15.023J / 12.848J / ESD.128J Global Climate Change: Economics, Science, and Policy
Spring 2008

Economics of GHG Control

- Review of concepts, terminology, issues
- CGE models + sample applications
- Example using price only
- The use of MAC curves
- Technology costing approaches
- Issues in the handling of technology
  - Endogenous change & “new” technology
  - Barriers, failures and the free lunch

Cost/Welfare Concepts

- Emissions price
- Area under marginal abatement curve
- Simple macroeconomic aggregates (models with one non-energy output)
  - GDP
  - Consumption (*e.g.*, Homework #2)
- Equivalent variation (economic welfare)
  - Income compensation to restore consumers to pre-constraint level of welfare (≈ consumption)

What to Include?

- What greenhouse substances?
  - CO_2 only?
  - CH_4, N_2O, HFCs, PFCs & SF_6
  - Aerosol precursors (e.g., SO_2, black carbon)
  - O_3 precursors
- Carbon sinks?
- Ancillary benefits of GHG controls?
  - Urban air pollution
  - Other?

Cost to Whom?

- What unit of analysis?
  - Nation
  - Global, or Annex I *vs*. Non-Annex I
  - Other?
- Issues of aggregation
  - Of nations
  - Of sub-national components

Approaches to the Task

	Shrt term	Long term	Trade effects	Tech'n detail
Carbon price	√	√		
Market-based (CGE)	≅√	√	√	
Technology-Cost	√			√
MAC curves	√			
Hybrids				
MARKAL-Macro	√	√		√
U.S. NEMS	√			√
Others (*e.g.*, EPPA)	≅√	√	√	≅√

CGE (EPPA): What Tradeoffs?

- Multiple objectives in design
  - Analysis of policy cost, short and long term
  - Drive the climate portion of the IGSM
- Emphasis in structure
  - Market interaction *vs*. focus on many specific technologies
  - Short-term detail *vs*. long-term economic change
  - CO_2 only or all GHGs
- Two versions based on agent expectations
  - Recursive-dynamic (the workhorse)
  - Forward-looking (some simplifications)

Factors Determining Results

- Population growth
- Labor productivity growth ← Toy
- Energy efficiency change (AEEI) ← Toy
- Substitution elasticities
- Vintaging assumption
- Costs of future technologies
- Non-CO_2 gas assumptions
- Fossil energy resources

Examples of EPPA Analyses

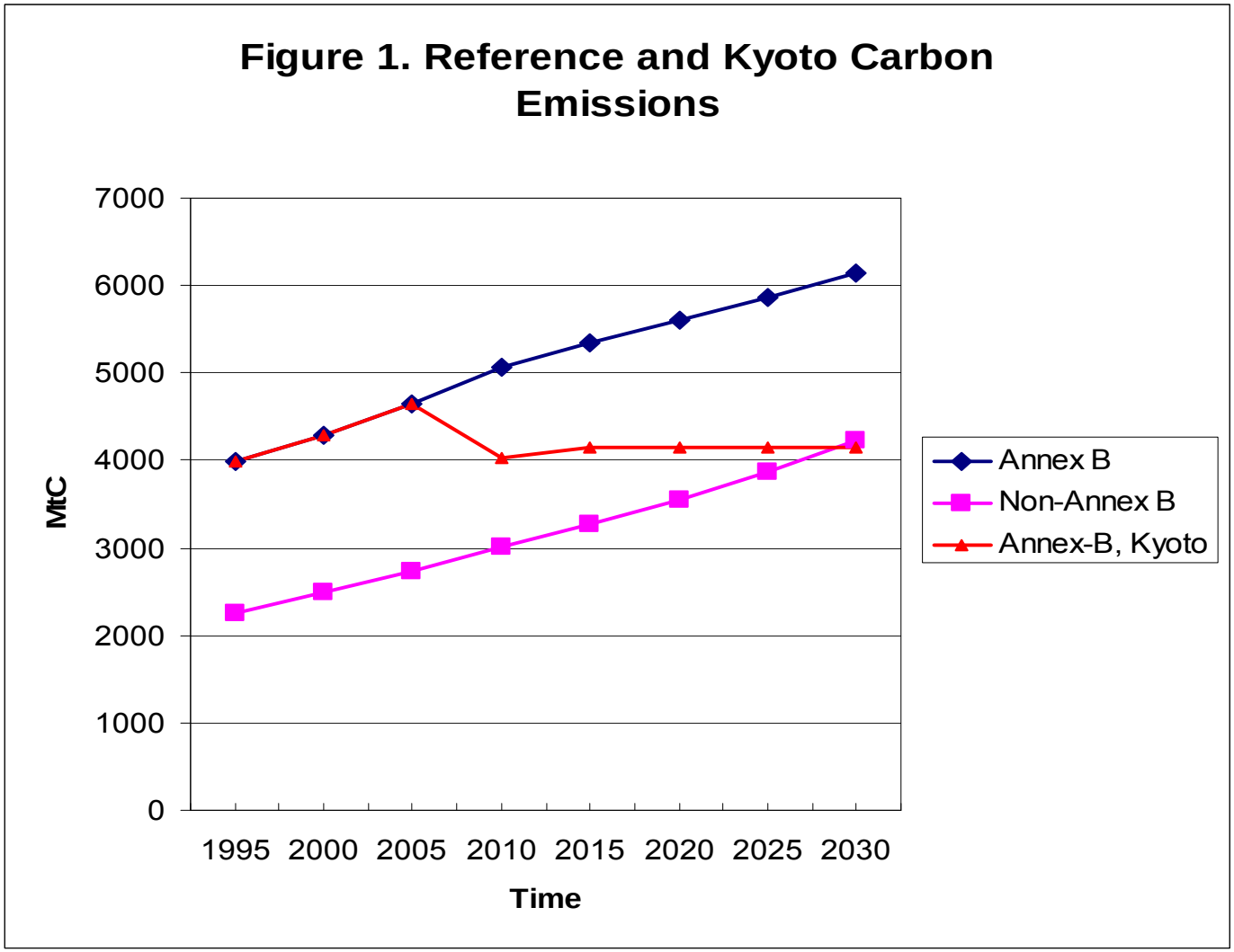
- Short-term mitigation targets
  - Trade effects ← Kyoto Protocol
  - Intensity *vs.* absolute targets
  - Emissions trading ← Cap-&-trade bills (4-2)
  - Inefficient policies
  - Multi-gas strategies *vs.* CO_2 only
- Long-term atmos. goals ← CCSP study
- Studies of particular technologies/fuels
  - Carbon capture and storage ← Coal study
  - Biomass, solar and wind, nuclear

Effects Through Trade
(Annex I Constrains CO_2, OPEC view)

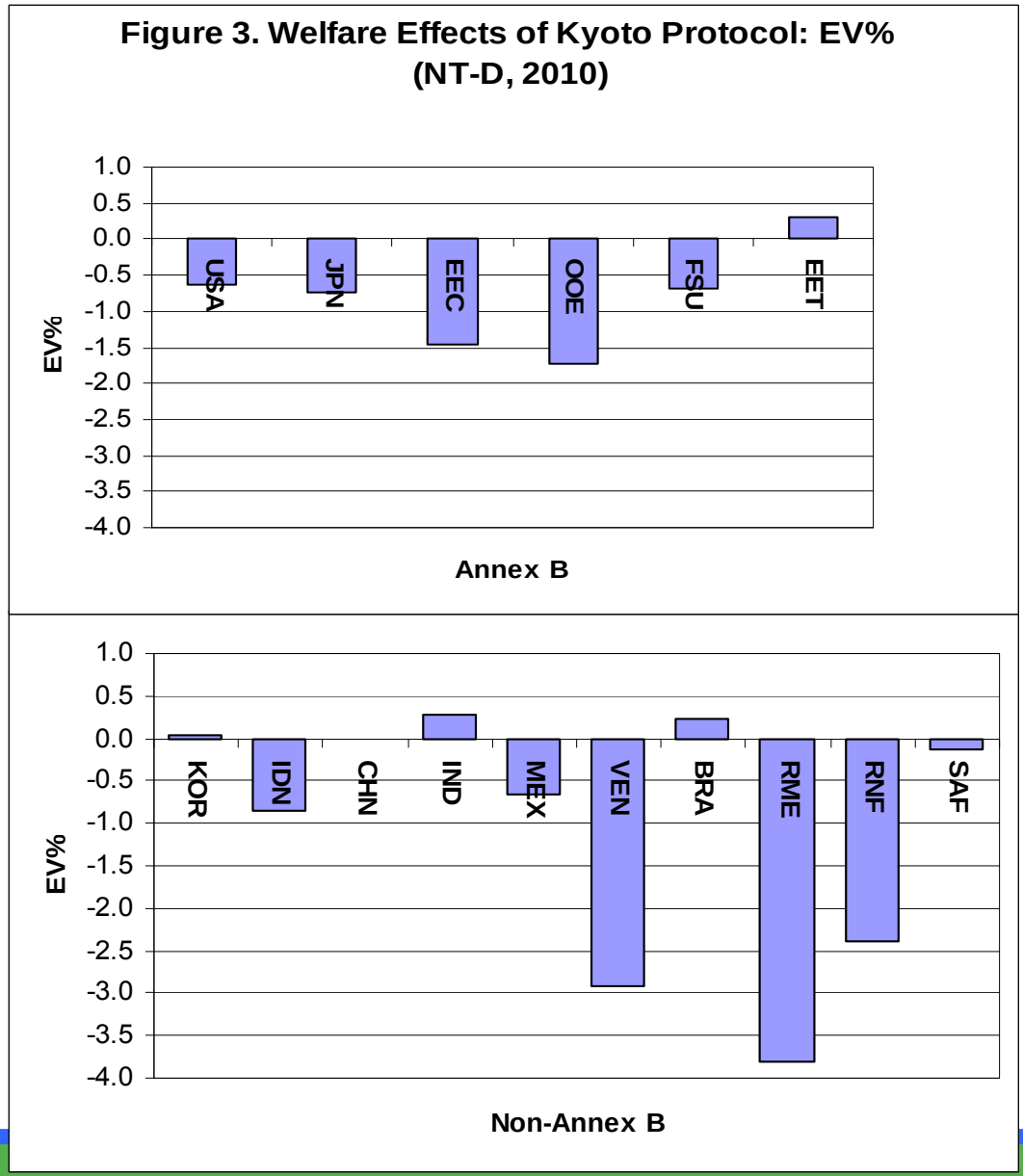
- Penalty on CO_2 emissions in Annex I
  - Price of Annex I energy use rises
  - ⬇ oil world oil demand: ⬇ export volume
  - ⬆ cost of manufacture of energy-intensive goods in Annex I, ⬆ cost of imports
- Change in the "terms of trade"
  - Prices of exports (oil, gas, coal) fall
  - Price of energy-intensive imports rises
- Net of all ➔ welfare loss

& view from US?

Kyoto Example

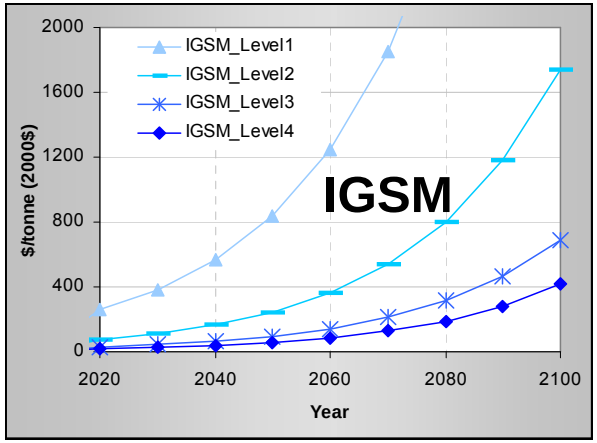


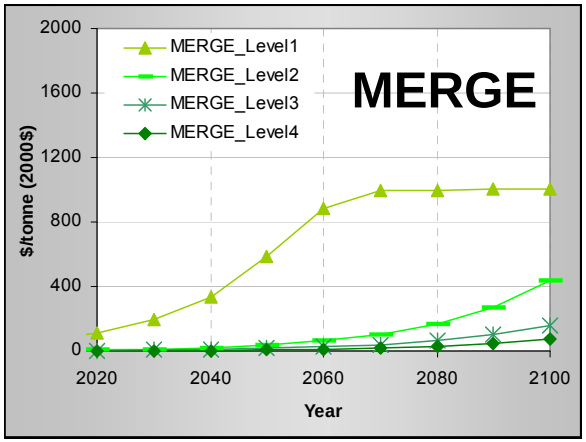
Transfer of Costs to Energy Exporters

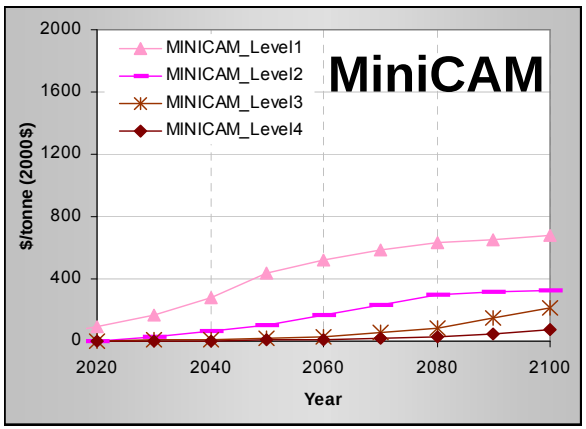


Cost of Long-Term Targets

- Total reduction required
  - Reference emissions growth
  - Carbon cycle (ocean/land uptake)
- The role of technological change
  - Ease of substitution
  - Autonomous change
  - Endogenous change (policy influenced)
- Sources of endogenous change
  - AEEI, σ = f(carbon price)
  - Explicit modeling of R&D, and its effects
  - Learning by doing: Cost = f($\sum$Q)
- Specification of a “backstop” technology

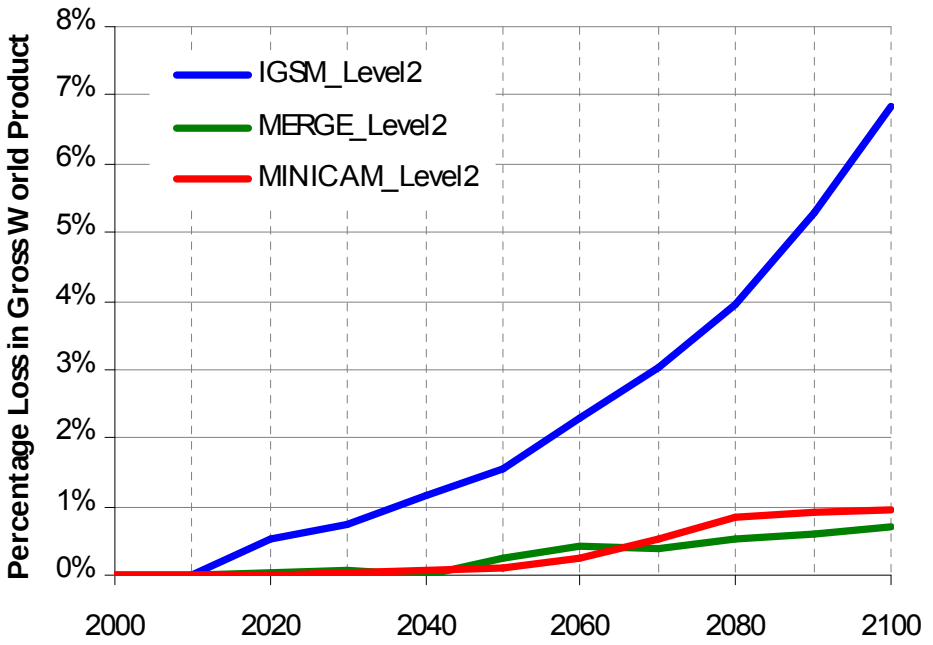






CO_2 Price Paths

% Loss in Global World Product 550 ppmv case (MER)



Origin of the Differences

- Required CO_2 reduction
- Assumptions about post-2050 technology

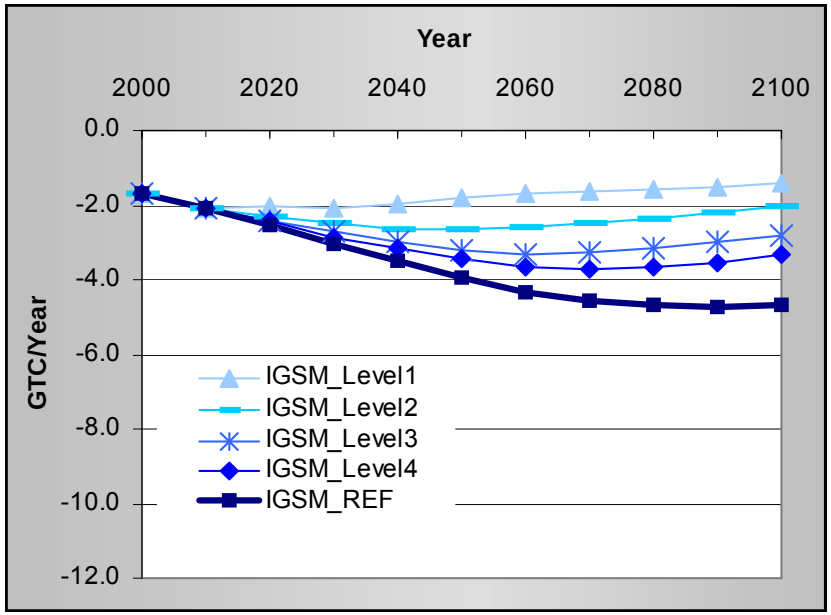
Cumulative Reduction (GtC 2000- 2100)

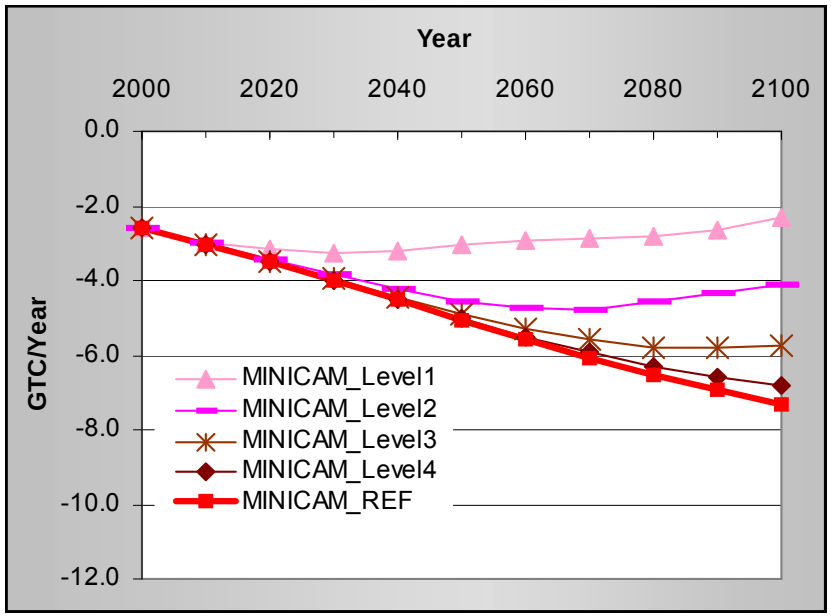
Target (ppmv)	IGSM	MERGE	Mini-CAM
750			
650			
550			
450			

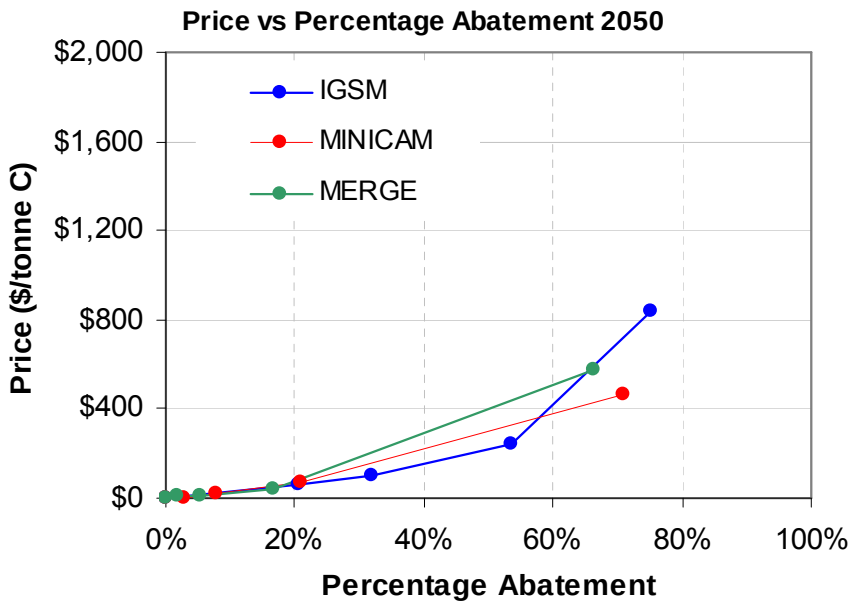
Determinants of the CO_2 Effort Required

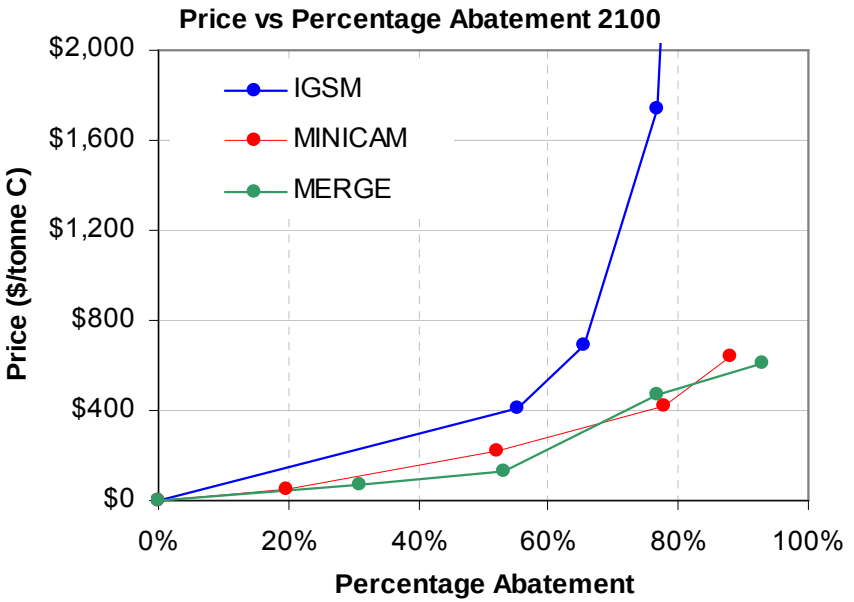
- No-policy emissions growth, uncertain over a century
- CO_2 uptake by the oceans & terrestrial biosphere, subject to scientific uncertainty
- Potential achievements with the non-CO_2 gases

Uncertainty in Ocean Uptake









Role of Science &Technology

- Differences in technology advance late in the century make a big difference in CO_2 price & cost
- The scenarios assume CCS and bio-fuels are unrestrained, and for two models same for nuclear
- In the more stringent cases electric power is essentially de-carbonized by century's end
- Differences depend on many technologies, but end-use ones are critical, e.g.,
  - Introduction of H_2 as a carrier in transport and other uses
  - Electrification of non-transport demand

Example Using Price Only
(The MIT Coal Study)

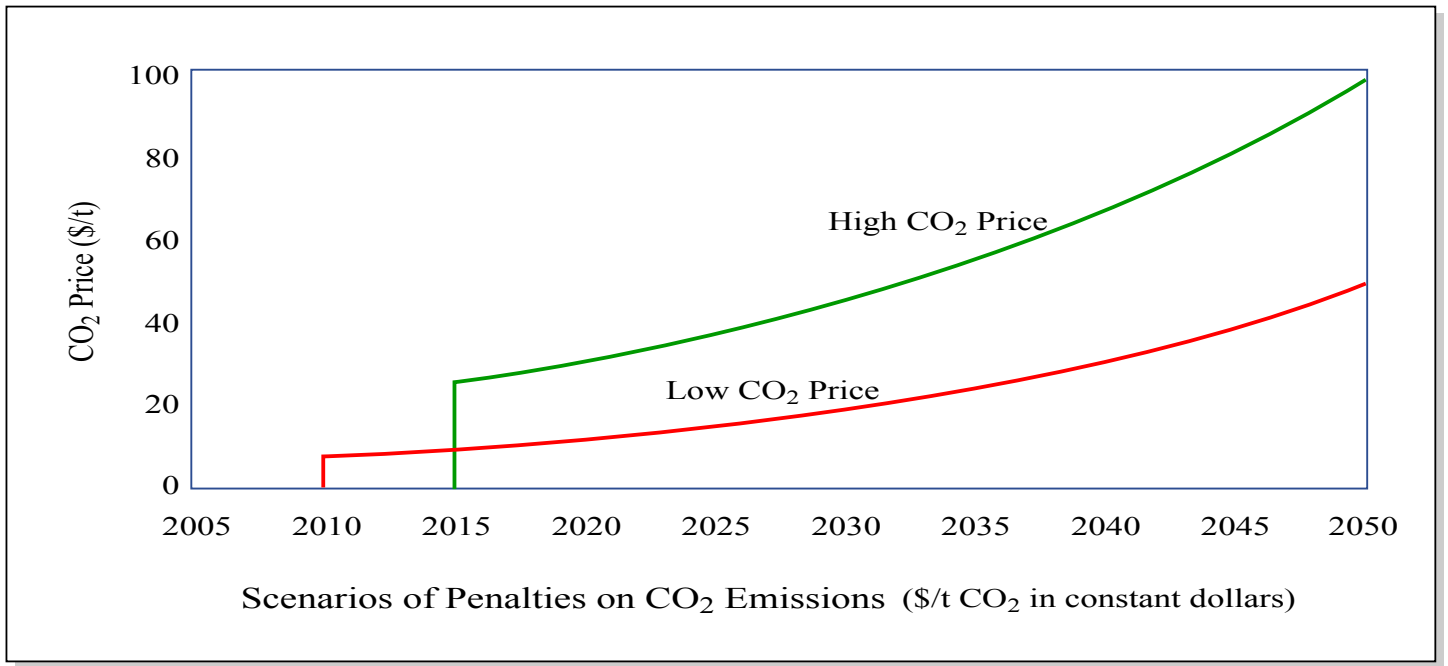
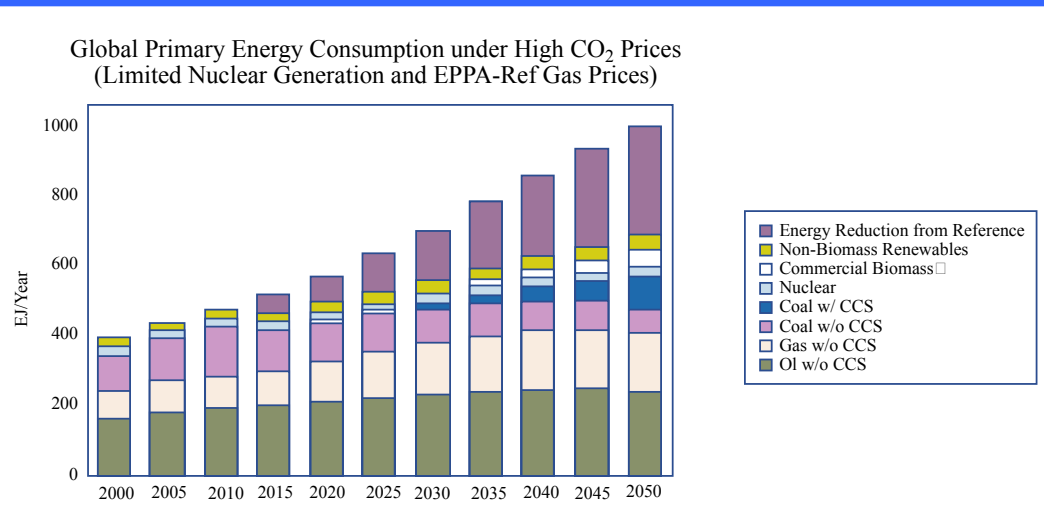


Figure by MIT OpenCourseWare.



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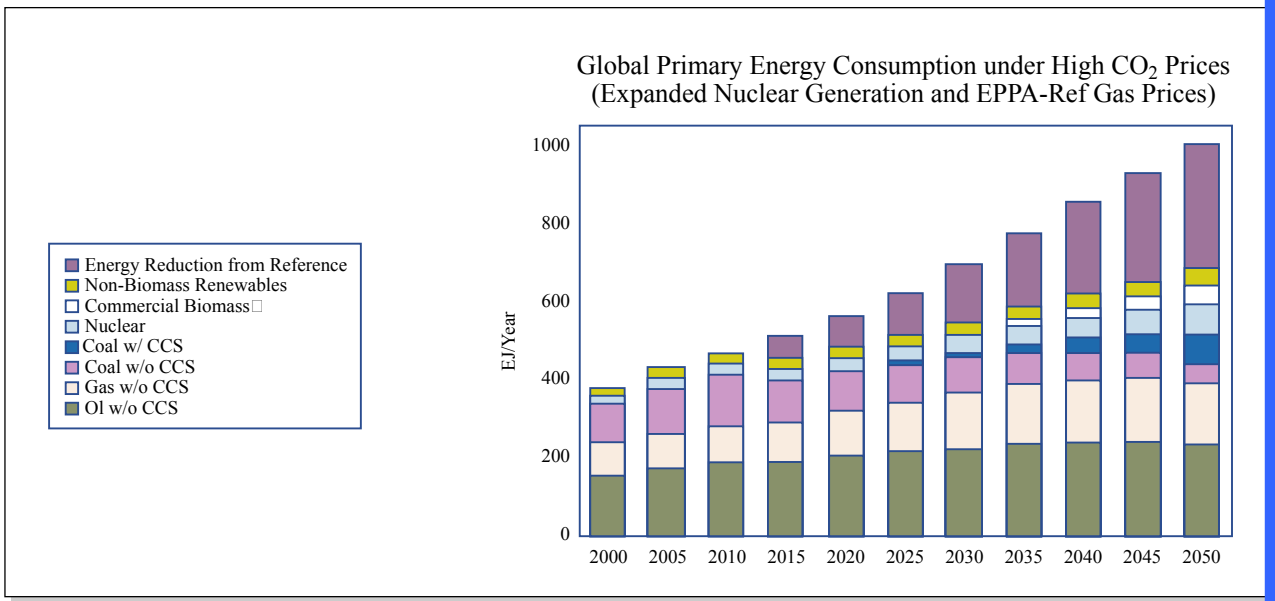


Figure by MIT OpenCourseWare.

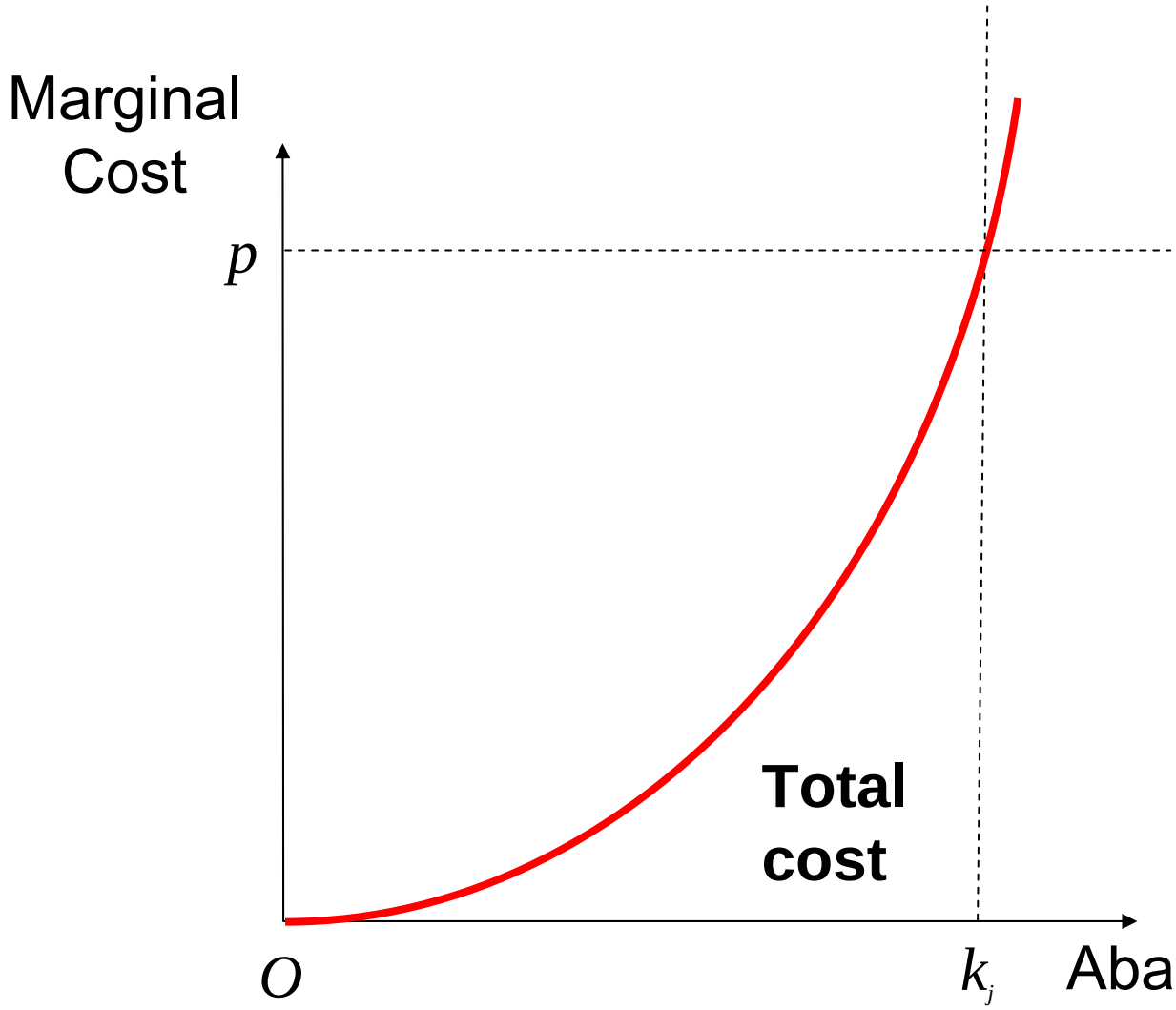
Exajoules of Coal Use (EJ) and Global CO_2 Emissions (Gt/yr) in 2000 and 2050 with and without Carbon Capture and Storage*

	Business As Usual		Limited Nuclear 2060		Expanded Nuclear 2050	
	2000	2060	With CCS	Without CCS	With CCS	Without CCS
Coal Use: Global	100	448	161	116	121	78
U.S.	24	58	40	28	25	13
China	27	88	39	24	31	17
Global CO_2 Emissions	24	62	28	32	26	29
CO_2 Emissions from Coal	9	32	5	9	3	6

* Universal, simultaneous participation, High CO_2 prices and EPPA-Ref gas prices.

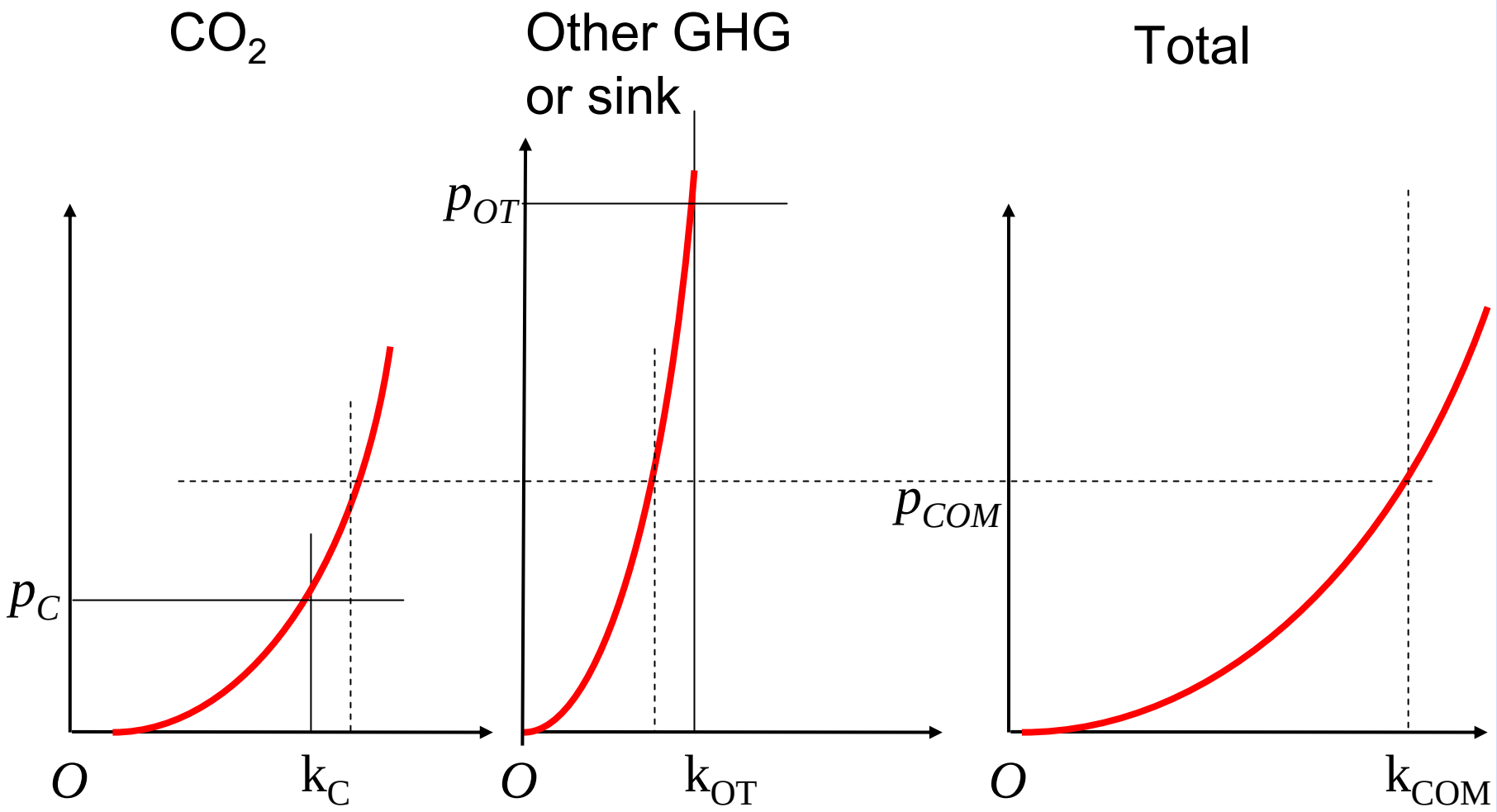
Figure by MIT OpenCourseWare.

Marginal Abatement Curve

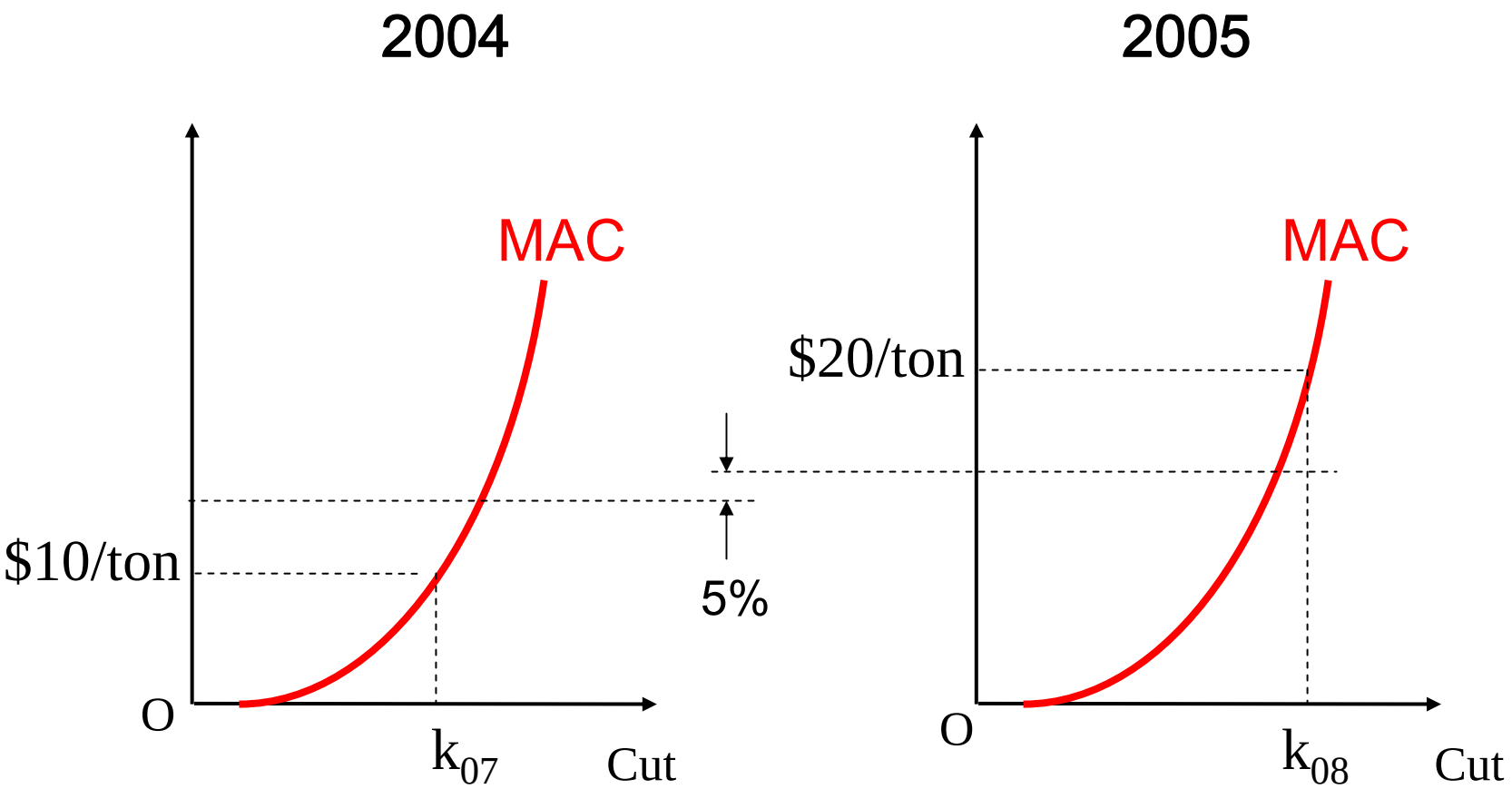


How to Construct?

Aggregating Gases

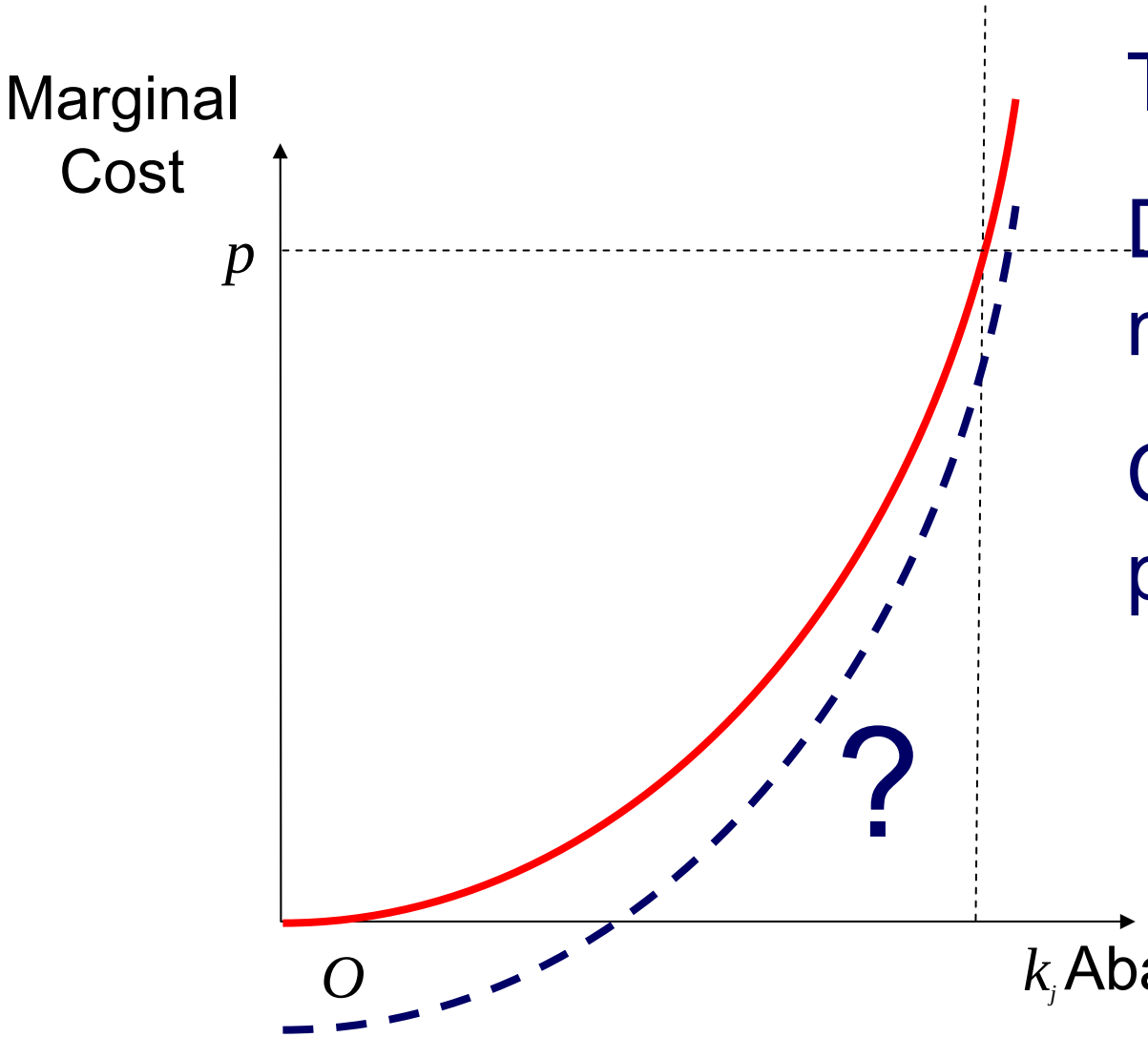


MACs and Banking



Discount rate = 5%/year

Shortcomings of MACs

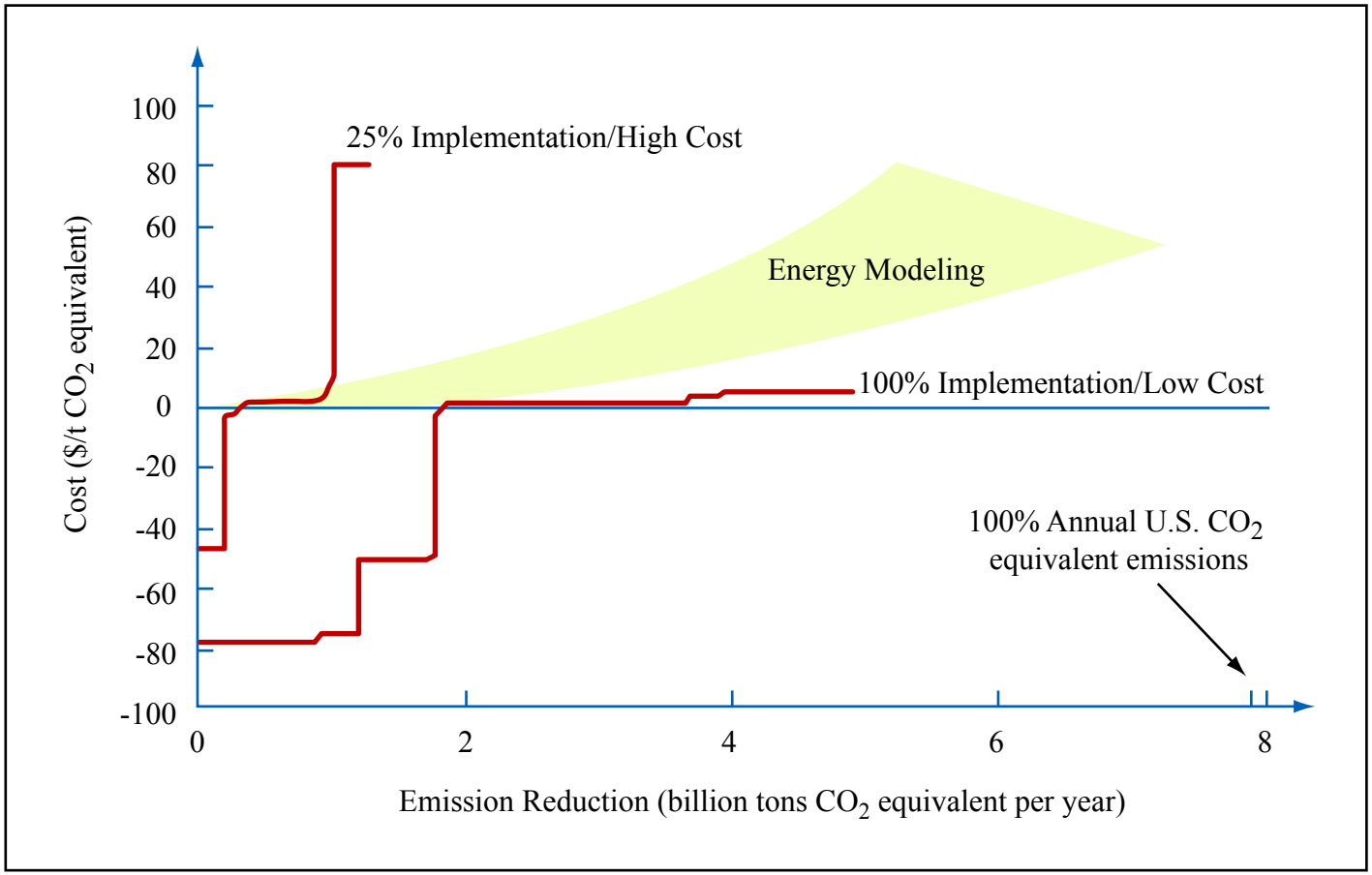


Trade effects

Distortions in markets

Calculation procedures

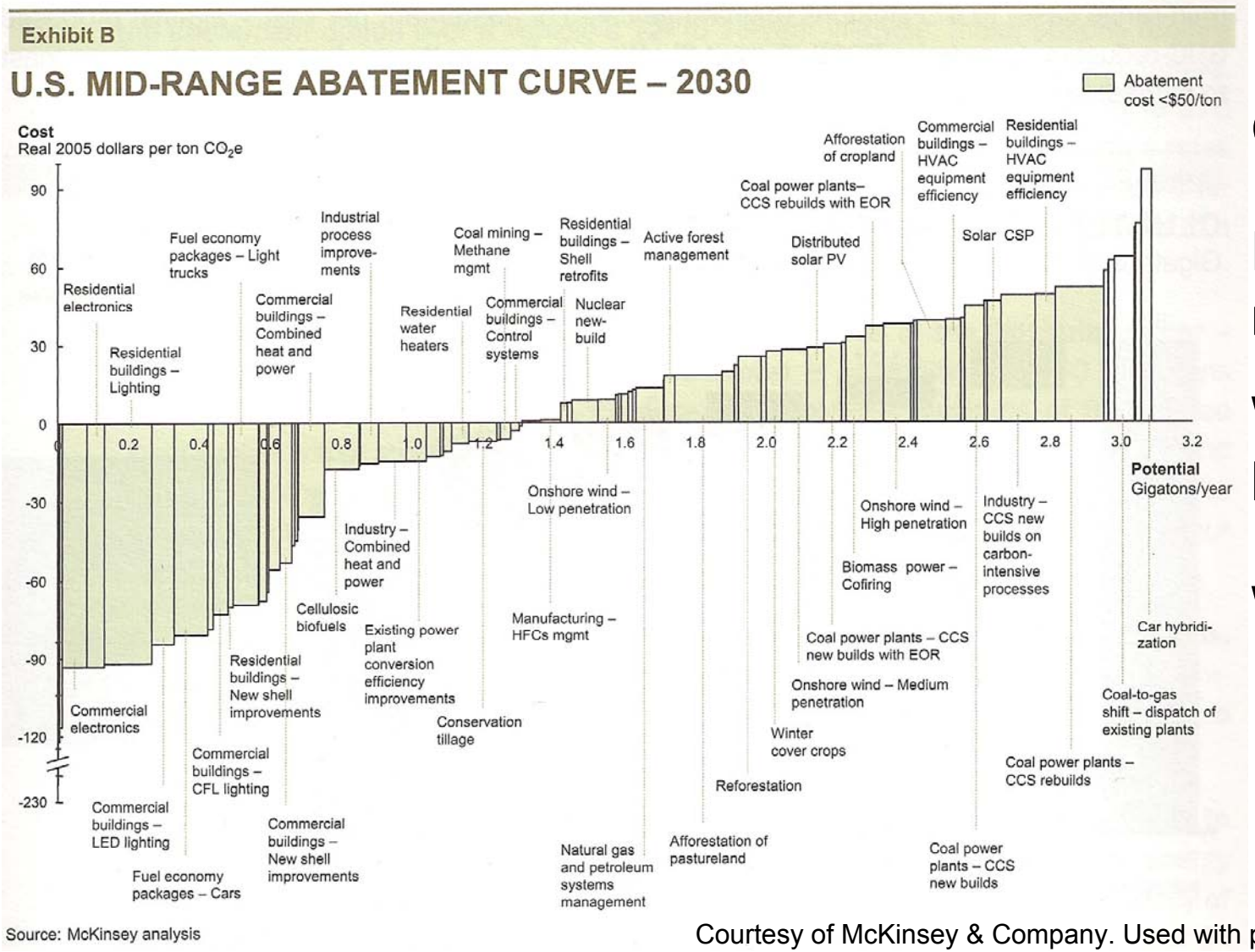
National Academies - 1991



Comparison of mitigation options using technological costing and energy modeling calculations.

Figure by MIT OpenCourseWare.

McKinsey - 2007



Courtesy of McKinsey & Company. Used with permission.

Cost basis

Discount rate

What is in baseline?

What use?

What is Happening to Cost?

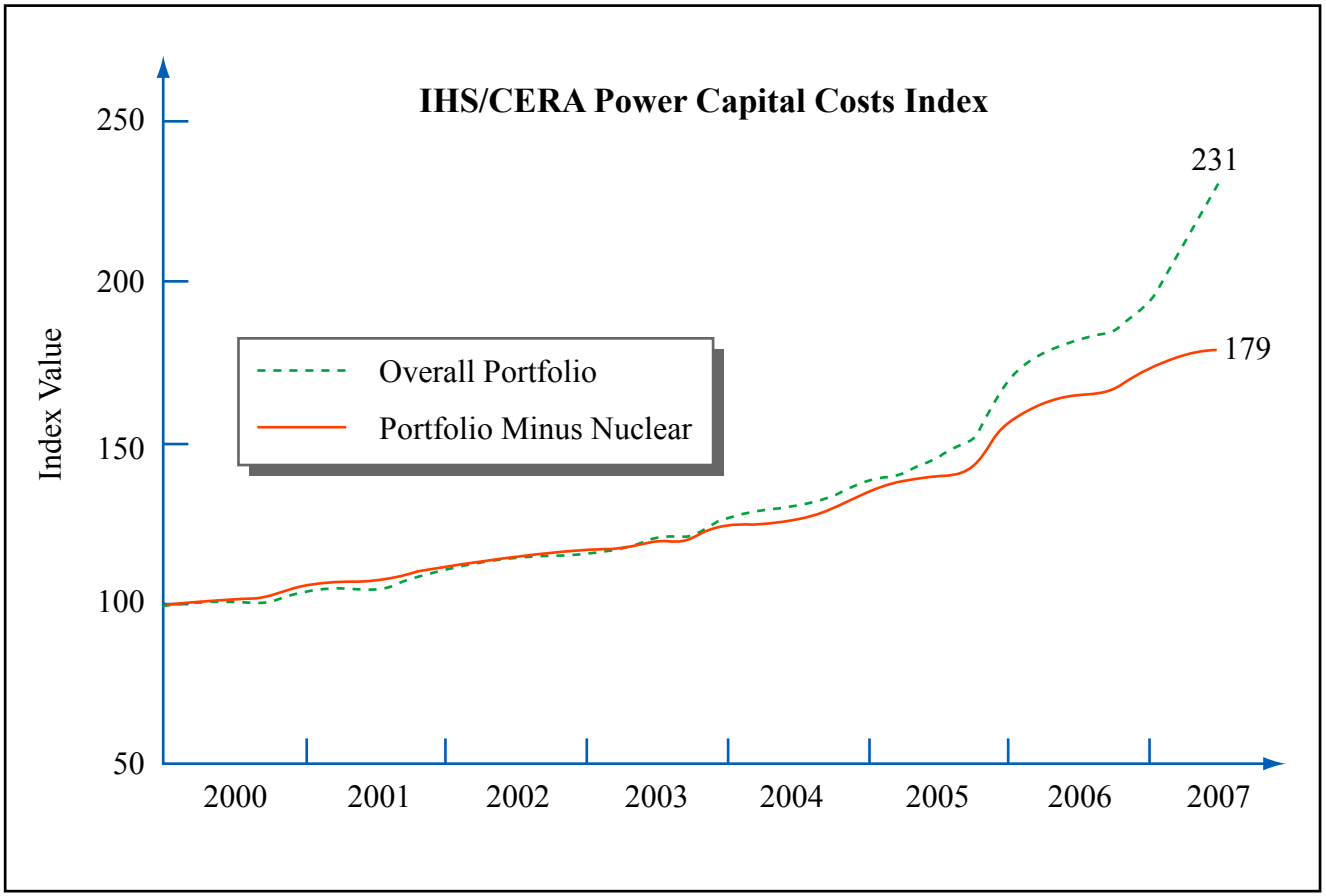


Figure by MIT OpenCourseWare.

Explaining Why Technologies Are Not Used

- Market failures: decision-makers don't see correct price signals
  - Lack of information
  - Principal-agent problems (e.g., landlord-tenant)
  - Externalities & public goods
- Market barriers
  - Hidden costs (*e.g.*, transactions costs)
  - Disadvantages perceived by users
  - "High" discount rates

Alternative Views of the Options

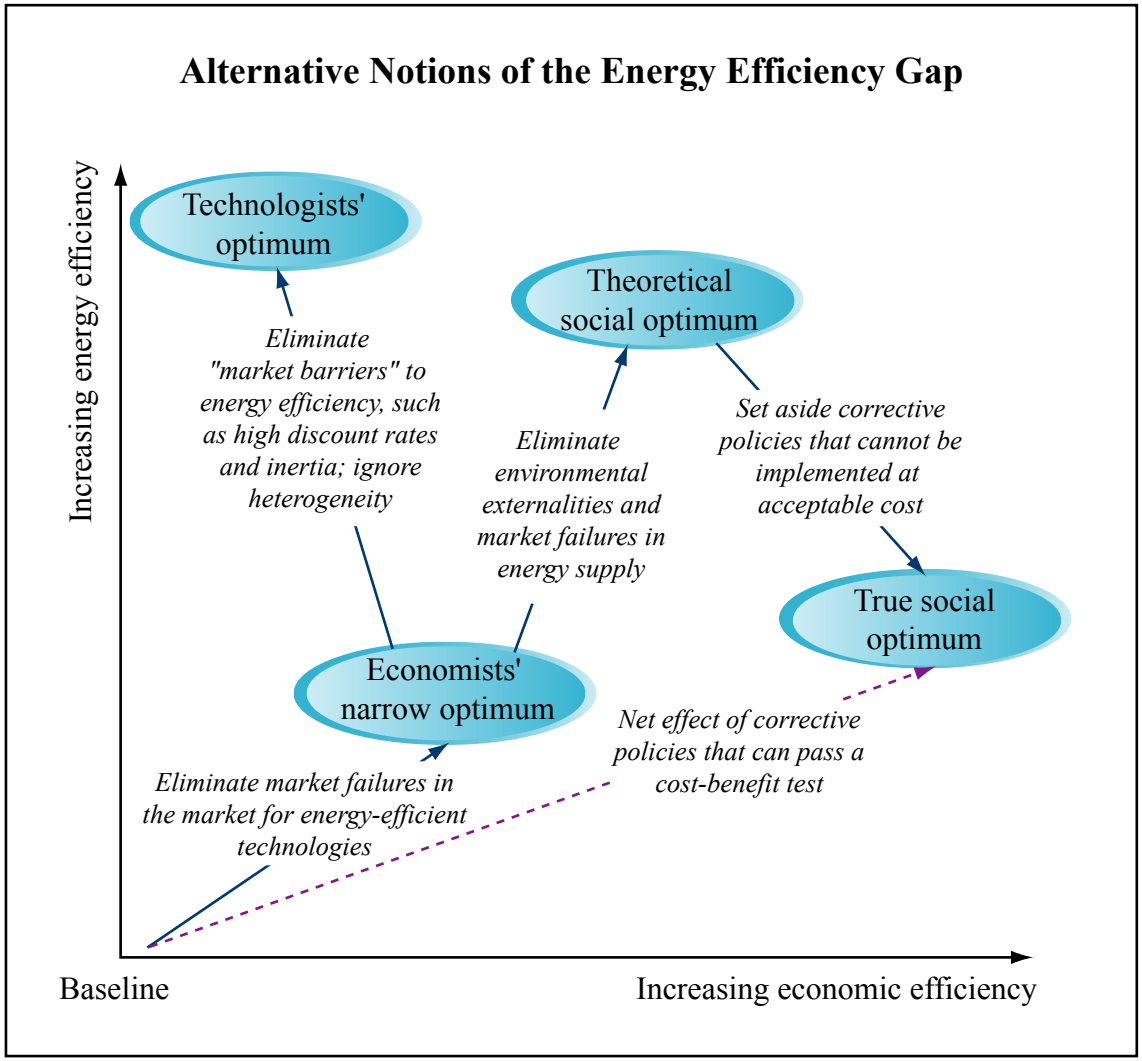
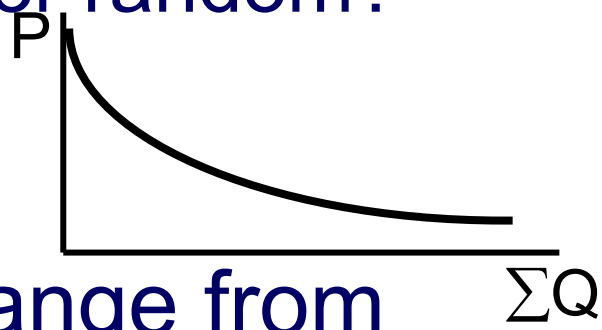


Figure by MIT OpenCourseWare, adapted from Resources for the Future.

Thinking about Technology

- What is technology, and tech. change?
- What leads to change?
  - Does change tend to economize on one factor or another, in response to prices?
  - What is the role of R&D expenditure?
  - To what degree is it *ad hoc* or random?
- Role of "learning by doing"



- How to distinguish tech change from
  - Change in inputs (in response to price)
  - Economies of scale

"New" Technologies

- Carbon capture and storage
  - From electric power plants
  - From the air
- Renewables
  - Wind & solar
  - Biomass
  - Tidal power
  - Geothermal
- New generation of fission, and fusion
- Solar satellites
- Demand-side technology
  - Fuel cells and H_2 fuel
  - Other? (lighting, buildings, ind. process, etc.)

What determines the likely contribution of each?