Black Carbon Subgroup under the Energy Modeling Forum-22

Benjamin DeAngelo, U.S. EPA
Junichi Fujino, NIES
Atsushi Kurosawa, IAE
Shilpa Rao, IIASA
Steven Smith, JGCRI/PNNL

5th AeroCom Workshop
Virginia Beach, Virginia
17 October 2006

Energy Modeling Forum (EMF)

- EMF is an international forum that operates organized working groups that focus their work by comparing the results of different economic, market, and planning models.
- Recent EMF efforts focused on climate change through the inter-comparison of long-term, global GHG emission and mitigation scenarios (see forthcoming special issue of *Energy Journal*).
- Many EMF participating modeling teams are the same as those that generated IPCC SRES scenarios.
- www.stanford.edu/group/EMF/projects/projectemf22.htm

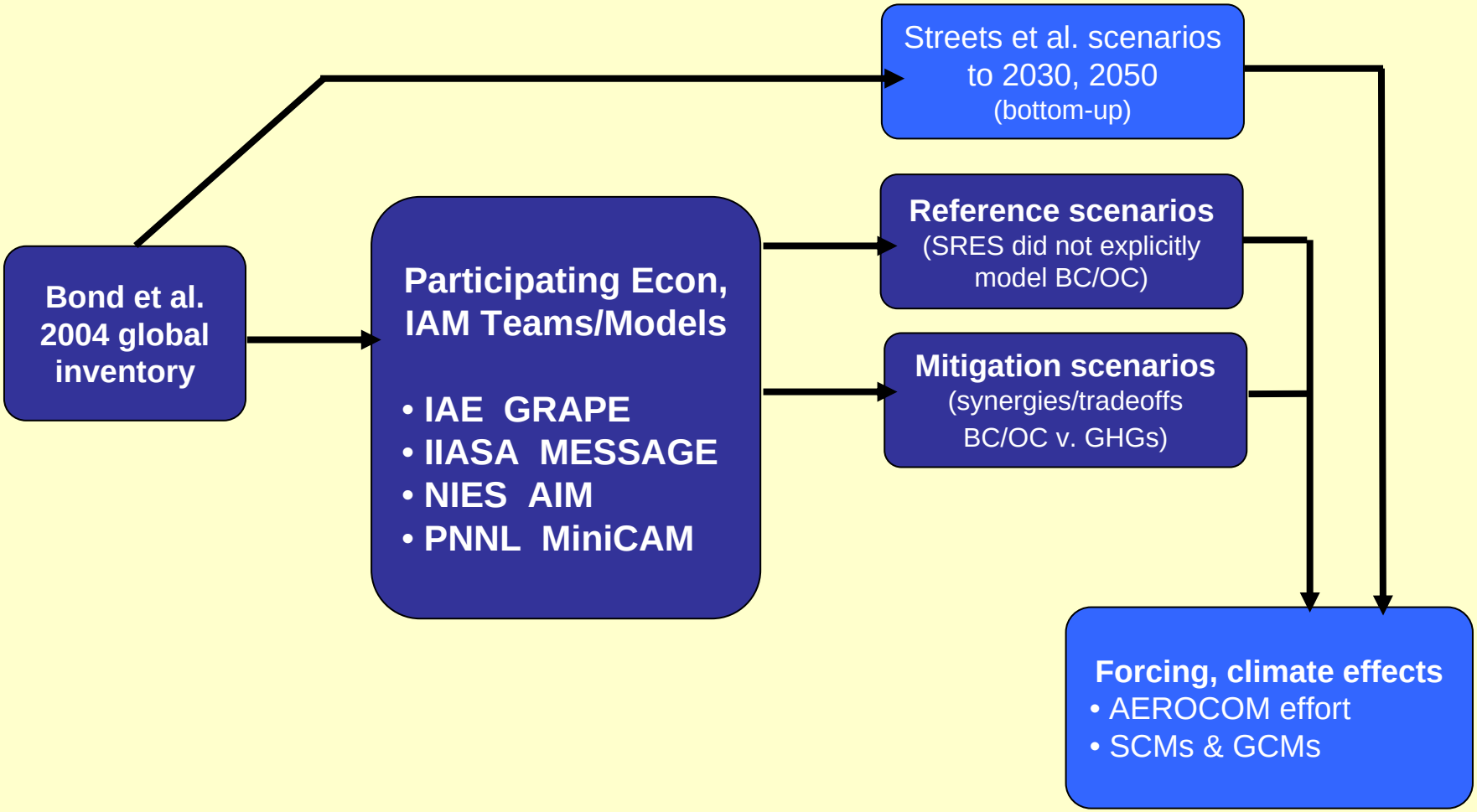
Objectives of the EMF Black Carbon Subgroup

- Develop capacity to represent BC and OC emissions in climate economic & integrated assessment models
- Improve medium- & long-term reference case scenarios
- Assess synergies & potential tradeoffs between GHG mitigation and BC/OC mitigation
- Improve understanding of the significance of BC/OC for mitigating climate change

EMF Black Carbon Subgroup, current participants

- Facilitator
  - Benjamin DeAngelo, US EPA
- Inventory development, bottom-up projections
  - Tami Bond, Univ of Illinois
- Climate-economic, integrated assessment modelers
  - Junichi Fujino, NIES w/ AIM
  - Atsushi Kurosawa, IAE w/ GRAPE
  - Shilpa Rao & Keywan Riahi, IIASA w/ MESSAGE
  - Steve Smith, PNNL w/ MiniCAM
- Climate, atmospheric modelers
  - Dorothy Koch, Columbia Univ/NASA GISS, w/ GISS GCM
  - Surabi Menon, LBNL w/ GISS GCM
  - Michael Schlesinger, Univ of Illinois w/ SCM
  - Michael Schultz, LSCE w/ AEROCOM

EMF-22 Black Carbon Subgroup, general plan



Black and Organic Carbon Emissions in MESSAGE

Shilpa Rao
Keywan Riahi
Zbigniew Klimont

International Institute of Applied Systems Analysis (IIASA)
Austria

The MESSAGE Model

- Bottom-up systems-engineering model
- Includes 400 individual energy conversion and end-use technologies
- 11 World Regions
- Time steps: 10 years
- Multigas (CO_2, CH_4, N_2O, SF_6, CF_4, HFC), SOX,NOX
- Calculates feasible energy supply technology structure, which ...

... requires least cost investment and

... satisfies a given useful-energy demand

BC & OC Emissions

Data Sources and Methodology

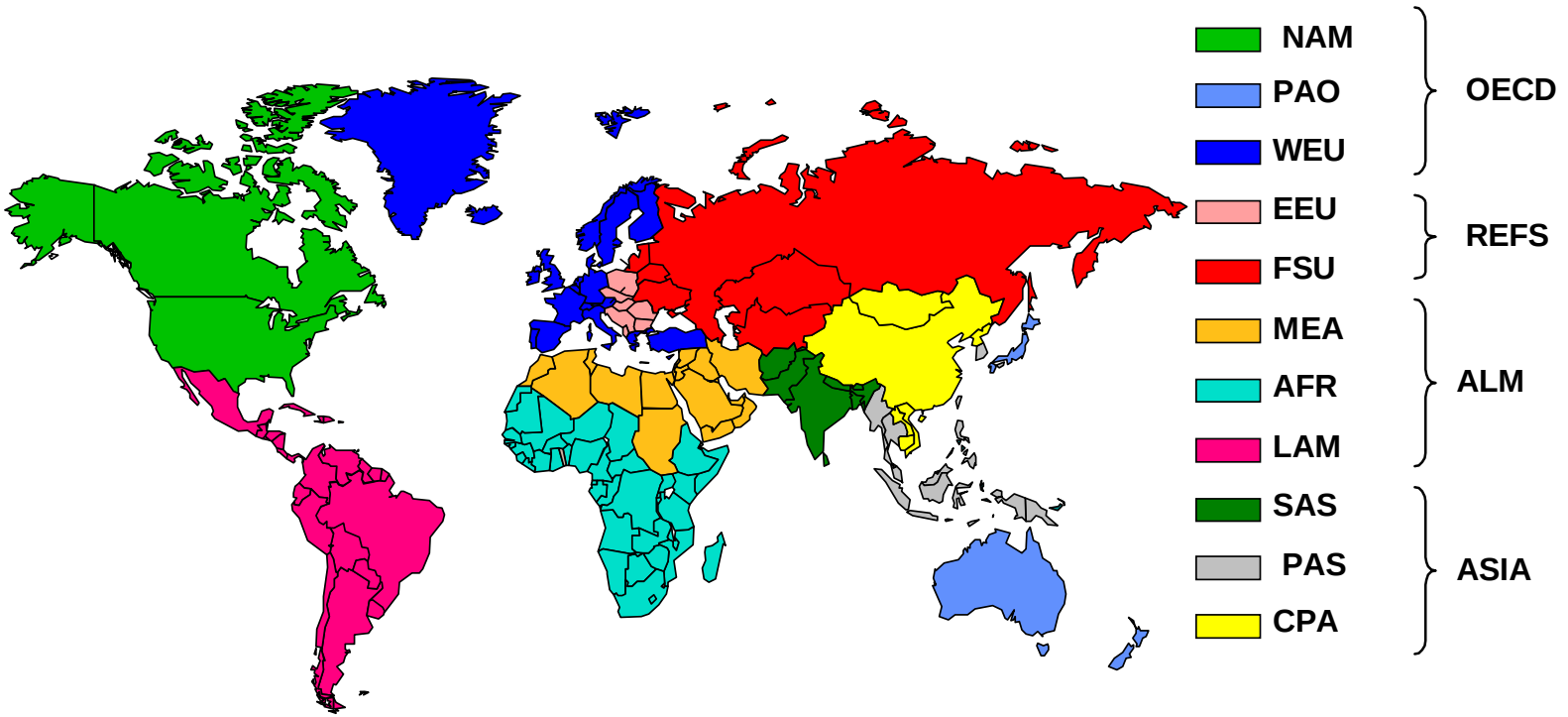
- Used Bond et al (2004) global inventory data for black and organic carbon emissions from fossil fuel and biomass burning
- Used IIASA RAINS model to approximate emission pathways from 2000-2030
- In the longer term, emission coefficients improve due to technological enhancements
- Coverage includes Residential, Industrial, Transportation and Power Sectors

Methodology

BC and OC emission factors for MESSAGE *based on*

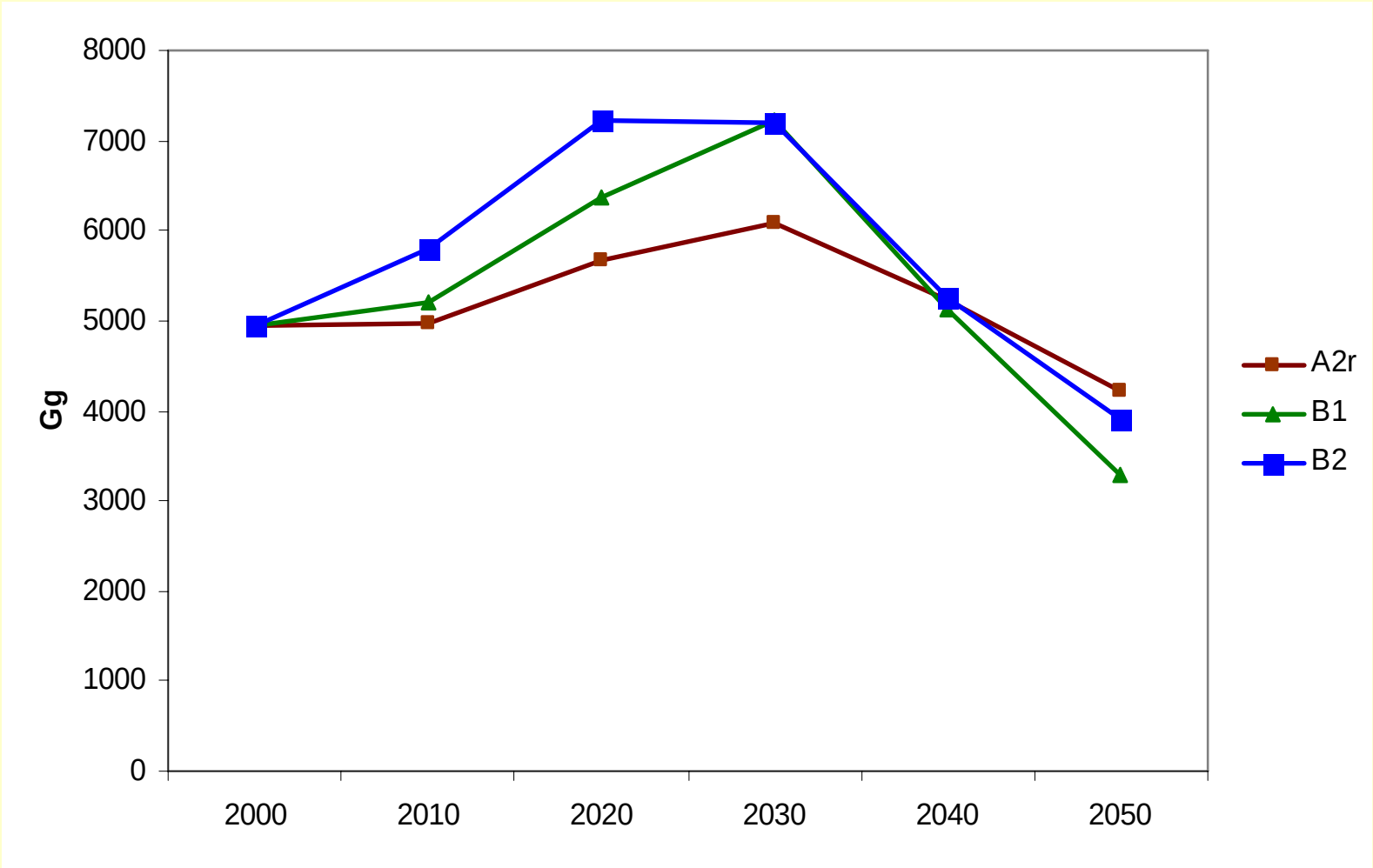
- The detailed sector- and technology-specific data in SPEW (Bond et al. 2004)
- Changes of region-specific sectoral emission rates projected by the IIASA RAINS model:
  - Country- and sector-specific penetration of abatement measures derived from requirements of existing and proposed legislation in various sectors.
  - This includes EURO standards in transportation, UNECE Convention for long range trans-boundary air pollution, National emission directives for sulfur and PM control etc.
  - Share of diesel fuel in transport explicitly considered

11 World Regions in MESSAGE



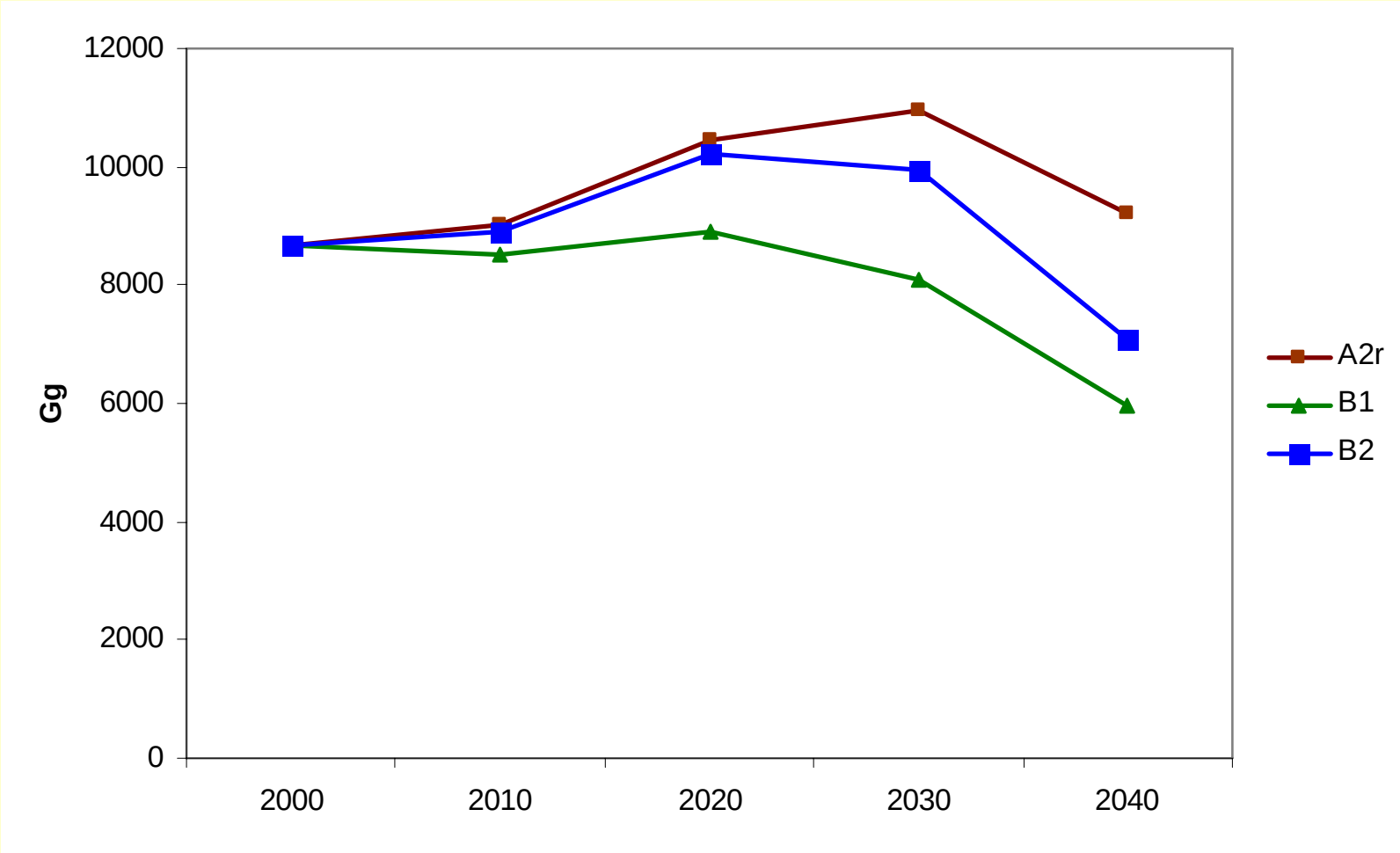
1 NAM North America
2 LAM Latin America & The Caribbean
3 WEU Western Europe
4 EEU Central & Eastern Europe
5 FSU Former Soviet Union
6 MEA Middle East & North Africa
7 AFR Sub-Saharan Africa
8 CPA Centrally Planned Asia & China
9 SAS South Asia
10 PAS Other Pacific Asia
11 PAO Pacific OECD

Black Carbon Emissions, 2000-2050



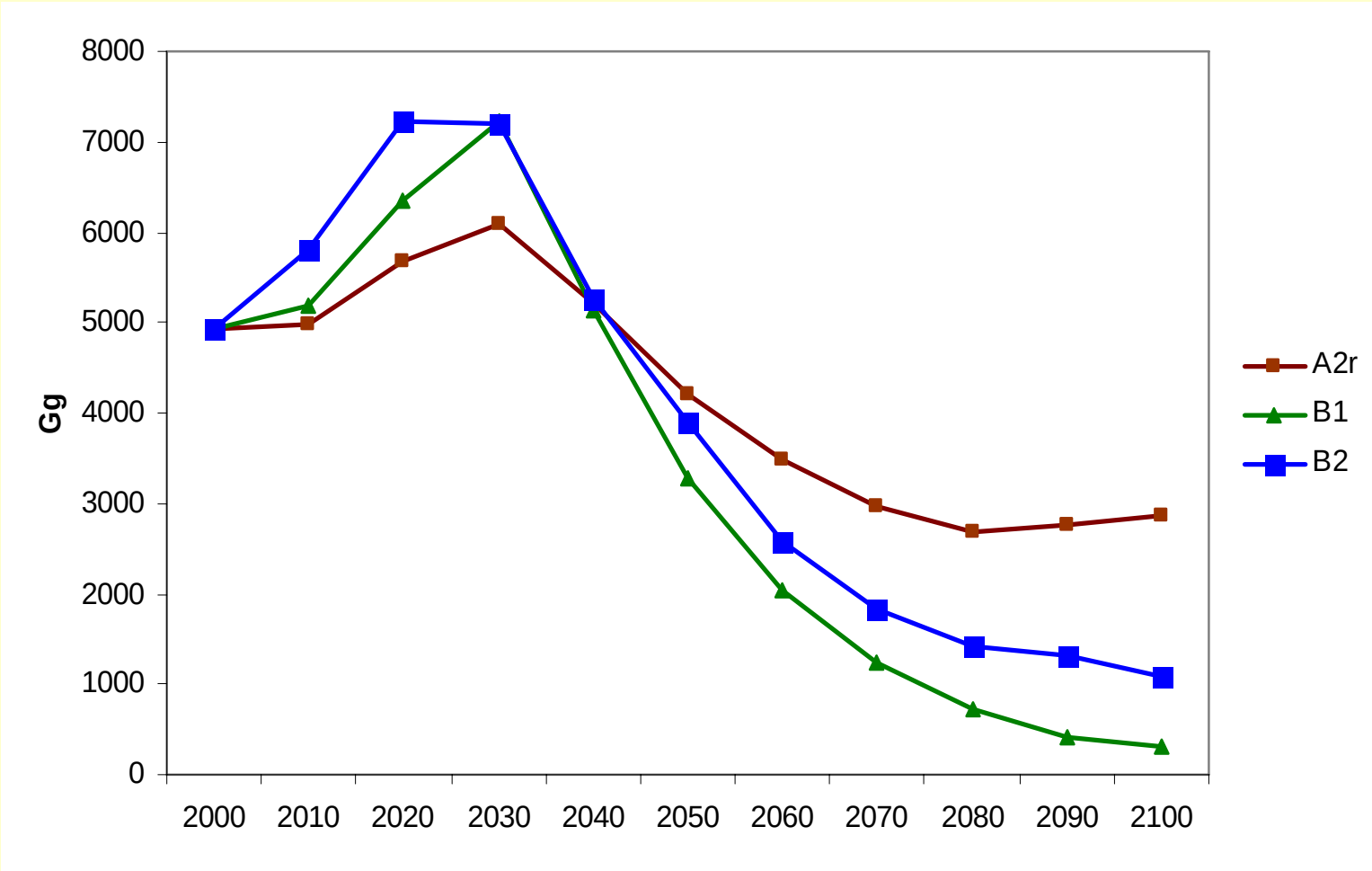
Source: Shilpa Rao, IIASA's MESSAGE model

Organic Carbon Emissions, 2000-2050



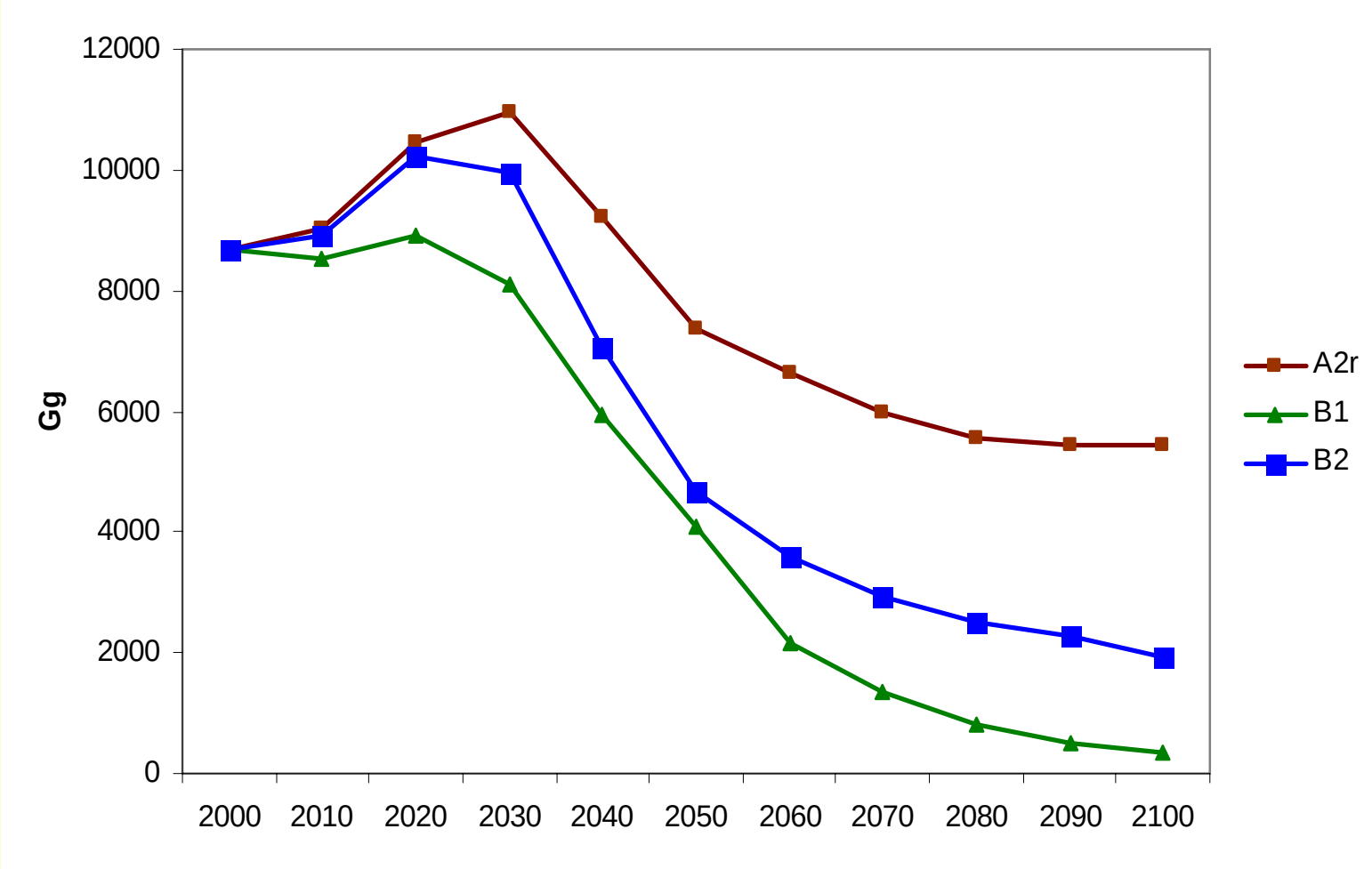
Source: Shilpa Rao, IIASA's MESSAGE model

Black Carbon Emissions, 2000-2100



Source: Shilpa Rao, IIASA's MESSAGE model

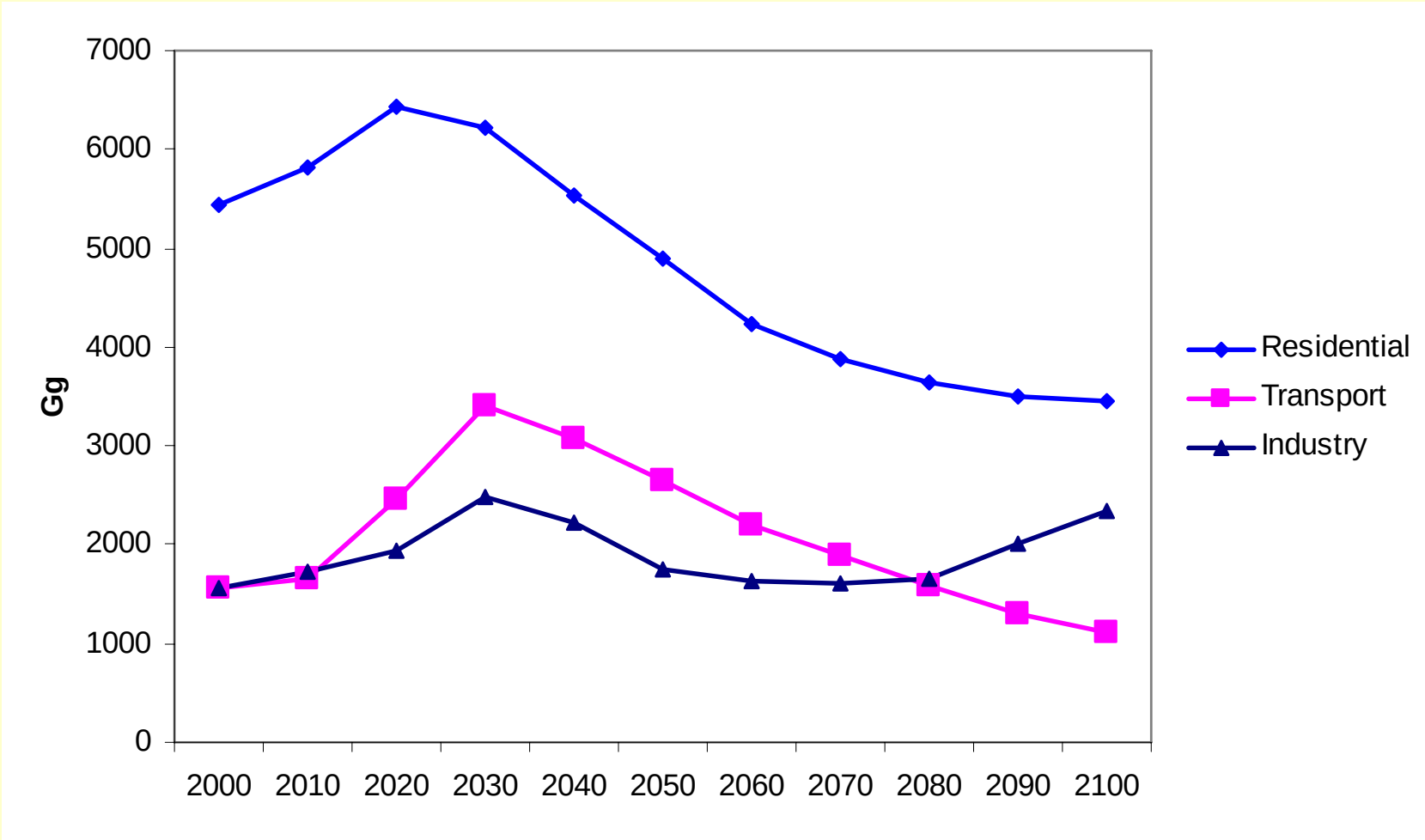
Organic Carbon Emissions, 2000-2100



Source: Shilpa Rao, IIASA's MESSAGE model

Sector Contribution

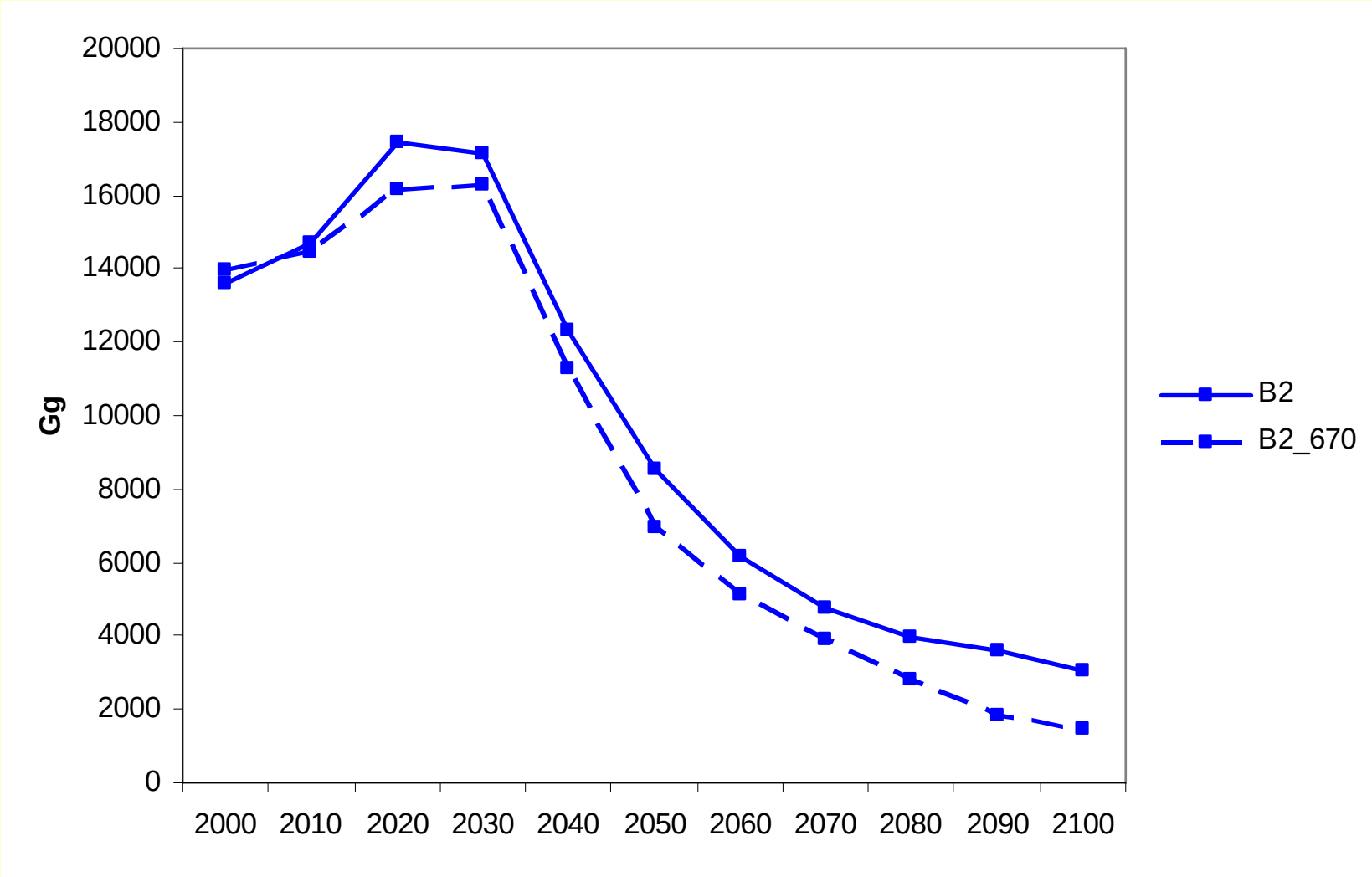
BC and OC Emissions in Developing Countries under A2



Source: Shilpa Rao, IIASA's MESSAGE model

Ancillary Benefits of Climate Mitigation

BC and OC Emissions: B2 vs. B2 with 670 CO_2 eq. Stabilization



Source: Shilpa Rao, IIASA's MESSAGE model

Source: Steven Smith (JGCRI)

Carbonaceous Aerosol Modeling in MiniCAM

1990 BC and OC base-year emissions from Bond *et al.*

- Emissions mapped to MiniCAM regions and source sectors (electric generation, transportation, industry, residential, land-use)
- The model determines aggregate sector emission factors

Emission drivers determined endogenously

Emissions factors change due to:

- Assumed improvements in technology
- Convergence between regions (as incomes increase)

Source: Steven Smith (JGCRI)

Carbonaceous Aerosols: Source Sectors

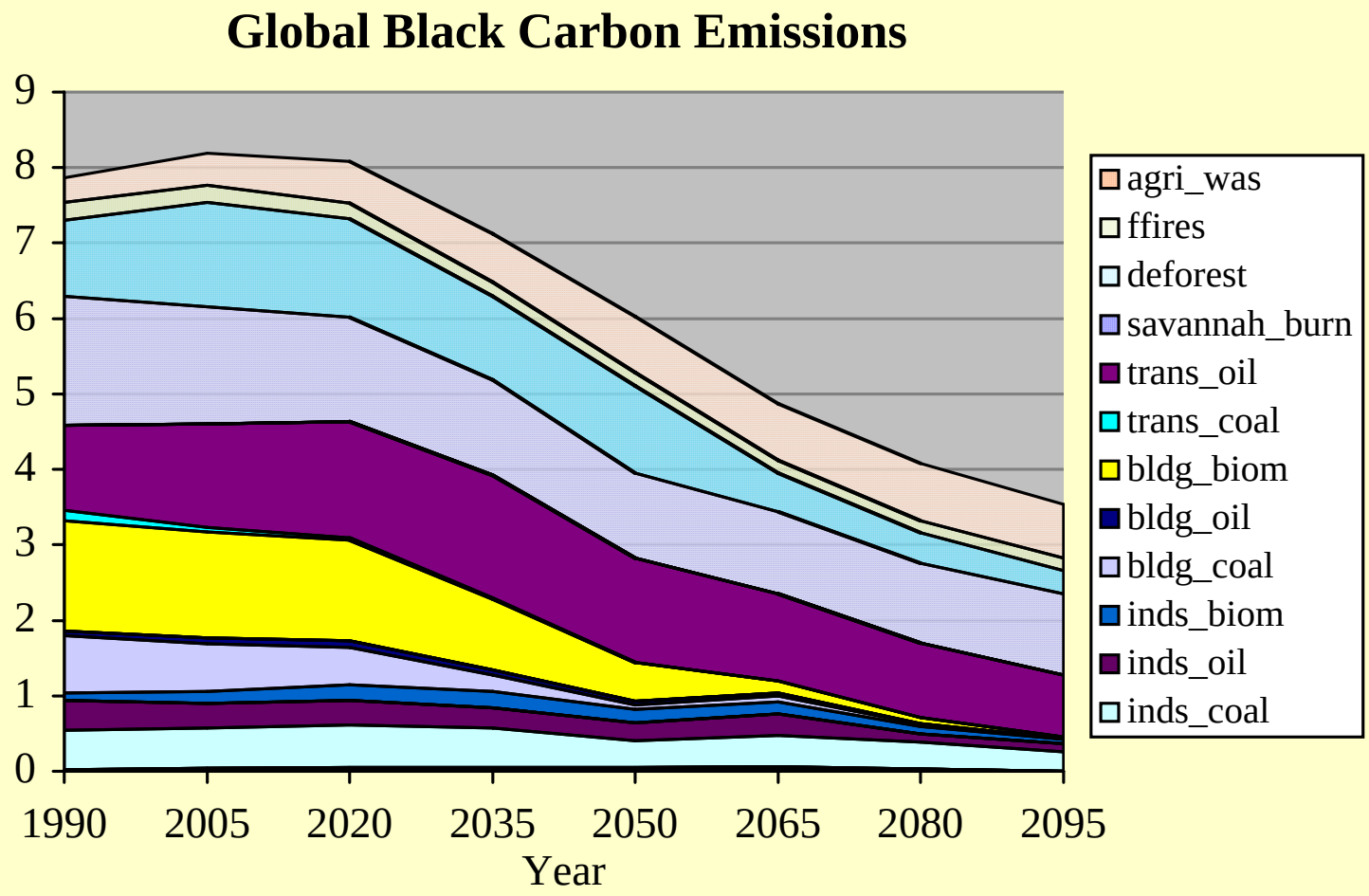
19 Source Sectors in MiniCAM

Model Categories	Driver
Transportation Fuel Use (Coal, Oil, Gas)	Fuel Use (ground vs air transport -- in progress)
Residential Fuel Use (Coal, Oil, Gas, Biomass)	Fuel Use
Industrial Fuel Use (Coal, Oil, Gas, Biomass)	Fuel Use
Savannah Burning	Area of Grassland
Deforestation	Above-ground biomass (less logging & biomass salvage)
Agricultural Waste Burning	Area of Agricultural Land
Forest Fires	Area of Forest

Reference: Smith, Steven J. and T.M.L. Wigley (2006) Multi-Gas Forcing Stabilization with the MiniCAM. *Energy Journal (*accepted).

Source: Steven Smith (JGCRI)

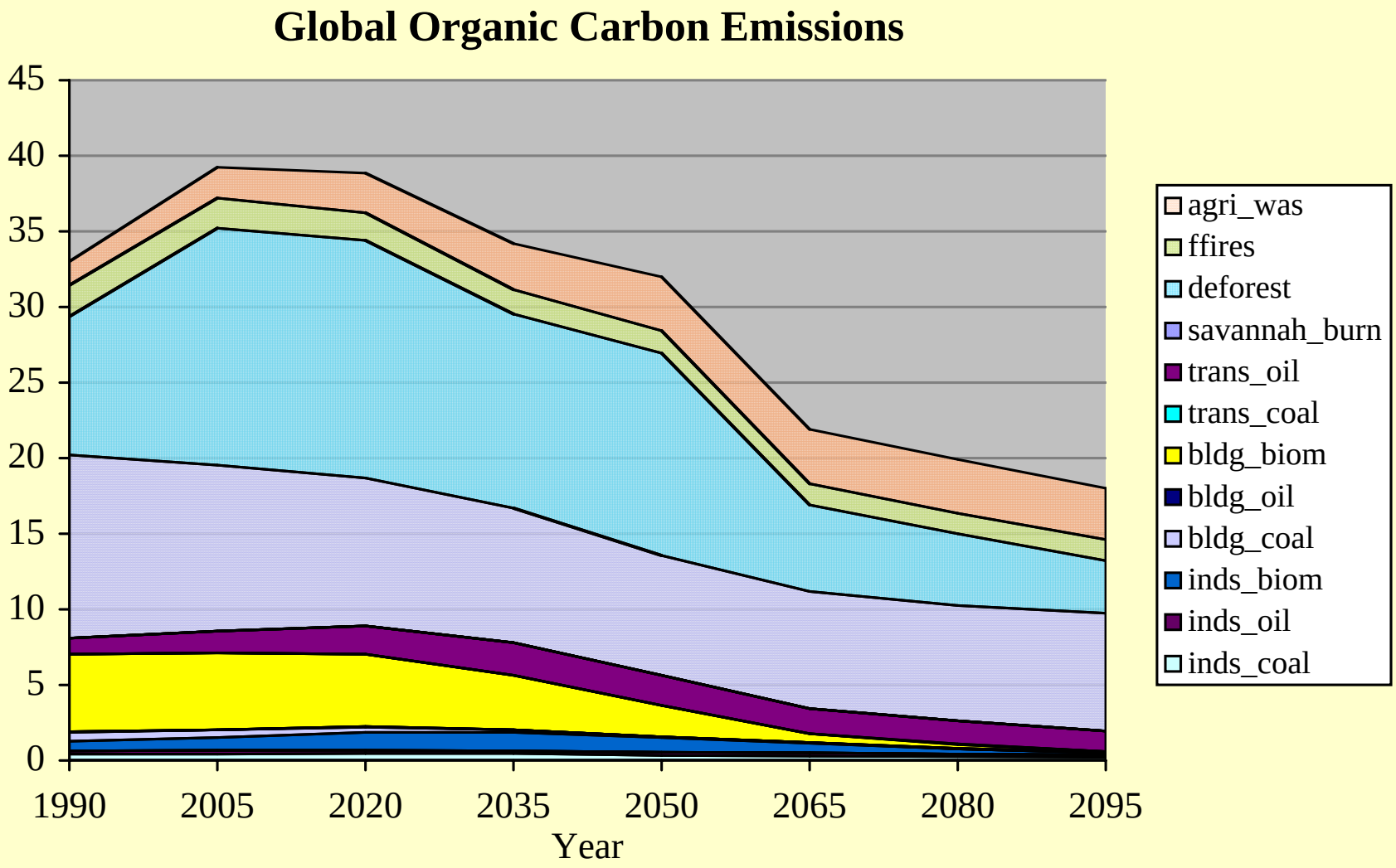
B2 Black Carbon Emissions by Source



Land-use and transportation emissions dominate by the end of the century

Source: Steven Smith (JGCRI)

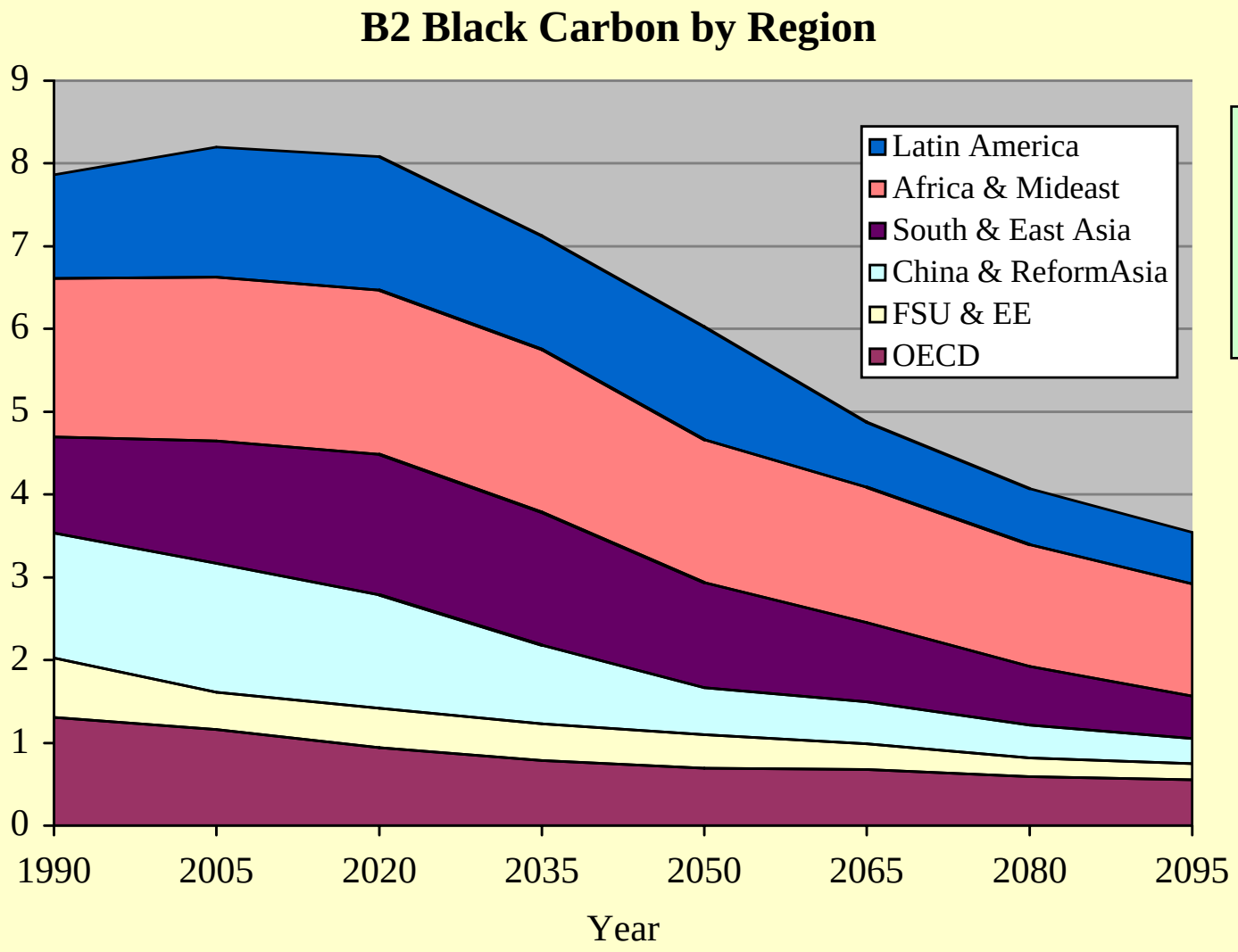
B2 Organic Carbon Emissions by Source



Land-use emissions dominate at all times

Source: Steven Smith (JGCRI)

Black Carbon Emissions by Region

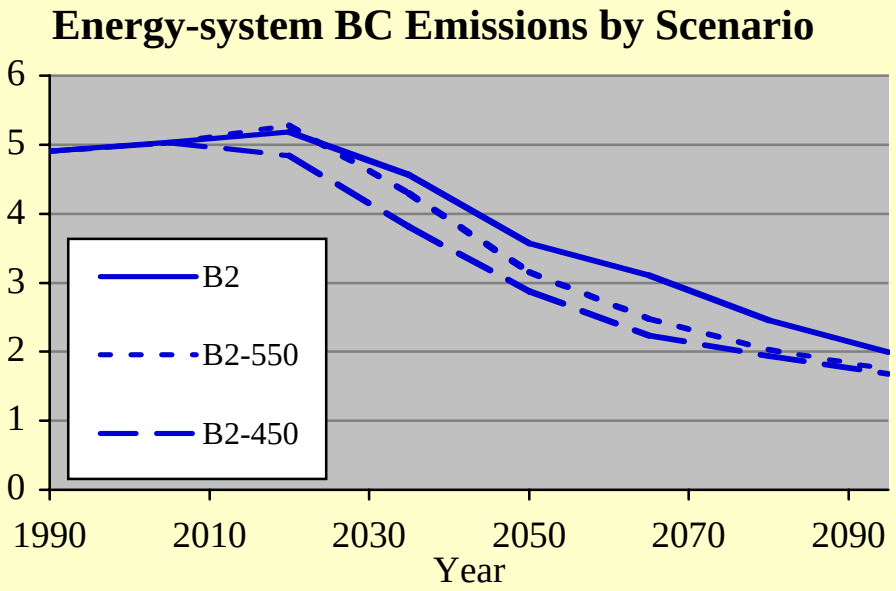


Emissions from Latin America and Africa dominate the end of the century

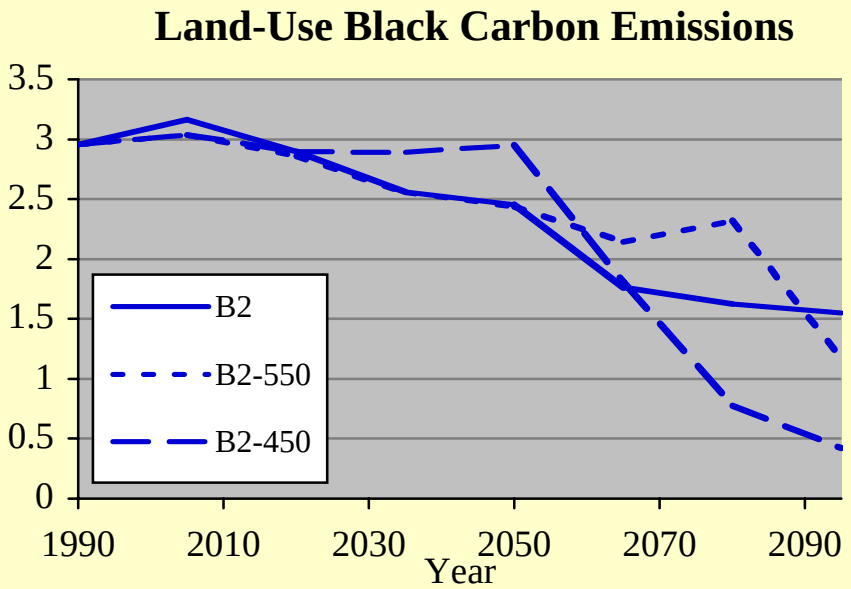
This assumes current land use patterns (savannah and ag-waste burning) continue!

Source: Steven Smith (JGCRI)

BC Emissions & Carbon Policy



Energy-related emissions consistently decrease in policy cases.

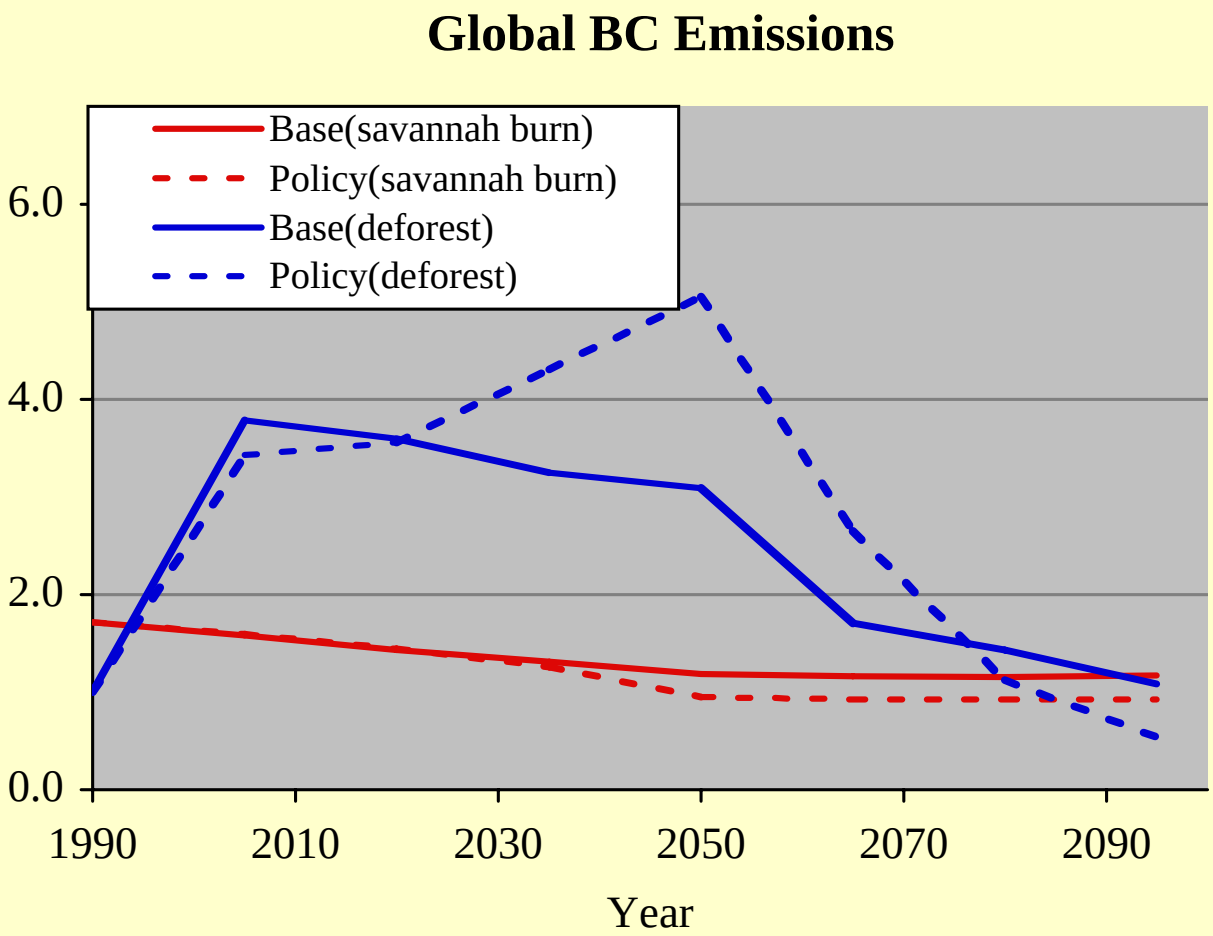


Land-use emissions can move in either direction.

No climate policy-induced changes in BC/OC emissions included

Source: Steven Smith (JGCRI)

Effect of a carbon policy on emissions



Under a carbon policy, land is used to produce biomass — causing more land conversion overall.

Deforestation emissions initially increase and savannah burning emissions decrease (due to decreases in savannah area).

Need improved characterization of current land-use emissions.

Land-use change emissions depend on 1) assumptions about valuation of standing carbon stocks, and 2) disposition of biomass during land-use clearing.

Preliminary BC/OC Projections of GRAPE using Bond Data

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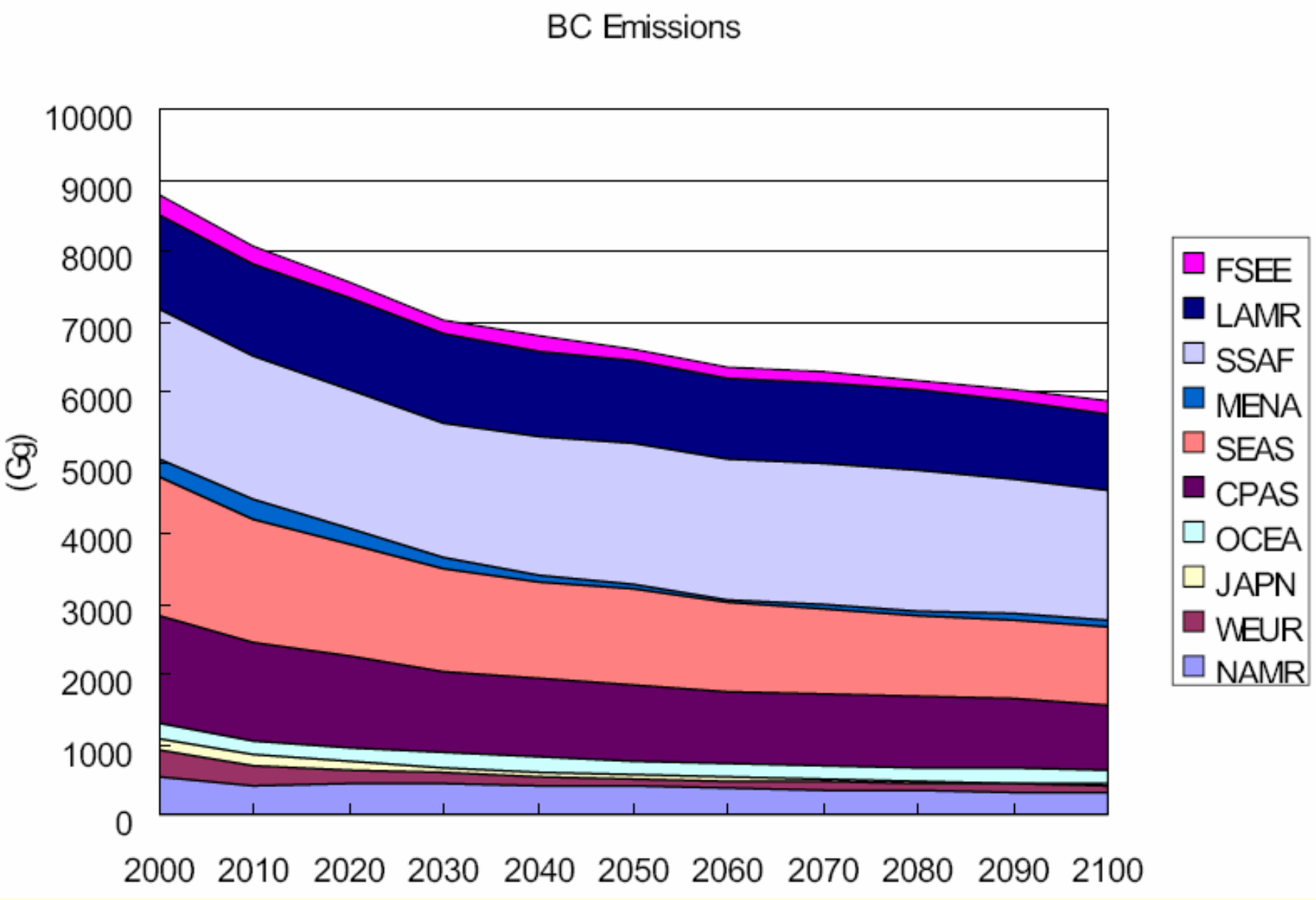
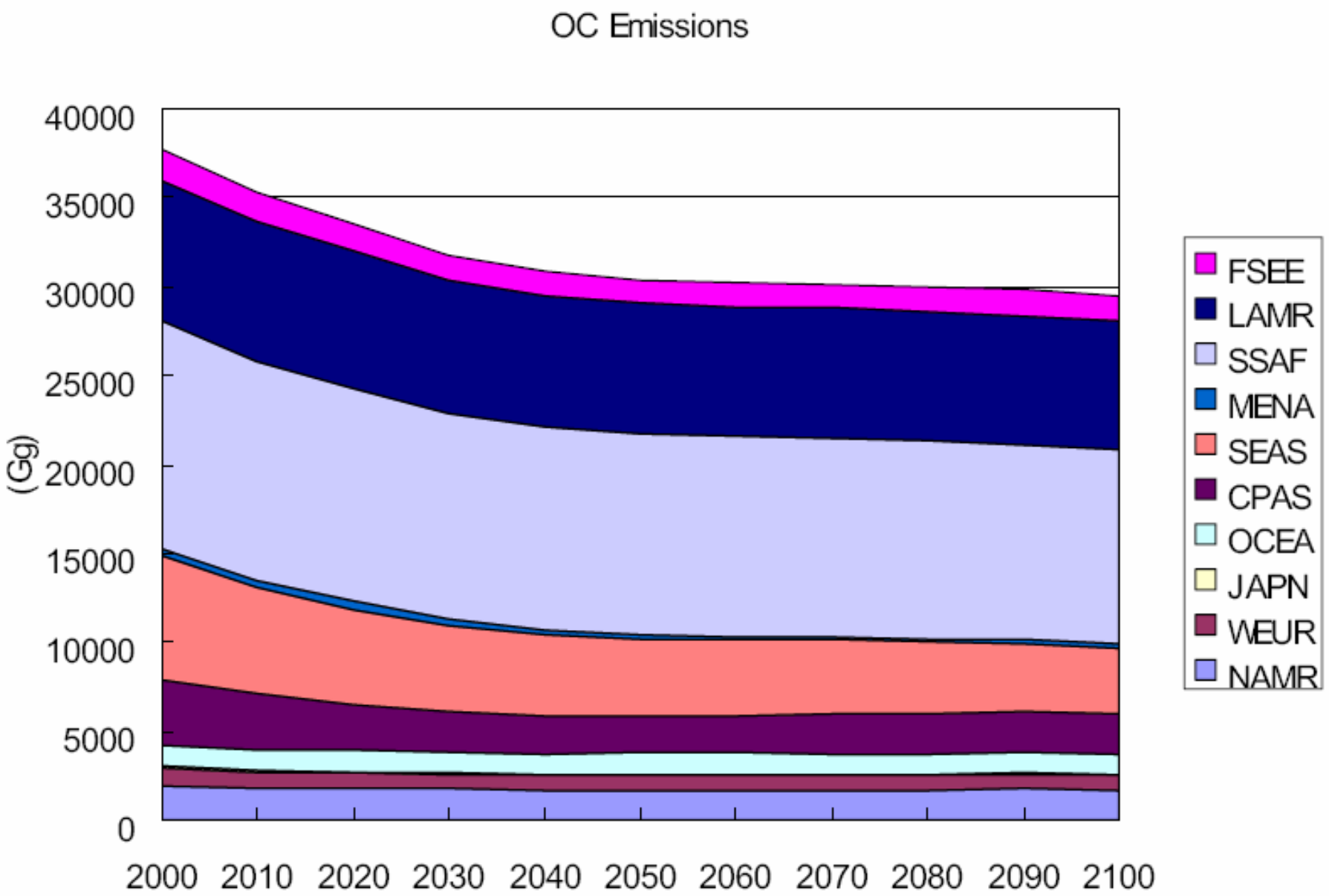
Energy Modeling Forum Meeting
Washington DC, USA
February 1 2006

The views are solely those of the individual author and do not represent organizational views of IAE.

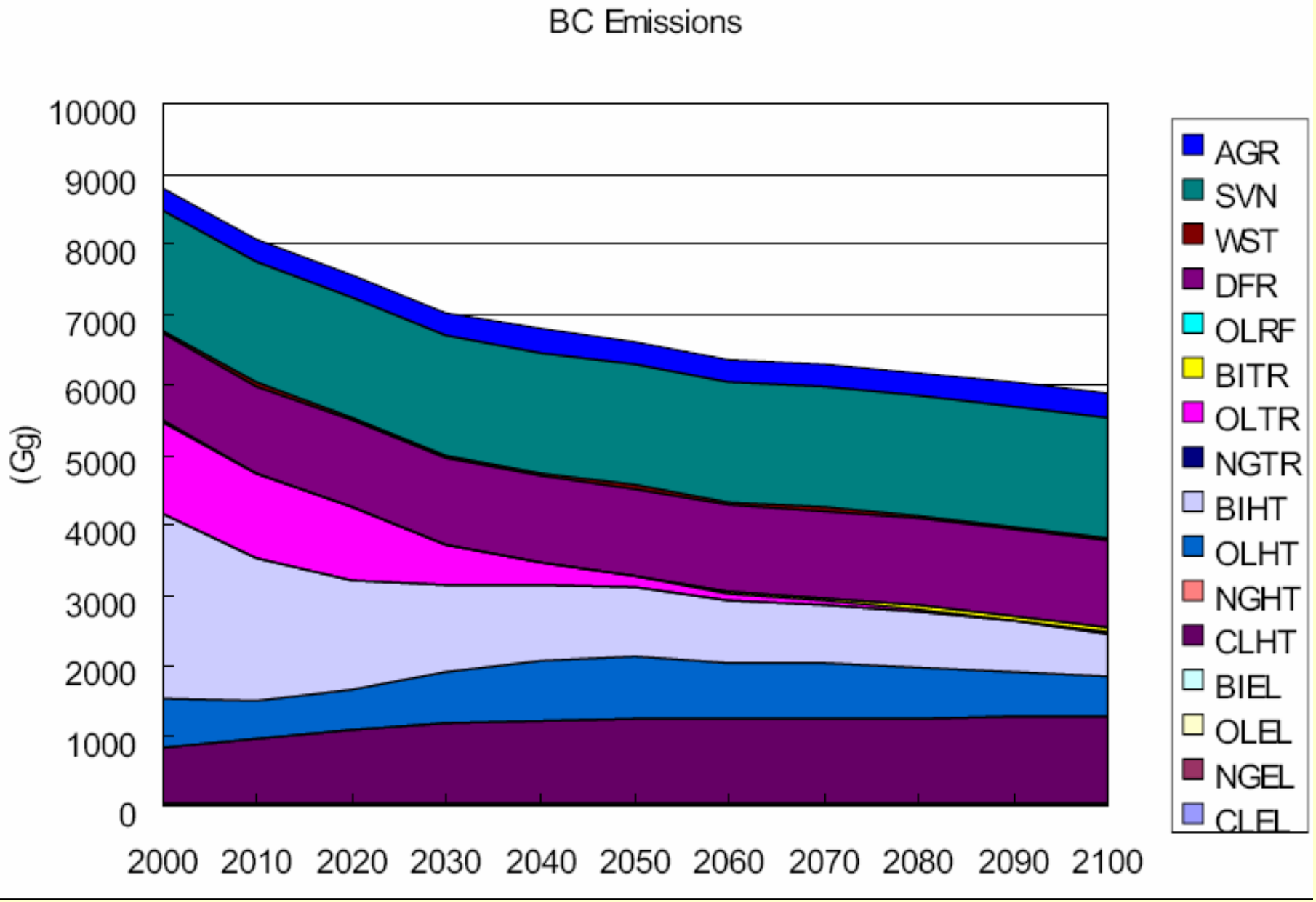
Global BC Emissions by Region



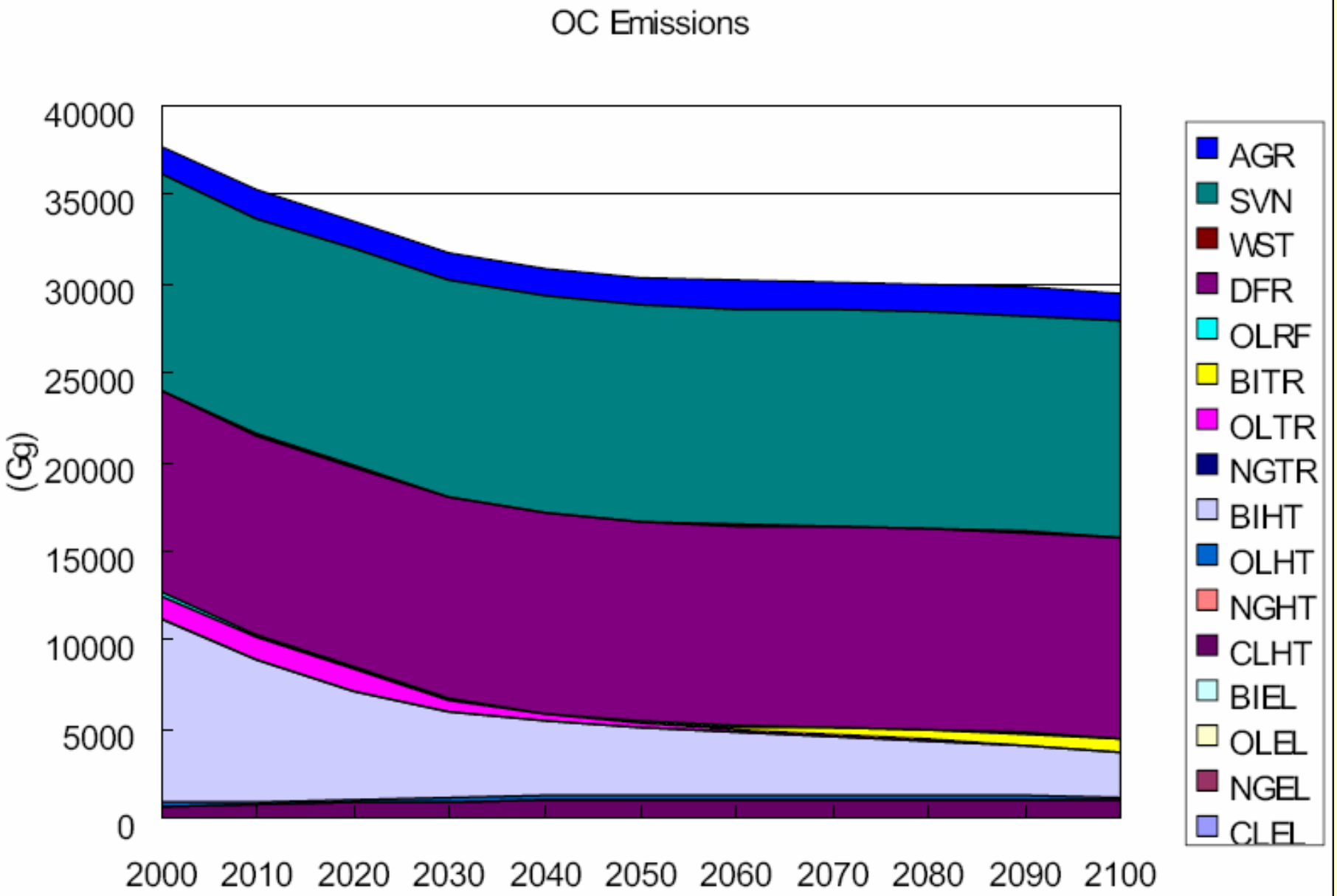
Global OC Emissions by Region



Global BC Emissions by Sector



Global OC Emissions by Sector



Preliminary Analysis on BC/OC Model using AIM

Junichi Fujino*, Mikiko Kainuma*,

Go Hibino**, Hiroki Hori**,

AIM (Asia-Pacific Integrated Model) team

NIES (National Institute for Environmental Studies), Japan

MHIR (Mizuho Information & Research Institute, Inc.)

EMF22 Working Group Meeting: Climate Change Control Scenarios

- Black Carbon and Land Modeling Subgroups

Washington, DC – February 1-3, 2006

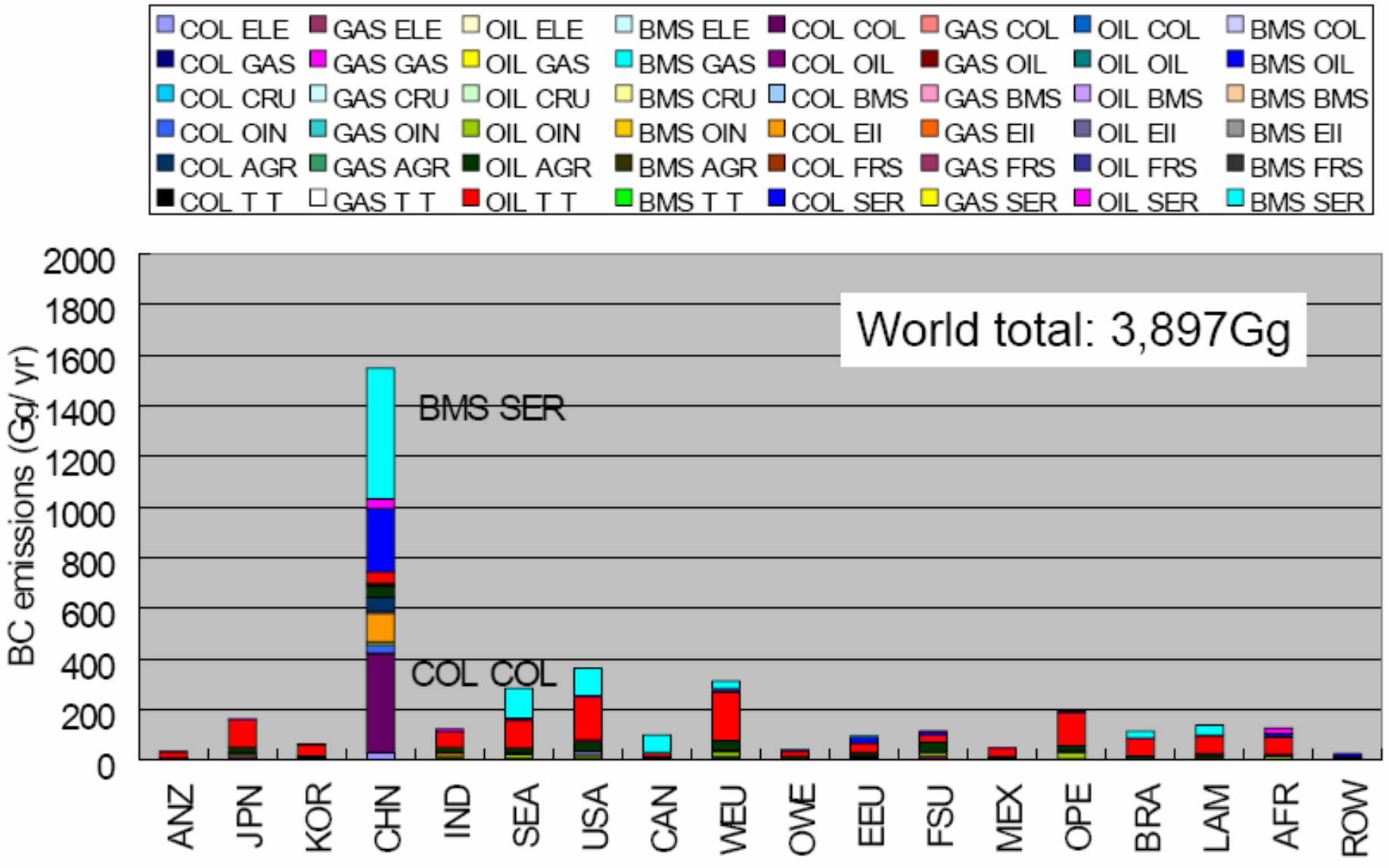
Regions of AIM/CGE

1	ANZ	Australia/NZ	10	OWE	Other Western Europe
2	JPN	Japan	11	EEU	Eastern Europe
3	KOR	Korea, Rep.	12	FSU	FSU
4	CHN	China	13	OPE	OPEC
5	IND	India	14	MEX	Mexico
6	SEA	South & SE Asia	15	BRA	Brazil
7	USA	USA	16	LAM	Latin America
8	CAN	Canada	17	AFR	Africa
9	WEU	EU15	18	ROW	Rest of the World

Sectors of AIM/CGE

1	GAS	Natural gas works	8	FRS	Forestry
2	ELE	Electricity and heat	9	FSH	Fishing
3	OIL	Refined oil products	10	EII	Energy Intensive Industry
4	COL	Coal transformation	11	OIN	Other Industry
5	CRU	Crude oil	12	T_T	Transport
6	AGR	Agriculture	13	SER	Service
7	LVK	Livestock			

BC emissions (Gg/yr) in 1997 which our model can cover



Next Steps for EMF-AEROCOM Interaction

- Further scenario development and refinement among some EMF modelers
  - Characterization of land use & open burning emissions needs attention
- Decide how many future emission scenarios AEROCOM should consider, and the timeframe for handing over emissions data
- Decide on reference-case only scenarios or also mitigation scenarios
  - GHG mitigation with BC/OC co-effects
  - Targeted BC/OC mitigation scenarios
- What suite of emissions does AEROCOM require from EMF models?
  - GHGs ✔
  - Black carbon and organic carbon ✔
  - SO_2 ✔
  - Other aerosols ?
- Develop data formatting requirements for emissions data transfer from EMF to AEROCOM models
  - Geographic and temporal resolution
  - Vertical resolution?