Stabilization and Global Climate Policy in a Multi-Gas World

Marcus C Sarofim*, Chris E Forest*, David M Reiner[†], John M Reilly*

*Joint Program on the Science and Policy of Global Change, MIT

[†]Judge Institute of Management Studies, Cambridge University

NIES and EMF Stabilization Workshop

Tsukuba, Japan, Jan. 22-23, 2004

Aim of the Research

- To examine the issues involved in current discussions of stabilization policy given a multi-greenhouse gas world
  - To encourage tighter definition of stabilization in academic and political discussion.
  - To reemphasize the importance of non-CO_2 greenhouse gases for effective, inexpensive temperature reduction on the two century time scale.
  - To examine stabilization under uncertainty.

Article 2 of the Framework Convention on Climate Change

- "The ultimate objective of this Convention... is to achieve... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt... to ensure that food production is not threatened, and to allow economic development to proceed in a sustainable manner."

Definitions of Stabilization

- Many anthropogenic greenhouse gases exist:
  - CO_2, CH_4, N_2O, SF_6, HFCs, etc.
  - Not including “climatically important substances” such as SO_2, black carbon, ozone precursors, etc.
- Stabilize CO_2 only? (EU 550 ppm position)
  - What are assumptions about other gases?
  - SRES A1B is often used for non- CO_2 gases.
- Stabilize overall radiative forcing?
  - Separate targets for each gas? CO_2 equivalents?
- Trading between gases?
  - The use of Global Warming Potentials (GWPs) is incompatible with stabilization.
- When? 2100? 2150? 2500? 3000?

Nature of Two Scenarios: CO2ONLY and GHGTRADE

- Estimate cumulative CO_2 emissions to 2100 consistent with 'stabilization' of CO_2 at 550 ppm
  - Actually 530 ppm in 2100 to allow for gradual stabilization after 2100.
- Allocate CO_2 reductions optimally over time.
  - Discounted marginal abatement equalized over time—price rises at the discount rate.
- Expand constraint to Other GHGs
  - Allow GHG trading using 100-year GWP to achieve reductions equal to CO_2 only case
  - Considered proportional reduction case (not shown)

Considerations

- Emissions path consistent with a frequently discussed policy target, reinterpreted in multigas terms.
  - Other interpretations possible.
- Economic rationale for initial allocation of reductions over time
  - but once expanded to other GHGs its no longer quite true
- Known concentration and climate outcomes associated with these emissions scenario
- Economic and climate outcomes are true for EPPA/MIT IGSM—not necessarily for other models.

Further Considerations

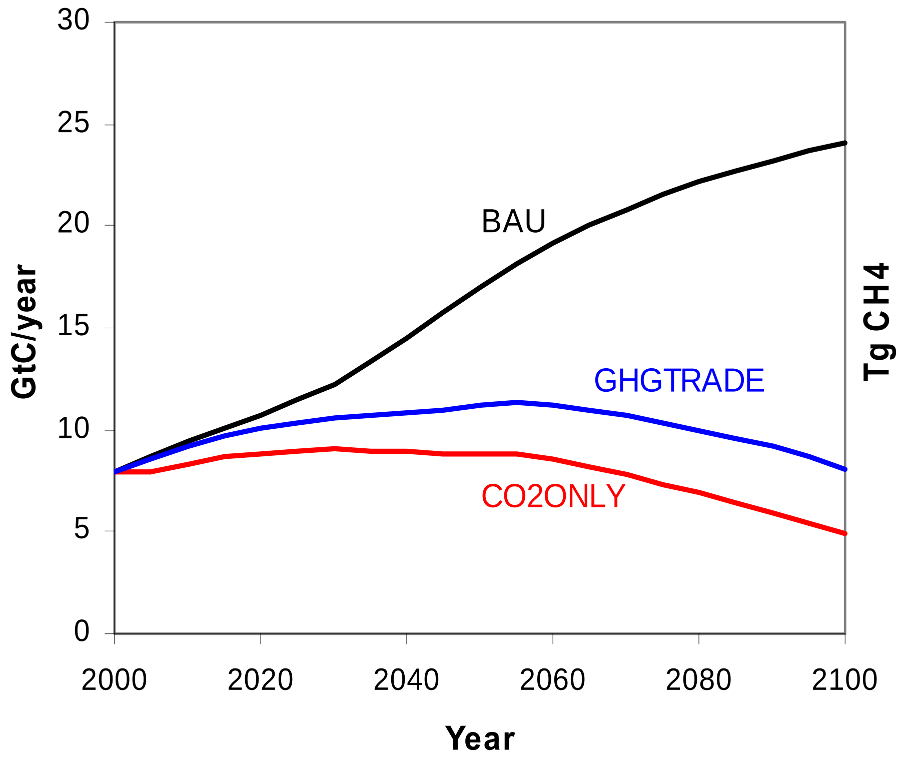
- Initial CO_2 path was achieved with a globally uniform carbon tax– equal marginal costs.
- After adding other GHGs, reinterpreted as a quantity constraint
- Concentration and climate effects depend little on the regional allocation
  - Regionally reallocate global totals as desired, and still be consistent with concentration and climate results.

EPPA: An Economic/Emissions Model

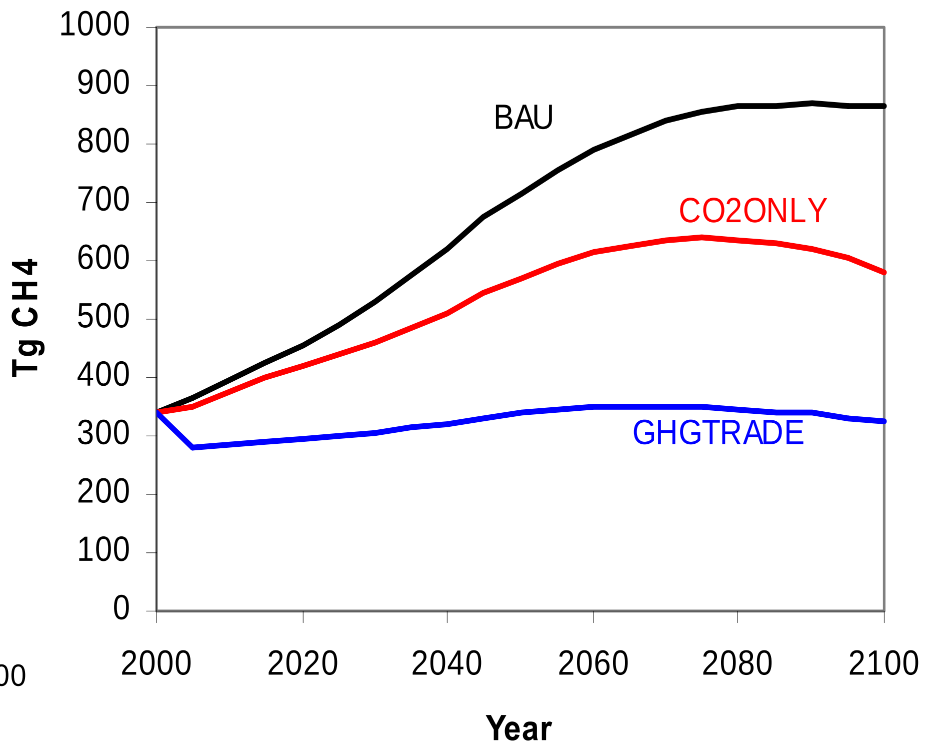
- CGE model of the world economy with all human activities and all CIS's.
  - GHGs: CO_2, CH_4, N_2O, SF_6, PFC, HFC .
  - Other air pollutants: NO_X, SO_X, CO, NMVOC, NH_3 and carbonaceous particulates.
  - Activities: Energy combustion and production, agriculture and land use, industrial processes, waste disposal (sewage & landfills).
- Designed for the 100 year time scale.

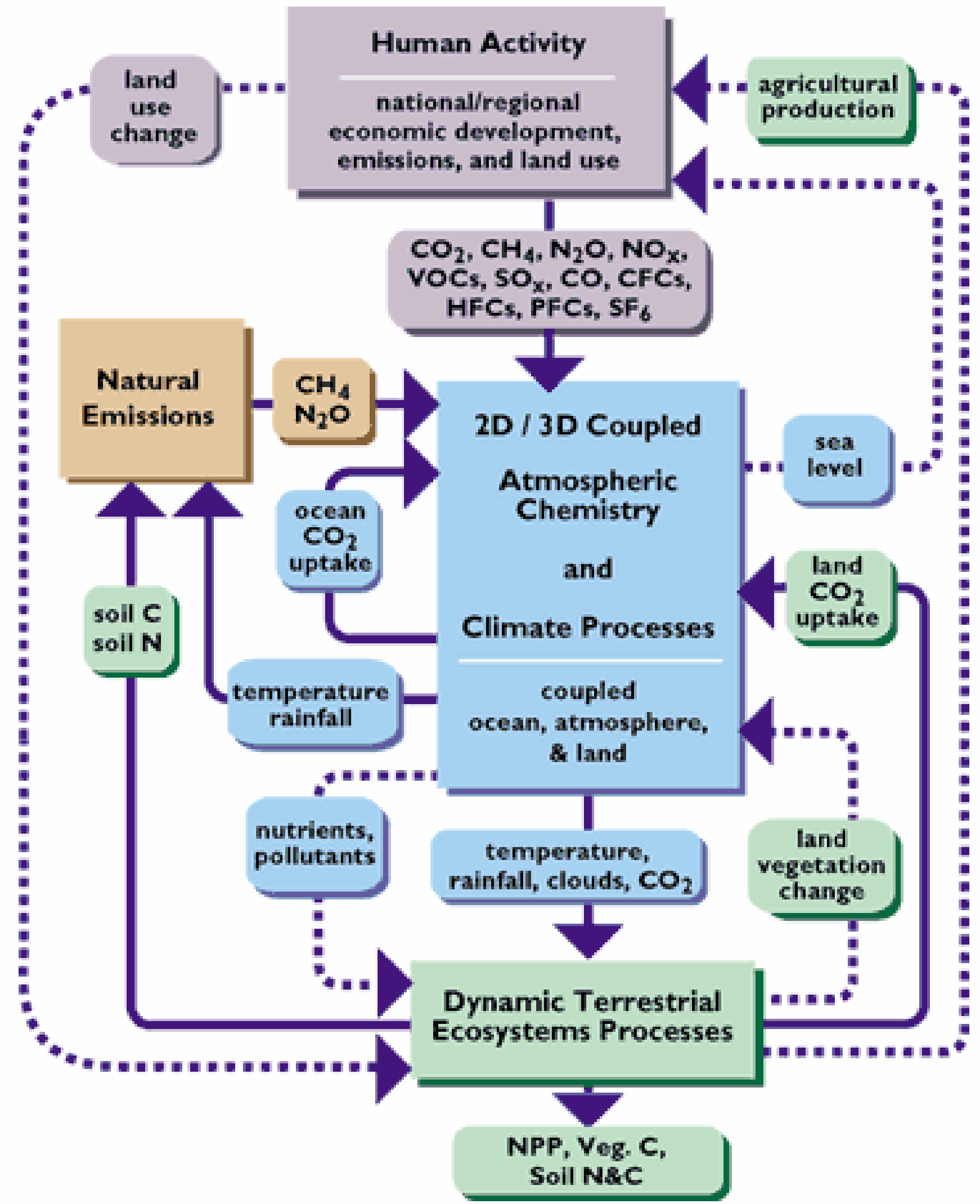
Emission paths (550 ppm)

Carbon Path



Methane Path





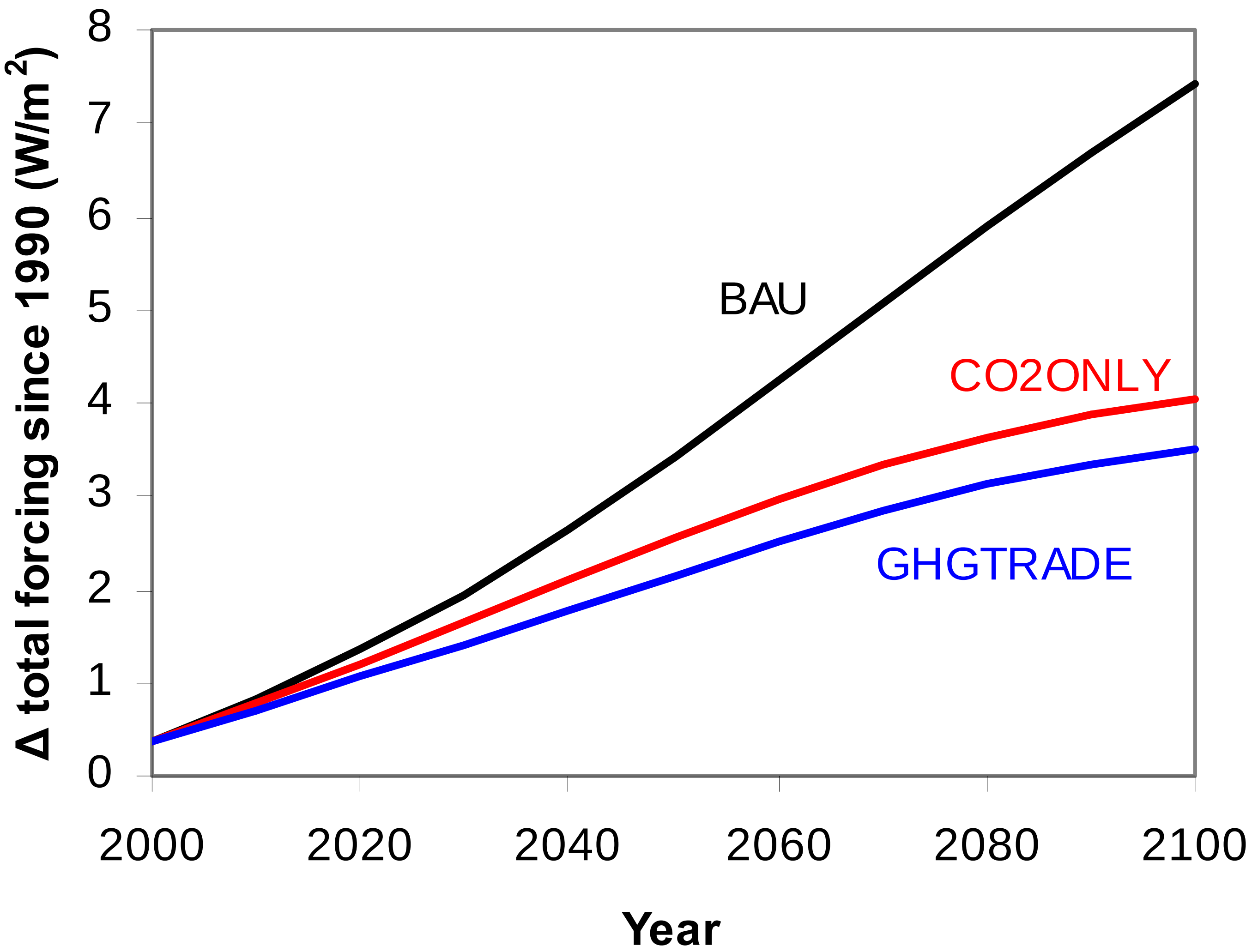
The MIT IGSM

A coupled chemistry, climate, ocean, and ecosystem model.

Some Aspects of the MIT IGSM

- Natural systems (ocean and terrestrial) integrated part of the coupled atmosphere-ocean model
  - ocean and terrestrial biology of C uptake
  - natural CH_4, N_2O, C affected by climate and atmospheric concentrations of CO_2
- Carbon from human land use assumed to be neutral over the century
- Active and integrated atmospheric chemistry resolved for urban and rural conditions
  - Tropospheric ozone as an additional warming effect
  - Sulfate aerosols as cooling effect
  - Oxidation of CH_4 explicit so lifetime is endogenous

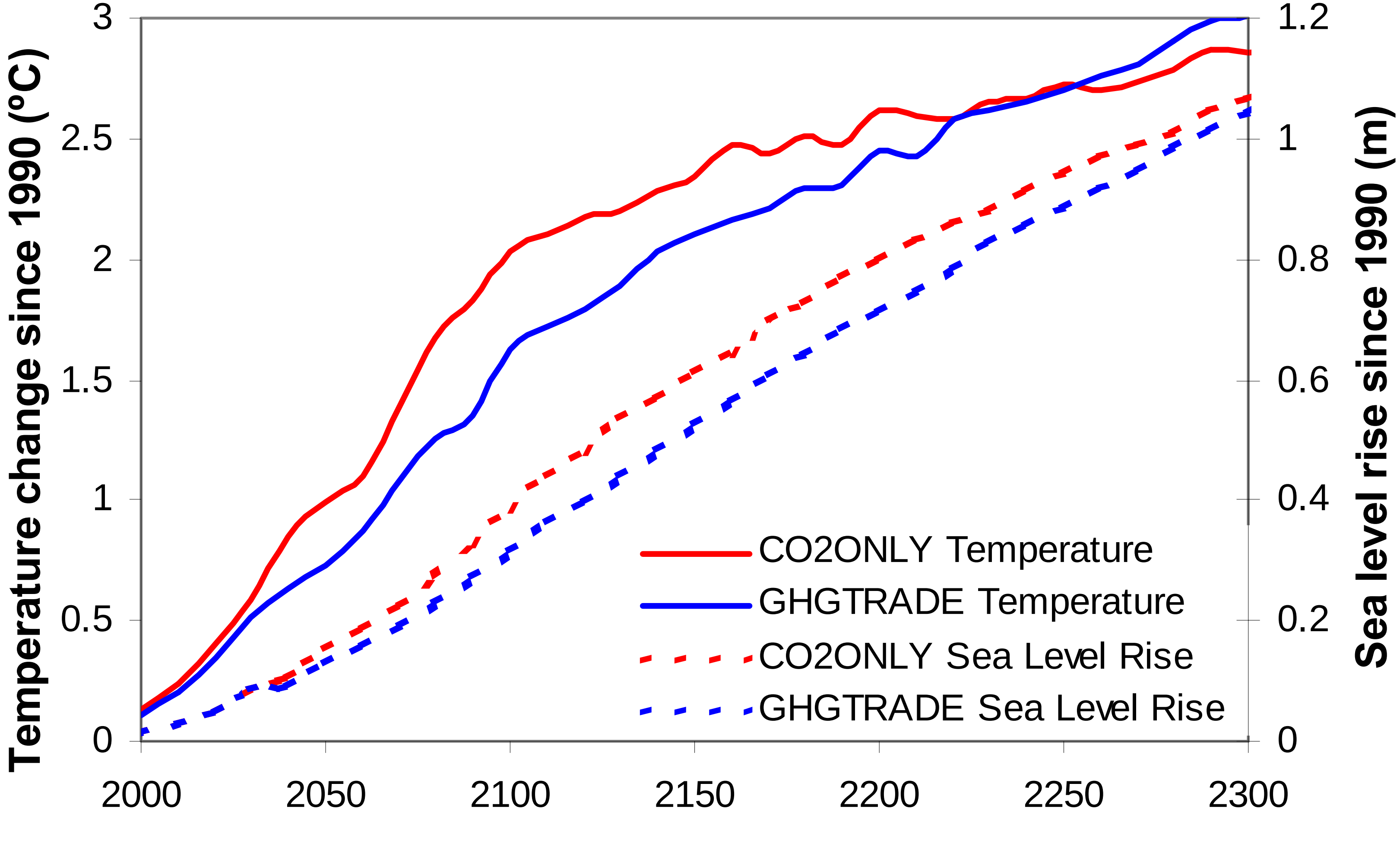
Total GHG Forcing (change since 1990)



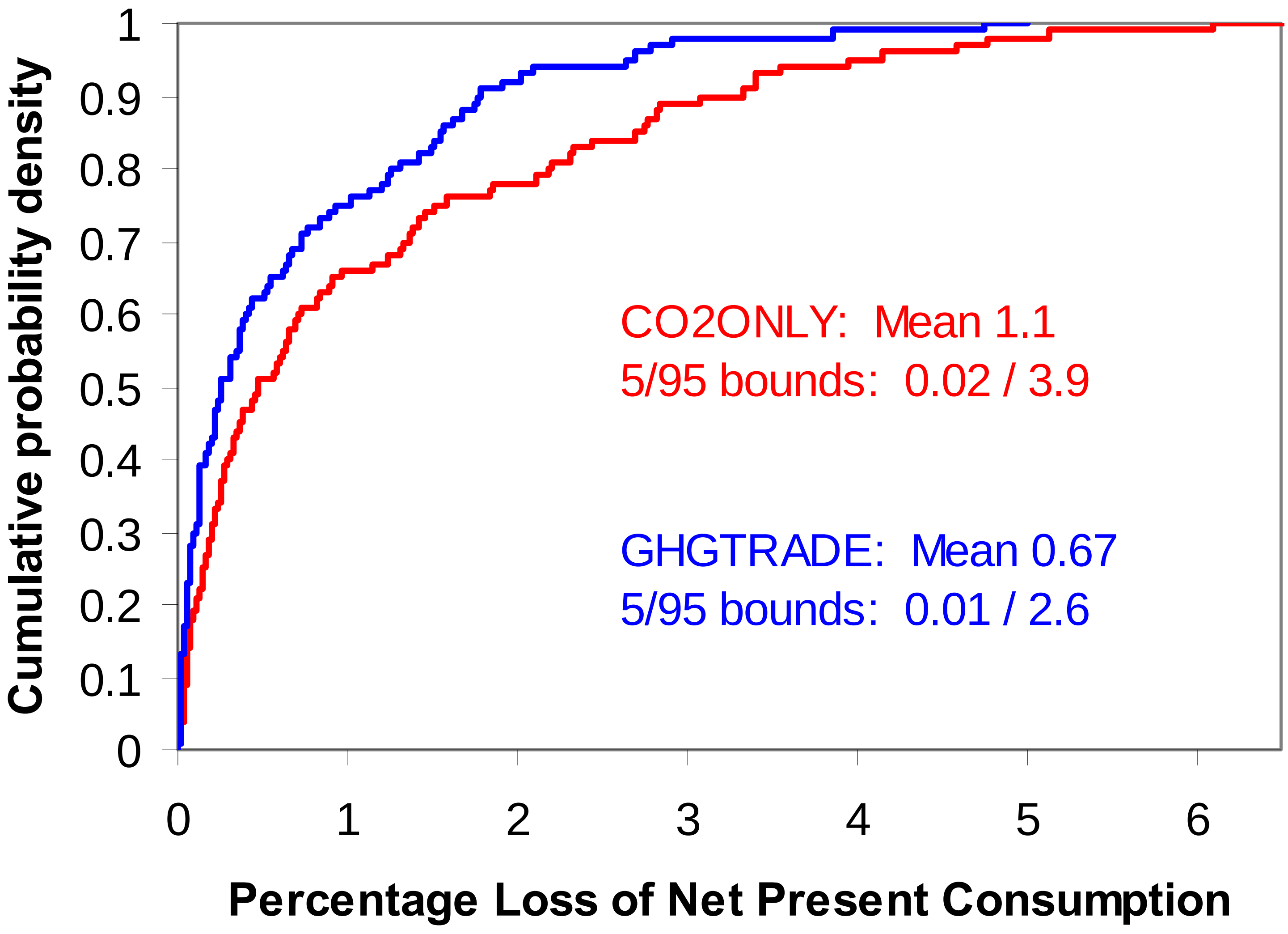
Results in 2100

	Temperature Reduction (From 2.8 ºC)	Reduction in Net Present Consumption
CO2ONLY	0.75 ºC	1.2%
GHGTRADE	1.18 ºC	0.5%

Long Term Studies (to 2300)

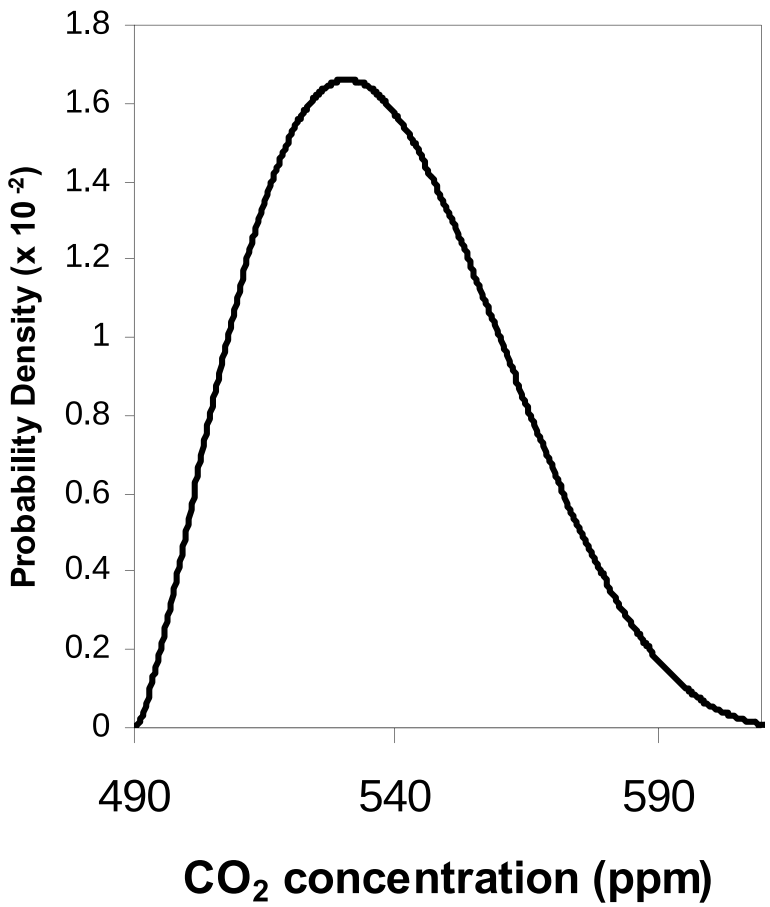


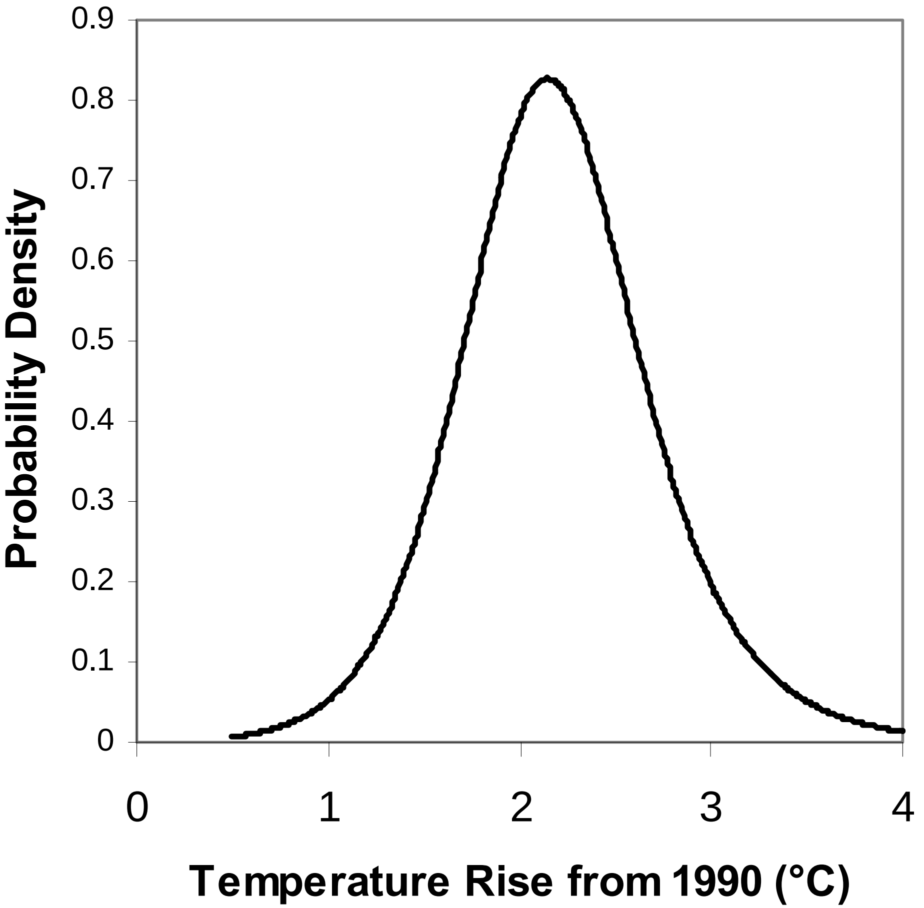
Uncertainty in Policy Costs



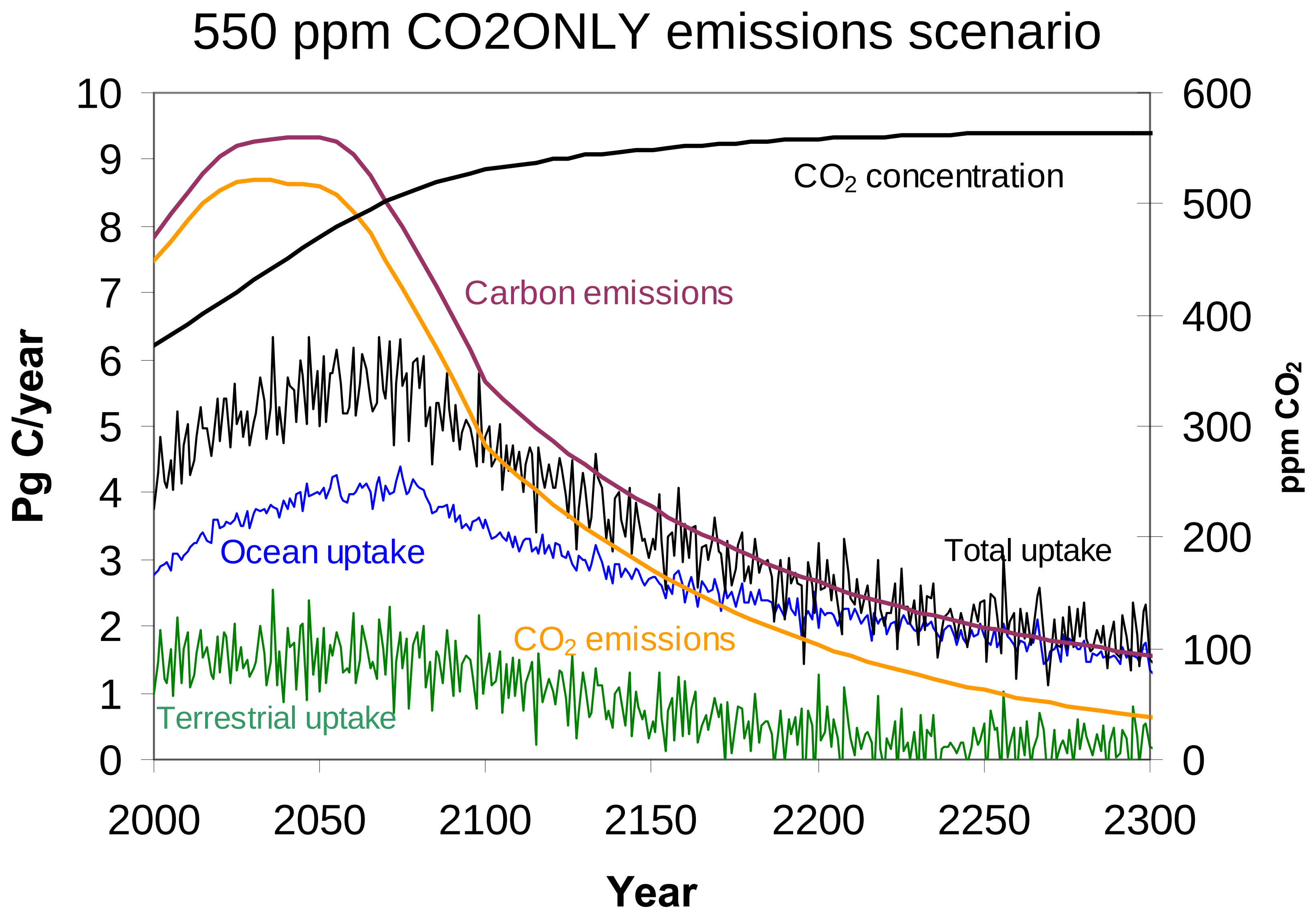
Uncertainty in Climate System Parameters

550 ppm CO2ONLY emissions scenario





Carbon Uptake



CAVEATS

- Modeling
  - Results depend heavily on abatement curves and technology assumptions in model.
  - Discount rate impacts emissions path and cost calculations: Absolute numbers but not conclusions are sensitive to choice of rate.
- Policy Implementation
  - Non-CO_2 sources are hard to monitor.
  - Reducing CO_2 emissions may require capital investments which should be started early.

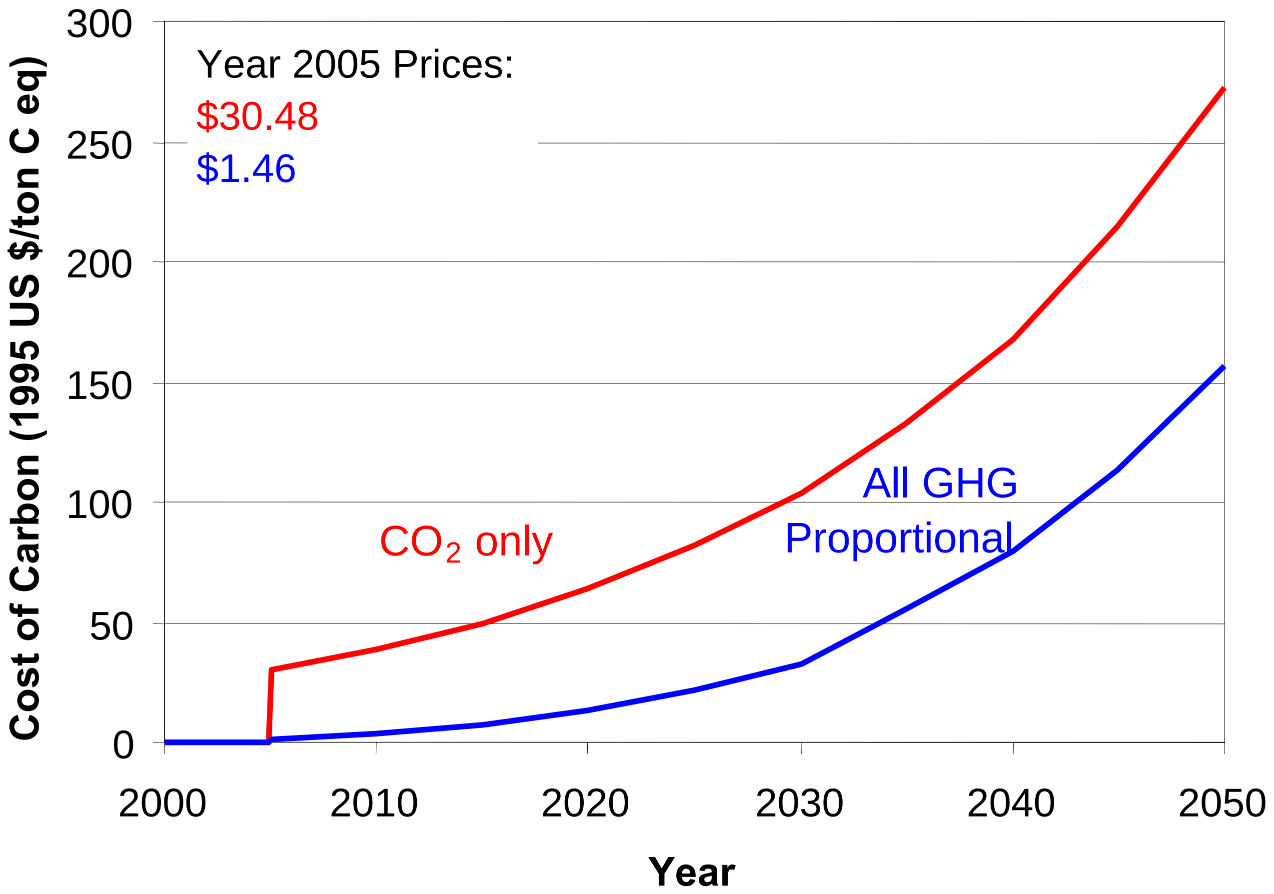
Future Work

- Uncertainty:
  - Impact of other gas emission uncertainty on global temperature change results.
  - Determining carbon emissions pathways given carbon uptake uncertainty.
  - Tradeoffs between cost and damages.
- Policy Improvements
  - Devising an "optimum cost over time" all-GHG policy.
  - More realistic policies: developing countries should have differentiated goals.

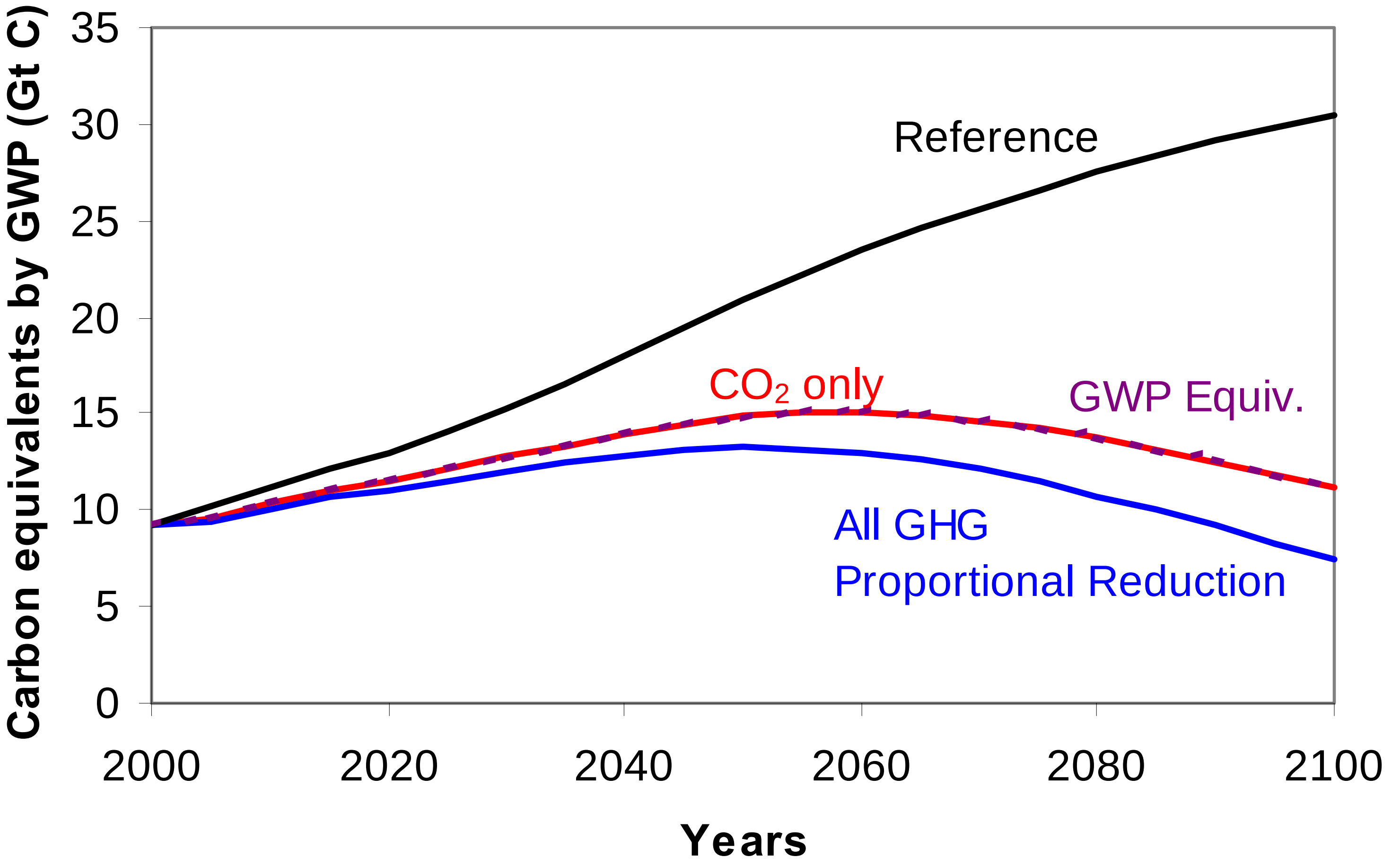
Conclusions

- Stabilization of carbon dioxide concentrations can be met at reasonable costs. However, these costs will be much less if trading is allowed between all gases. Additionally, an all-gas policy is much more effective than CO_2 only policies on the two century scale.
- Uncertainty in costs and uncertainty in impacts should be incorporated into the determination of appropriate targets.
- Imprecision in language should be addressed before creating long term policy frameworks.

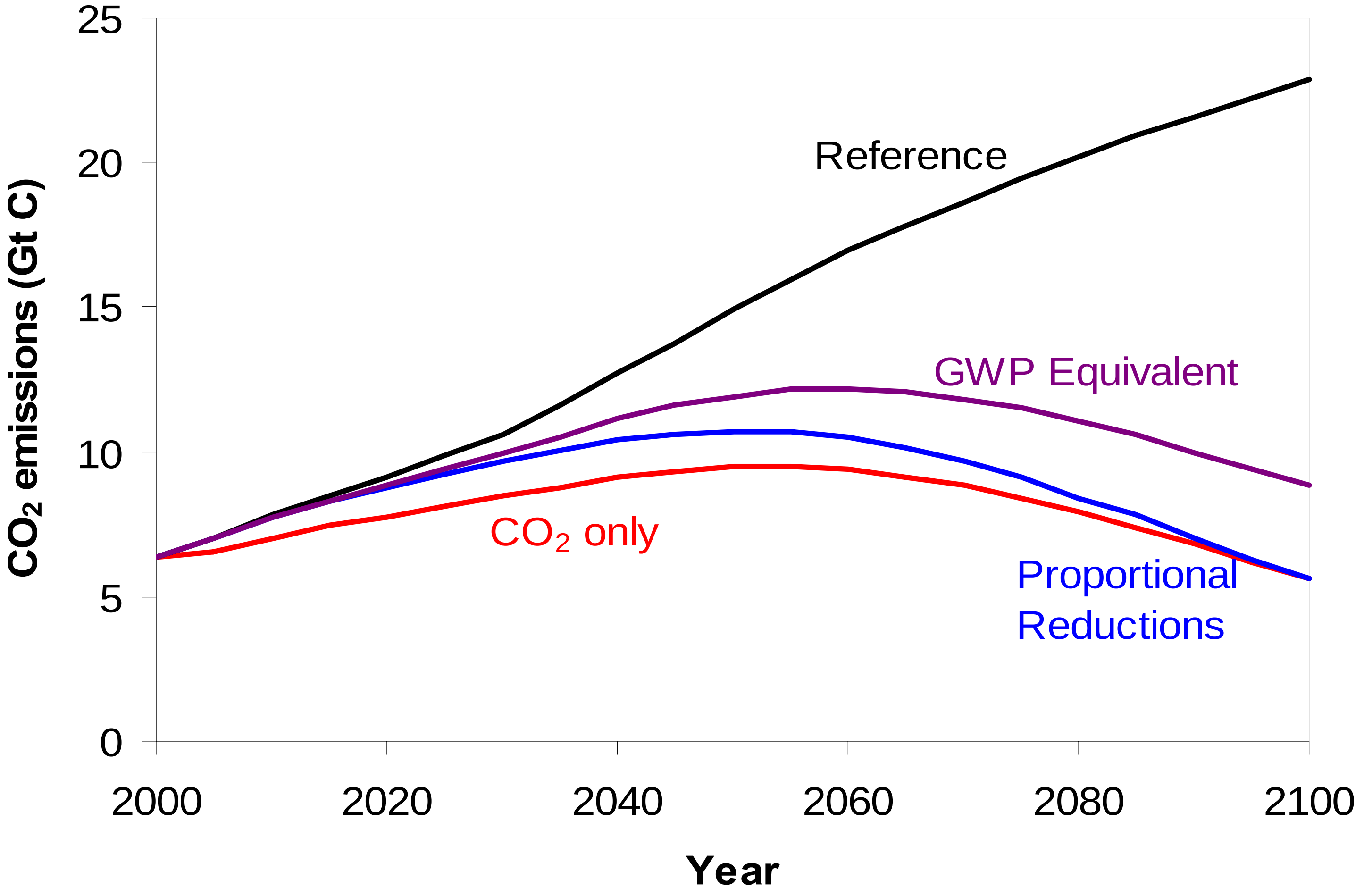
Carbon-Equivalent Prices 2005-2050



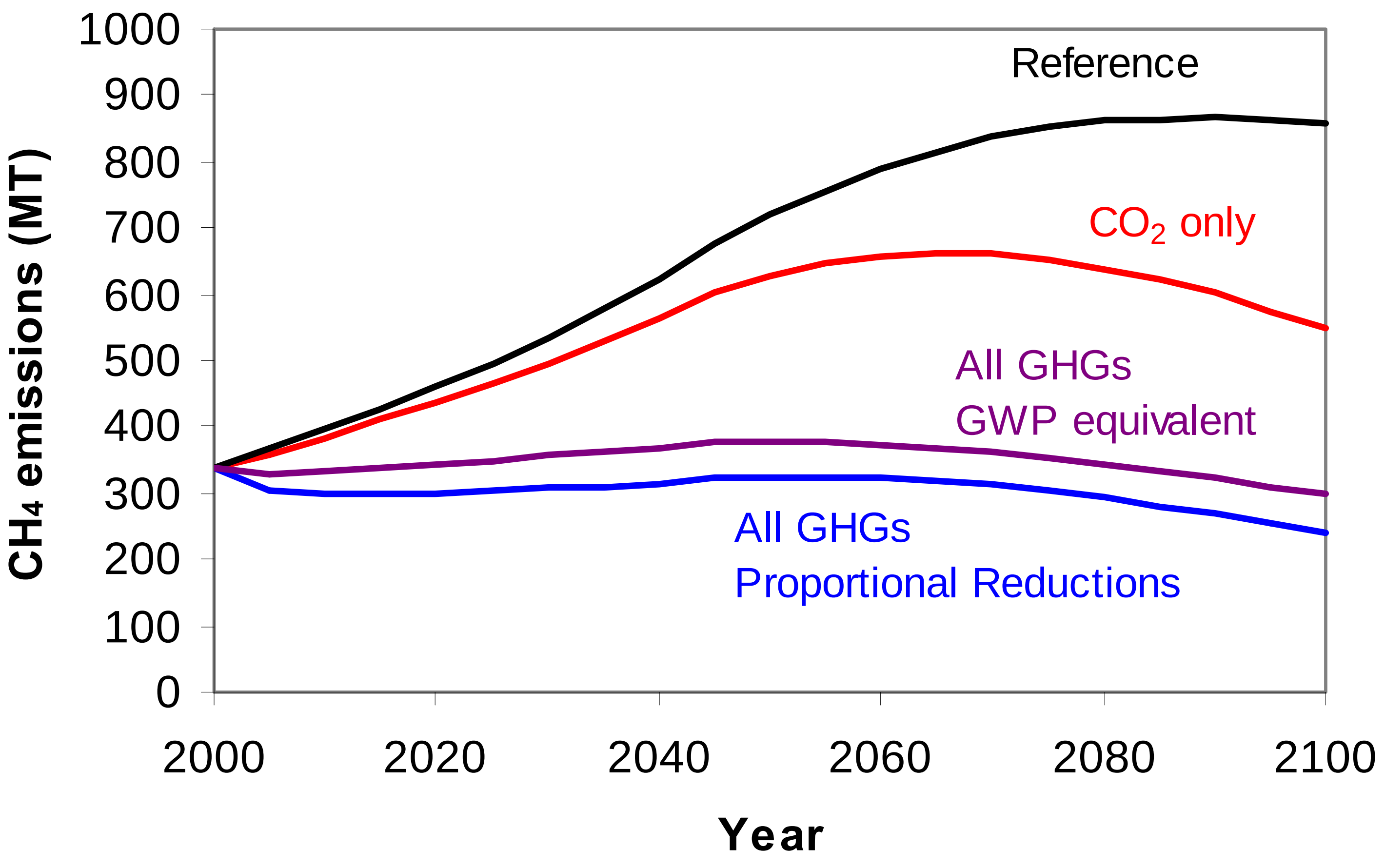
Total GHG Emissions, GWP weighted



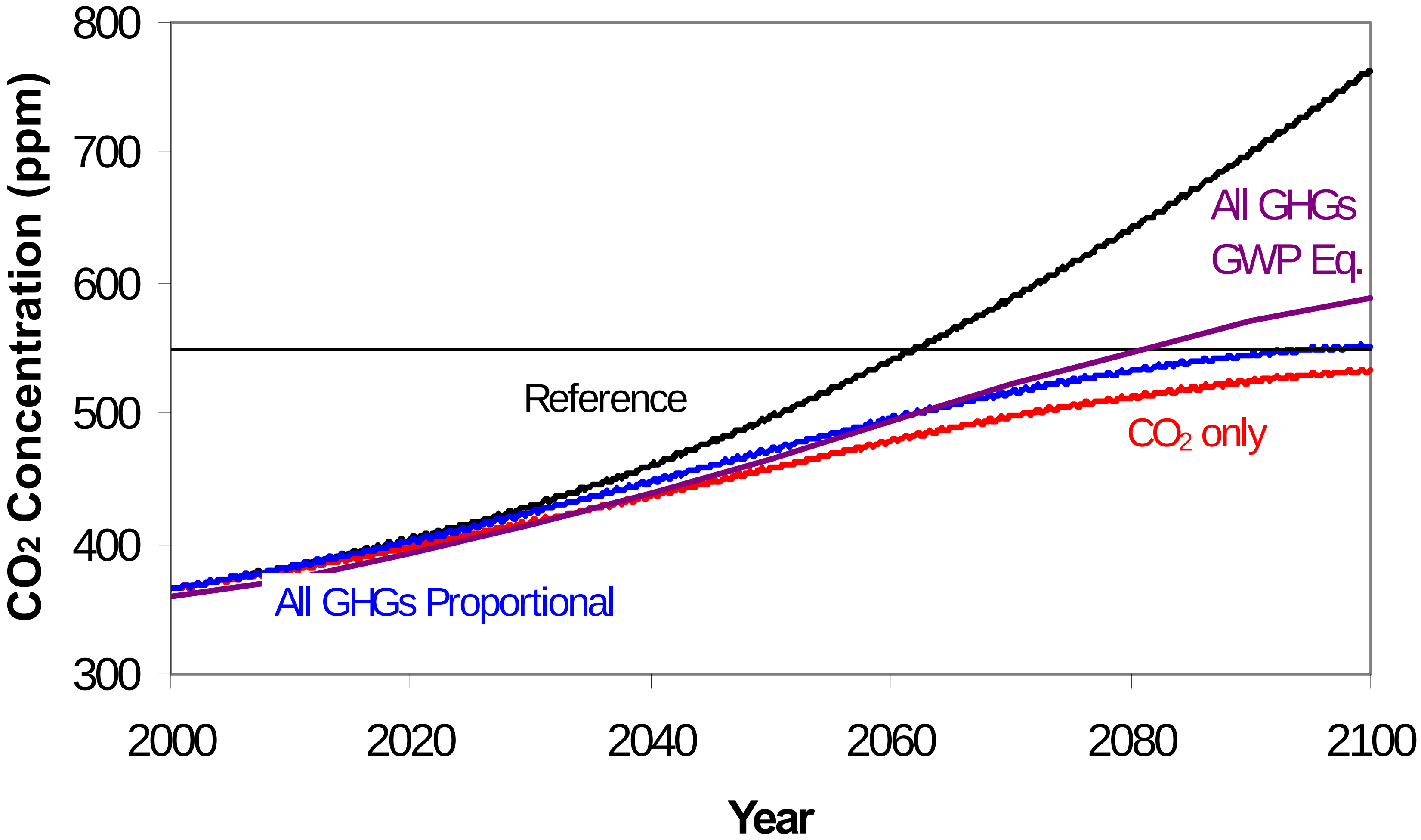
Total Carbon Emissions



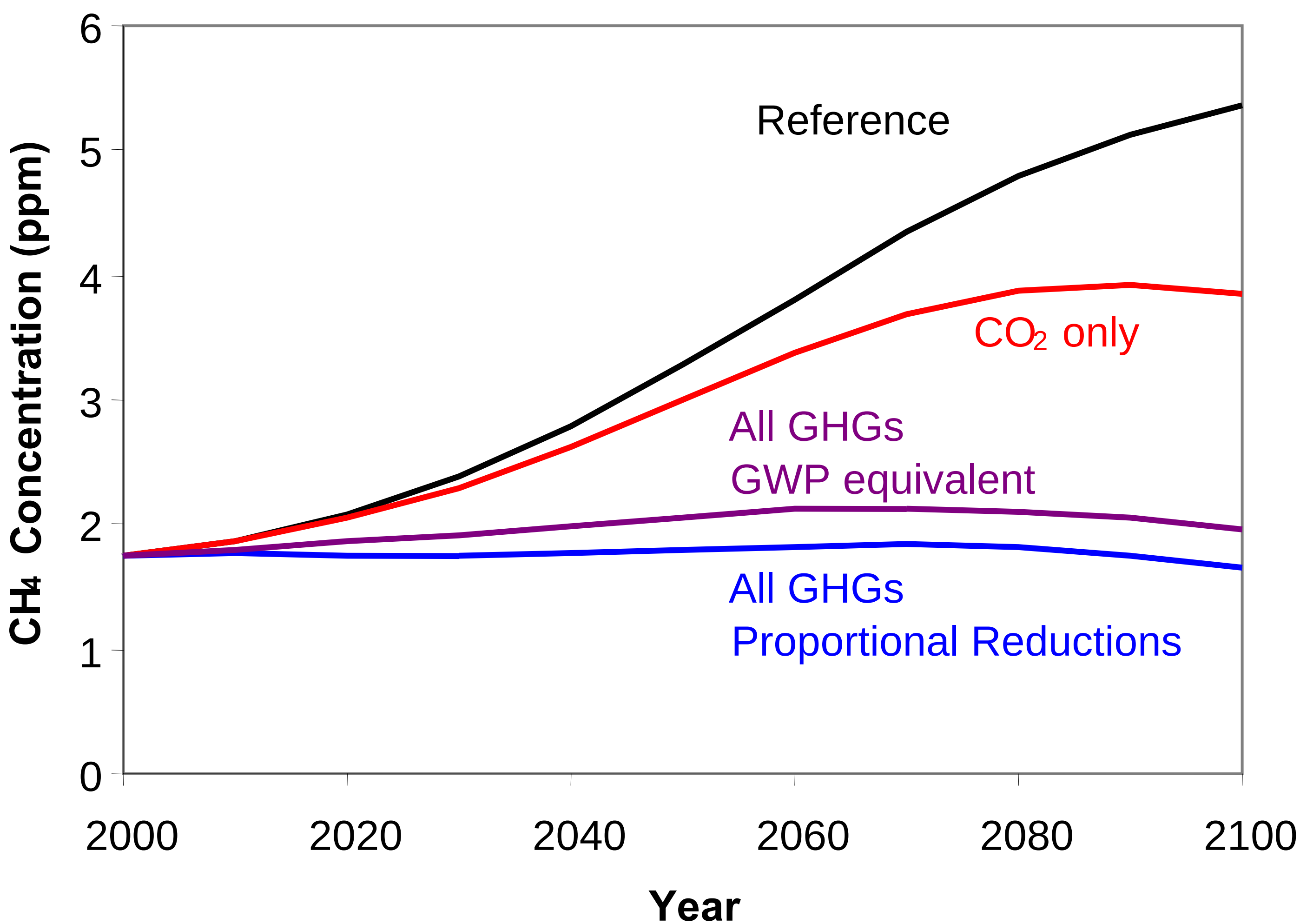
Total Methane Emissions



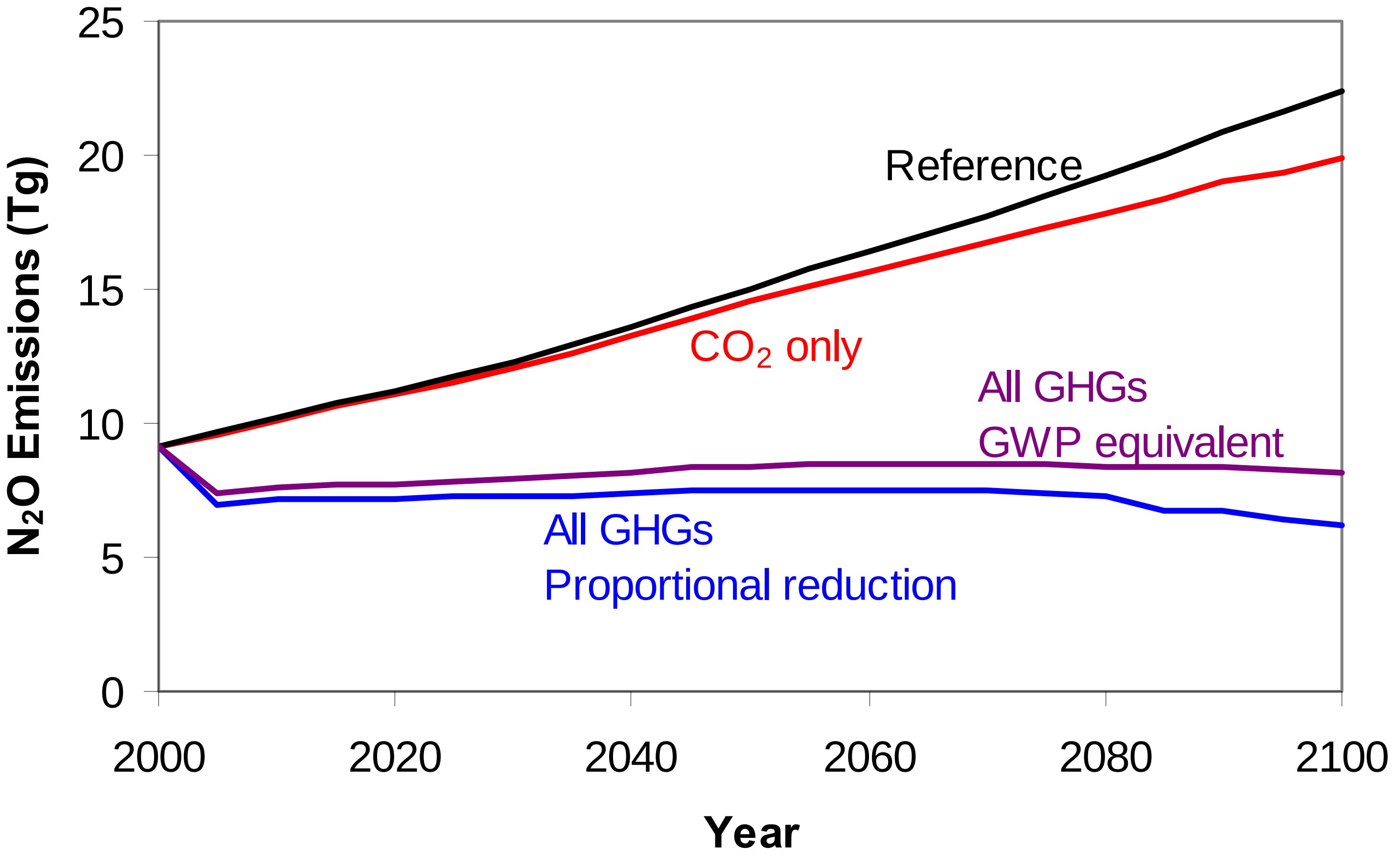
CO_2 Concentrations



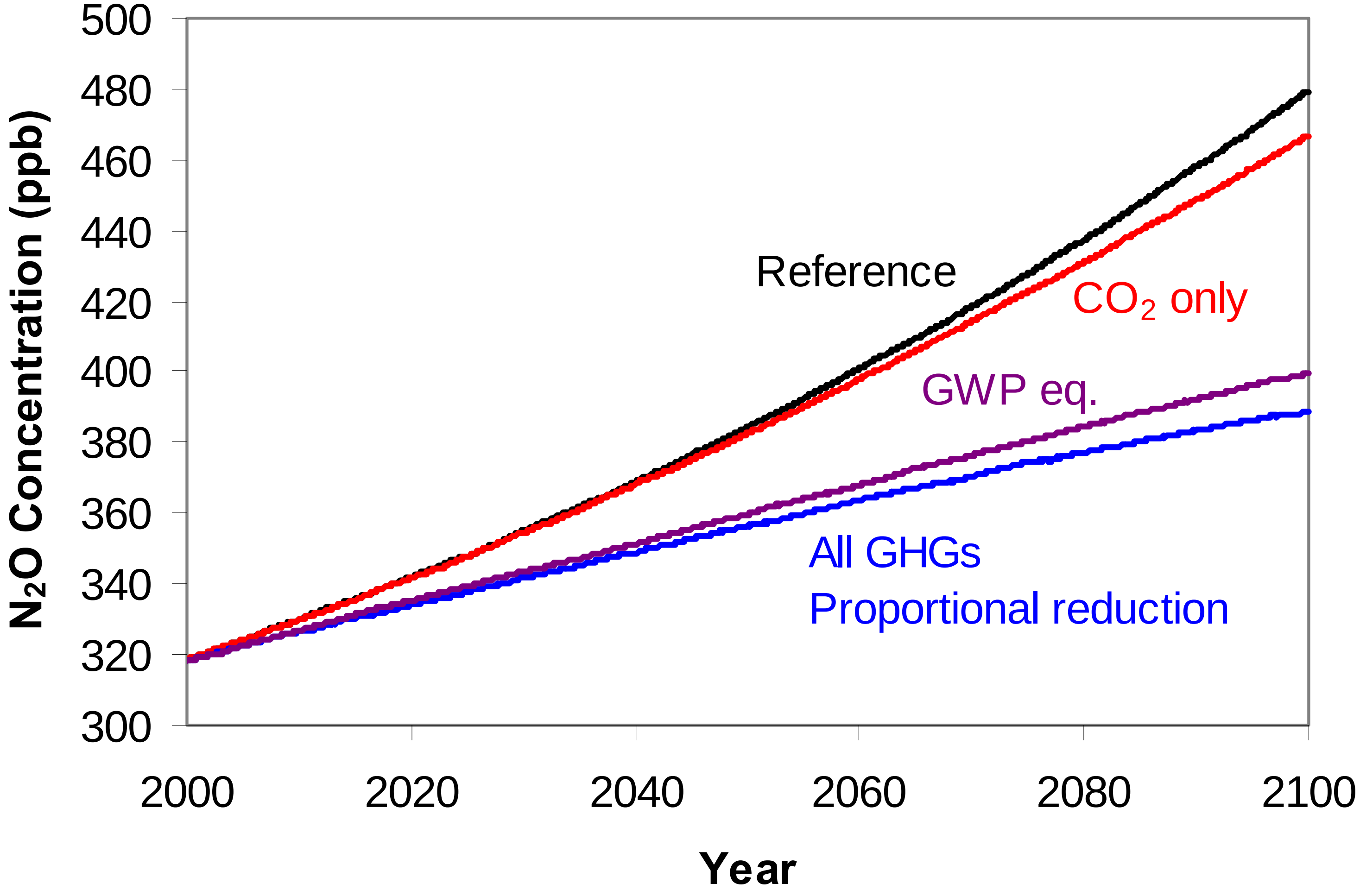
Methane Concentration



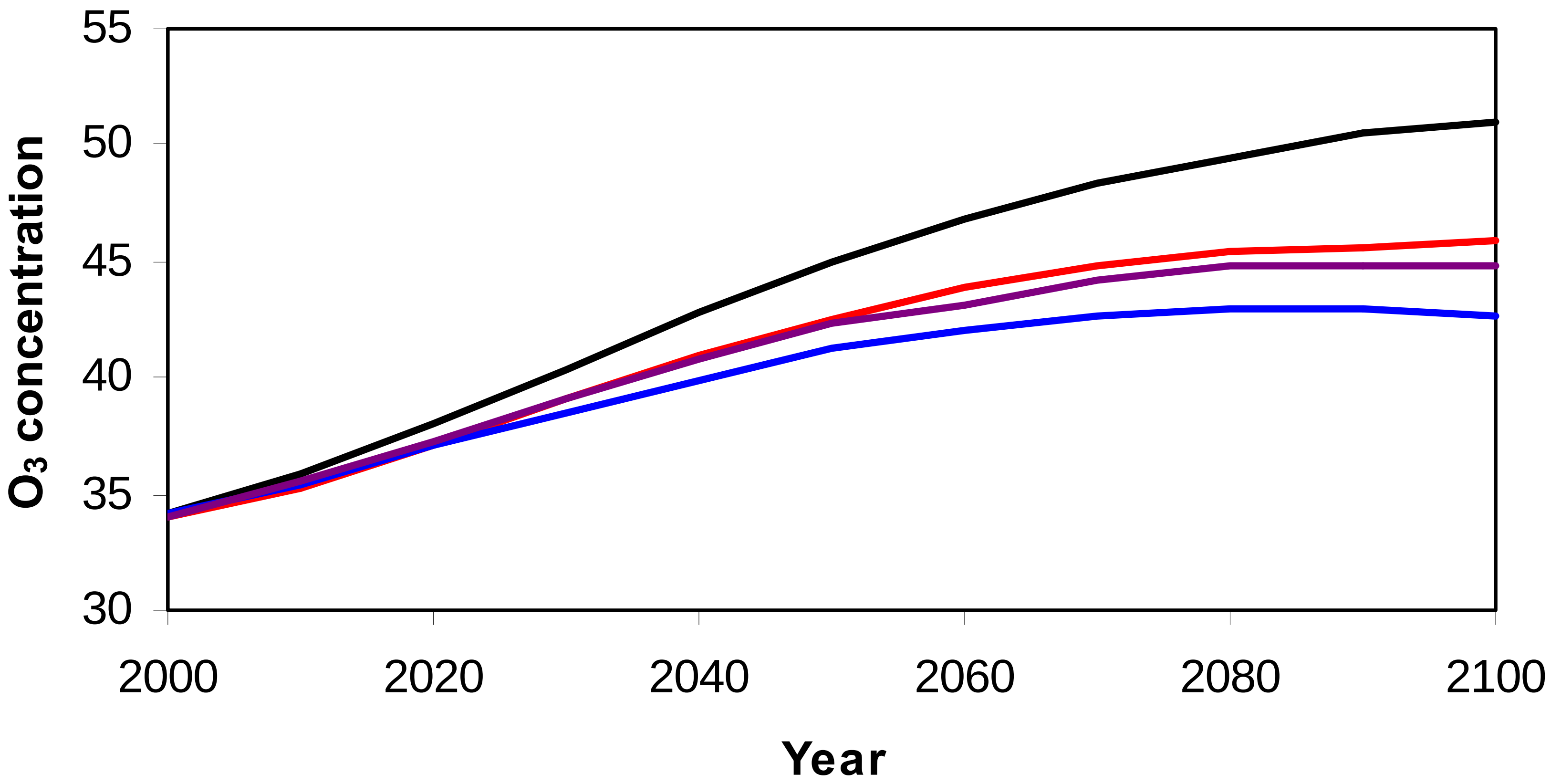
Total N_2O Emissions



N_2O Concentration



Ozone Concentration



Global Mean Temperature Change: 2000-2100