ISSUES IN MODELING GREENHOUSE EMISSIONS MITIGATION

China Economic and Environmental Modeling Workshop

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- EPRI

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PURPOSE

- *To review issues relevant to modeling and analysis of potential international agreements, such as the Kyoto Protocol.*
- *Comment on applications to China and the United States.*

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MODELING ISSUES

1. **Approach--***Top-down & bottom-up*
2. **Trade--***Direct & indirect effects*
3. **Uncertainty and expectations**
4. **Non-CO_2 greenhouse gases**
5. **Sinks--***Land-use emissions*
6. **Measurement of costs**
7. **Ancillary benefits**
8. **Endogenous technical progress**

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APPROACH

What needs to be modelled?

- ★ ***Modeling agreements like the Kyoto Protocol is at its heart an energy issue.***
- ★ ***But it is also involves--agriculture, land-use, chemical manufacture.***
- ★ ***Physical effects on the energy***
- ★ ***Economic effects on the economy***

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APPROACH

TOP-DOWN & BOTTOM-UP

- **Top-down are varied--but all have *economic* principles at their hearts**
- **Bottom-up models are also varied--but all have *engineering* at their hearts.**

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TOP-DOWN VARIATIONS

- ★*Partial equilibrium*
- ★*General equilibrium*
- ★*Optimization*
- ★*Recursive*
- ★*Macro*

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TOP-DOWN MODELS *EXAMPLES*

- ★*CETA*
- ★*G-CUBED*
- ★*FUND*
- ★*MERGE3*
- ★*MIT*
- ★*MRT*
- ★*OXFORD*
- ★*RICE*
- ★*SGM*
- ★*MiniCAM*

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TOP-DOWN MODELS

★*Insure Consistency--all markets clear--no "double counting" a la*
Policy Implications of Greenhouse Warming

★*Generate both Prices & Quantities*
★*International Trade & trade effects*

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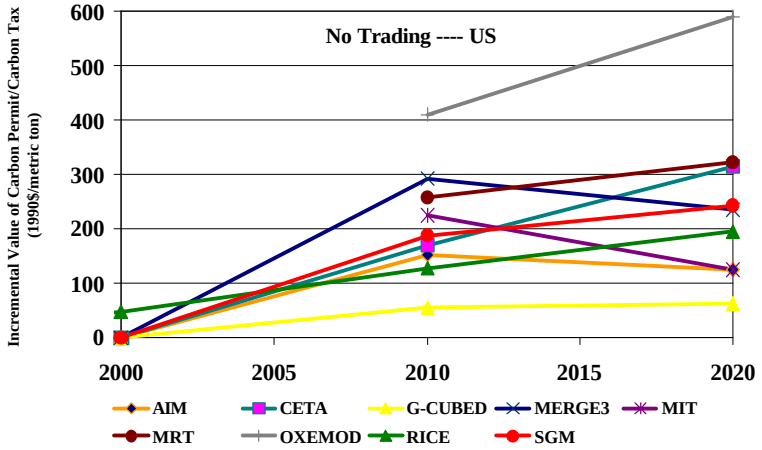
EMF-16 COST ESTIMATES



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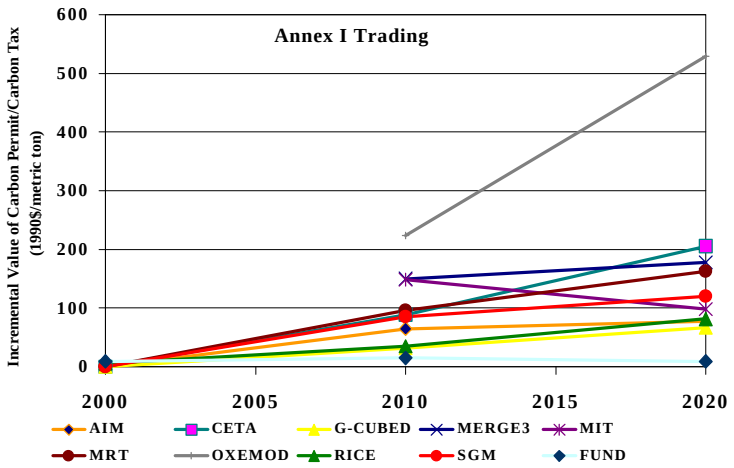

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TRADE

TRADE in EMISSIONS RIGHTS

REDUCES COMPLIANCE COSTS

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TRADE

Indirect Effects on Non-Participants

★*Lower oil prices--exporters hurt*
★*Others could either gain or lose--effects are complex and uncertain.*

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MODELING CHINA

China is Different from OECD Economies

★ ***Rapid economic growth.***
★ ***Coal dominated energy system.***
★ ***Demographic transition from rural to urban occurring rapidly.***

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MODELING CHINA

- ★ ***Mixed economy--regulated and free markets--state-owned enterprises compete with private enterprises.***
- ★ ***Public sector decisions play larger role in investment decisions.***
- ★ ***International trade is regulated--exchange rates, energy trade.***

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BOTTOM-UP VARIATIONS

★***Optimization--MARKAL***
★***Recursive--AIM, IMAGE2, 5-Lab Study***

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BOTTOM-UP MODELS

★*Solid engineering foundations*
★*Gap between bottom-up mitigation cost estimates and top-down model mitigation cost estimates*

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THE GAP

Cost to Return US
CO_2 Emissions to 1990 Levels
INDEPENDENT COMPLIANCE
(1992 constant US $, NEO97)

★*5-Lab Study--$50/tonne C*
★*SGM----$110/tonne C*

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EXPLAINING THE GAP EMF-13

★*Technology Assumptions*
★*Capital Stock Turnover*
★*Internal Rates of Return*
★*Ancillary Benefits*

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EXPLAINING THE GAP EMF-16

AIM--A BOTTOM-UP MODEL

★ *$65/tonne C, Annex I trading*
★ *$153/tonne C, US indep. comp.*
★ *higher than some top-down models, e.g. RICE*

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EXPLAINING THE GAP
US Interagency Analysis Team

5-LAB STUDY--$50/tonne C

★ ***~$50/tonne C ancillary benefits from emissions reductions of SO_2, NO_x, and VOCs***

★ ***~$100/tonne C gross marginal cost***

★ ***Not significantly different from SGM***

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THE GAP
TOP-DOWN STUDIES

The Range of Marginal Cost Estimates is Larger Among Top-Down Models than Between Top-Down & Bottom-Up Models

(1992 US $/tonne C, US Independent Compliance)

★***G-Cubed--$55/tonne C***

★***Oxford $410/tonne C***

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EXPLAINING THE LACK OF GAP

★***Many of the Top-Down models are at their foundations, Bottom-Up models.***

★***e.g. MERGE3***

★***MARKAL/MACRO***

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UNCERTAINTY

Uncertainty operates to raise costs.

★ *Decision makers can as easily loose by preparing for a policy that does not materialise as for a policy that does.*

- ★Ordering gas turbines & building pipelines are expensive if they are not needed.
- ★Risk minimising strategy--wait and plan to de-rate coal-fired plants and buy gas.

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UNCERTAINTY

Uncertainty affects instrument choice.

★ *Because mitigation cost elasticities are greater than benefit elasticities.*
- ★Price instruments (Common Taxes) outperform quantity instruments (Tradable Permits).
- ★Jorgenson, Nordhaus, Manne & Richels, Peck & Teisberg.

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EXPECTATIONS

- ★*Long-term* elasticities are greater than *short-term* elasticities.
- ★Models with perfect foresight will have lower costs, *ceteris paribus*, than models in which agents do not anticipate a constraint.
- ★*SGM & RICE costs < Oxford & EIA*

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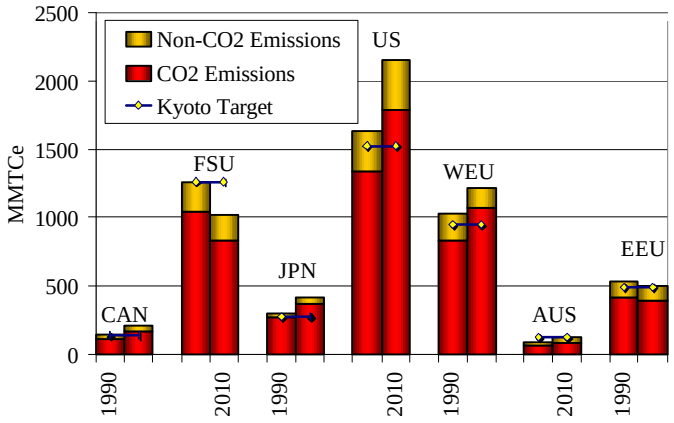
NON-CO_2 GHGs



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NON-CO_2 GHGs

Non-Energy Sectors

★*Crops--N_2O*

★*Land-use--N_2O, CH_4, CO_2*

★*Livestock--CH_4*

★*Rice--CH_4*

★*Landfills--CH_4*

★*Chemicals--HFCs, PFCs, SF_6*

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NON-CO_2 GHGs

Few Models Have the Detail to Treat Non-CO_2 GHG Emissions Endogenously

★***IMAGE2***

★***MiniCAM***

★***Requires merging top-down & bottom-up approaches.***

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SINKS

★**Land-use emissions--1.6 PgC/yr**

★**Fossil fuel emissions--6.0 PgC/yr**

STOCKS

★*Terrestrial carbon stocks--560 PgC*

★*Soils -- 1200 PgC*

★*Fossil fuels--> 15,000 PgC*

★*Atmosphere -- 750 PgC*

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SINKS

★**Soils**--not covered by Kyoto
★**Biomass**--only afforestation and reforestation covered by Kyoto.
★*In the Kyoto time frame sinks are an accounting issue. There is insufficient time to make major changes to above ground stocks of carbon.*

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TREES

In the long term sinks are a biomass energy issue.

★ Trees mature and transition to a steady-state stock of carbon.
★ Continued uptake means removing the trees from the site and either sequestering them, or using them as biomass energy to back out fossil fuels.

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SOILS

Soils have significant potential for carbon removal, but pose major institutional problems to exploit.

★ 0.3 to 0.6 tonnes C/ha/yr.
★ 40-80 PgC/century

Early Years
★ > 1 tonne C/ha/yr.
★ > 1 PgC/yr.

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MEASUREMENT OF COST

★*Marginal Cost*--market price or value of an additional tonne of carbon mitigation.
★*Direct Cost*--integral under the marginal abatement curve.
★*Net Purchases of Allowances*--market value of purchases or sales of emission allowances.
★*GNP Change*
★*Change in Consumption*
★*Compensated Welfare*

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MEASUREMENT OF COST

- ★Marginal Cost, Direct Cost, and Net Purchases of Allowances *are comparable across models*
- ★GNP and Consumption *have potential accounting issues in models with multiple sectors.*
- ★Compensated Welfare *may not be available from models with multiple actors.*

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MEASUREMENT OF COST

- ★Different *accounting practices* may lead to significant differences in measured GNP or Consumption cost.
- ★Accounting practices may imply *gains to trade* for individual sellers, but not to society.
- ★GNP or Consumption cost measures can be affected by *tax revenue disposition or distribution of permits*.

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ANCILLARY BENEFITS

Few attempts have been made to construct a fully integrated model of emissions mitigation that encompasses both GHGs and non-greenhouse gases.

- ★Requires costs & benefits of non-CO_2 gases.
- ★Geographic scale differences

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ANCILLARY BENEFITS

Examples

- ★US DOE 5-Lab Study
- ★PNNL *Ancillary Benefits of Stabilizing CO_2 Emissions: Conventional Air Pollutants.*

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ANCILLARY BENEFITS

Reductions in GHG emissions implies reductions in other pollutants.

- ★Exception--cap & trade regimes (e.g. US sulphur control program).
- ★Marginal benefits may be hard to quantify, and if emissions reductions are non-marginal, subject to diminishing returns.

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ANCILLARY BENEFITS

Reductions in non-GHG pollutants sometimes imply reductions in GHGs.

- ★SO_2 control may increase CO_2 emissions and accelerate realised warming.
- ★Could be important interaction, e.g. *Korean substitution of natural gas for oil in urban transportation.*

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TECHNOLOGICAL CHANGE

★Not an issue in the Kyoto time frame.
★Economic growth is an issue.

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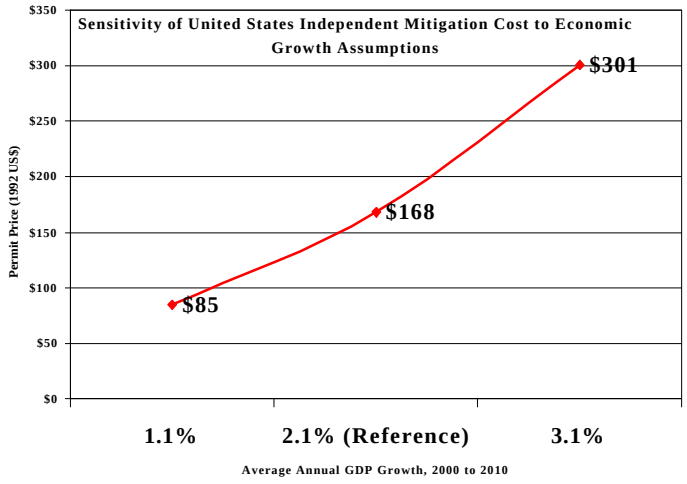
ECONOMIC GROWTH



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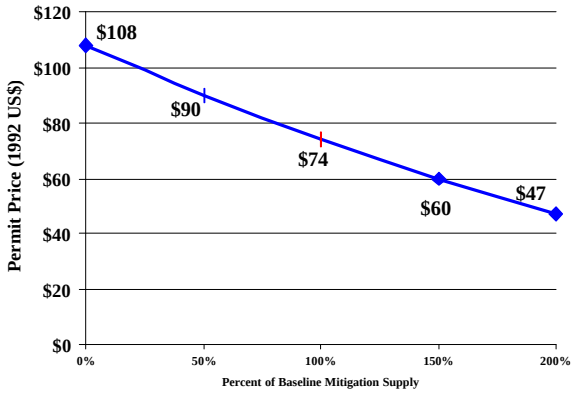
ECONOMIC GROWTH

Sensitivity of Annex I Permit Price to FSU Supply of Emissions Mitigation



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TECHNOLOGICAL CHANGE

★Long-term.
★Makes a difference

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Stabilizing the Atmosphere

- Carbon must be controlled,
- But fossil fuel phase out not required.

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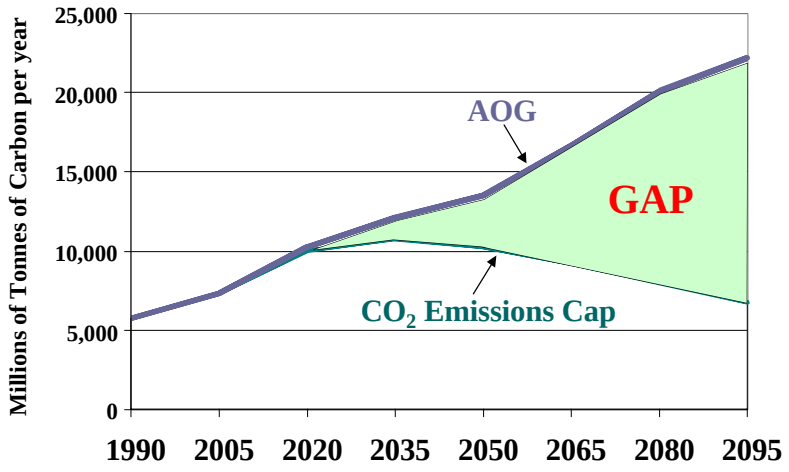
The "Gap"

Stabilizing Concentrations @ 550 Ppmv

(Both Reference Emissions Pathway and Cap Illustrative)



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Gap Technologies

- No "silver bullet."
- A portfolio of technologies required.
- This project--
  - ★Analyze technology portfolios
  - ★Multiple criteria

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Technology & R&D

- Climate change is a major new motivation for energy R&D.
- Both marginal and radically new technologies needed.

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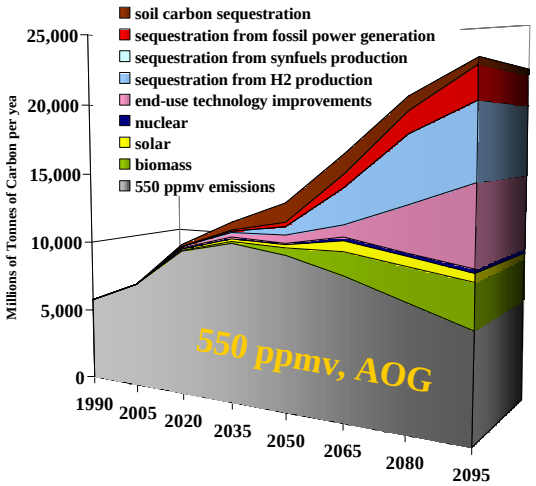
Filling the Gap



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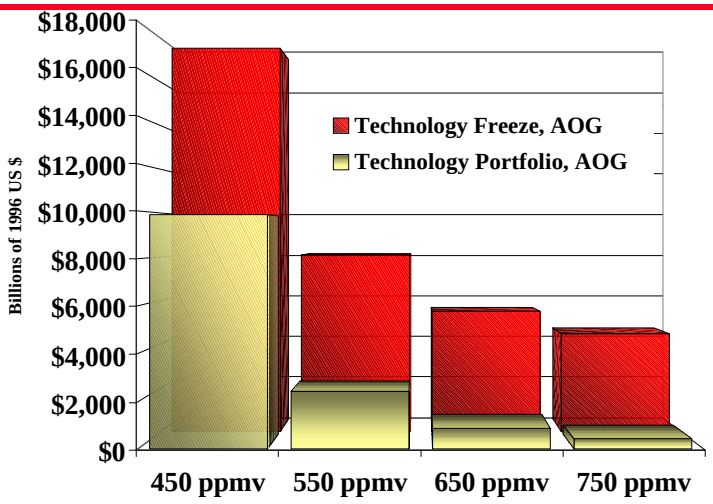
Value of One Possible Portfolio



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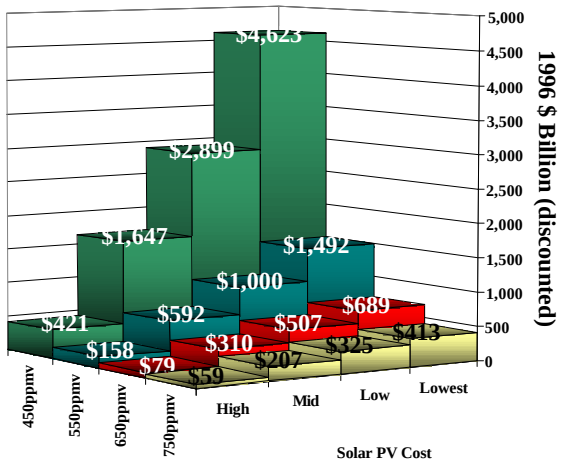
VALUE of IMPROVING SOLAR RELATIVE to HIGHEST COST



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Endogenous TECHNOLOGICAL CHANGE

- ★ Endogenous R&D--*technological change depends on investments in R&D.*
- ★ Learning-by-doing--*technological change depends on cumulative previous production.*

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Endogenous TECHNOLOGICAL CHANGE

- ★ Goulder & Schneider, Nordhaus.
- ★ Endogenous technological change tends to lower costs.
- ★ Endogenous R&D lowers taxes and shifts emissions mitigation to the future.
- ★ Learning-by-doing has an ambiguous effect on timing.

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CONCLUSIONS

1. **Approach--***Top-down & bottom-up*
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3. **Uncertainty and expectations**
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