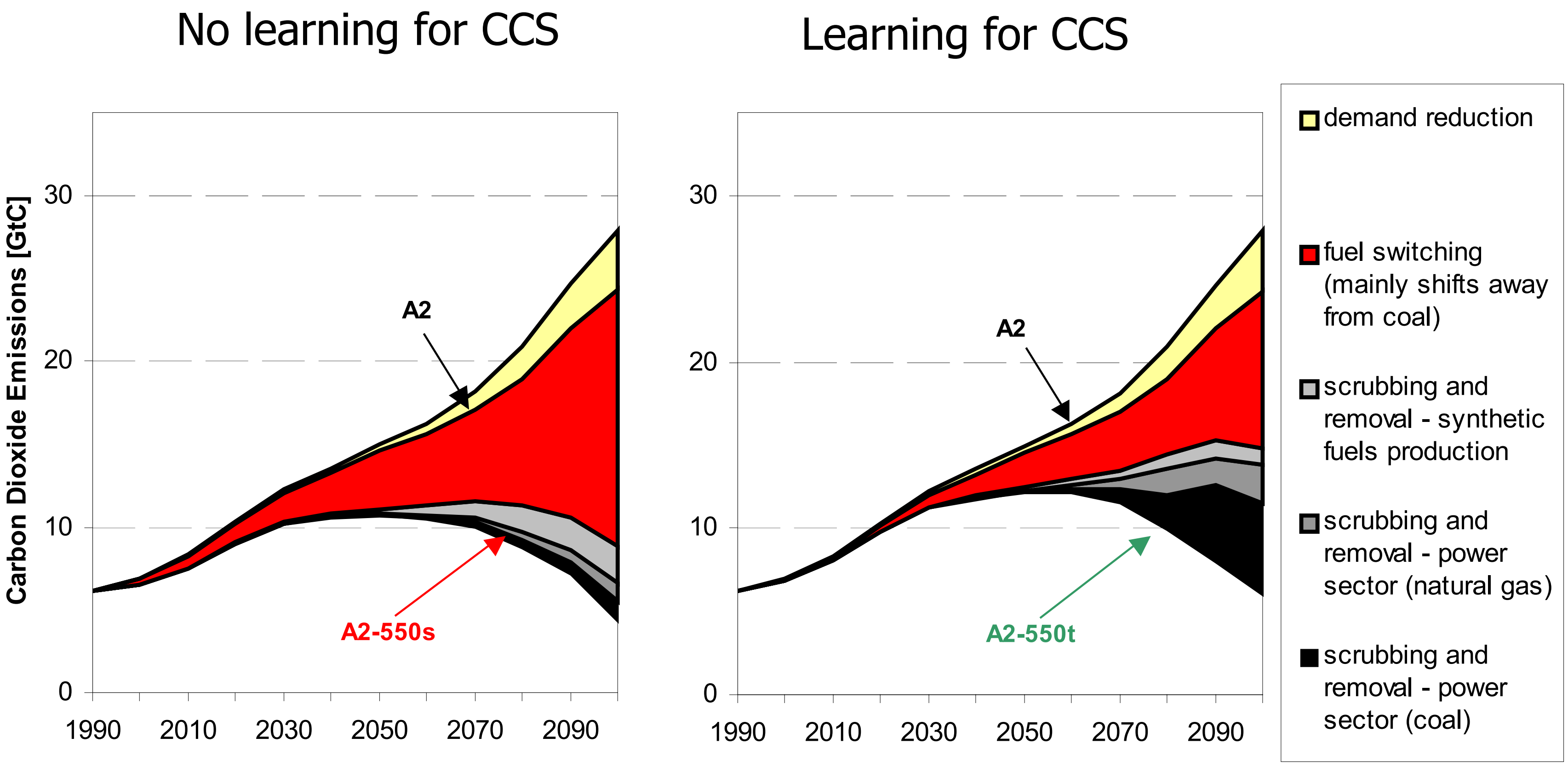
(stabilize atmospheric CO_2 at 550 ppmv by 2100)

No learning for CCS

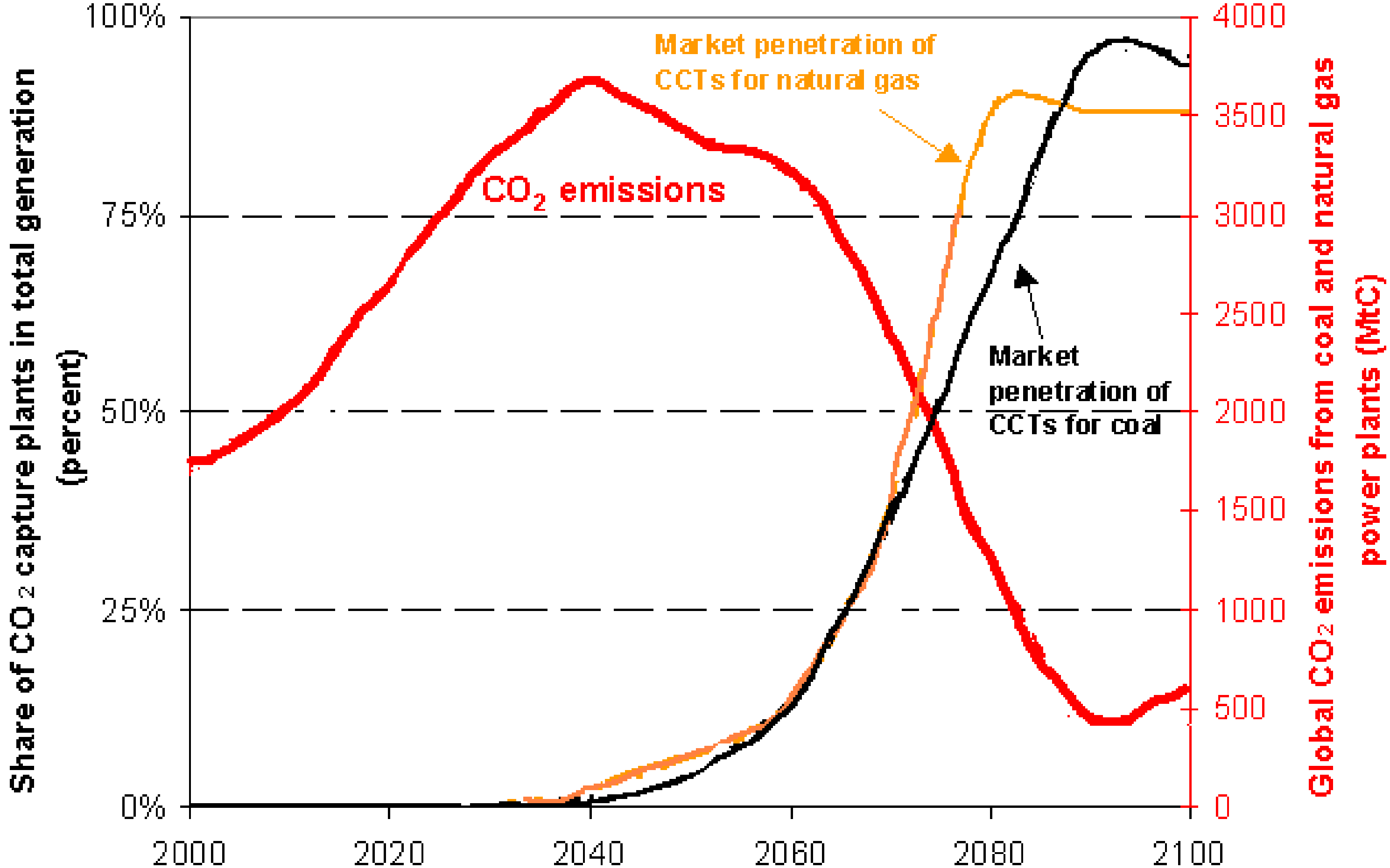


Main Mitigation Measures

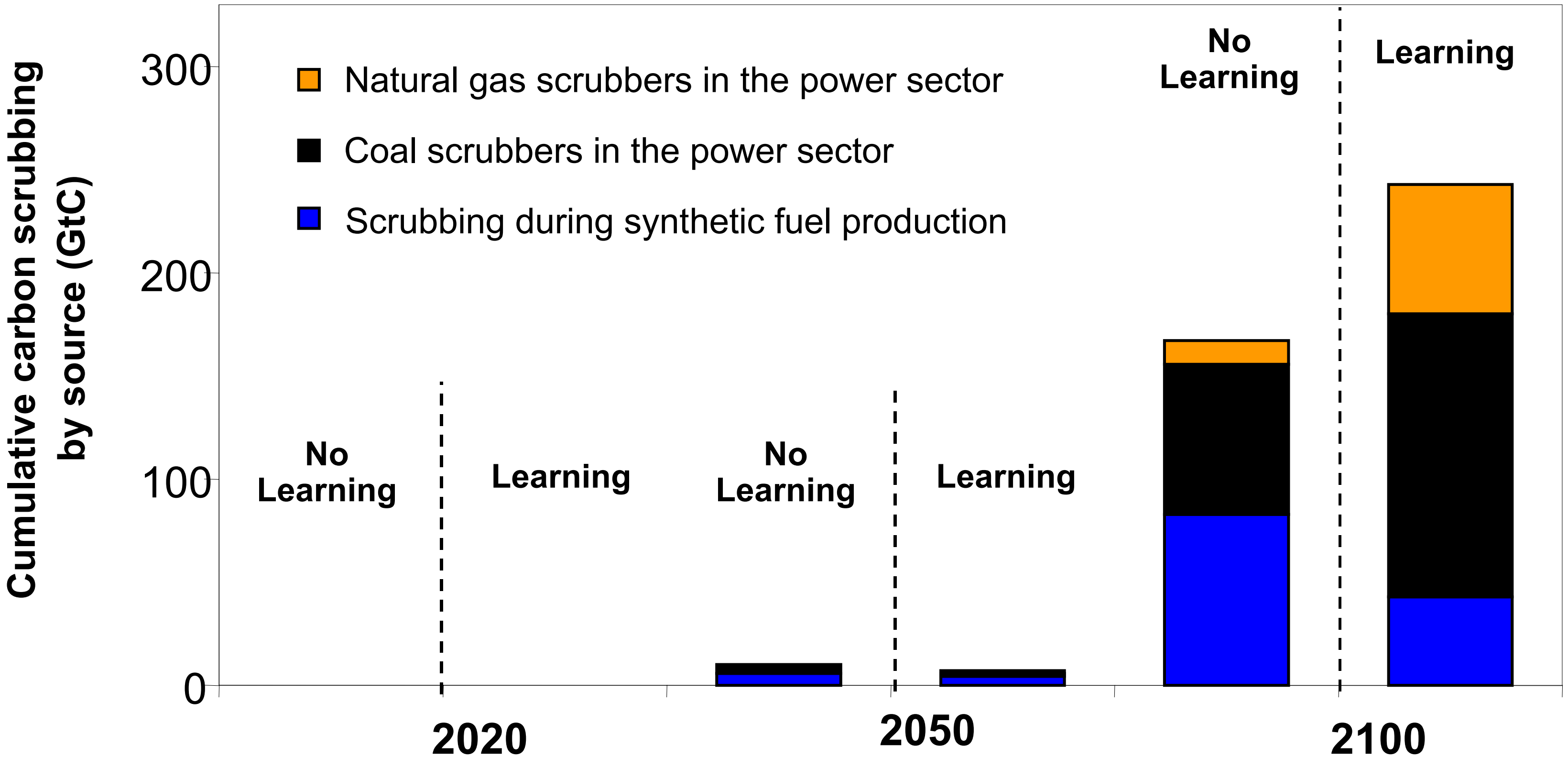
(stabilize atmospheric CO_2 at 550 ppmv by 2100)



Market Penetration of CCS
(no learning case)



Cumulative Carbon Sequestration



Average Carbon Tax (1990 US$/t)

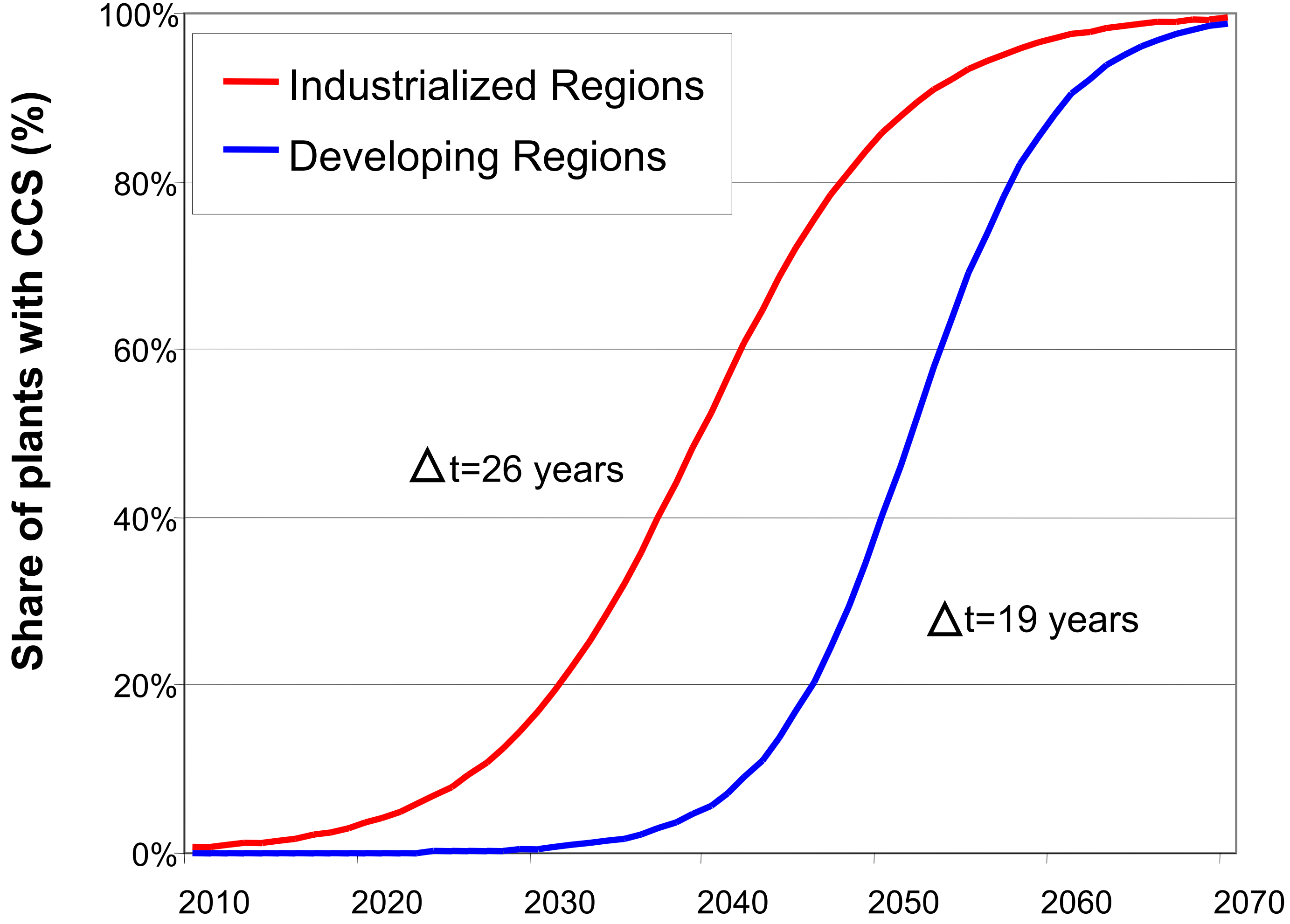
Scenario	**2020**	**2050**	**2100**
A2-550 - No Learning	25	82	496
A2-550 - Learning	19	27	490

Results for the Technology-Based Policy Scenario

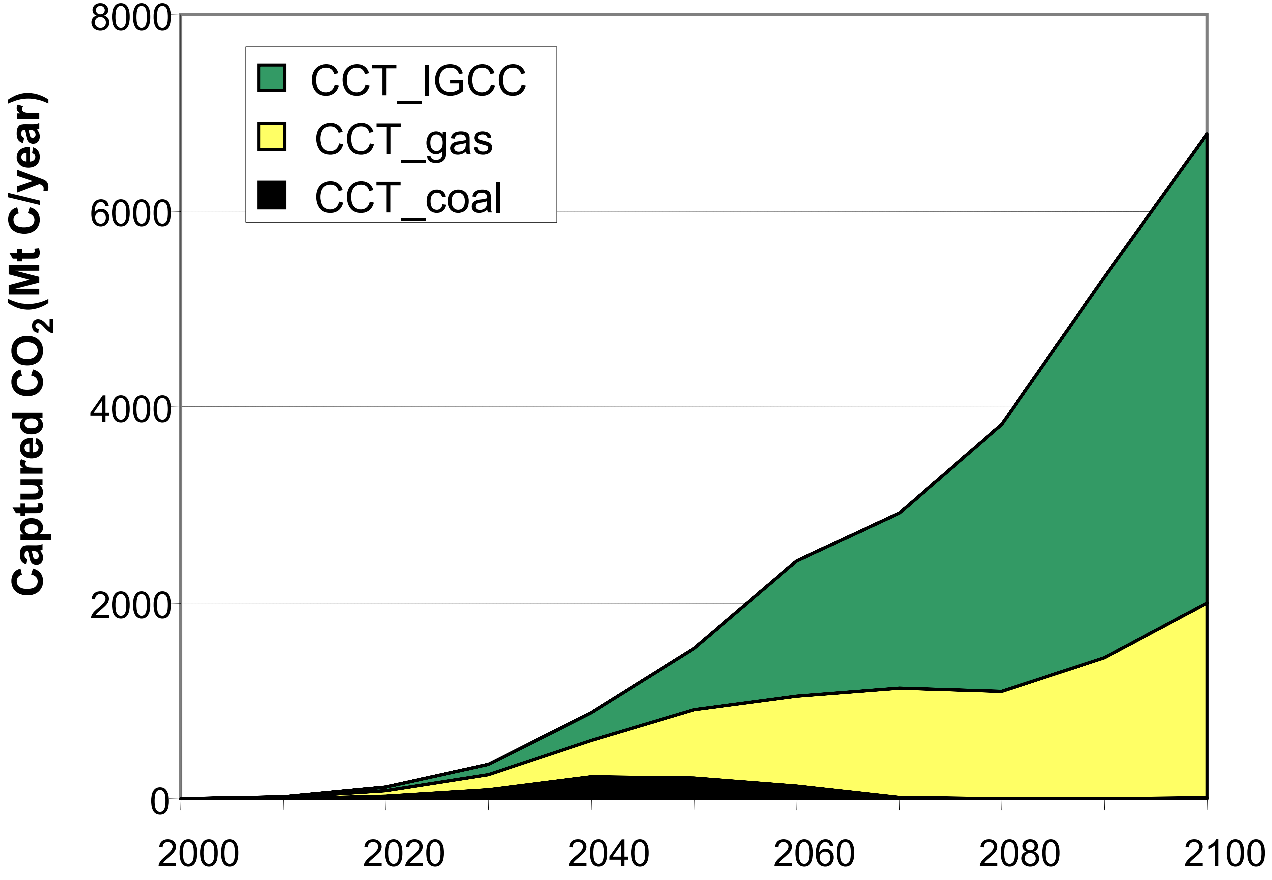
Technology-Based Policy Scenario

- An illustrative “technology forcing” policy is imposed on fossil-fueled power plants (only)
- A minimum time-increasing share of the total fossil-fuel capacity is required to capture and store 90% of potential CO_2 emissions
- Different schedules for industrialized and developing countries
- Cases are examined with and without endogenized learning for CCS technologies

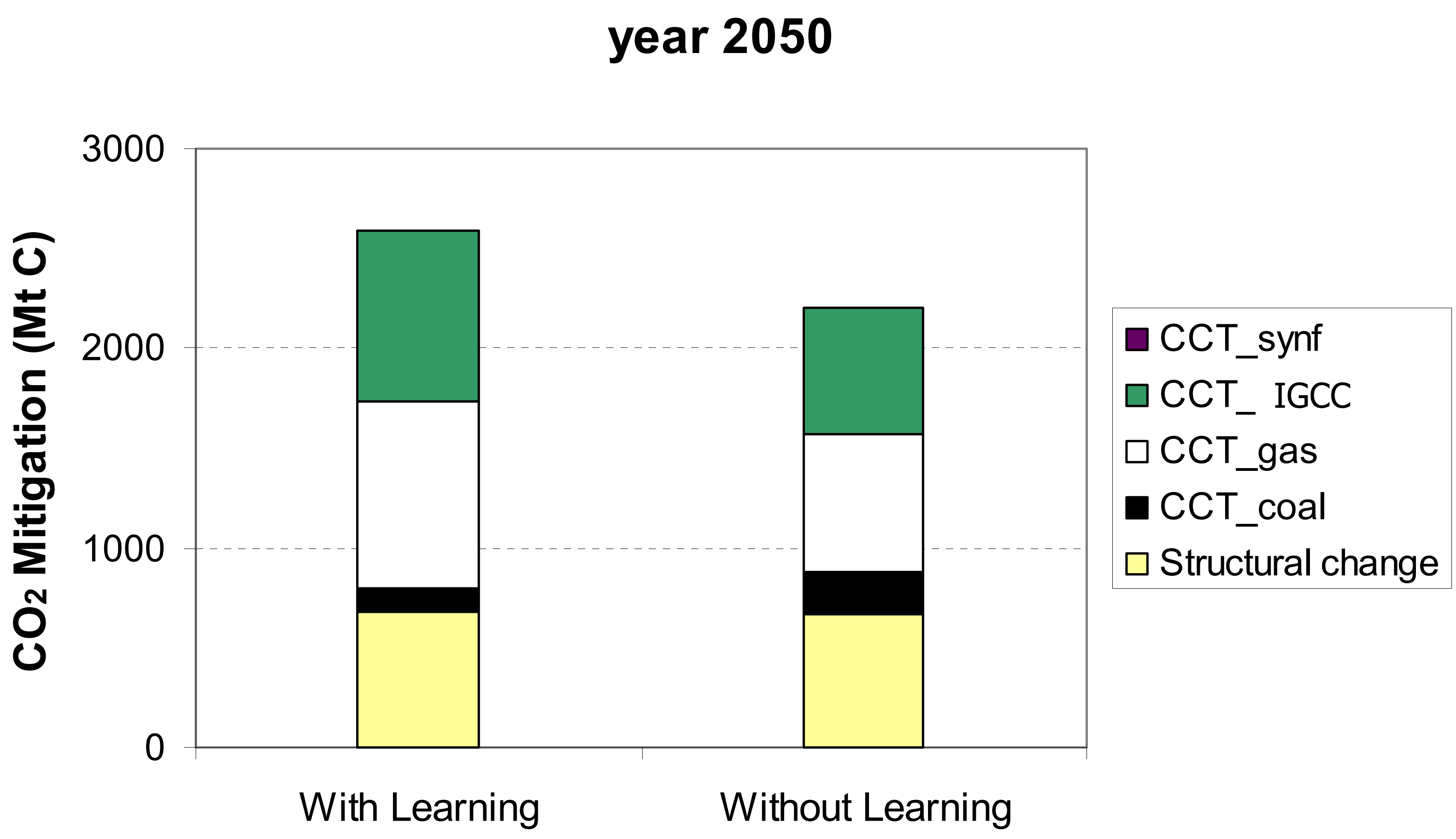
Minimum Deployment of CCS for Fossil-Fuel Power Plants



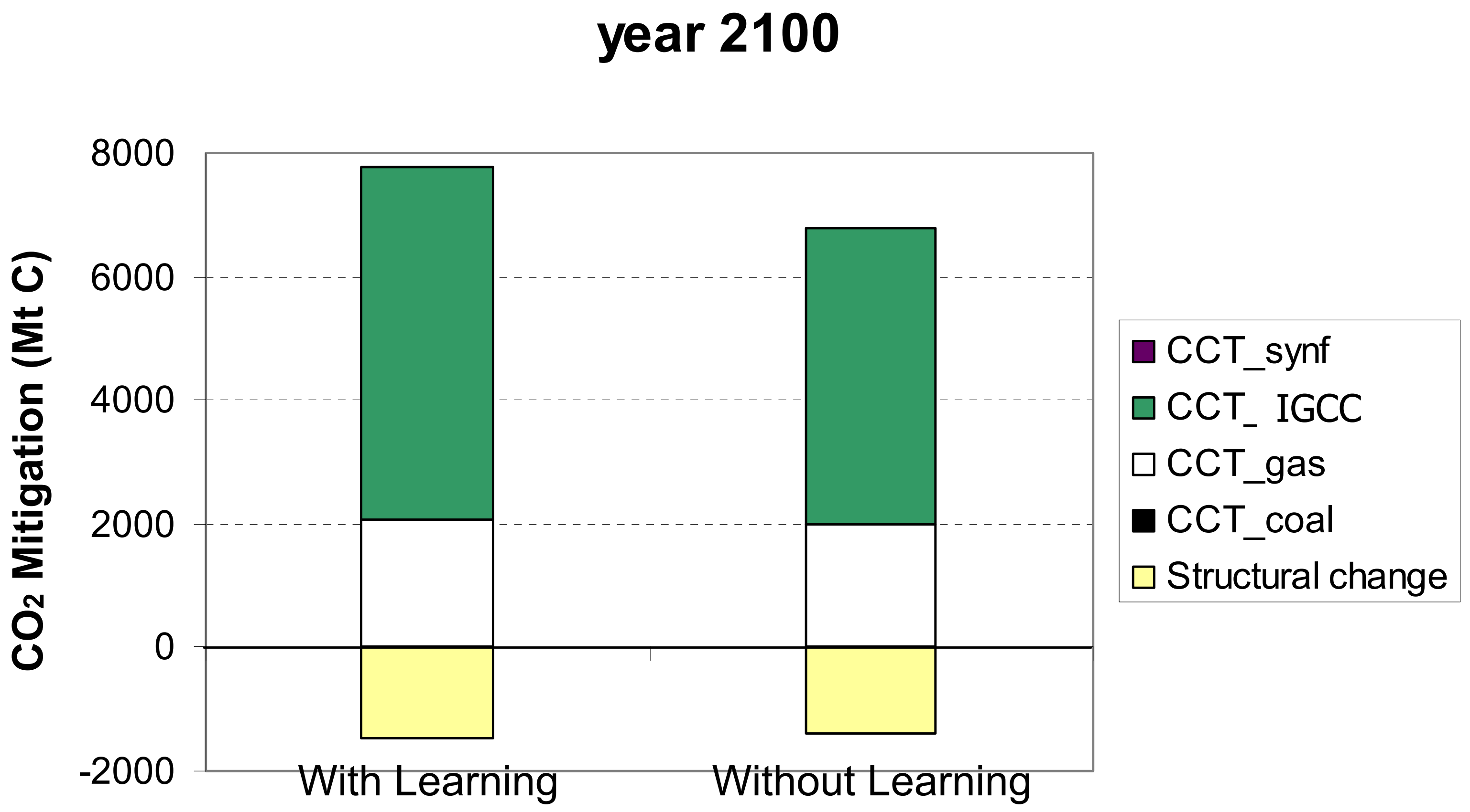
Captured CO_2 in Electricity Sector
A2-CCT Scenario (no learning)



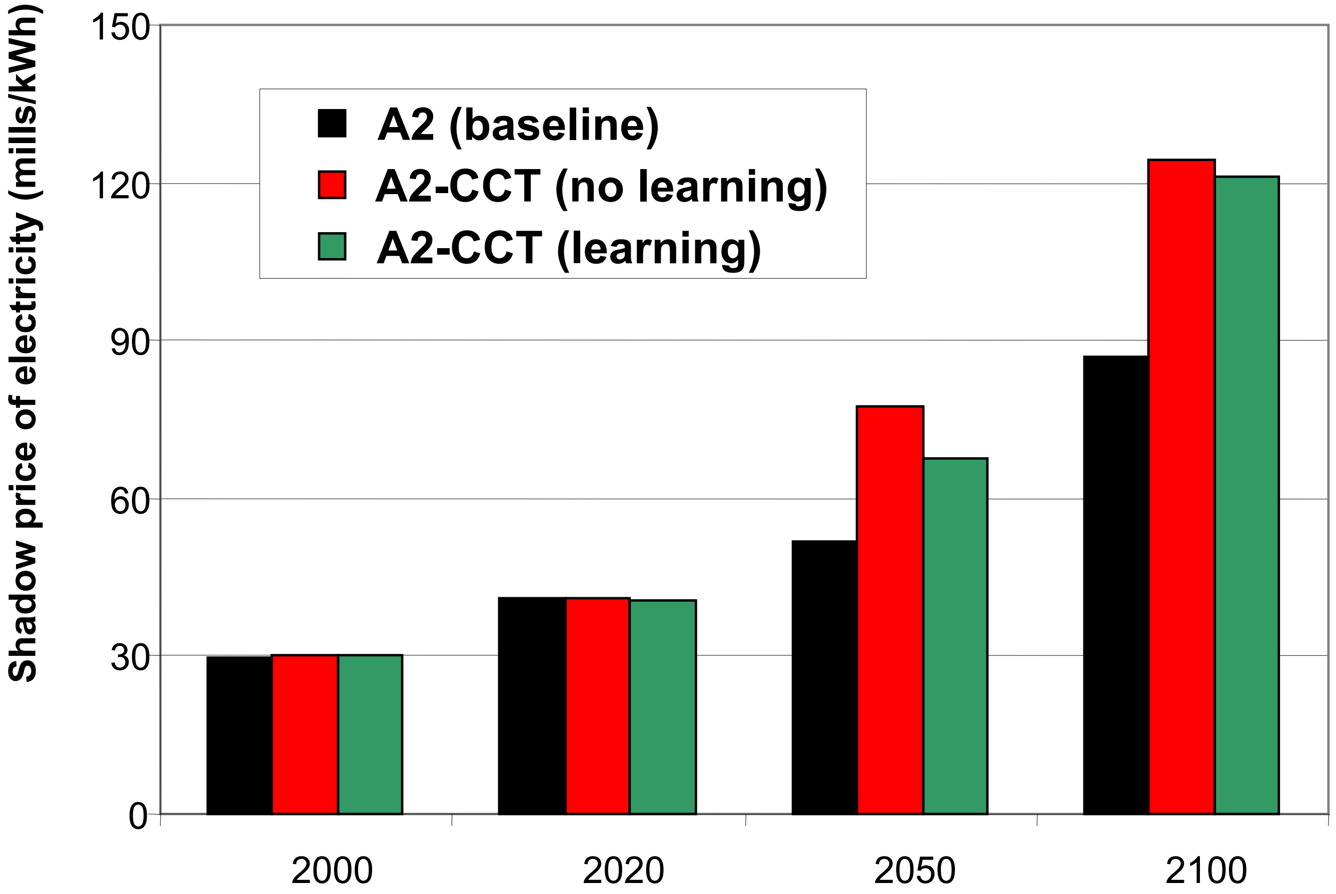
CO_2 Mitigation in 2050



CO_2 Mitigation in 2100



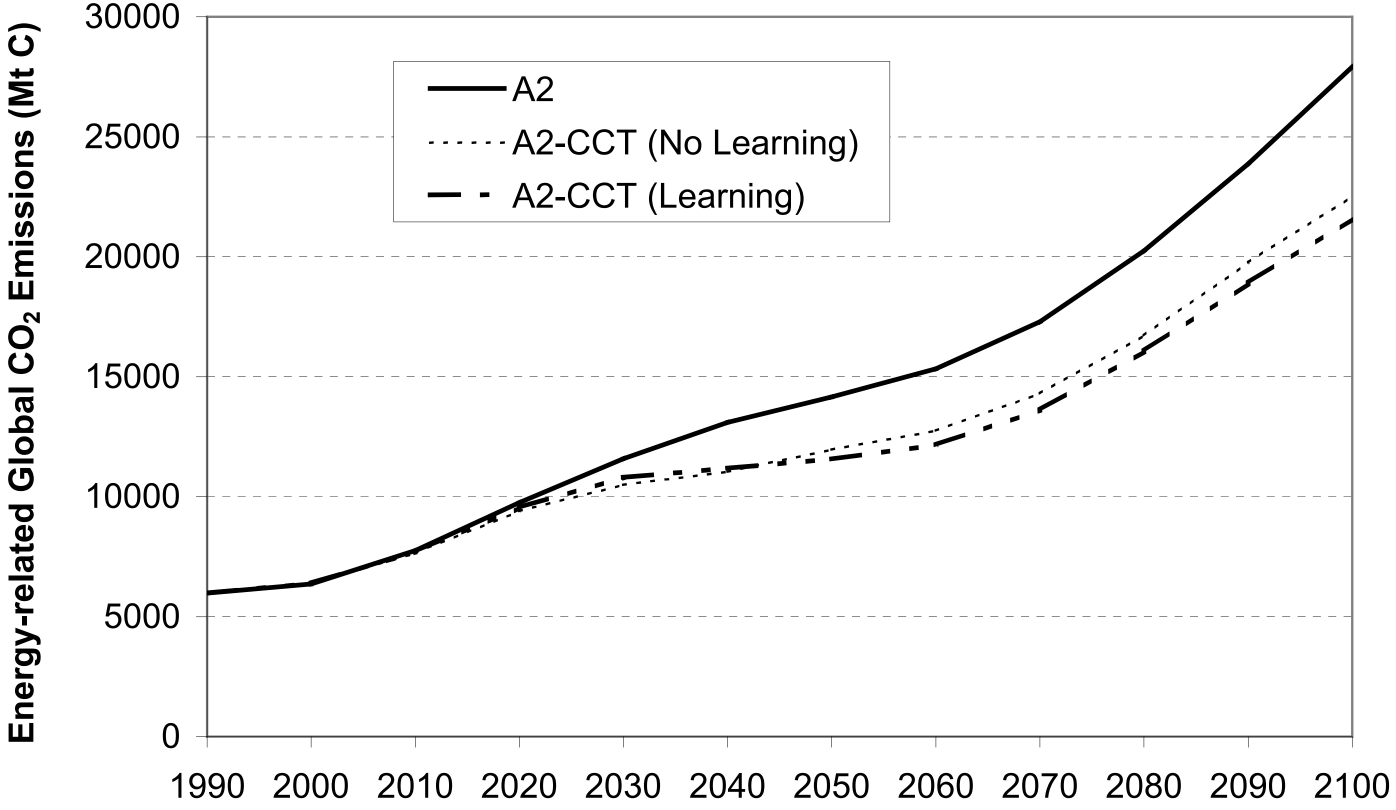
Electricity Prices



Average Cost of Carbon Abatement (1990 US$/t)

Scenario	2020	2050	2100
A2-CCT - No Learning	103	98	84
A2-CCT - Learning	100	87	56

Global Energy-Related CO_2 Emissions



Conclusions

- Consideration of technological learning can have a significant influence on the expected role of CCS technologies, and the cost of alternative climate mitigation policies
- The magnitude and timing of impacts depends strongly on the policy scenario, and the reference case assumptions
- More work is needed to better understand and model the key factors that influence technology innovation, especially for environmental technologies like carbon capture and storage