

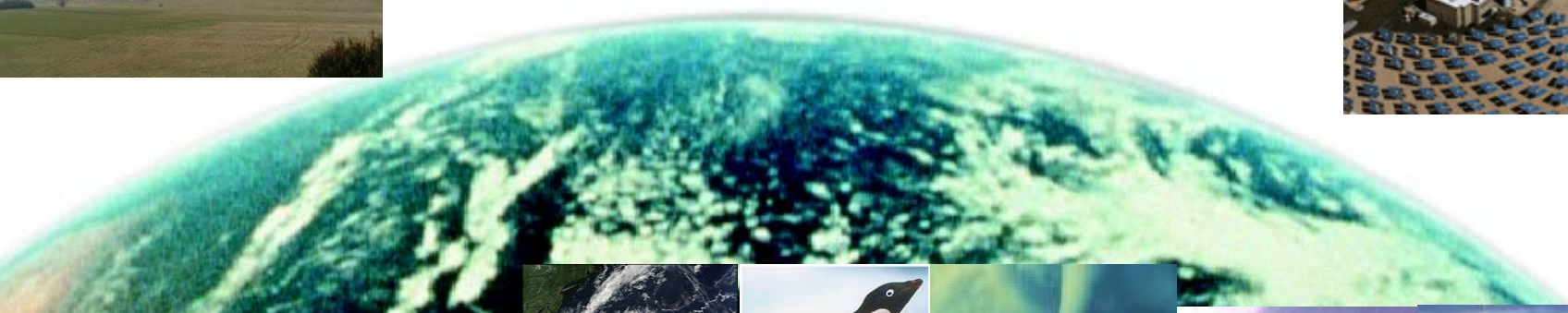
Tools for Interactive Decision-making under Uncertainty on Energy and Climate Change

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scheffra@uiuc.edu**

Climate Science in Support of Decision Making

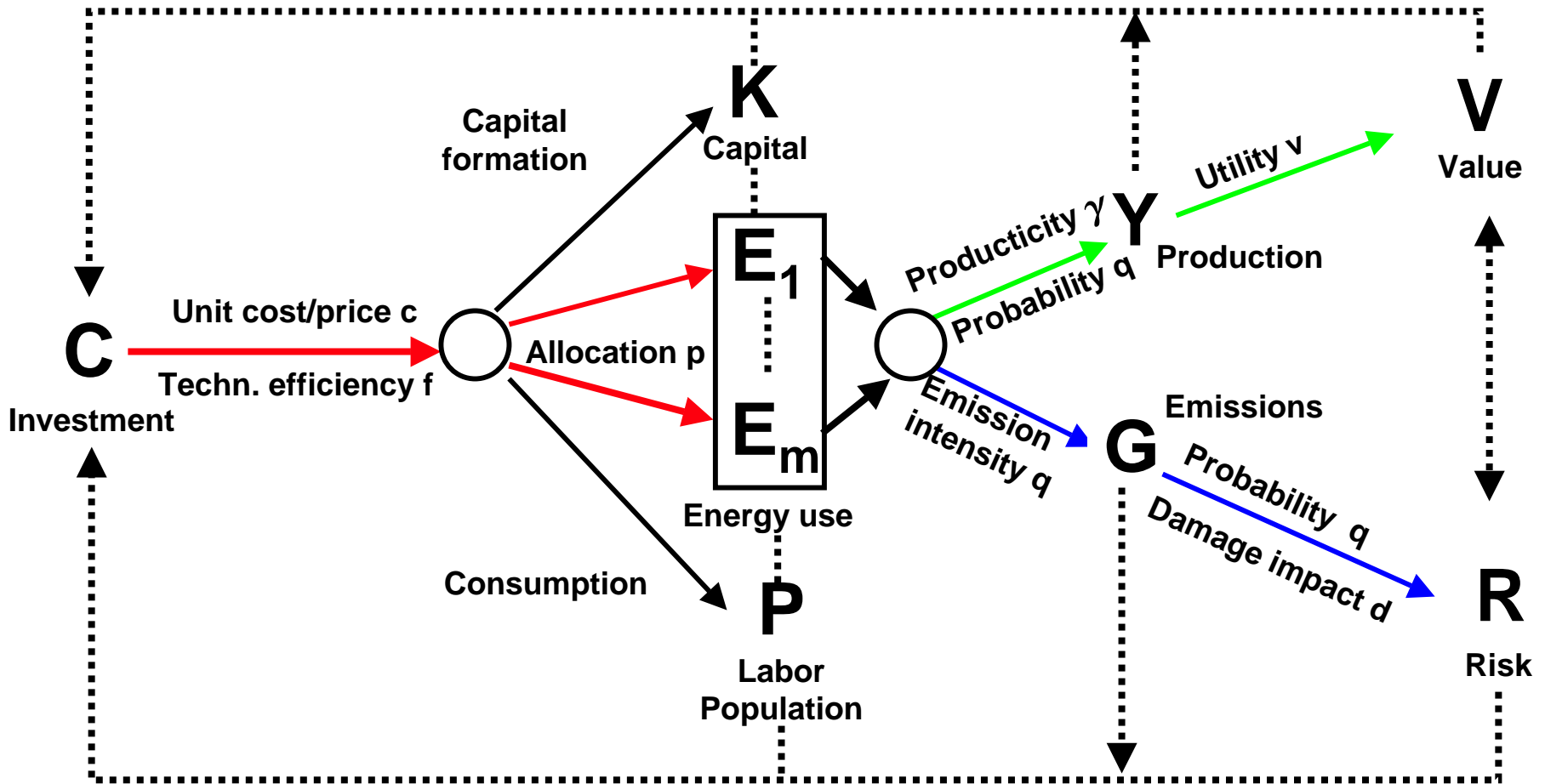
Washington, DC, November 15, 2005



Outline

- 1. Integrated decision-making on energy options**
- 2. Adaptive control vs. optimal control in climate modeling**
- 3. Data and uncertainty in integrated assessment**
- 4. Interactive decision-making among multiple actors**

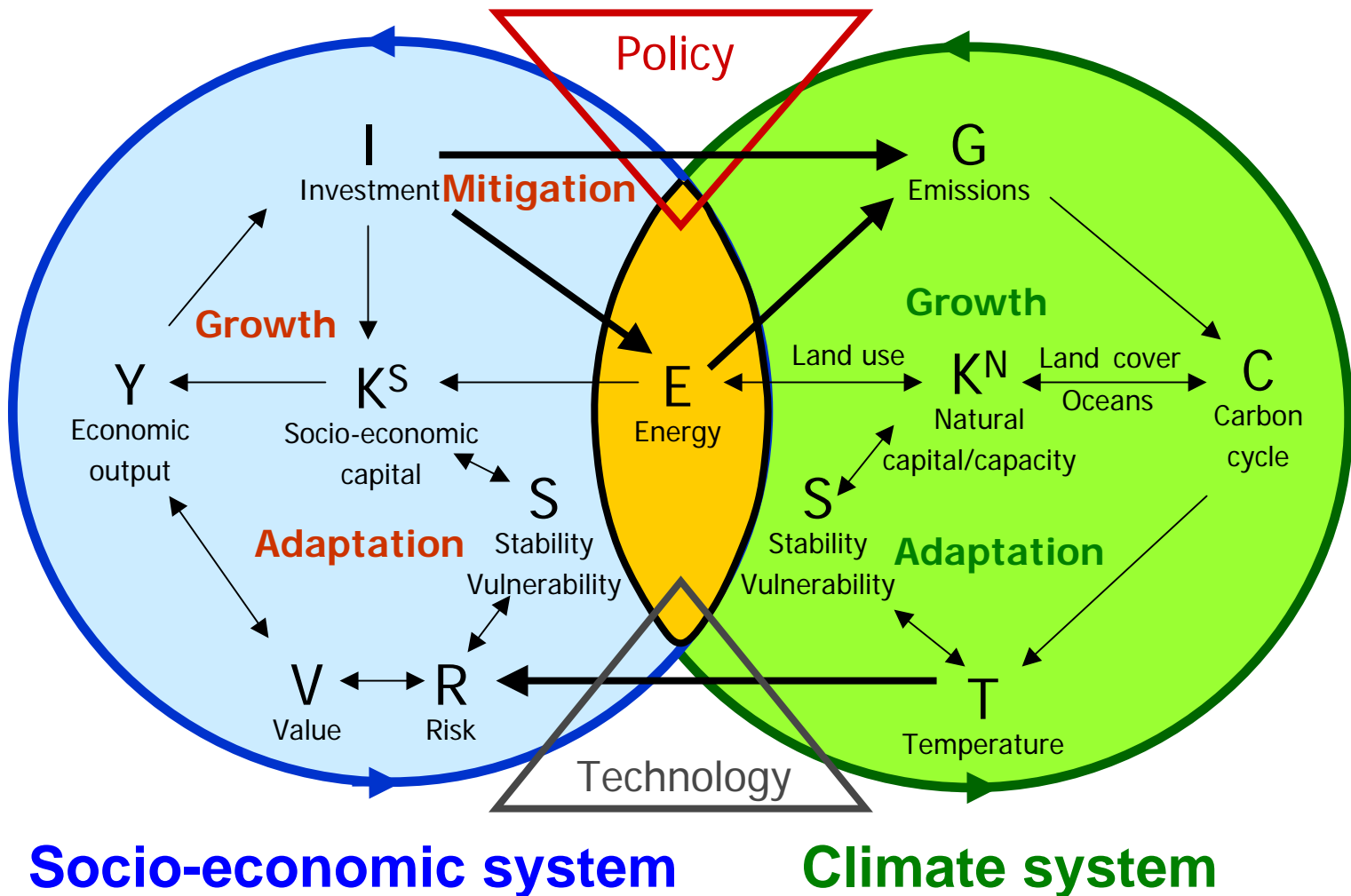
Integrated Decision-making on Energy Options



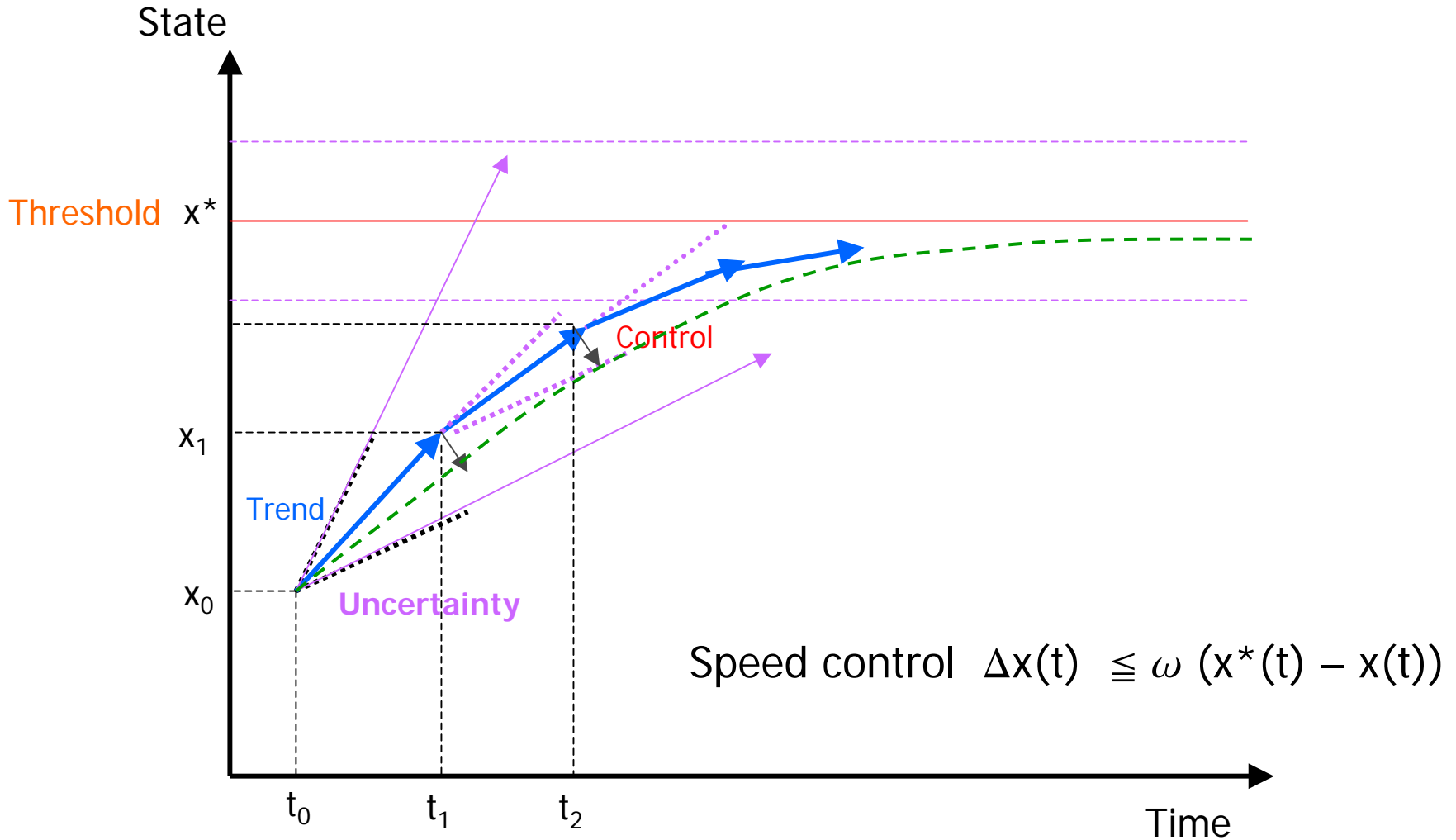
$$V(E) = p f \gamma u C(E) / c$$

$$R(E) = q (D/G) (G/E) (E/Y) (Y/P) P = q r g e y P$$

Energy in Integrated Assessment

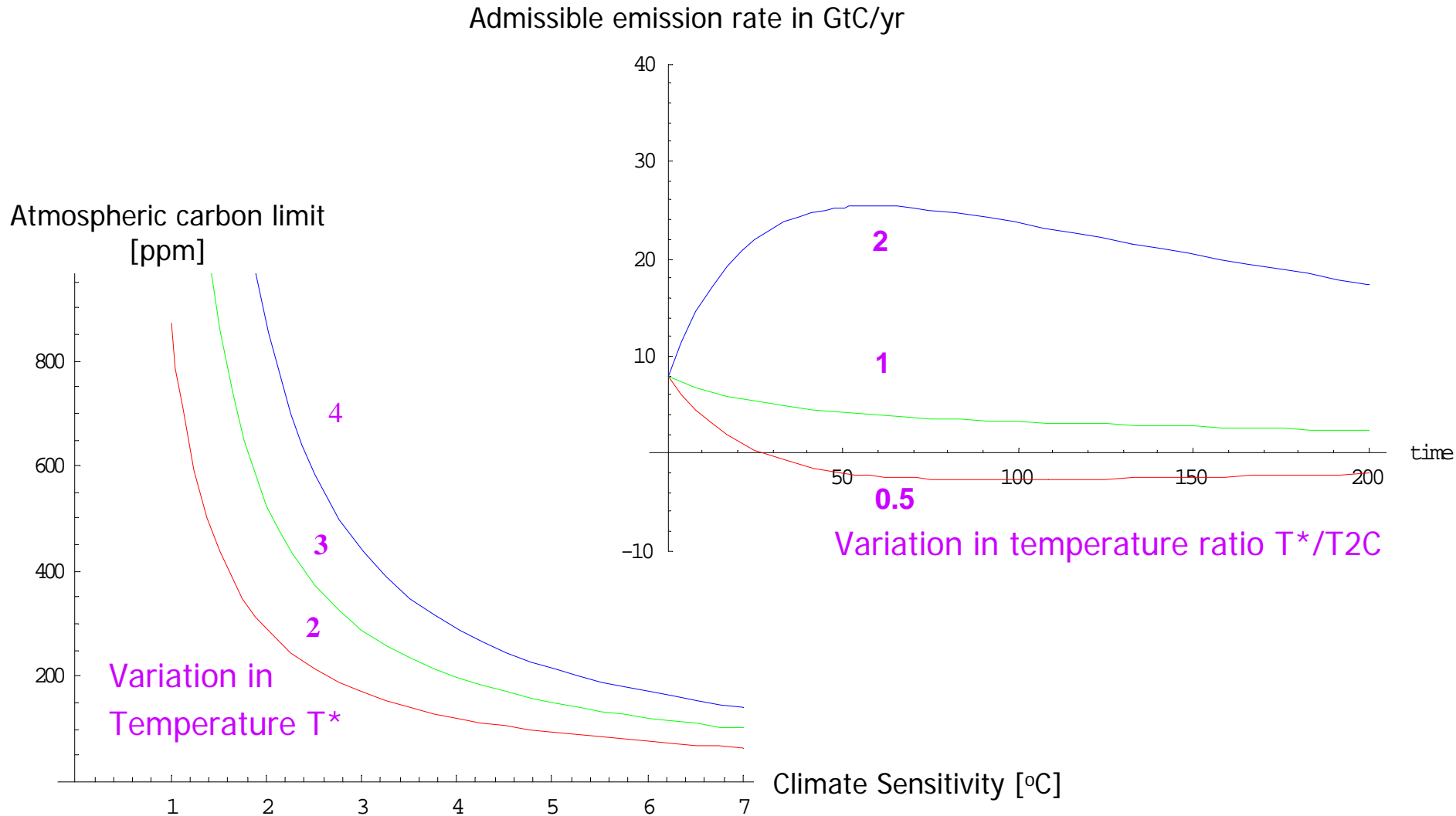


Adaptive Control Under Uncertainty



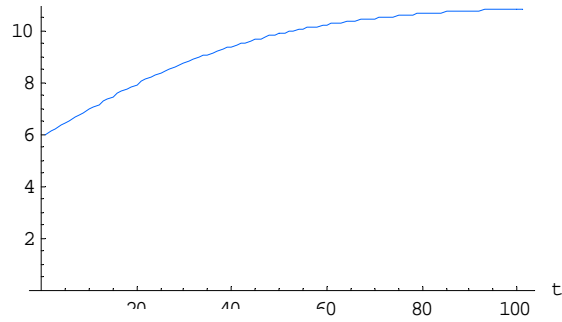
Adaptive decision rules: $\Delta x(t) = \omega(x,t) D(x,t)$

Carbon Limits and Adaptive Emission Rates

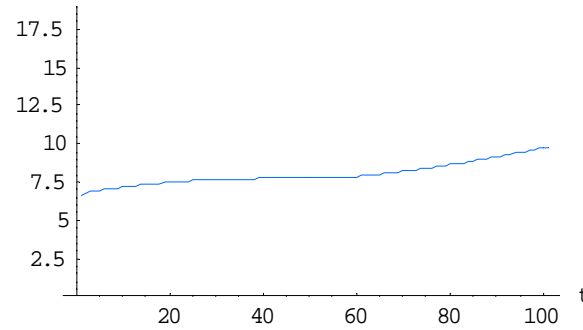


Technical Change and Climate Damage

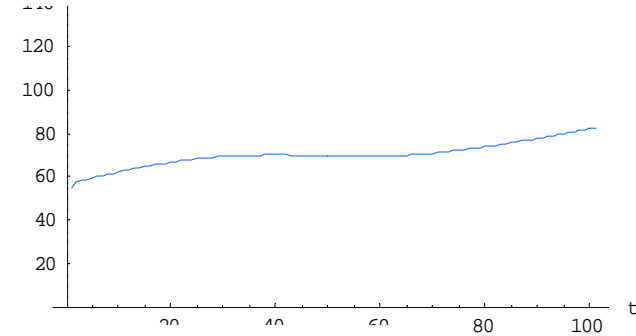
Population in bio.



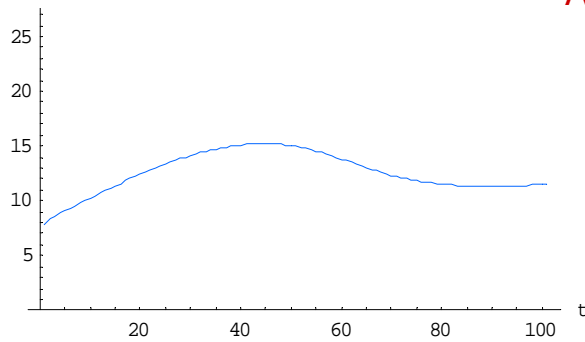
Production/capita in \$10,000



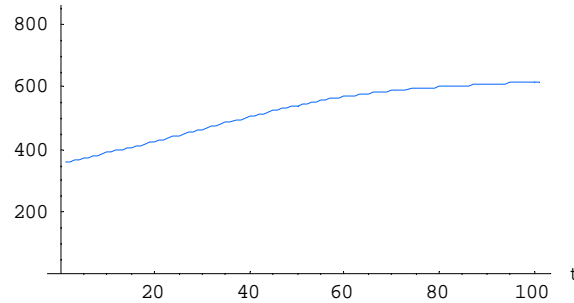
Energy/capita in GJ



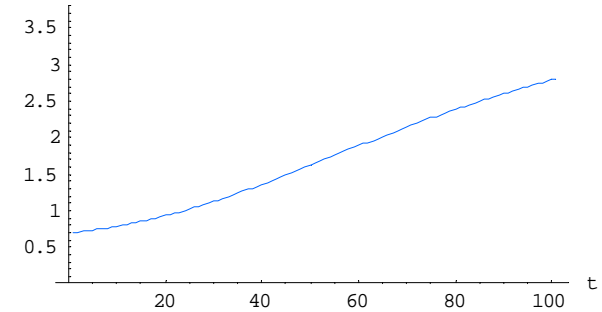
Emissions in GtC/a



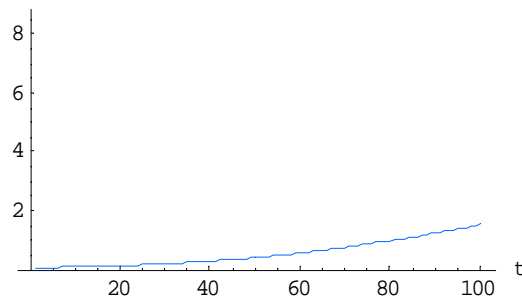
Atmospheric carbon in ppm



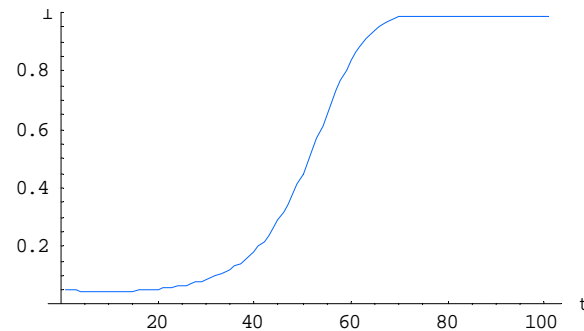
Temperature change in °C



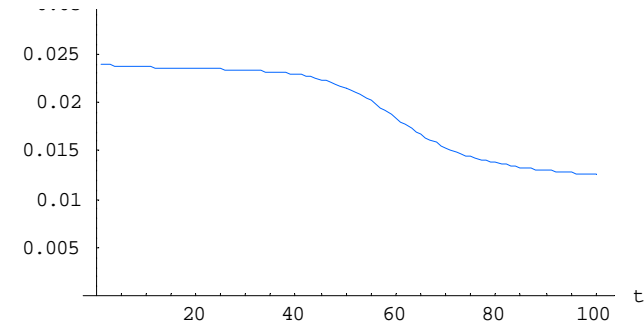
Climate damage/capita in \$10,000



Allocation to low-emission energy

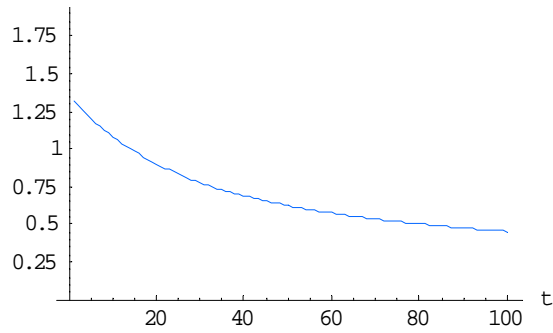


Carbon intensity of energy in GtC/EJ

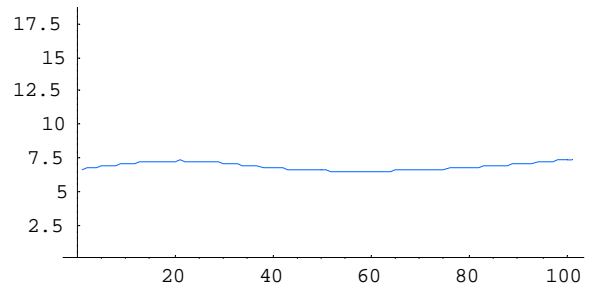


Technical Change and Adaptive Control

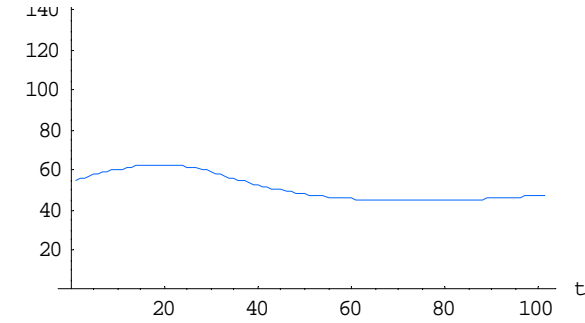
Emissions/capita in tC/cap



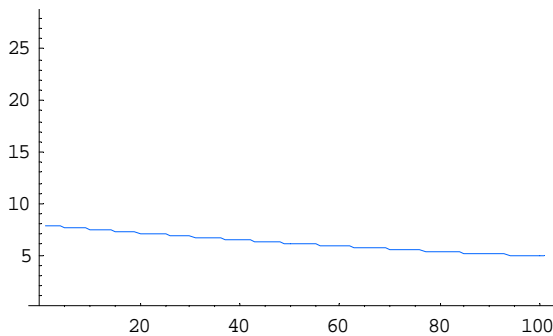
Production/capita in \$10,000



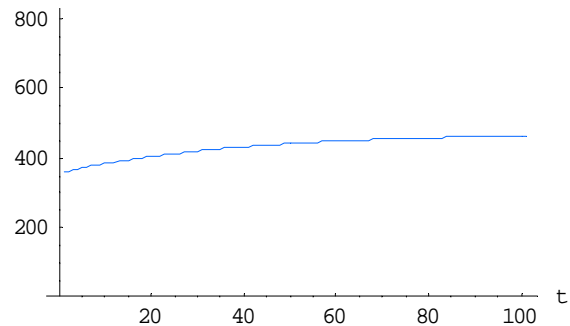
Energy/capita in GJ



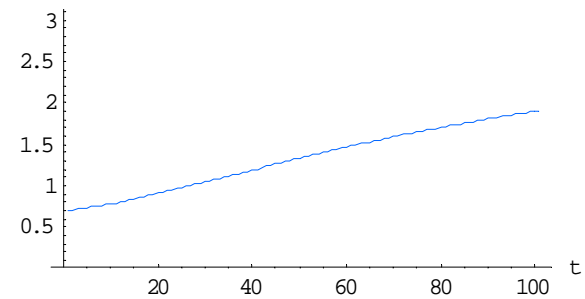
Emissions in GtC/a



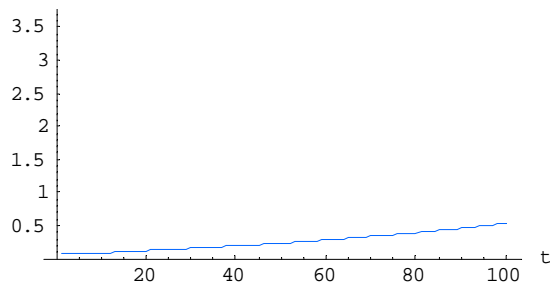
A Atmospheric carbon in ppm



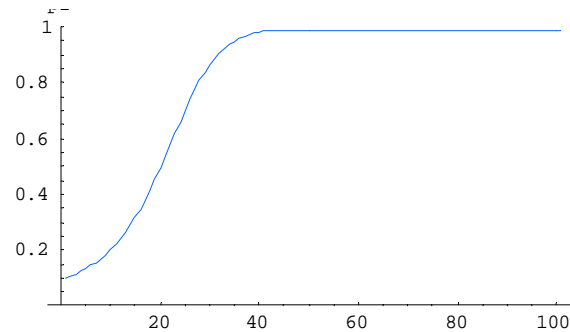
Temperature change in °C



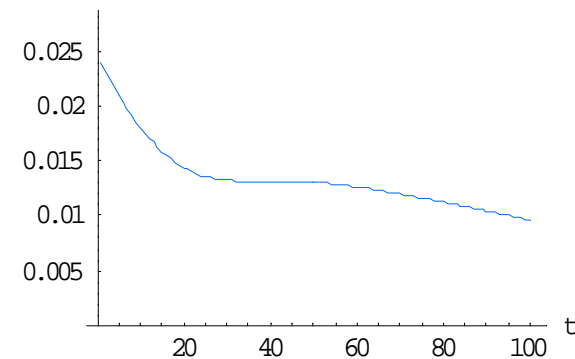
Climate damage/capita in \$10,000



Allocation to low-emission energy

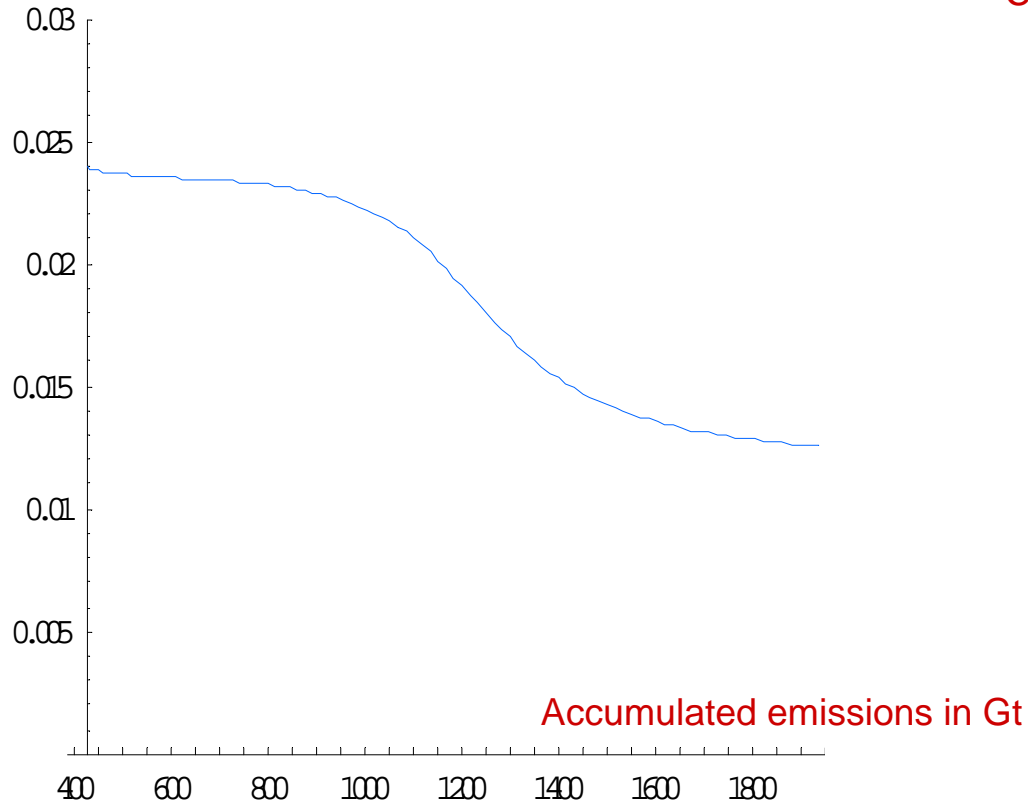


C Carbon intensity of energy in GtC/EJ



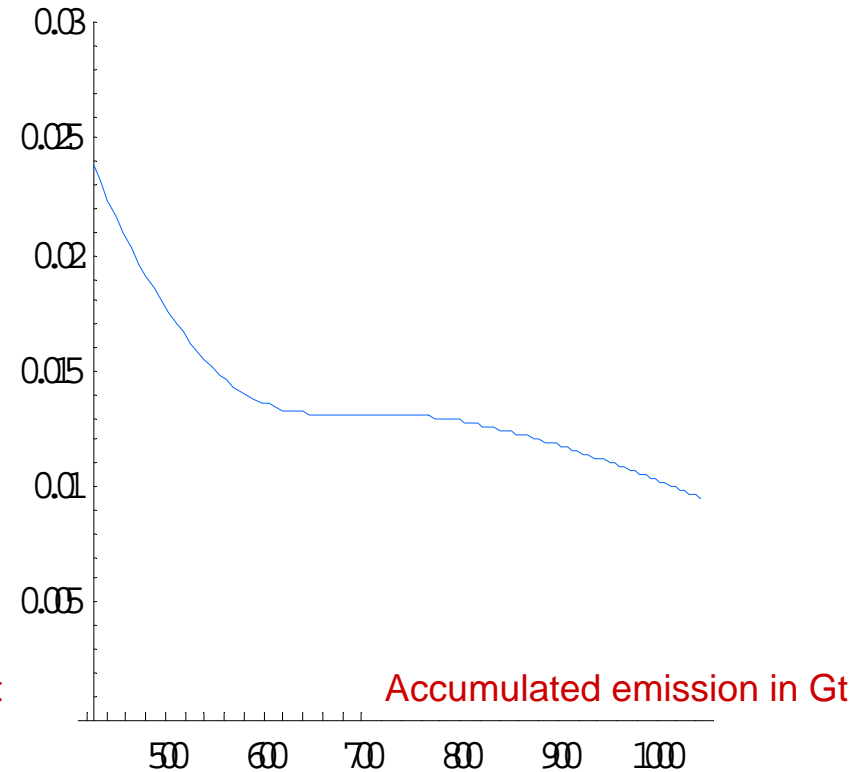
Carbon Intensity vs. Accumulated Emissions

Carbon intensity of energy in GtC/EJ



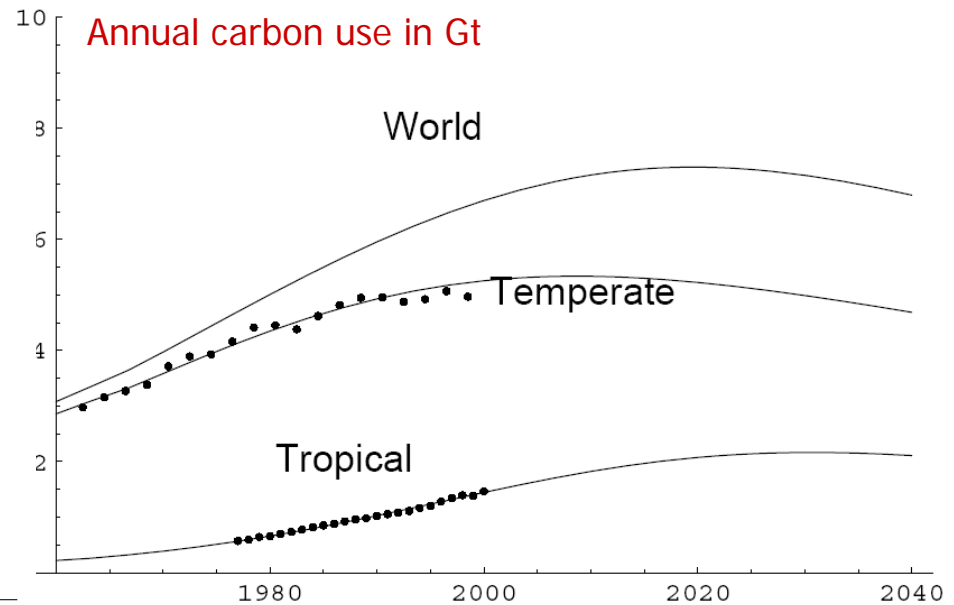
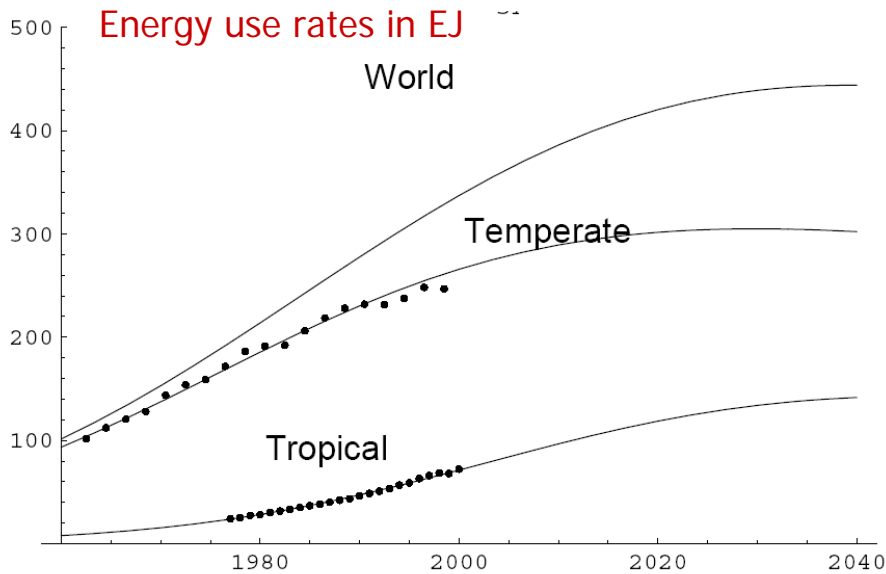
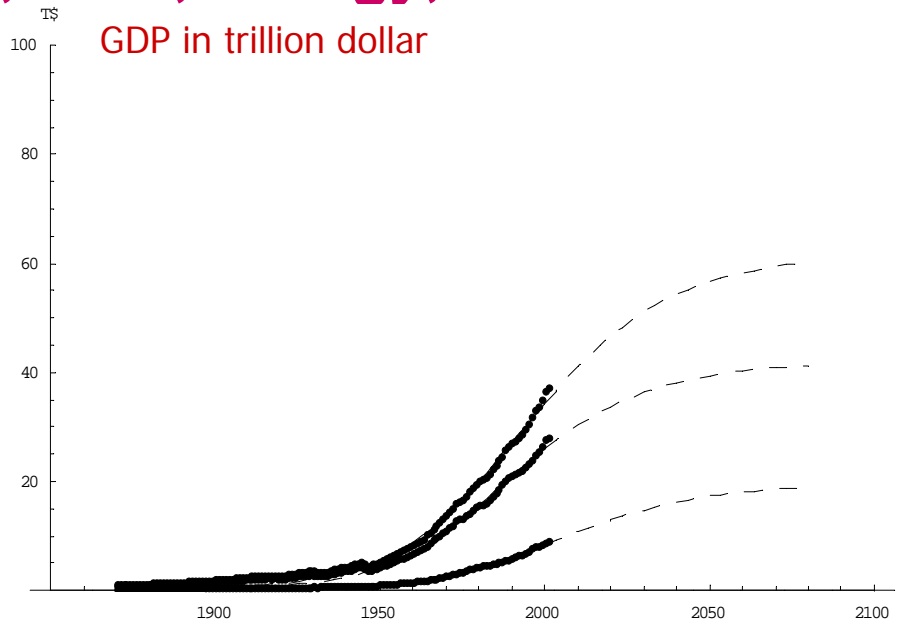
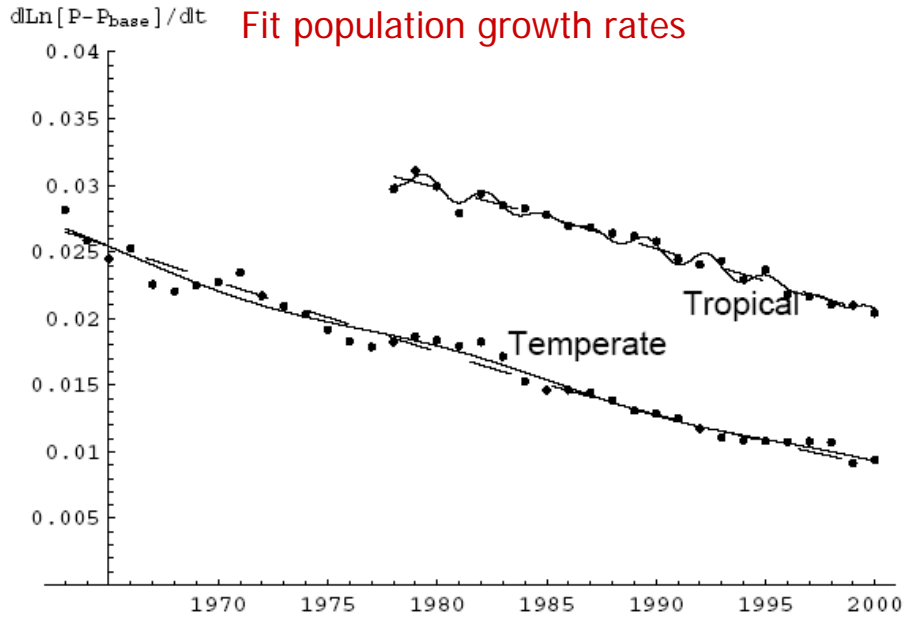
Damage-induced control

Carbon intensity of energy in GtC/EJ



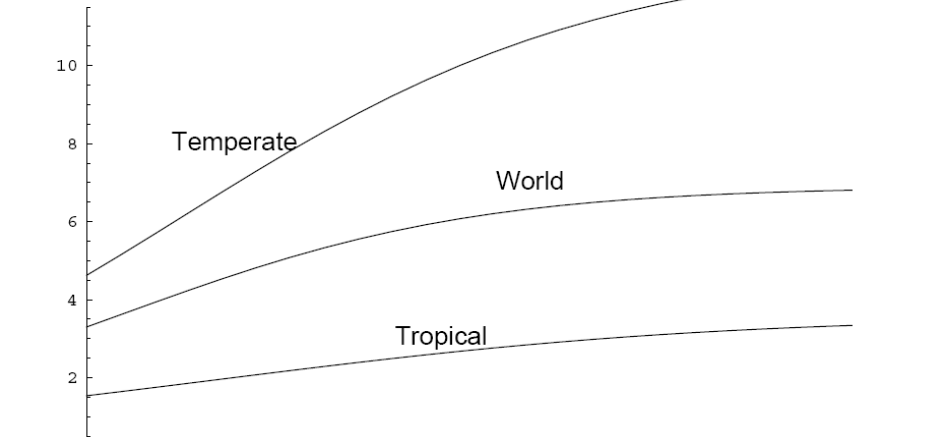
Adaptive control

Projections for Population, GDP, Energy, Carbon

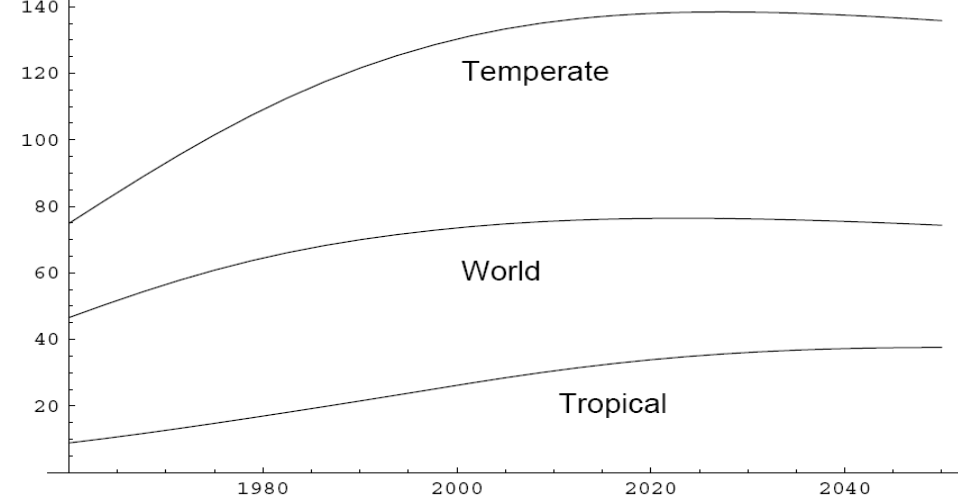


Relevant Factors

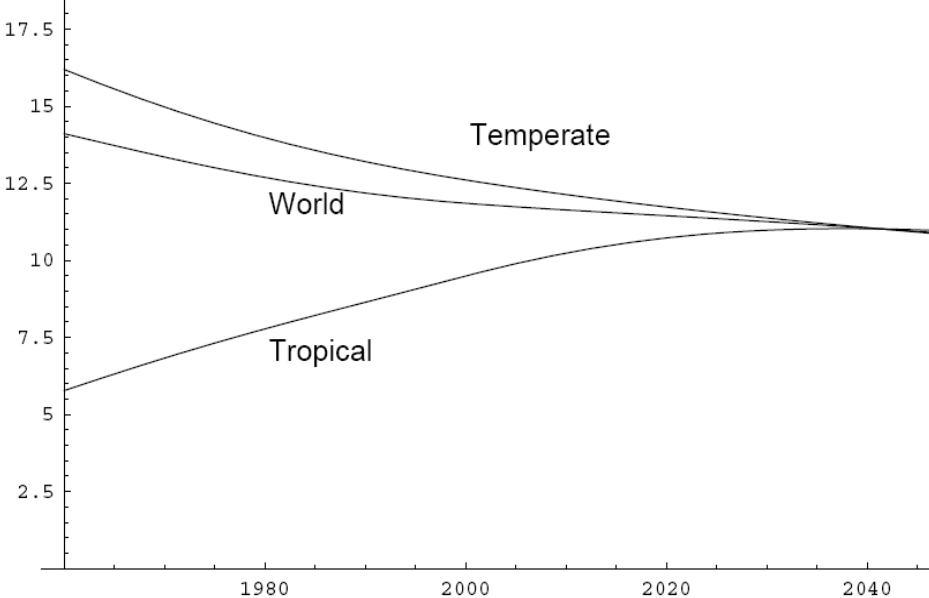
Annual GDP per capita energy use
in thousand 1990 dollars/person



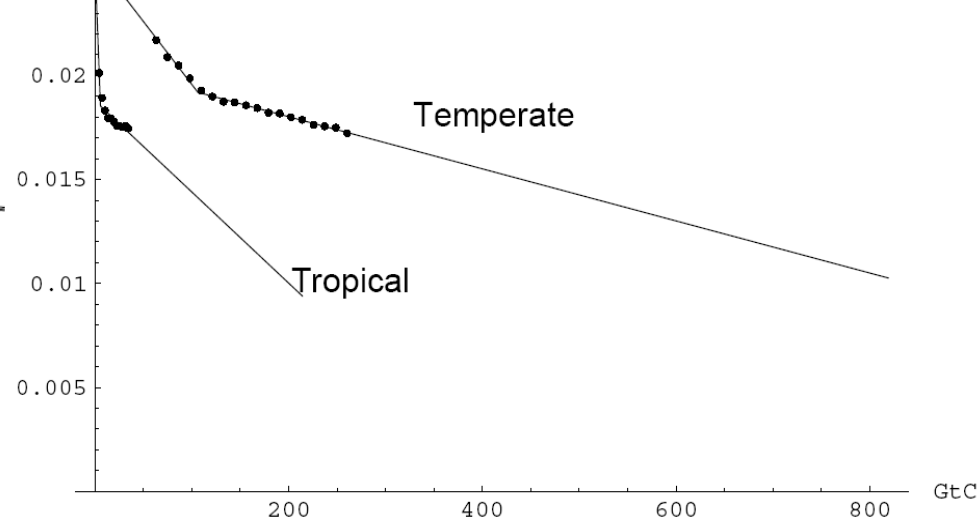
Annual per capita energy use in GJ/person



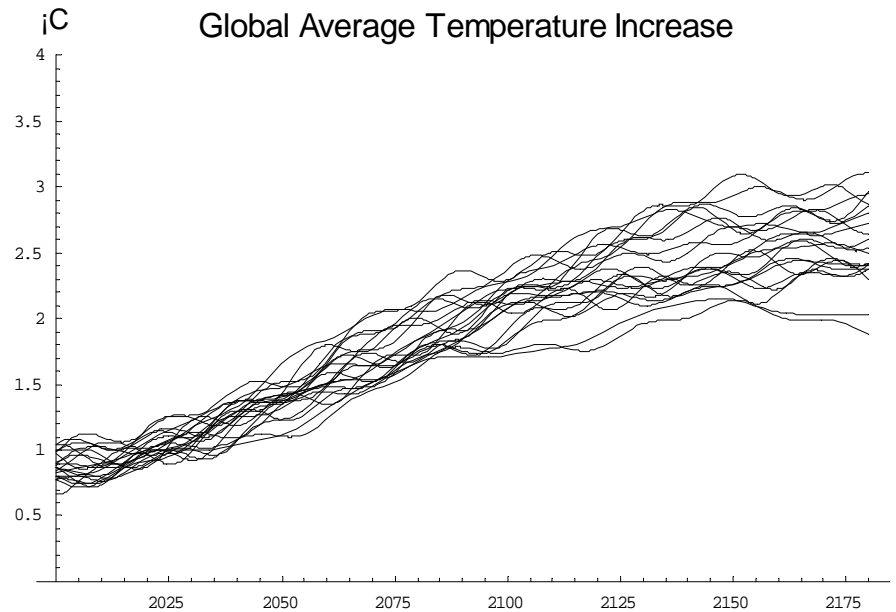
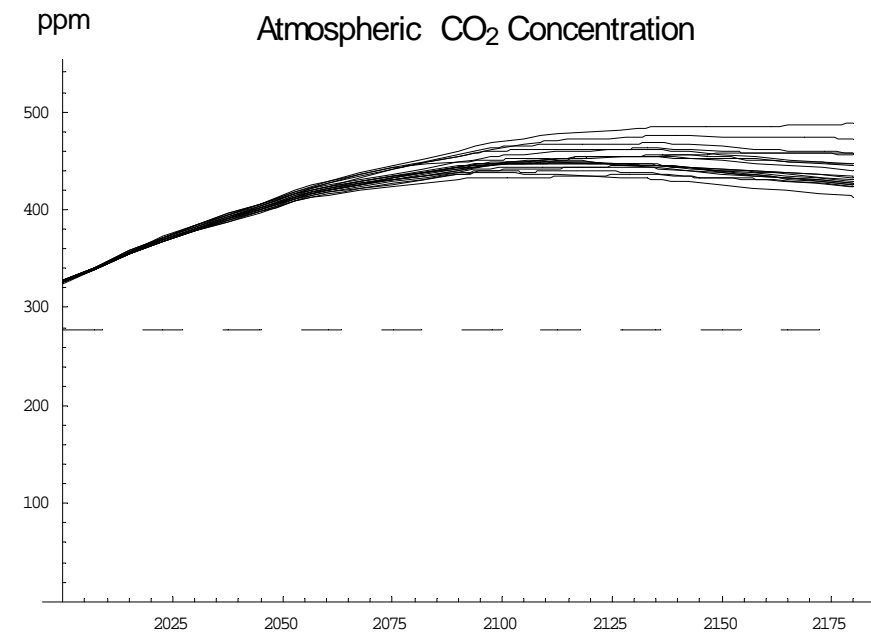
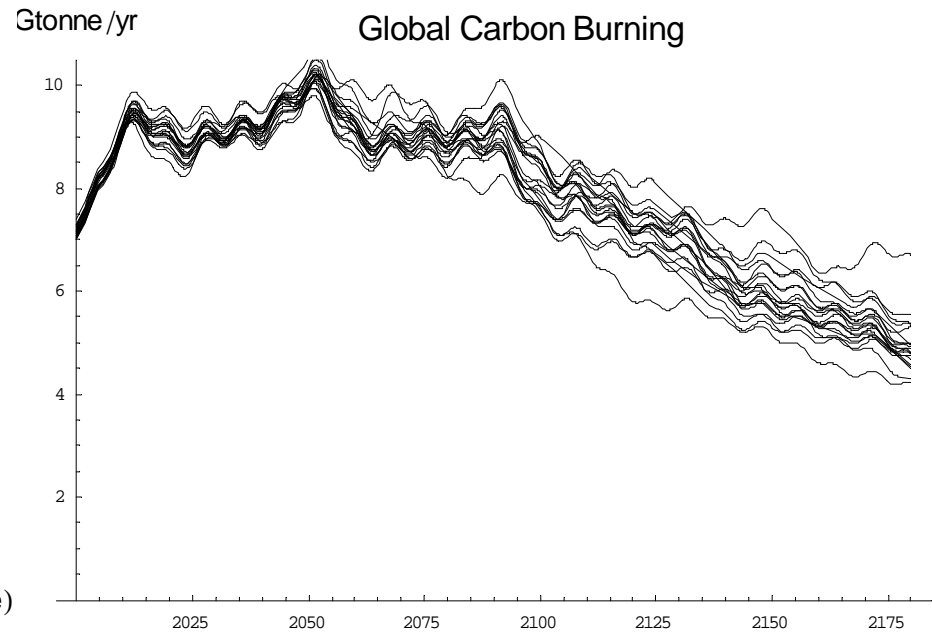
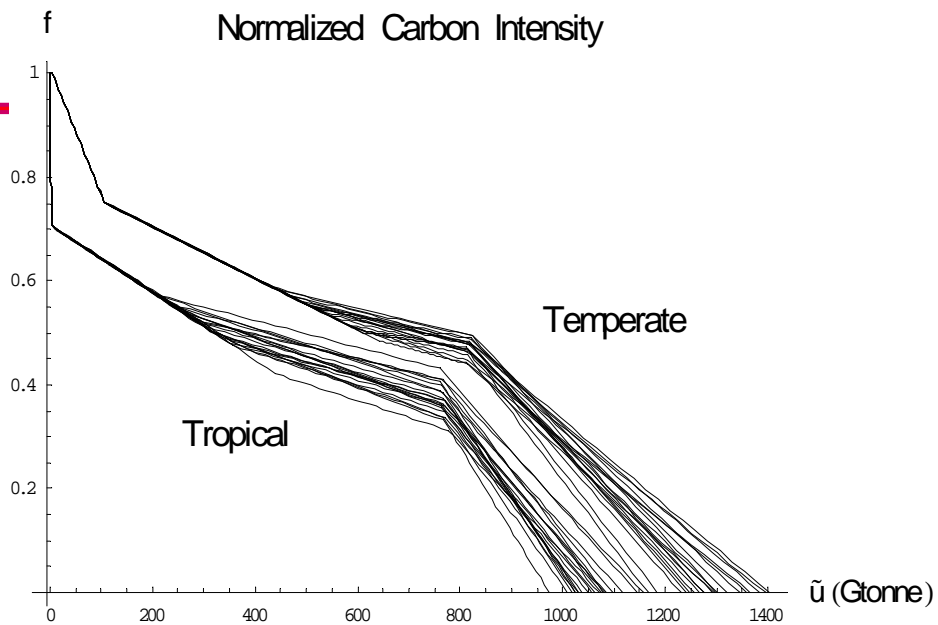
Energy intensity of GDP (GJ per thousand 1990 PPP dollars)



Linear fit carbon intensity of energy use in GtC/EJ

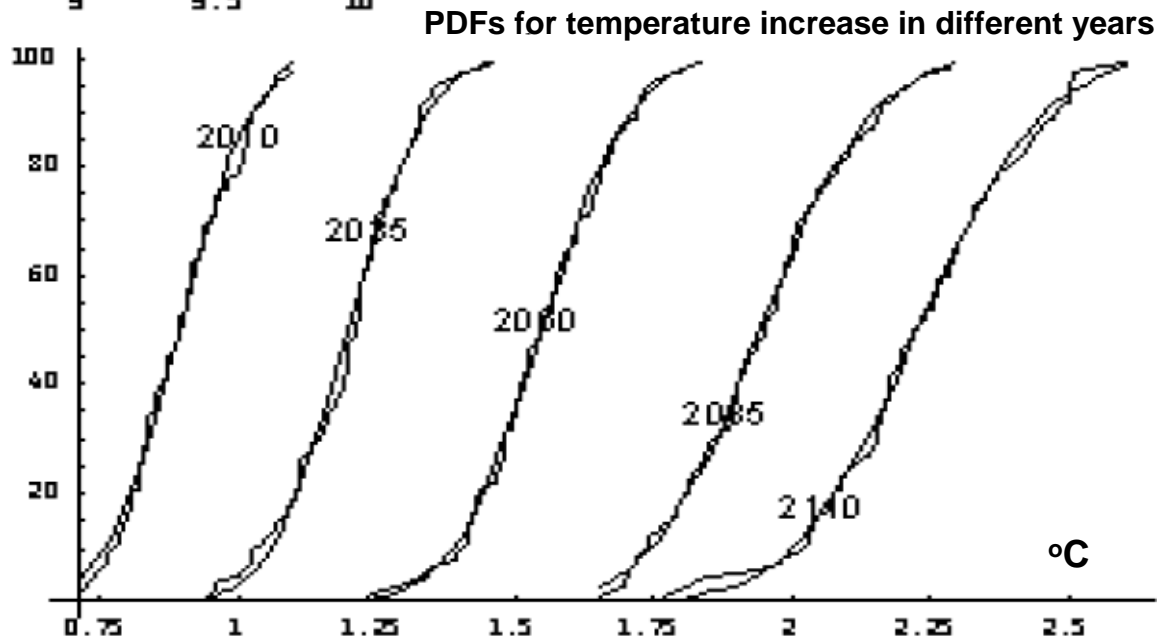
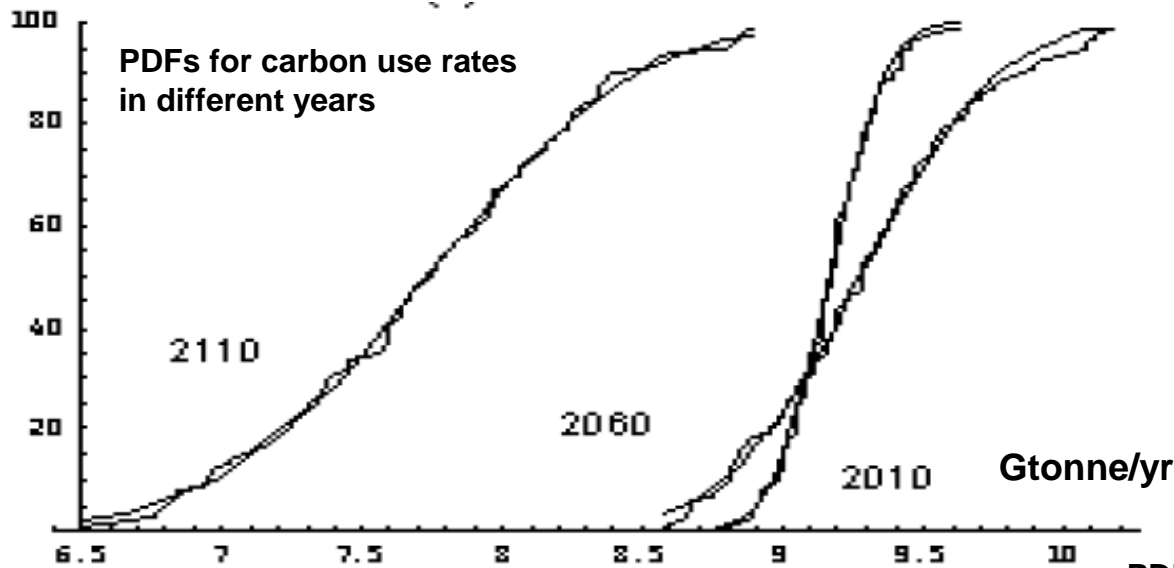


Randomly Sampled Climate Variables



Adapted from Clifford Singer 2005

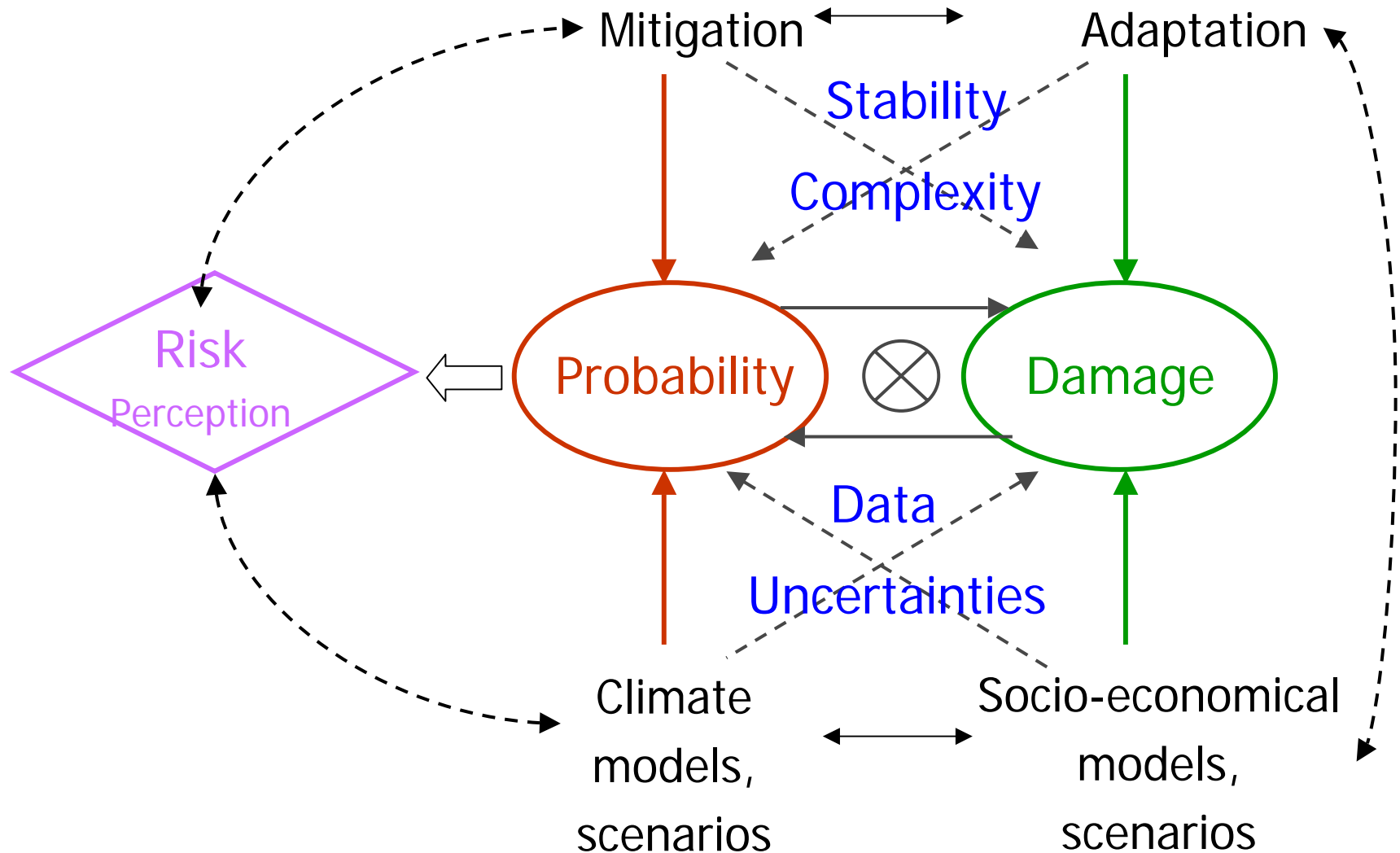
Cumulative Probability Distributions



Cumulative probability distribution centiles (jagged plots), and cumulative normal distributions fit to the central 95 centiles (smooth curves) for the indicated years.

Adapted from Clifford Singer 2005

Factors of Climate Risk Assessment



Emission Reduction: a Global Cooperation Problem

$$G(t) = \sum_i G_i(t)(1 - r_i(t)) \leq G^*(t)$$

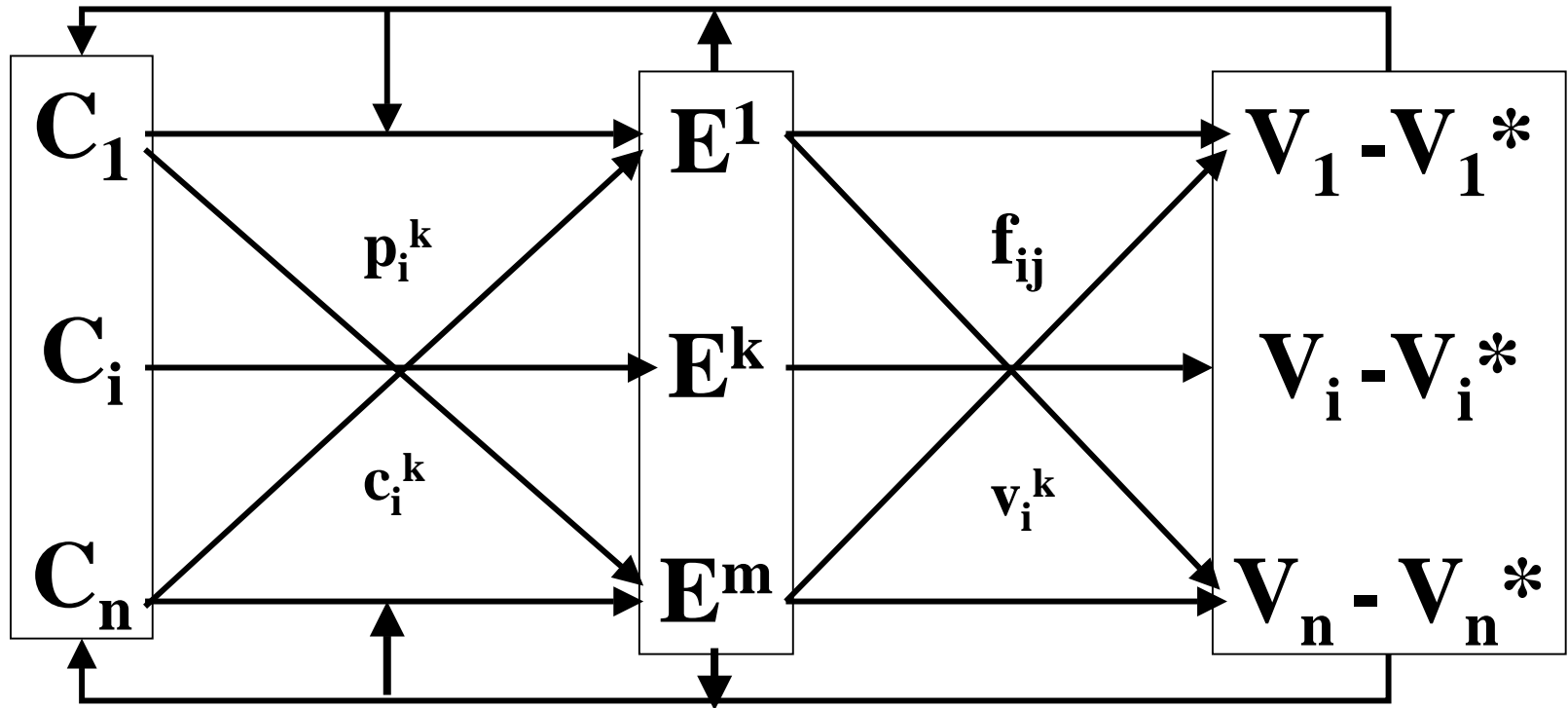
$G(t)$: Global emissions at time t

$G^*(t)$: Global emission target at time t

$G_i(t)$: Baseline emissions path of actor i

$r_i(t)$: Emission reduction of i from baseline

Integrated Assessment with Multiple Actors



Investment

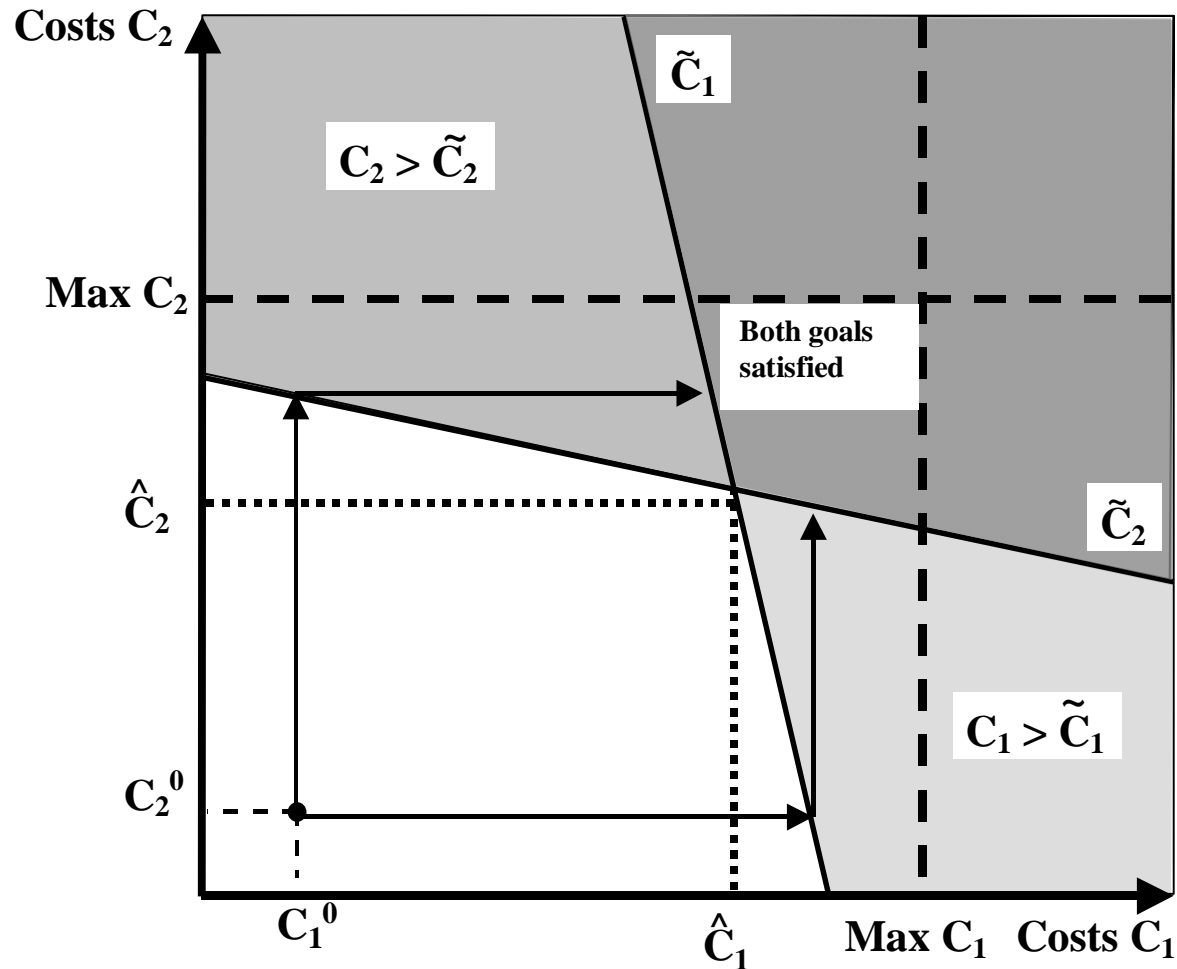
Allocation
Costs
Prices

Energy
Systems

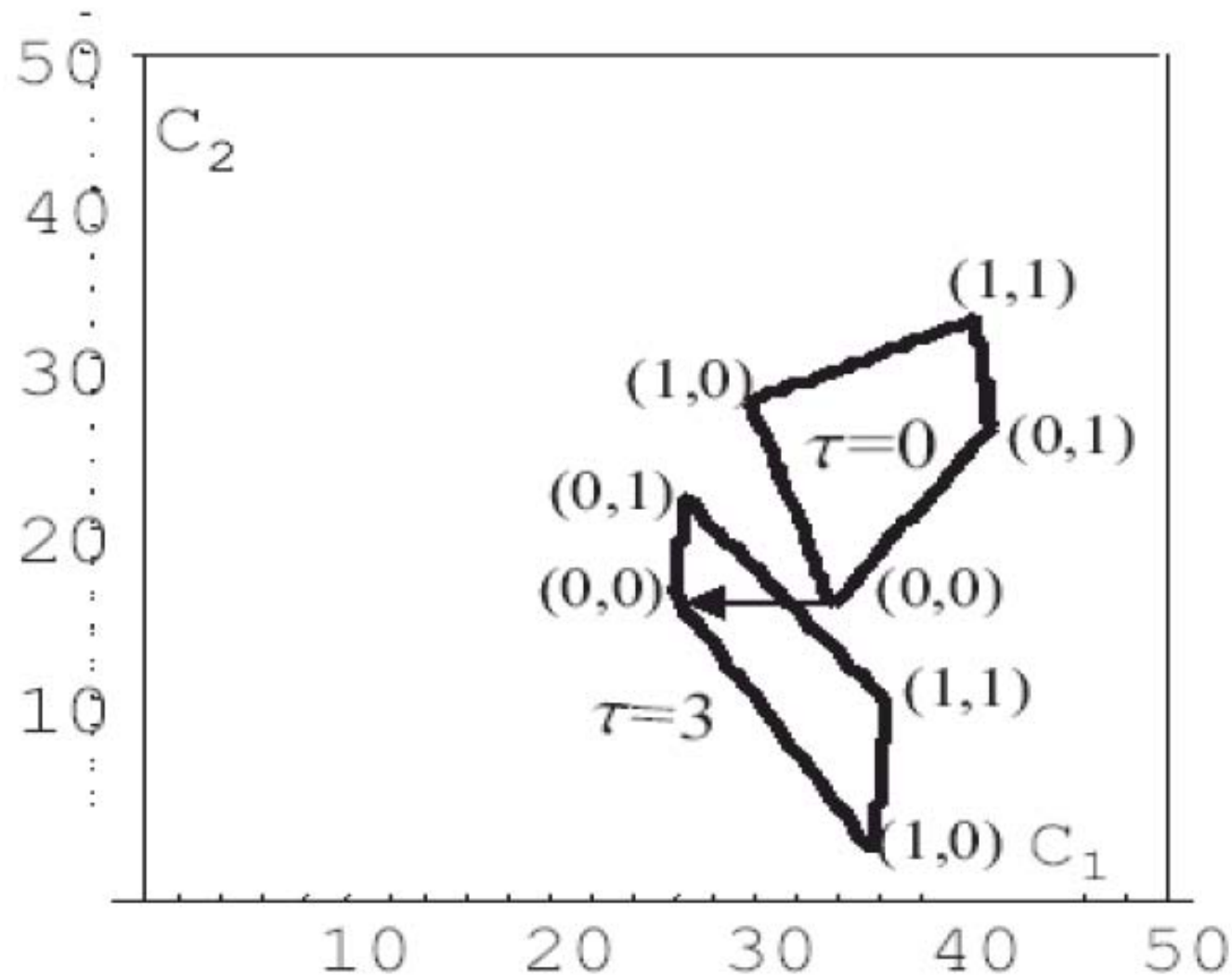
Efficiency
Benefits
Risks

Values
Goals

Compatibility of Targets between Two Actors



Tax-induced Technology Switching Among Economic Competitors

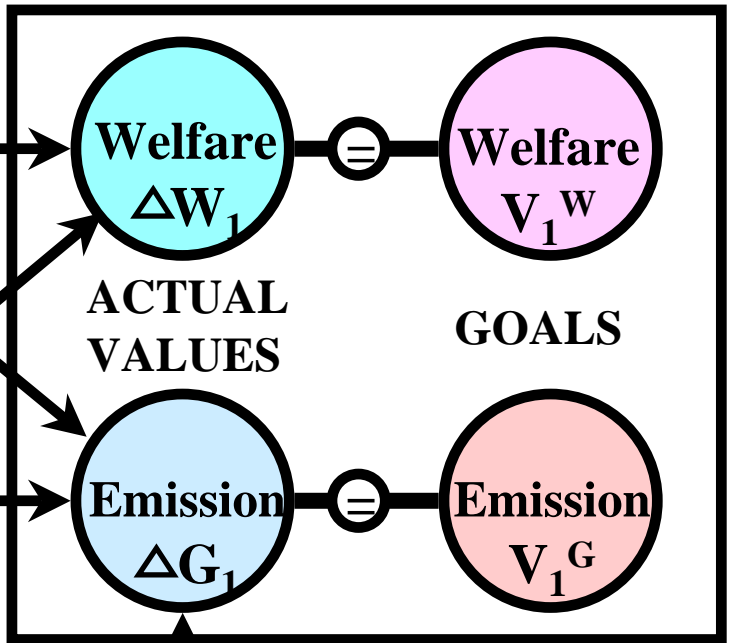
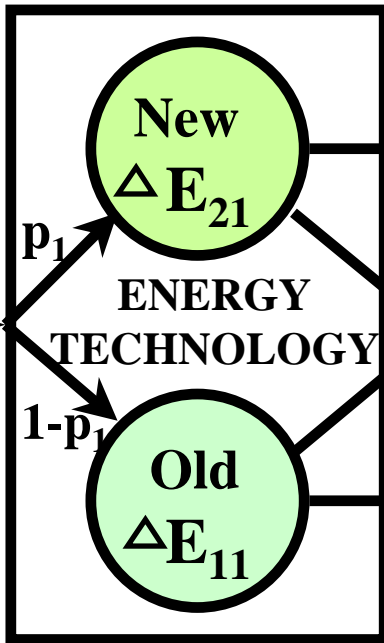


Equilibria in investment space (C_1 , C_2) of two firms with choice between high emission technology ($p=0$) and low emission technology ($p=1$) for tax $\tau = 0$ and $\tau = 3$.

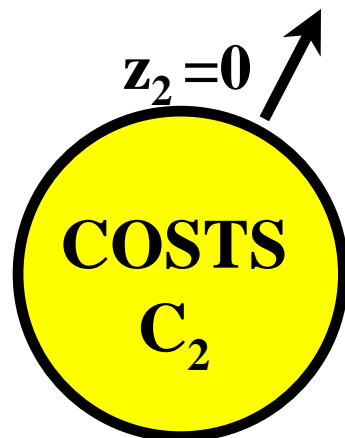
Industrialized Country (IC)



$z_1 C_1$ for Clean Development

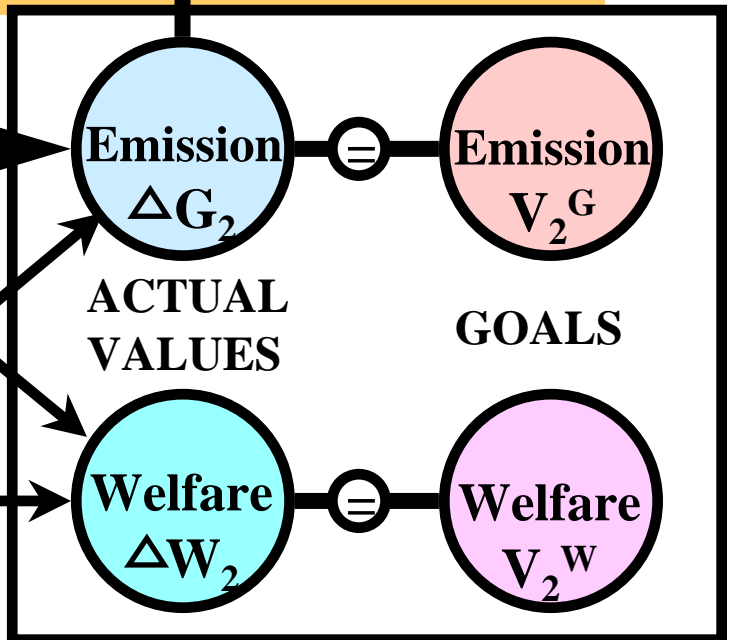
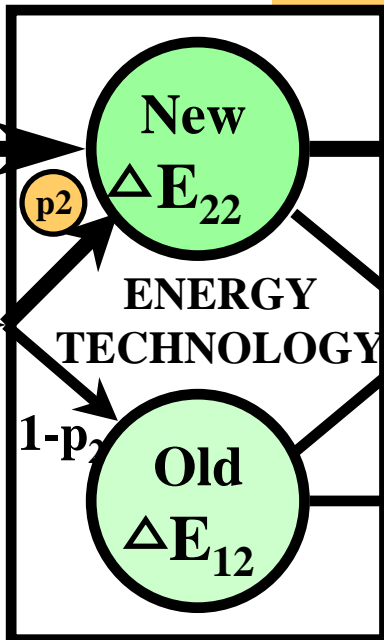


CDM emission reduction for IC

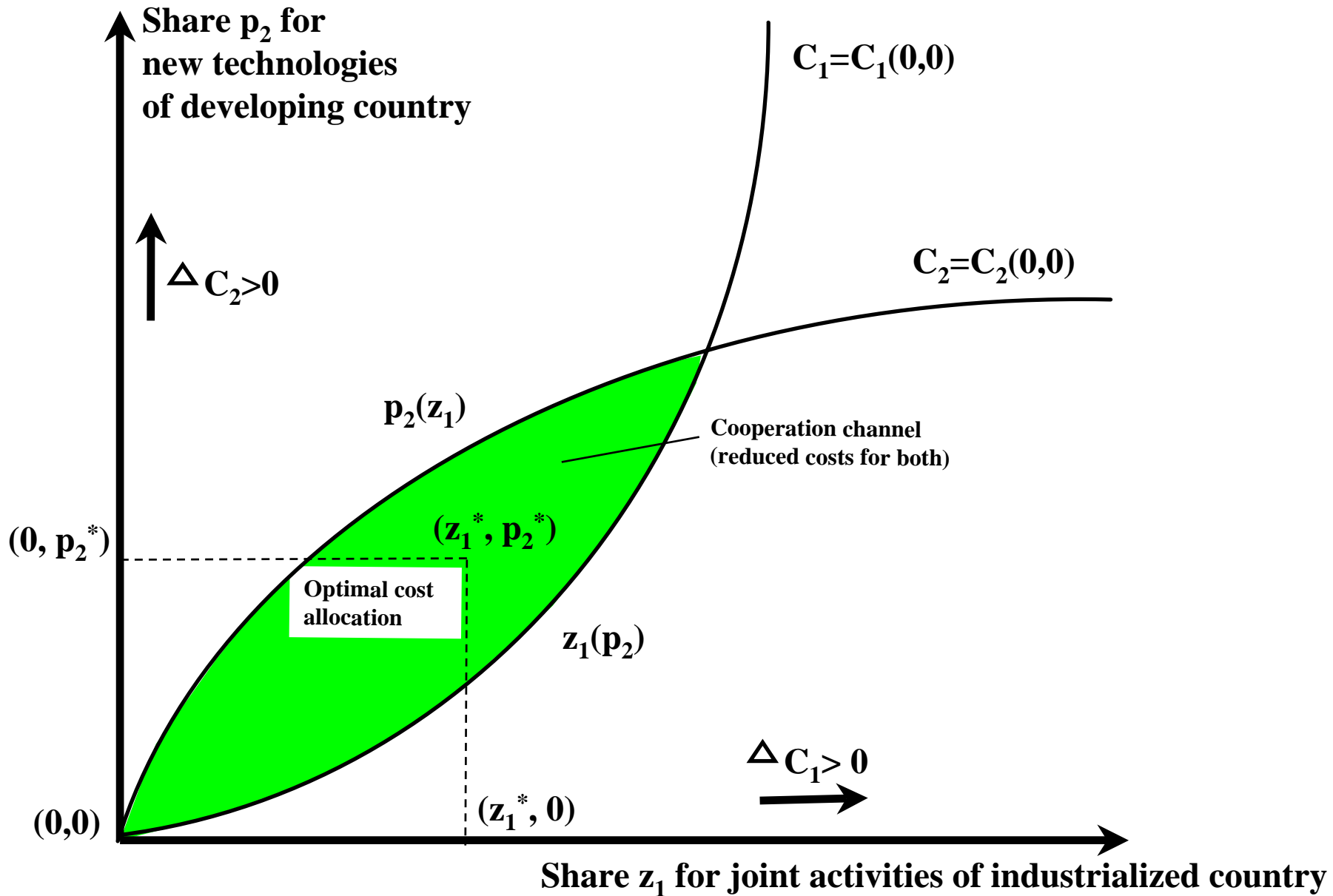


Developing Country (DC)

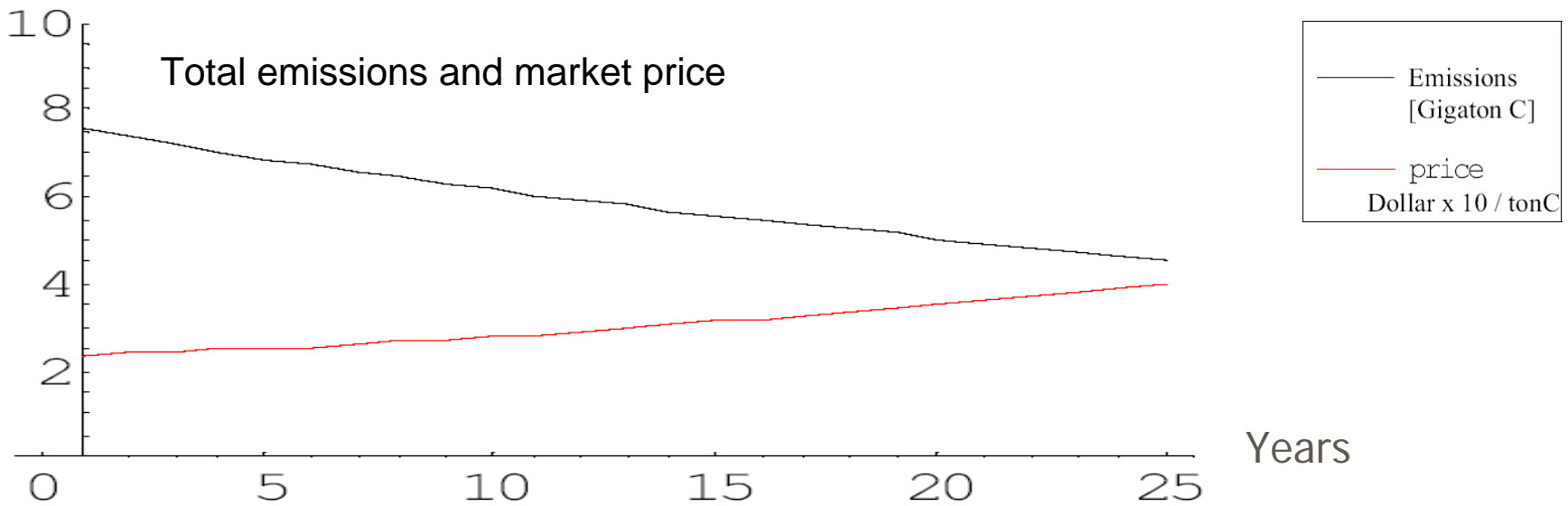
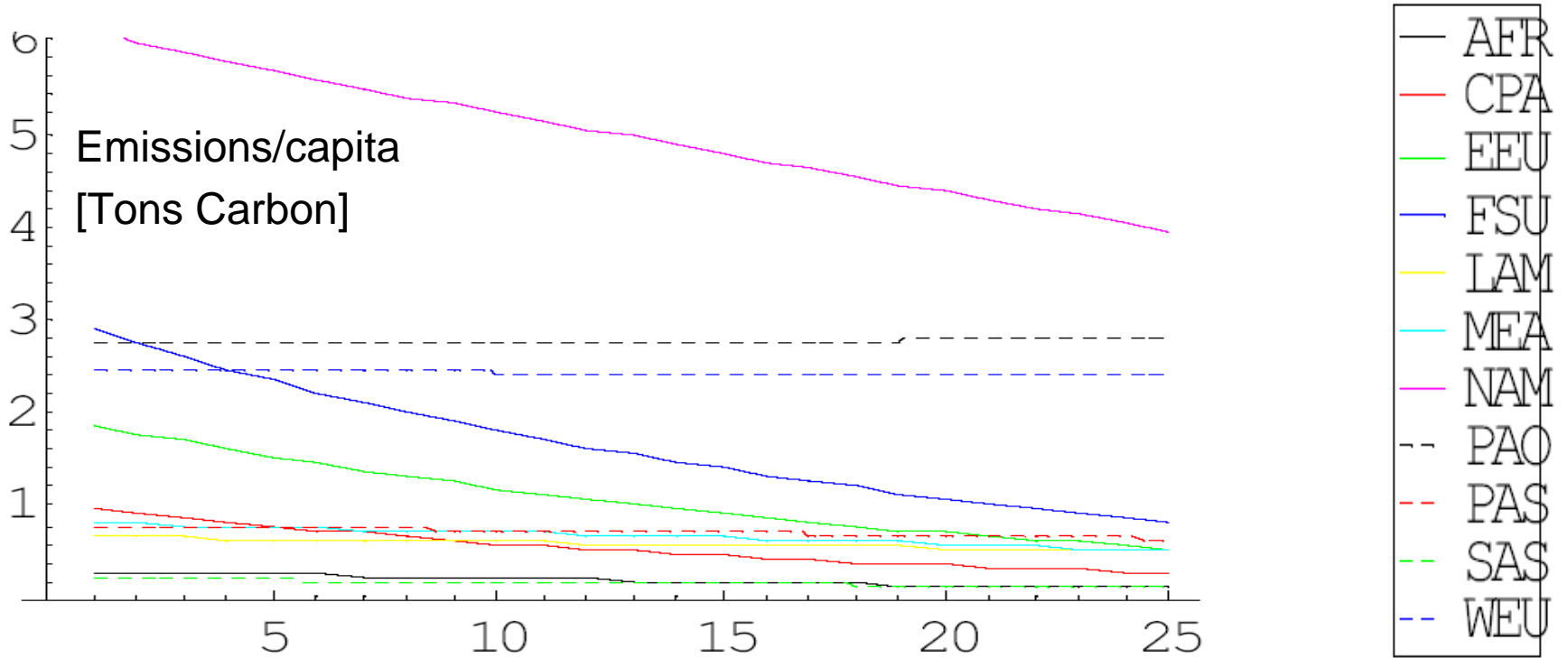
$z_2 = 0$



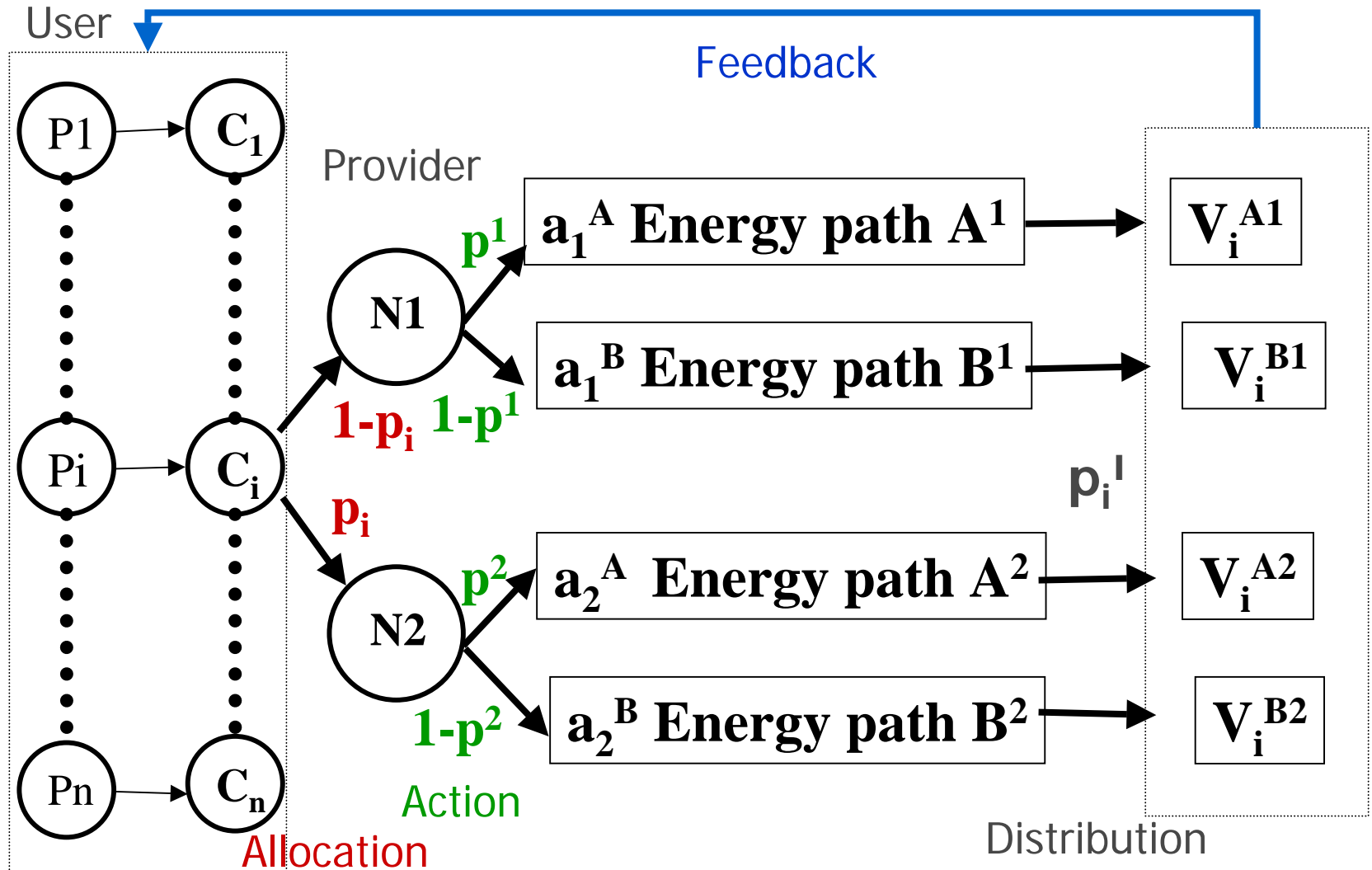
Cooperation Channel for Low Emission Technology



Simulation of Emission Tradings Among 11 World Regions

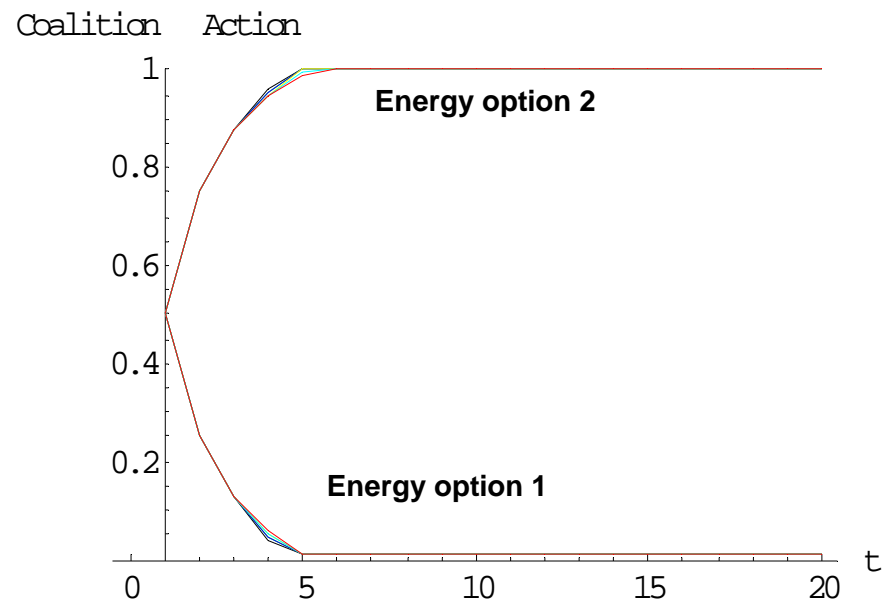
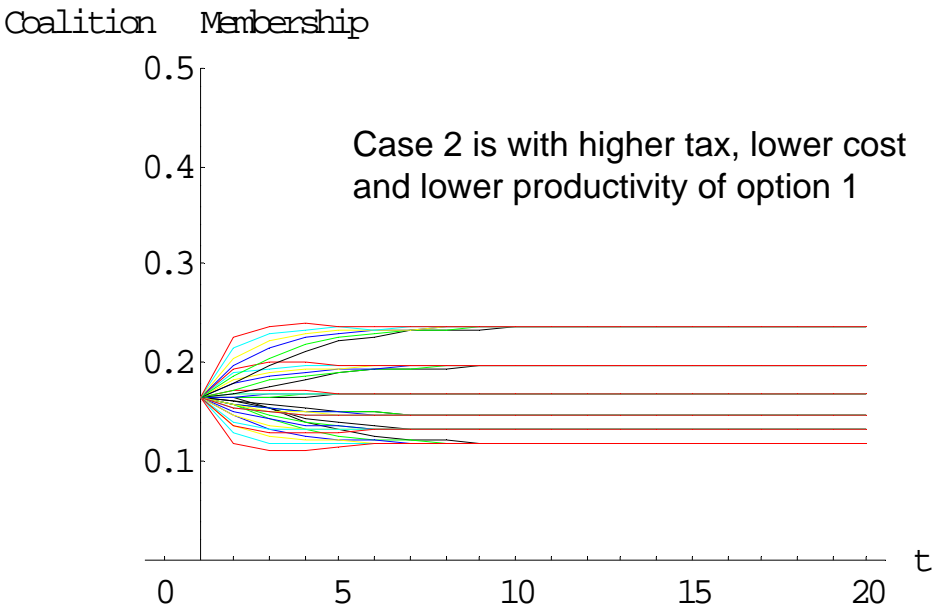
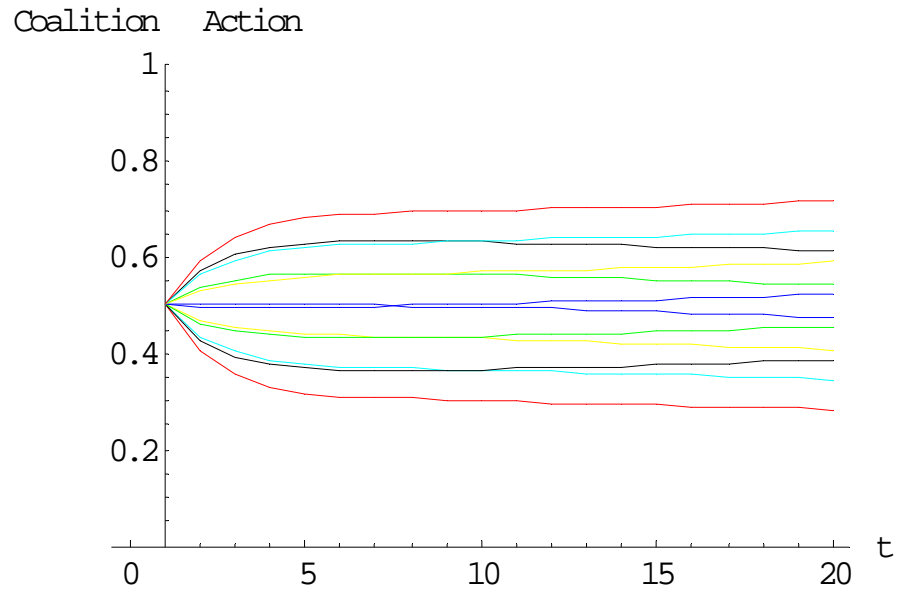
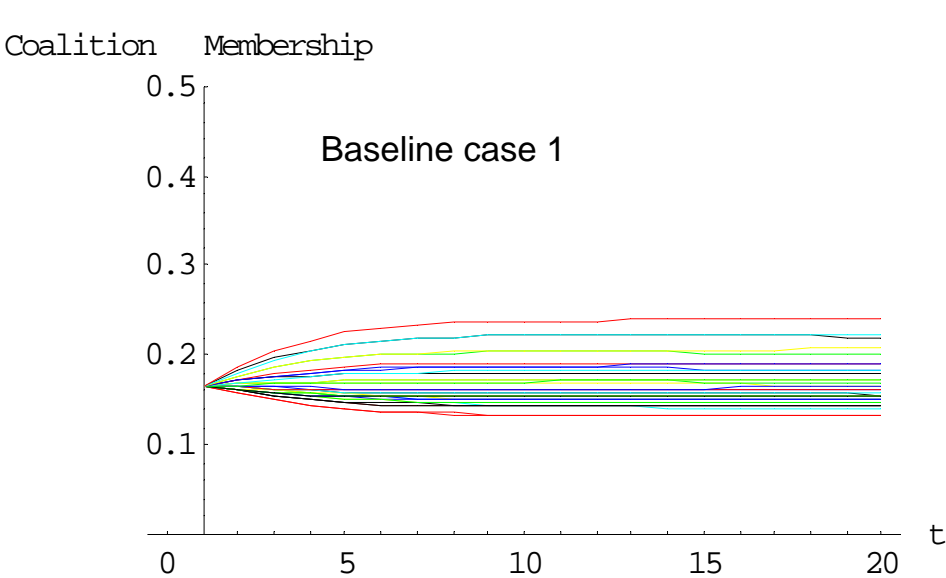


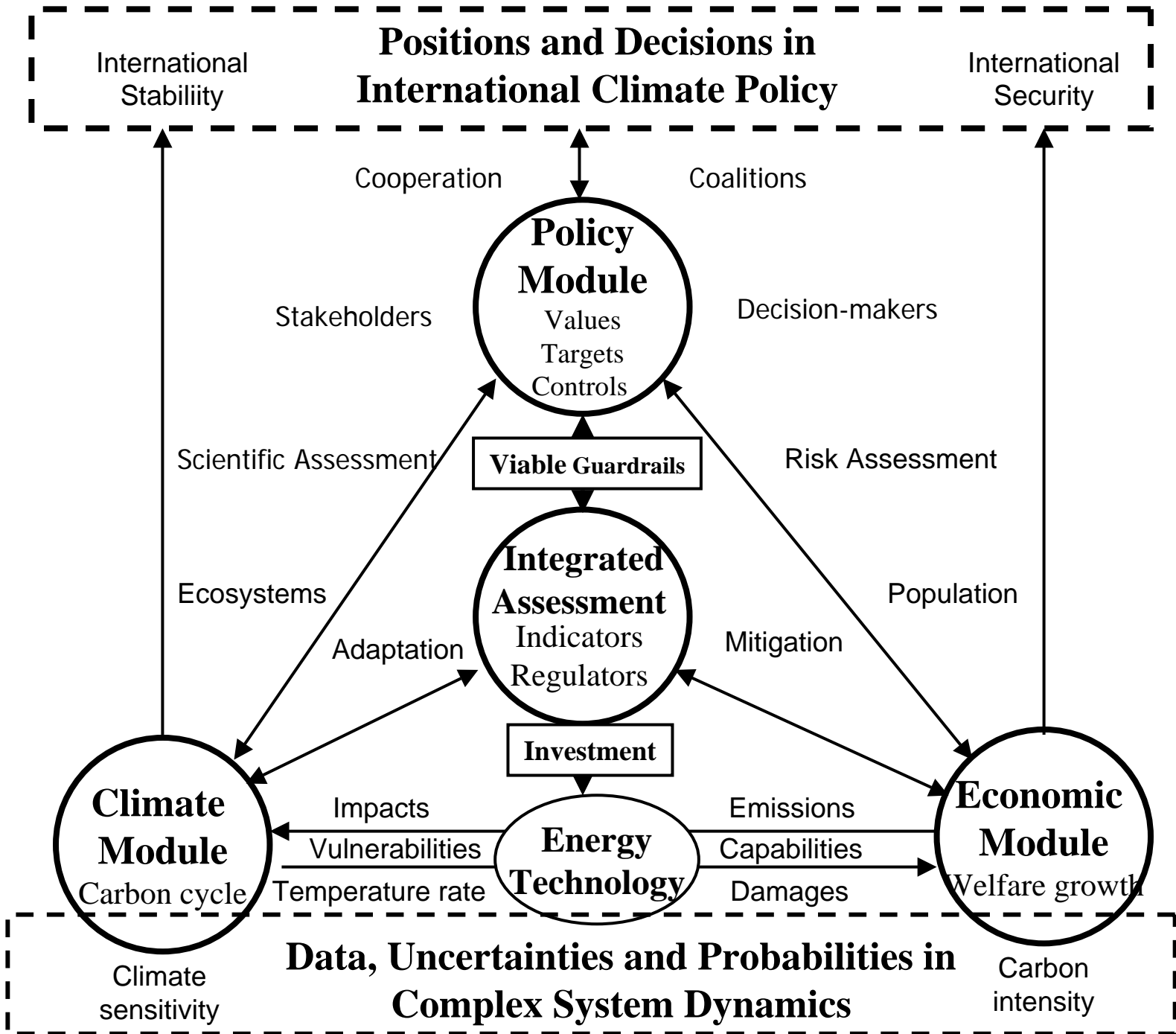
Coalition Formation in Energy Use



Coalitions in Energy Management

Simulation with 6 users and 6 providers of energy





Outlook

- Analyse and compare specific energy technologies and paths with regard to economic and environmental conditions, including climate change and risk assessment
- Use advanced methods and modeling tools within integrated assessment framework
- Provide data-based modeling tools for adaptive control and decision-making under uncertainty
- Develop and integrate climate, economy and decisionmaking tools into a probabilistic integrated assessment framework on emission reductions and climate change
- Involve multi-actor interaction in understanding the chance of realization of policy actions.