Long-Term Multigas Mitigation Strategies using MESSAGE

Shilpa Rao & Keywan Riahi

IIASA

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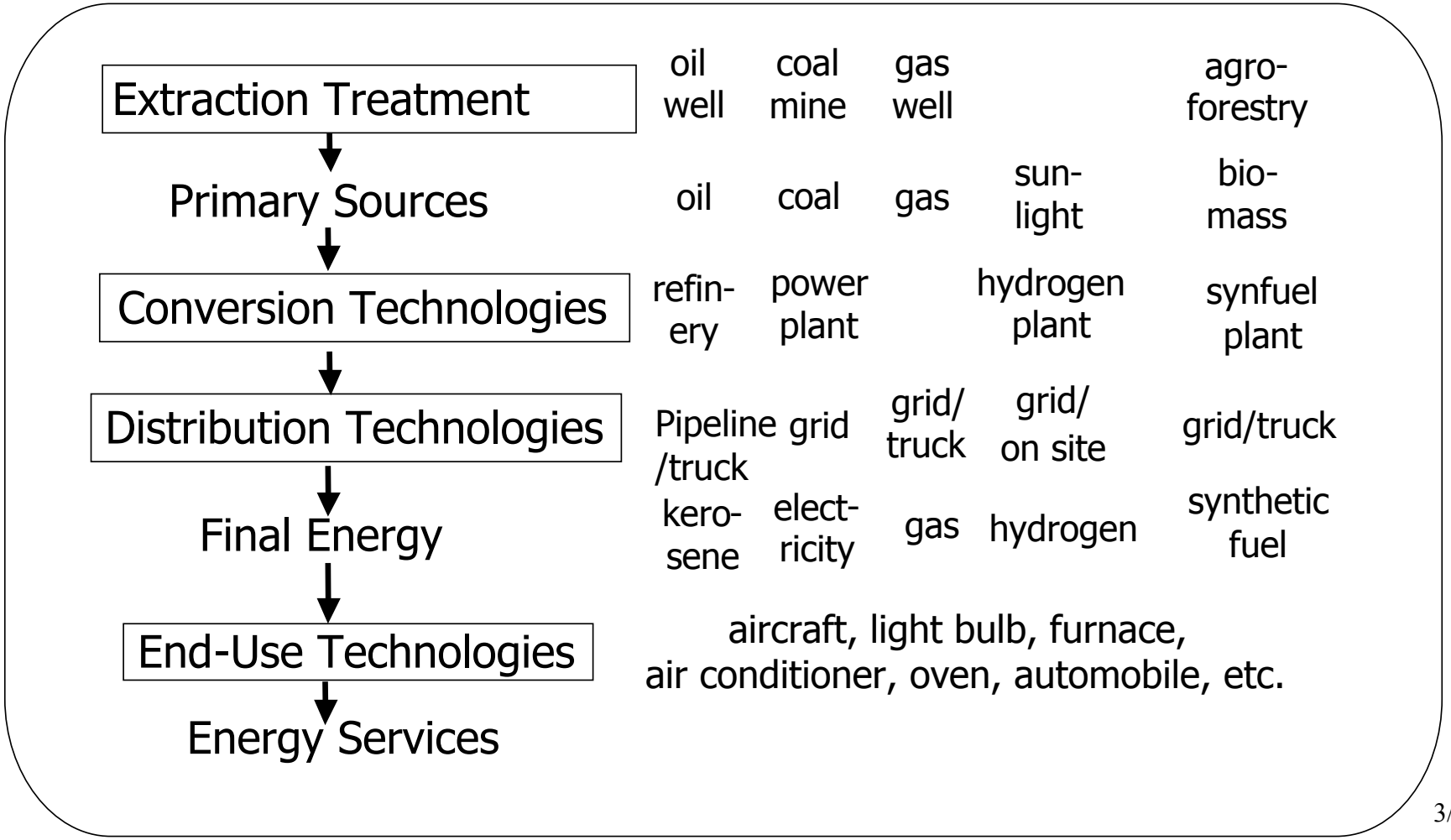
The MESSAGE Model

- Bottom-up systems-engineering model
- Includes 400 individual energy conversion and end-use technologies
- 11 World Regions
- Calculates feasible energy supply technology structure, which …
- … requires least cost investment and
- … satisfies a given useful-energy demand

The Reference Energy System



Methodology- I

- Full endogenization of energy related and most industrial emissions

  (CO2, CH4, N2O, SF6, CF4, HFC)
- Combination of various economic drivers used to develop the long-term path for non-energy emissions in the baseline
  - Include: Total and Urban Population; Total GDP, Agricultural & Industrial GDP; Energy Consumption; Transportation Demand; Electric T&D
  - Productivity improvements and decreasing emission factors were assumed for most of the sources

Methodology- II

- Bottom-up representation of mitigation technologies, wherever information available
- Endogenized energy feedback effects from non CO2 mitigation (capture of CH4 in coal mines, CH4 from landfills, etc.)
- Estimation of ancillary benefits for ALL gases
- MAC approach for CH4 emissions from rice & enteric fermentation; and N2O from soil

Long-Term Scenarios

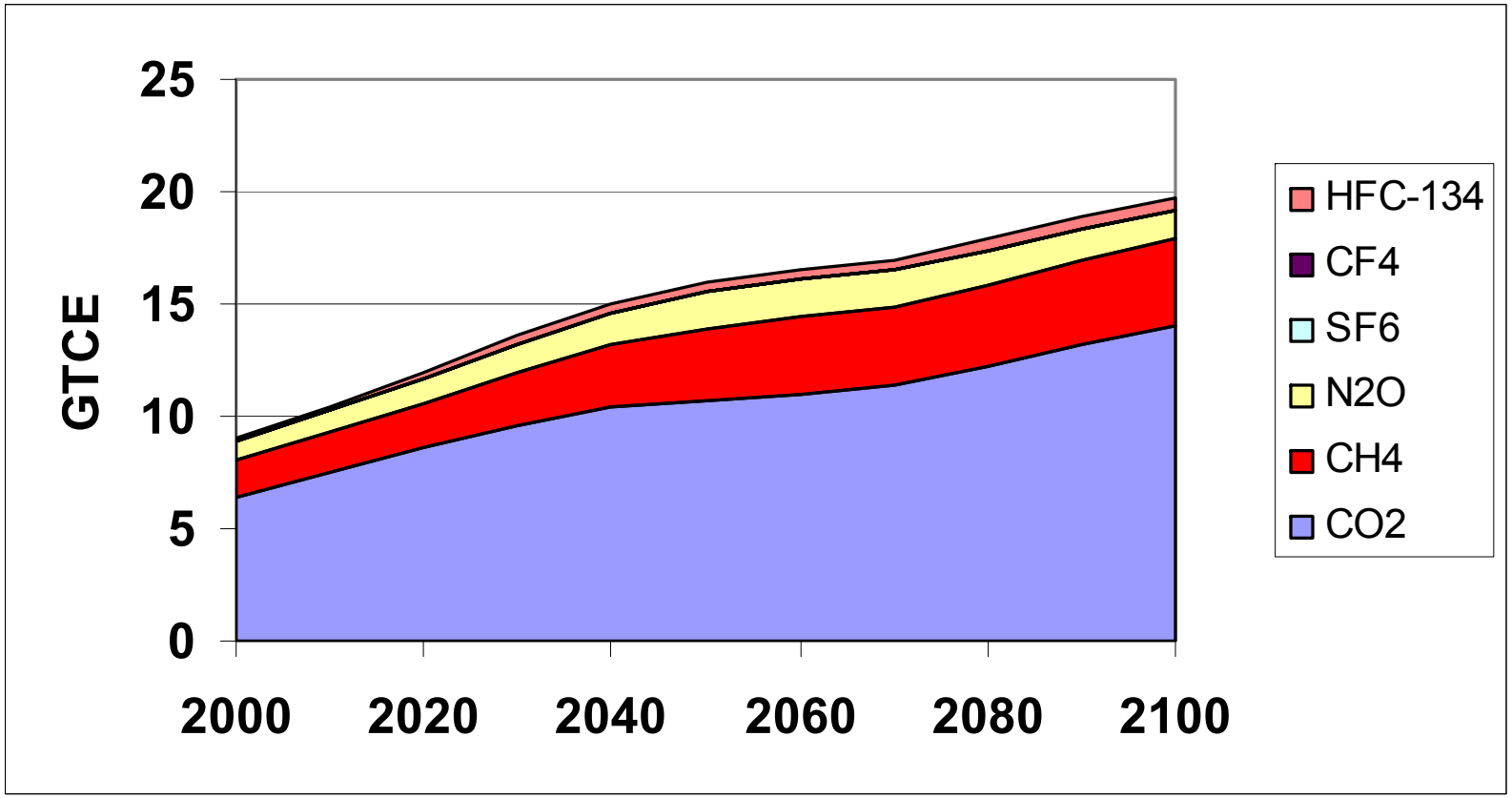
- Baseline :B2-SRES Scenario
- Mitigation Scenario (CO2 only)
- Mitigation Scenario (Multigas)

Reference Scenario

B2 scenario
(based on IPCC SRES)

	2000	2100	
Population (billion)	6.1	10.4	(x2)
GDP (trillion $1990)	28	235	(x8)
Primary Energy (EJ)	408	1357	(x3)
CO_2 Emissions (GtC)	7.2	14	(x2)
Atmos. CO_2 Conc. ppmv	370	603	(x1.5)

Baseline Emissions



Sources of Emissions

- CO2: fossil fuels; cement and gas flaring
- CH4: fossil fuel extraction, distribution and enduse; biomass; solid waste; manure management; enteric fermentation; rice cultivation
- N2O: fossil fuel; biomass; nitric and adipic acid industries; agricultural soil
- SF6: Electric GIS; Magnesium production
- CF4: Aluminum production; semiconductors
- HFCs: Residential, commercial and mobile refrigeration and air-conditioning; insulation foams; other sources

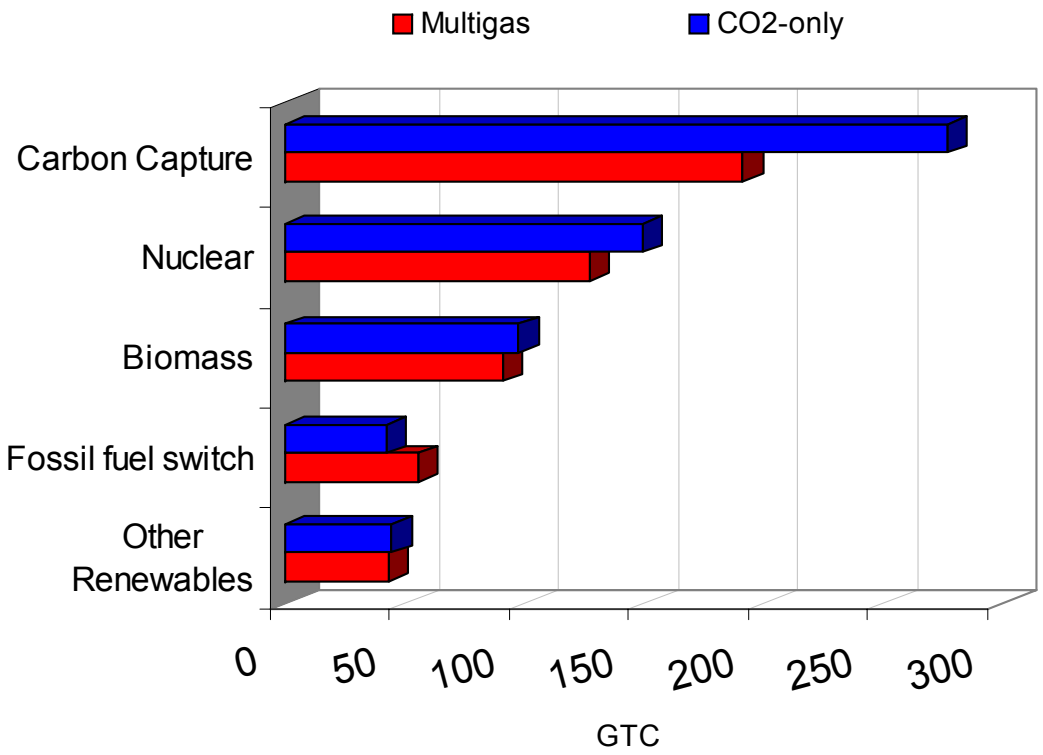
Mitigation Scenario (CO_2 only)

- Identified a concentration constraint that is consistent with 4.5 W/m^2 global radiative forcing (since preindustrial)
- Only CO_2 emissions can be reduced to meet this constraint. (full spatial and temporal flexibility of reductions)

Mitigation Scenario (Multigas)

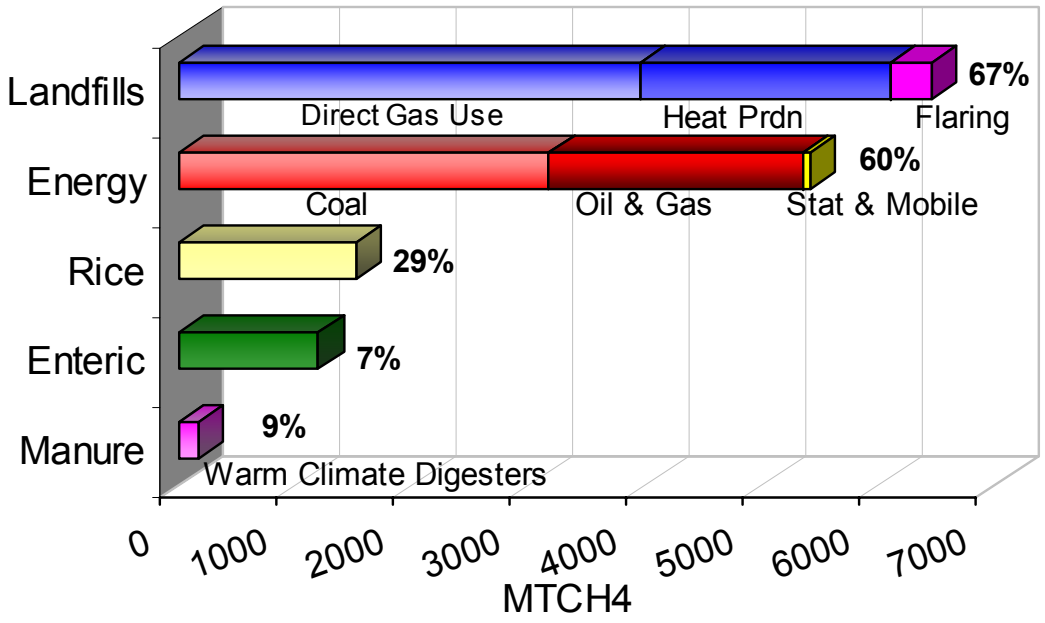
- Mitigation flexibility between all gases
- Scenario constrained to meet the Total Carbon Equivalent of the gases from the CO2 only scenario.
- Used 100-year GWPs for calculations

Cumulative CO2 Reduction (2000 - 2100, GTC)



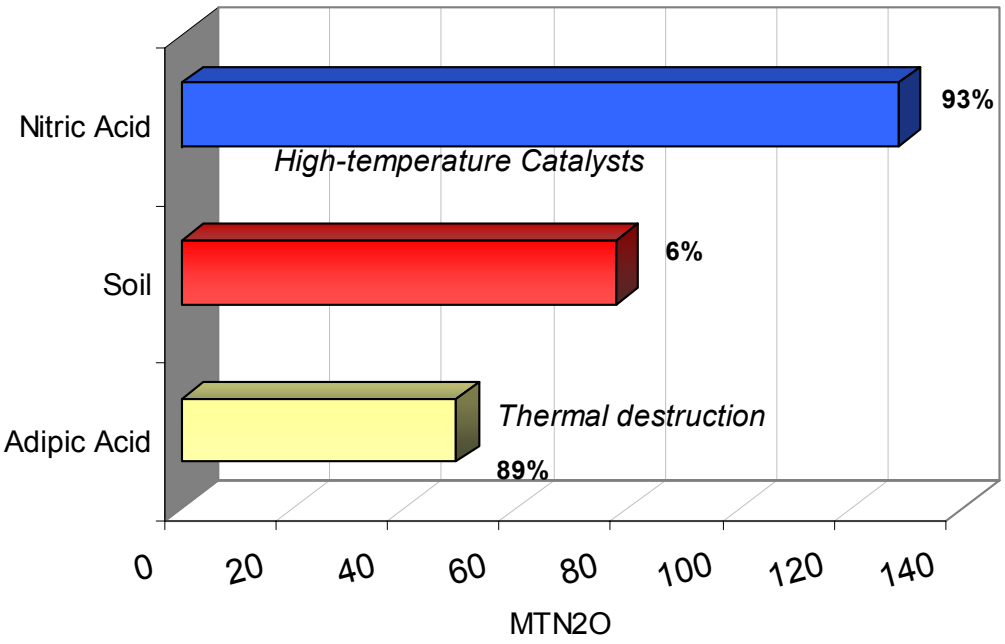
- Carbon Capture is the largest contributor to CO2 reduction.
- Nuclear energy dominates the shifts in the energy system.
- Biomass plays an important role in the latter half of the century when biomass scrubbers become important.

Cumulative CH4 Reduction (2000-2100 MTCH4)



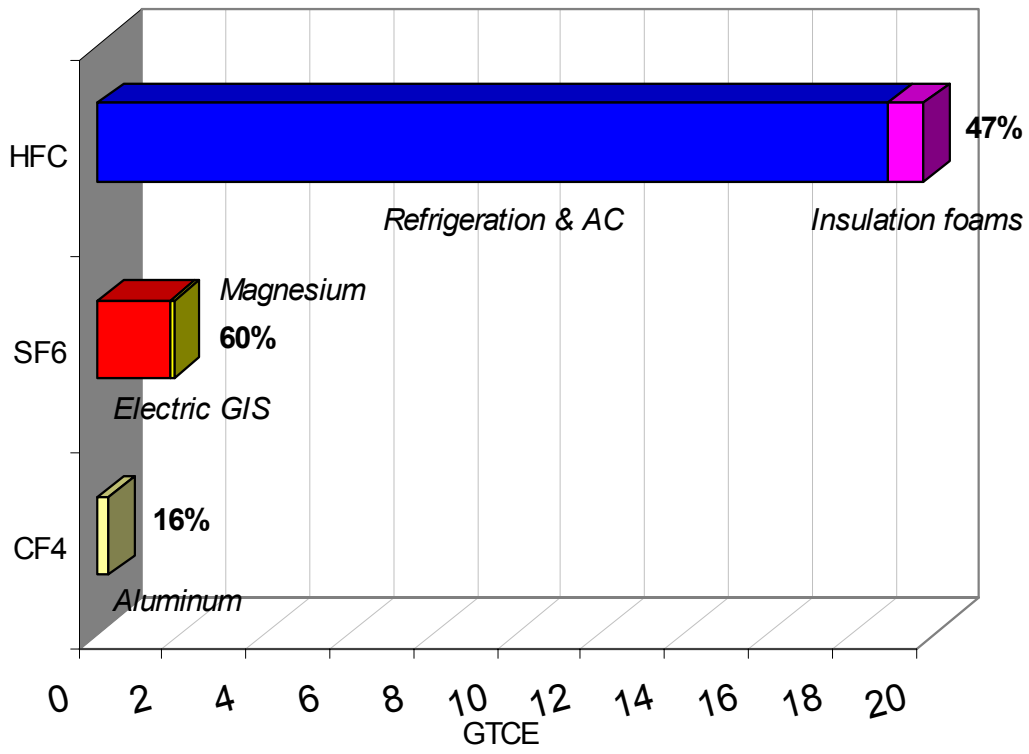
- Bottom-up methodology enables us to evaluate optimum and point source technology strategies for reductions
- Solid waste and Energy sectors offer a large range of mitigation options.
- Regional differences are accounted for- anaerobic digesters for manure management are significant in developing countries.

Cumulative N2O Reduction (2000-2100, MTN2O)



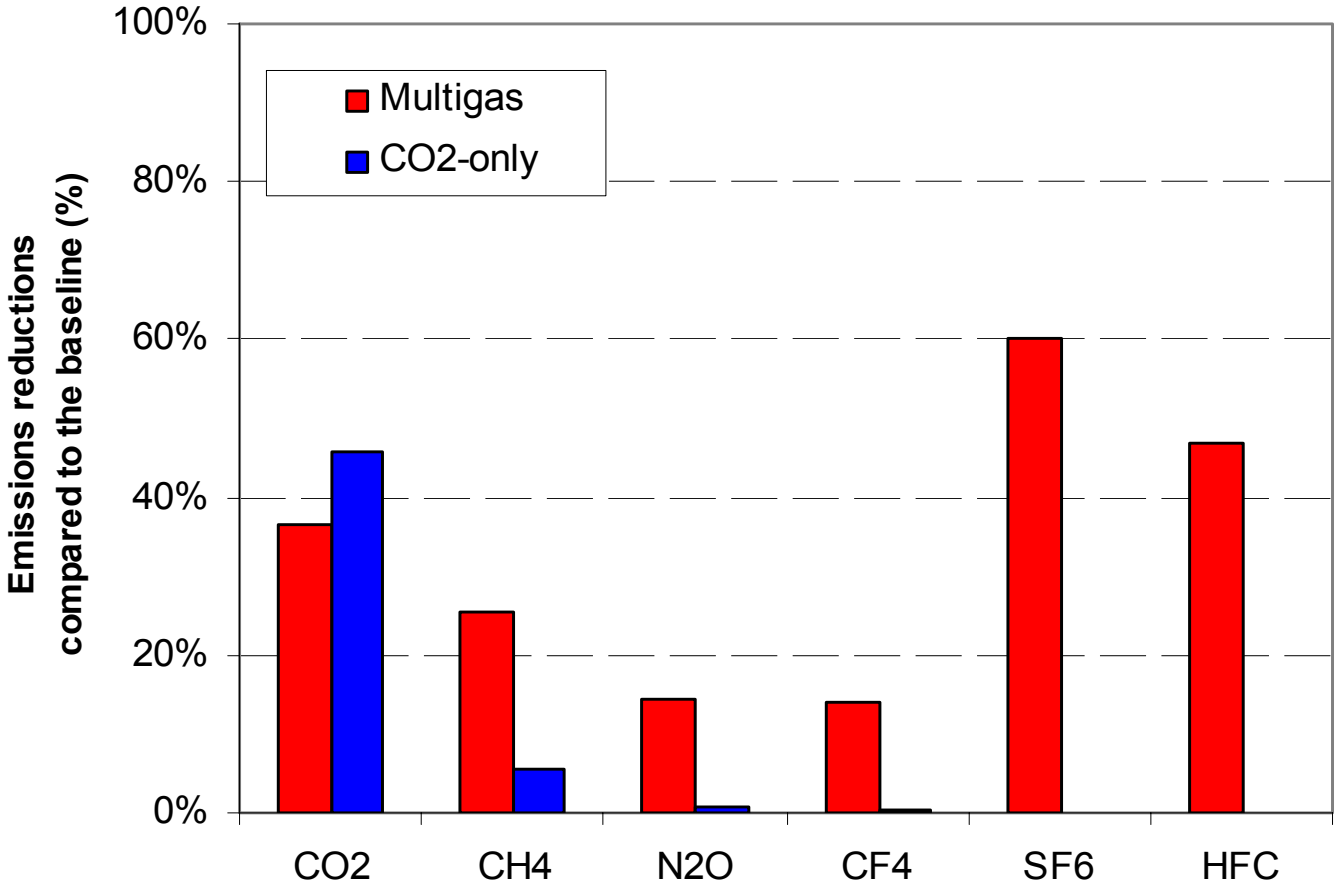
- In the industrial sector, high efficiency options offer maximum potential for global abatement (in spite of higher costs).
- Reductions from agricultural soil are assumed to be limited based on EMF-MACs.

Cumulative F-Gas Reductions (GTCE)

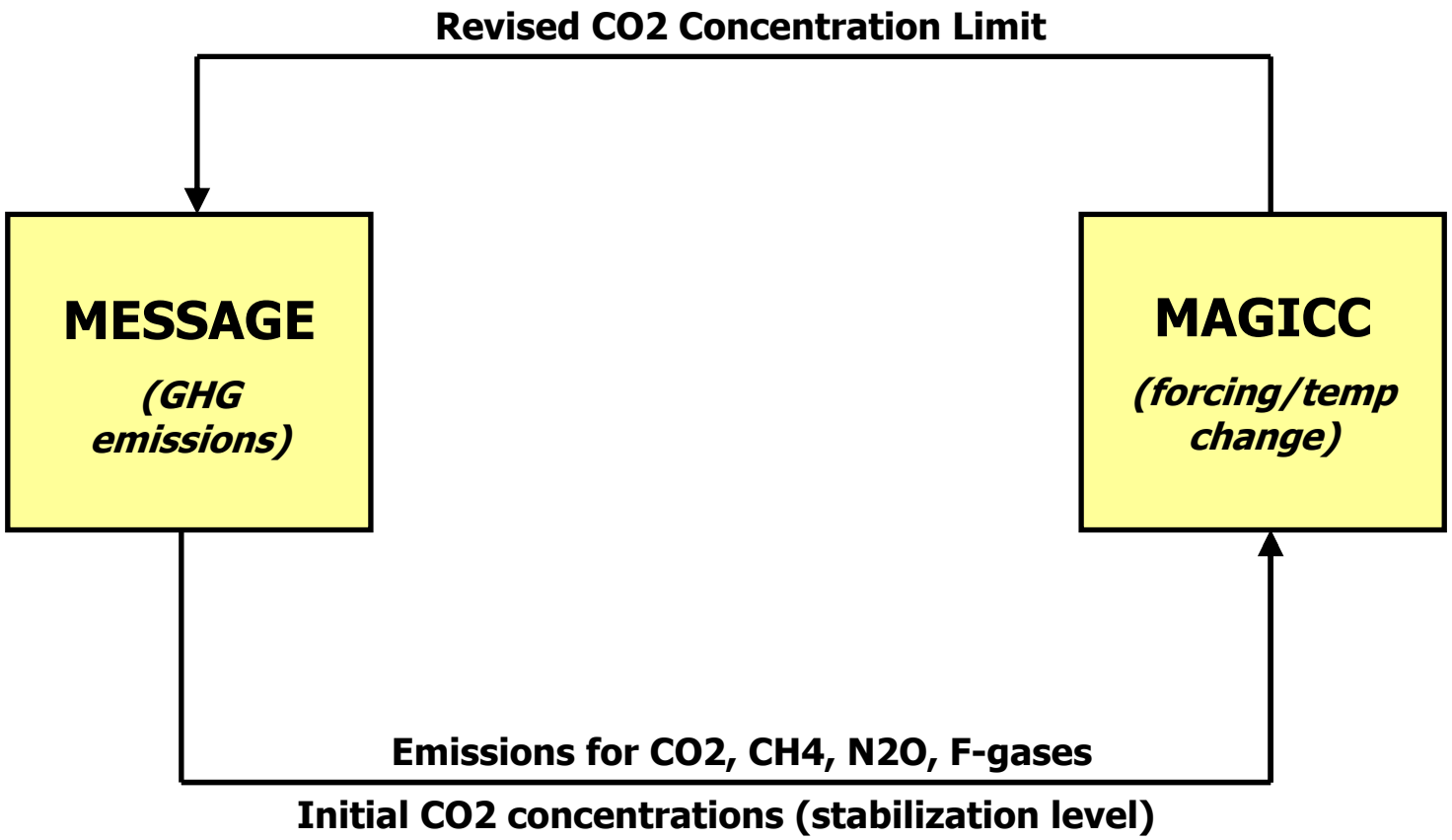


- HFCs from refrigeration and air-conditioning are a fast growing source of GHG emissions and offer considerable potential for reduction.
- Electrical switchgear (leak repair and recycling) is the most attractive source for mitigation of SF6.
- Baseline already accounts for worldwide decrease in CF4 from aluminum. Main mitigation option is improvement of process control systems.

Cumulative Emissions Reductions (2000-2100)

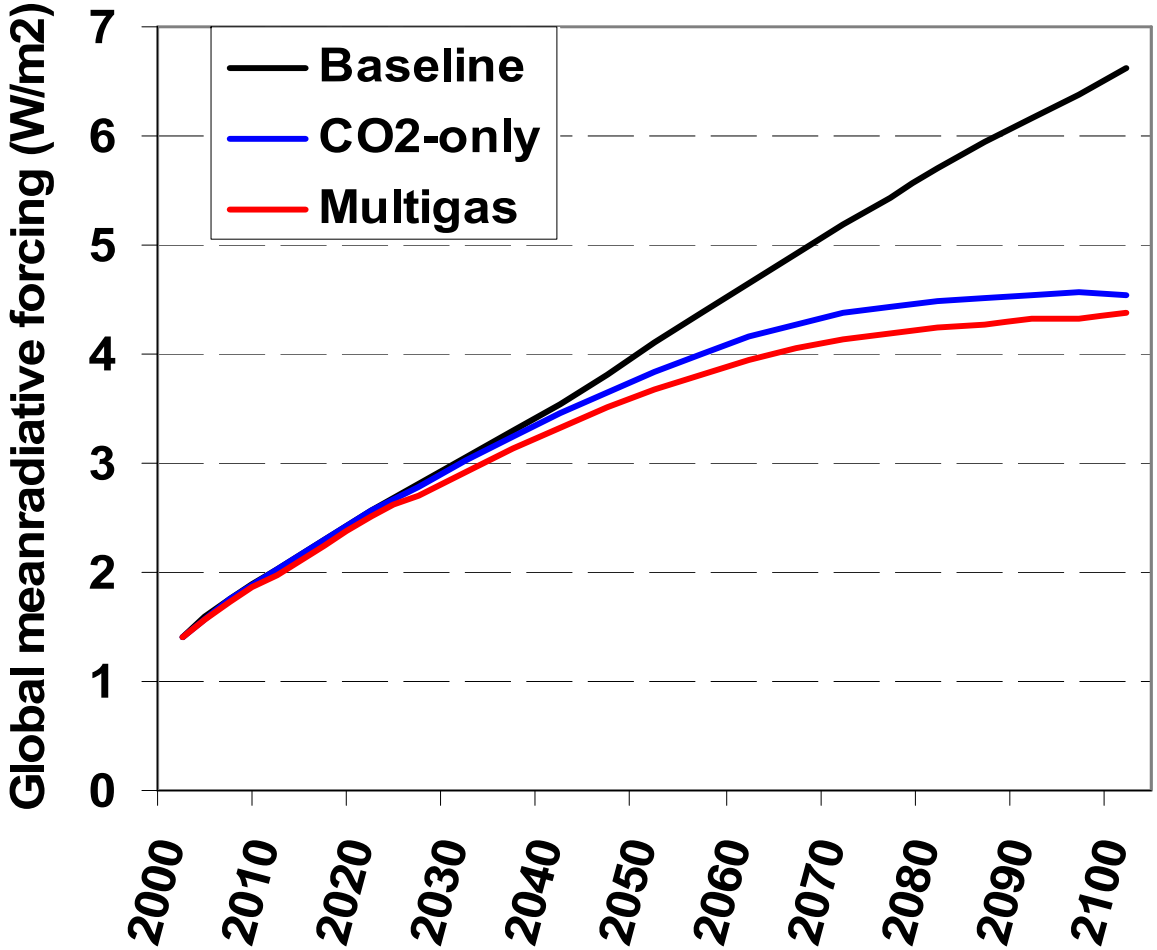


Mitigation Scenario (CO2 only)

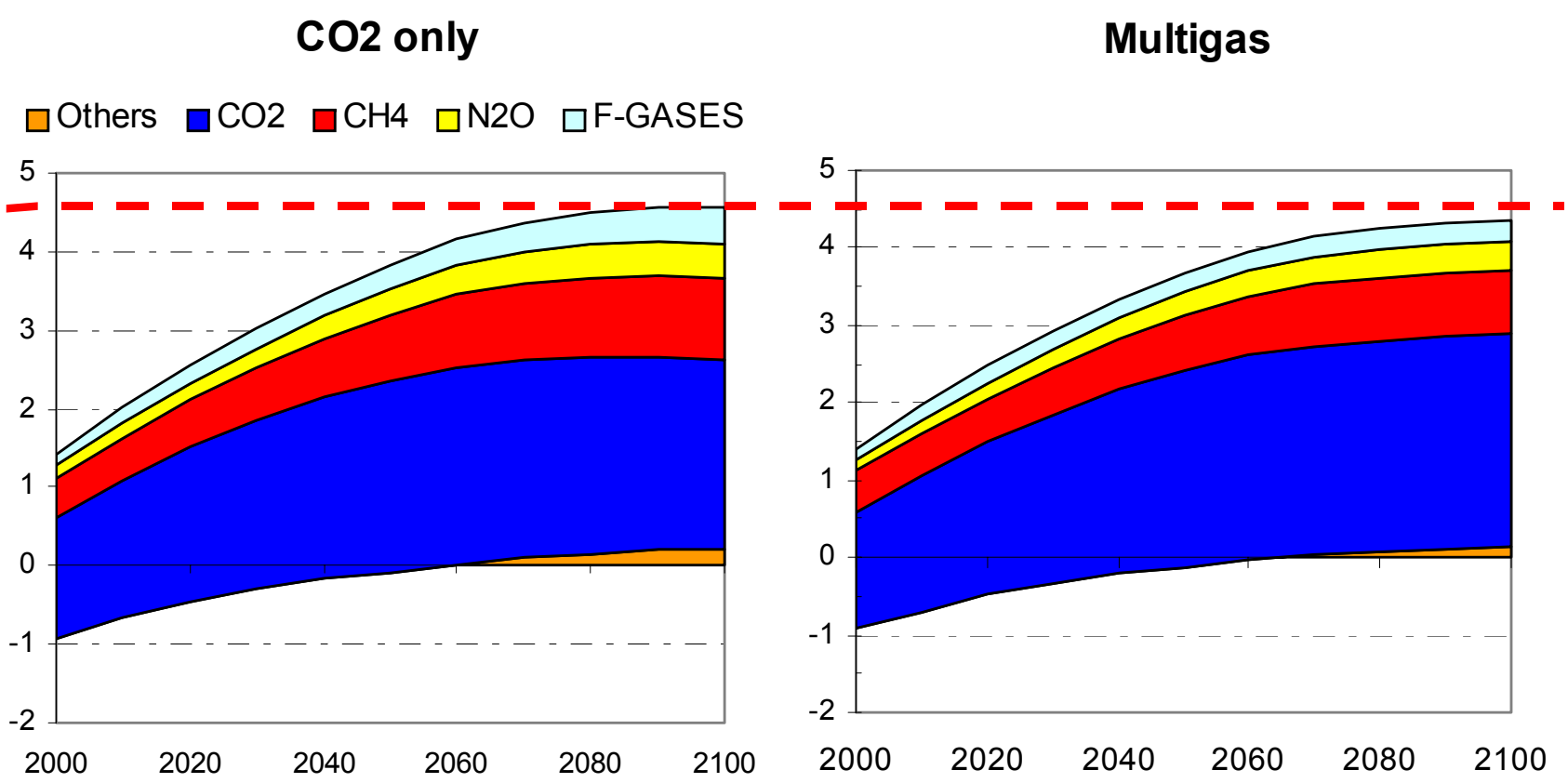


MAGICC 4.0, Model for Assessment of Greenhouse Gas Induced Climate Change, Wigley et al.

Total Radiative Forcing

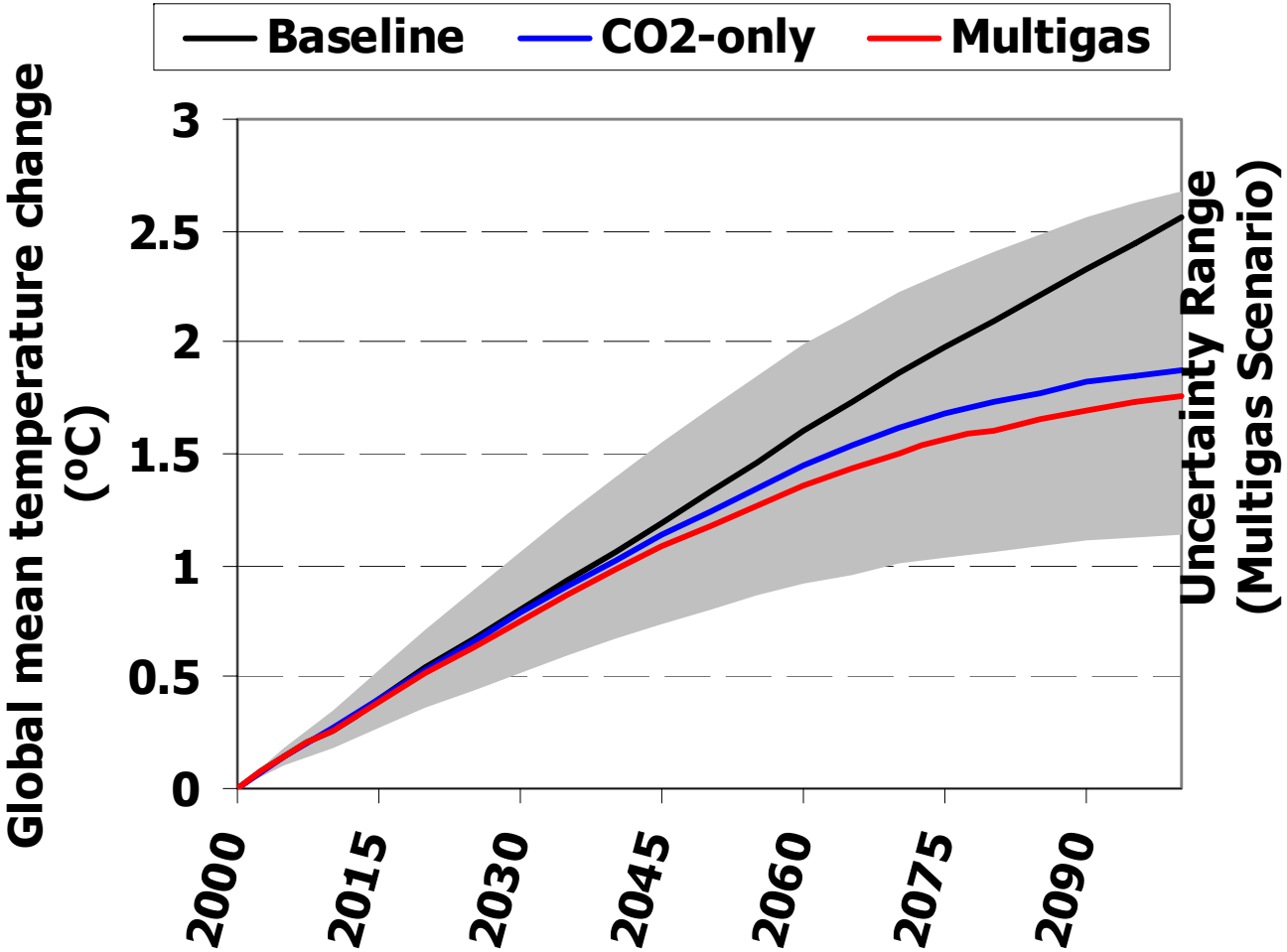


Changes in Radiative Forcing

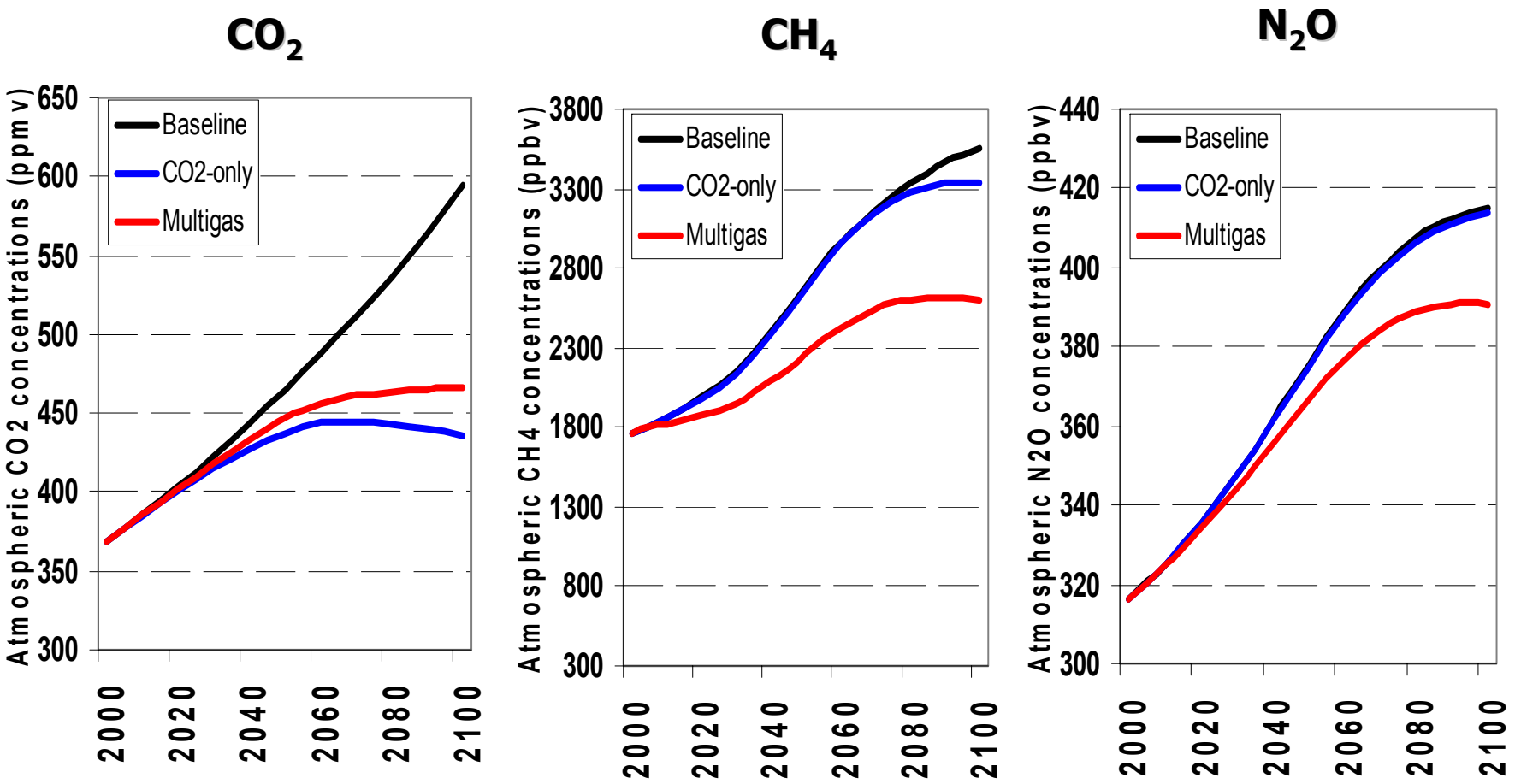


'Others' here includes forcing from tropospheric ozone, black carbon, sulfate and bio aerosols

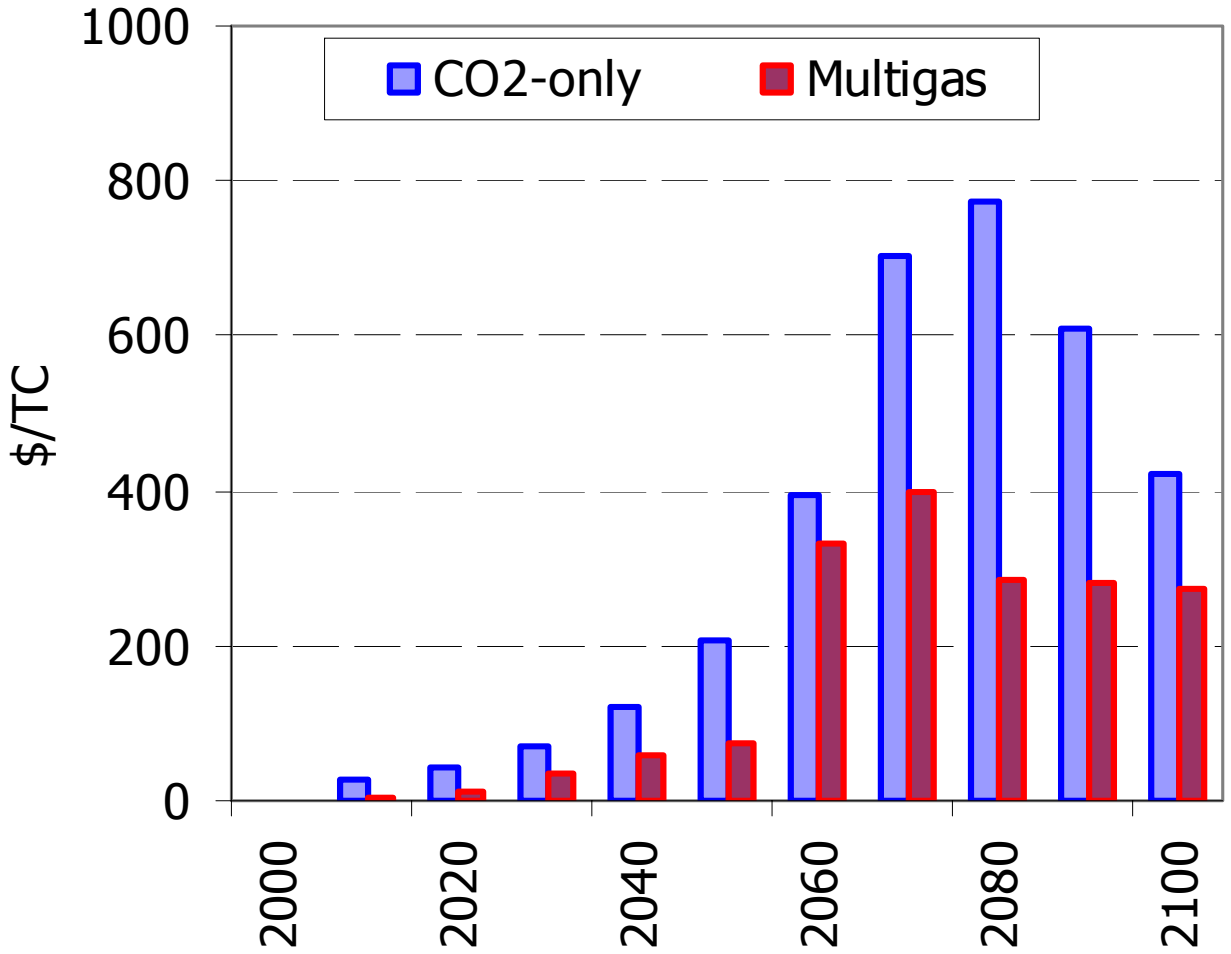
Global Temperature Change (from 2000)



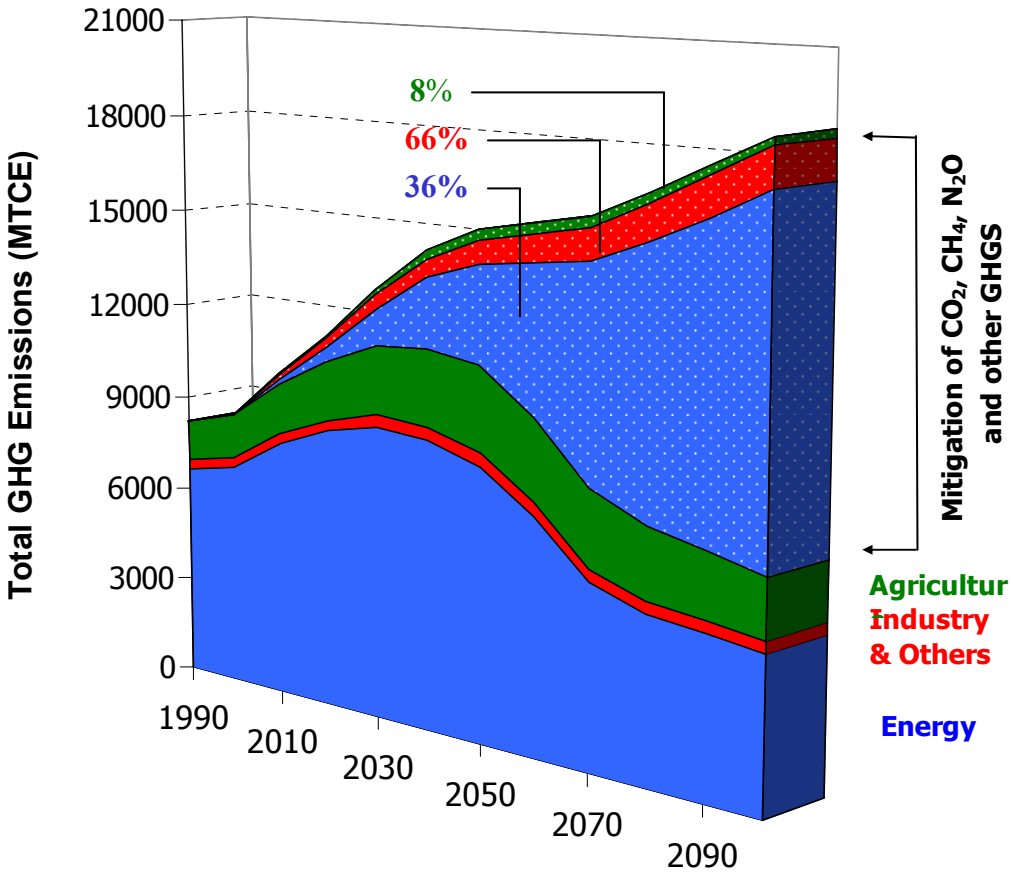
Atmospheric Concentrations



Shadow Prices of CO_2 ($/TC)



Multigas Mitigation



- The figure shows the various sources of GHGs and the mitigation achieved from the baseline in the multigas scenario.
- Industry(including solid waste) represents the top non-energy sector for potential mitigation.
- Agriculture is a larger source of GHG emissions but mitigation potential is limited.

Conclusions

- In a multigas strategy, the bulk of emission reductions still comes from CO2.
- Industry, waste and agriculture are important potential sources of non-CO2 mitigation.
- Mitigation options in these sectors are technically and regionally diverse.
- Inclusion of non-CO2 gases leads to lower costs.